APPENDIX E:

Loch Raven West Watershed Characterization Report

(WSP | PB 2016)

Loch Raven West
Watershed Characterization Report

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FINAL

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List of Acronyms and Abbreviations

BIBI	Benthic Index of Biotic Integrity
BMP	Best Management Practice
CWP	Center for Watershed Protection
DNR	Department of Natural Resources
ENR	Enhanced Nutrient Removal
EPS	Environmental Protection and Sustainability
ESD	Environmentally Sensitive Design
GIS	Geographic Information System
HSI	Hotspot Site Investigation
ISI	Institutional Site Investigation
MACS	Maryland Agricultural Water Quality Cost-Share
MDA	Maryland Department of Agriculture
MDE	Maryland Department of the Environment
MDP	Maryland Department of Planning
MET	Maryland Environmental Trust
MPN	Most Probable Number
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Service
NSA	Neighborhood Source Assessment
OIT	Office of Information Technology
PAA	Pervious Area Assessment
PSI	Pollution Severity Index
ROI	Restoration Opportunity Index
SCA	Stream Corridor Assessment
SHA	State Highway Administration
SSURGO	Soil Survey Geographic database
SWAP	Small Watershed Action Plan
SWM	Stormwater Management
TMDL	Total Maximum Daily Loads
TP	Total Phosphorus
TSS	Total Suspended Solids
URDL	Urban/Rural Demarcation Line
USDA	United States Department of Agriculture
USGS	United States Geological Survey
USSR	Unified Subwatershed and Site Reconnaissance
WIP	Watershed Implementation Plan
WLA	Waste Load Allocations
WRE	Water Resources Element

CHAPTER 1: INTRODUCTION

1.1 Purpose

The purpose of the Loch Raven West Watershed Characterization Report is to:

1. Summarize the factors that may affect the water quality of the Loch Raven West watershed such as landscape, geomorphology, hydrology, and biological characteristics;
2. Explain the current conditions of the Loch Raven West watershed and its natural resources;
3. Describe human impacts on the watershed such as development and land use; and
4. Identify restoration and preservation strategies appropriate for accomplishing watershed improvement goals.

The observations and conclusions presented in this watershed characterization report will be used to develop a Small Watershed Action Plan (SWAP) for the Loch Raven West watershed.

1.2 Watershed Location and Scale

The Loch Raven Reservoir watershed is located in the Piedmont physiographic province of Maryland and Pennsylvania, encompassing a large portion of central Baltimore County. The Loch Raven Reservoir watershed has been divided by the county into five distinct SWAP watersheds due to its large size. Only the portion of the watershed that resides northwest of the Loch Raven Reservoir impoundment, identified as SWAP Area W, is addressed in this watershed characterization report and SWAP. Herein, it will be referred to as the Loch Raven West watershed (see Figure 1-1). The Loch Raven West watershed has an extent of approximately 38,488 acres (60 square miles). The watershed drains the headwaters and tributaries of Western Run, including 33 miles of the Western Run main stem. Western Run flows from the Loch Raven West watershed into the Lower Loch Raven Reservoir watershed and continues another 13 miles to its confluence with the main stem of Gunpowder Falls. Gunpowder Falls drains to the impoundment of the Loch Raven Reservoir, after which it continues to the Gunpowder River and the Chesapeake Bay. The Loch Raven West watershed is bordered to the north by the Prettyboy Reservoir watershed, to the east by the eastern portion of the Loch Raven Reservoir watershed, to the south by the lower portion of Loch Raven Reservoir watershed, the Jones Falls watershed, and the Gwynns Falls watershed, and to the west by the Liberty Reservoir watershed and Carroll County.

The Loch Raven West watershed was subdivided into smaller drainage areas or subwatersheds, which are listed in Table 1-1 with respective drainage areas in acreage and square miles. In addition to characterizing the entire SWAP area, analyses were also conducted at the subwatershed scale to provide more detailed information for these smaller areas and to focus recommendations for restoration and preservation efforts. The success of restoration efforts can be more easily monitored and measured at this smaller

scale. Figure 1-2 shows the 11 subwatersheds comprising the Loch Raven West watershed. Methods used for the delineation of the watershed and subwatersheds are described in further detail in Chapter 2.

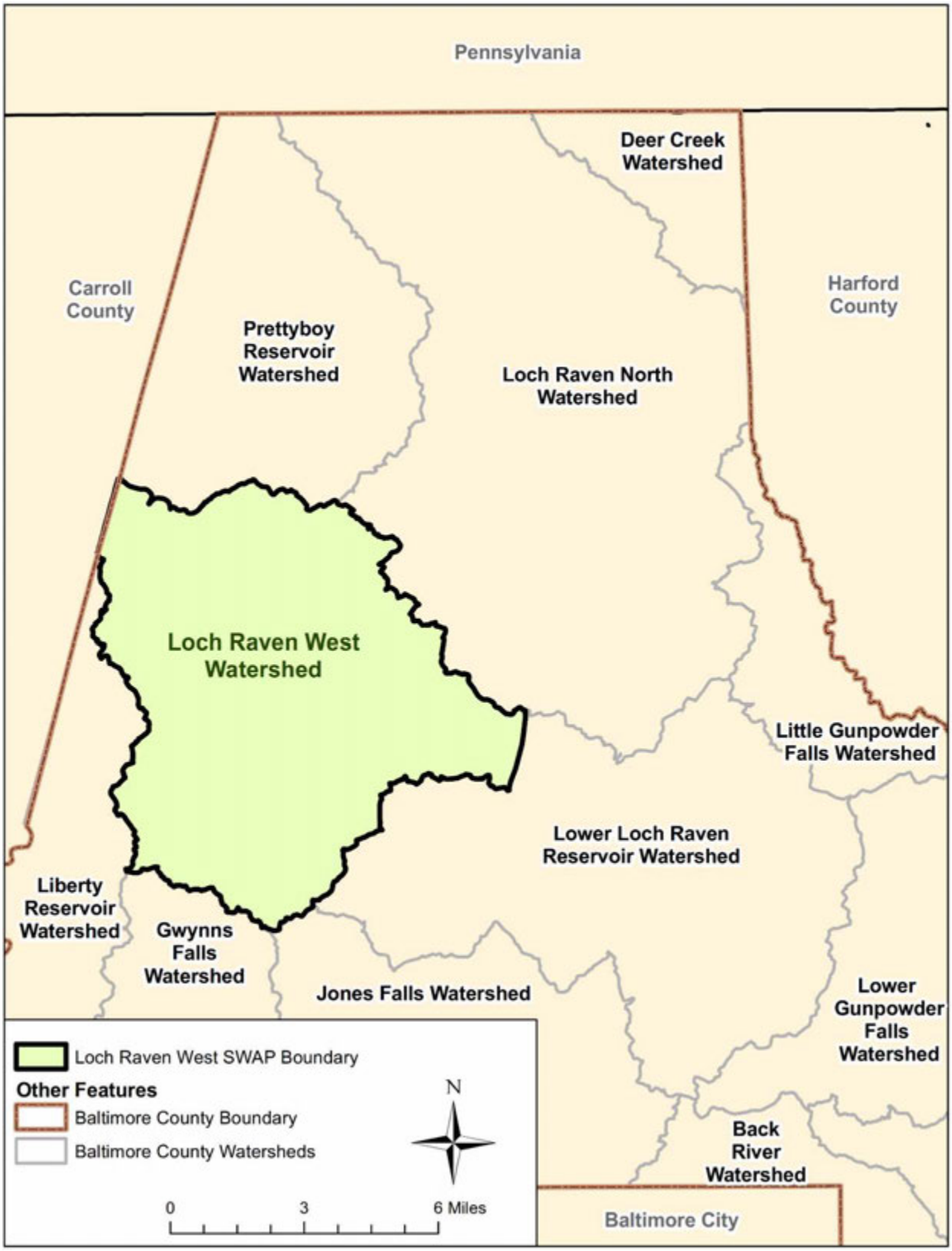

Figure 1-1: Location of Loch Raven West Watershed

Table 1-1: Loch Raven West Subwatershed Areas

Subwatershed	Area (Acres)	Area (Sq. Miles)
Piney Run	6,244	9.76
Blackrock Run	7,117	11.12
Little Piney Run	1,257	1.96
Indian Run	2,454	3.83
McGill Run	4,077	6.37
Western Run	7,510	11.73
Slade Run	2,849	4.45
Delaware Run	2,283	3.57
Councilman's Run	2,436	3.81
Waterspout Run	1,163	1.82
Deadman's Run	1,098	1.72
Total	***38,488***	***60.14***

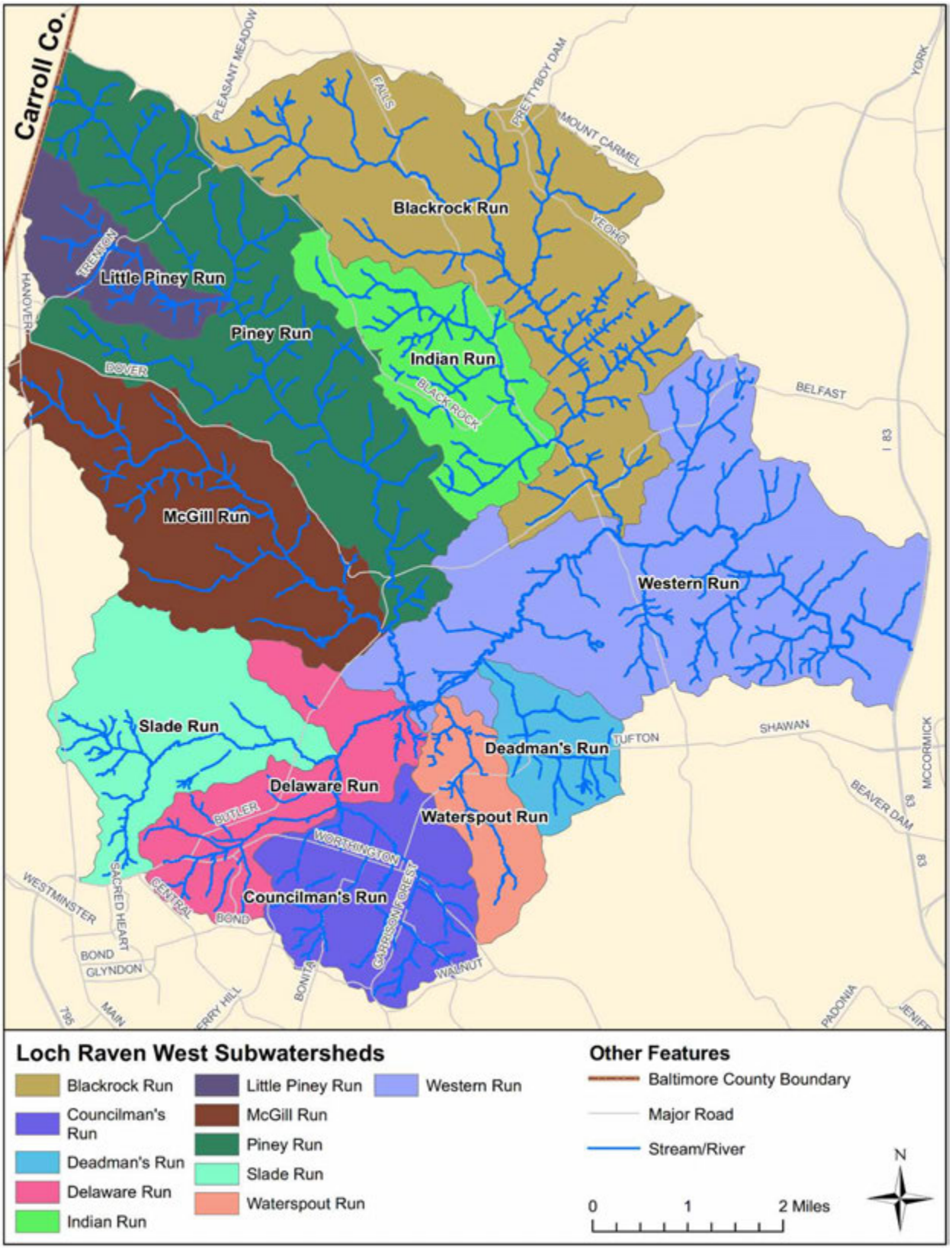

Figure 1-2: Loch Raven West Subwatersheds

1.3 Report Organization

The Loch Raven West Watershed Characterization report is organized into the following six chapters:

Chapter 1 – Explains the purpose of the report and the location and scope of the watershed characterization.

Chapter 2 – Summarizes characteristics related to landscape and land use that may affect natural resources and water quality in the Loch Raven West watershed. This chapter contains landscape information related to natural features such as geology, topography, soils, forest cover, and streams. Information pertaining to human influence on landscape is also discussed, including land use, population, impervious cover amount, water distribution, and stormwater infrastructure.

Chapter 3 – Discusses water quality and quantity conditions in the watershed based on available monitoring data and historic mill dam assessment data. It also describes several stream and mill dam restoration opportunities based on field observations.

Chapter 4 – Describes the upland assessments conducted to identify pollutant sources and restoration opportunities for four assessment categories: neighborhoods, hotspots, institutions, and pervious areas.

Chapter 5 – Presents restoration and preservation strategies appropriate for accomplishing watershed goals developed by the community and the Loch Raven West SWAP Steering Committee.

Chapter 6 – Lists the references consulted during the development of this report.

CHAPTER 2: LANDSCAPE AND LAND USE

2.1 Introduction

This chapter discusses land cover and land use in the Loch Raven West watershed, describing characteristics of both the natural land surface as well as development activities taking place within the watershed. Natural characteristics such as soil type and development related features such as impervious cover strongly influence the quantity and quality of watershed runoff. For example, the infiltration capacity of soils found on pervious ground affects the amount and rate at which precipitation will be absorbed into the ground surface; impervious surfaces, such as buildings and paved areas, impede rainfall infiltration, which can lead to flooding, erosion, and eventually a decrease in groundwater supply. In addition, the type and extent of pollutants carried by stormwater are affected by land use characteristics. Residential or agricultural areas may contribute fertilizers and pesticides to stormwater runoff. Depending on the land use activities taking place, developed areas may transmit pollutants such as trash, bacteria from livestock and pet waste, and chemicals directly to receiving water bodies if there is an inadequate vegetative buffer to filter out the pollutants before the runoff reaches the water. The information presented in this chapter provides the physical setting and background necessary to evaluate watershed elements including water quality, natural resources, restoration, and management.

2.2 Natural Landscape

Natural land surface characteristics relevant to watershed properties and processes are described in the following sections. These topics include climate, watershed delineation, topography, geology, soil properties, forest cover, and stream systems.

2.2.1 Climate

Climate is an important consideration when evaluating water quality, because it can influence soil and erosion processes, stream flow patterns, and topography. Climate affects vegetative growth and determines the species composition of terrestrial and aquatic life of a region. In addition, rainfall patterns are an important component of the hydrology of a watershed and can affect watershed management strategies.

The Loch Raven West region has a humid continental climate with four distinct seasons. It has a relatively temperate climate due to the combined effects of the Appalachian Mountains to the west and the Chesapeake Bay and Atlantic Ocean to the east. Average annual rainfall in Baltimore, Maryland is 42.48 inches based on 144 years of data (1871-2015) (NOAA, 2016a). Rainfall is uniformly distributed throughout the year, with monthly averages ranging from 2.95 inches for November to 4.29 inches for August. Most snowfall occurs in December, January, February, and March with an average annual snowfall of 21.9 inches based on 130 years of data (1883-2016) (NOAA, 2016b).

2.2.2 Watershed Delineation

A watershed-based approach for evaluating water quality conditions and improvement potential requires determining the drainage areas that contribute runoff and groundwater to a specific water body. Drainage areas vary greatly in size depending on the scale of the stream system of interest. Drainage areas for large river, estuary, and lake systems are typically on the order of several thousand square miles and are often

referred to as basins. The Chesapeake Bay basin covers over 64,000 square miles, which includes over 100,000 tributaries, and spans across portions of six different states (CBP, 2012). Basins consist of smaller sub-basins, which refer to drainage areas on the order of several hundred square miles and may consist of one or more major stream networks. Maryland has 13 sub-basins including the Upper Western Shore sub-basin, which encompasses the study area for this report. Sub-basins are further subdivided into watersheds and then subwatersheds, which are the most commonly used and practical hydrologic units for management and restoration purposes. There are 138 state-defined watersheds (called 8-digit watersheds) in Maryland, ranging in size from 20 to 100 square miles, and these are comprised of over 1,100 subwatersheds (called 12-digit watersheds) identified by the Maryland Department of Natural Resources (DNR). A subwatershed refers to the drainage area of a specific stream or particular reach of a stream, and typically covers ten square miles or less (DNR, 2005).

There are 14 8-digit watersheds in Baltimore County. The 8-digit Loch Raven Reservoir watershed (02-13-08-05) is approximately 218 square miles and encompasses the majority of northern Baltimore County. Due to the large size of the Loch Raven Reservoir 8-digit watershed, the county has divided the watershed into five separate SWAP watersheds (I, O, R, W, and X). Area W is the Loch Raven West watershed, measuring approximately 60 square miles (38,488 acres). For planning and management purposes, the Loch Raven West watershed has been further subdivided into 11 subwatersheds by Baltimore County, as illustrated in Figure 1-2. Watershed delineations were provided by the Baltimore County Office of Information Technology (OIT) via spatial data based on 1998 Maryland state-defined 8-digit and 12-digit watershed information. Studies for the other four SWAP study areas of the Loch Raven Reservoir watershed are being completed separately by Baltimore County.

2.2.3 Topography

The topography of a region describes the shape of the land including locations and elevations of surface features such as ridges and valleys. Land shape characteristics such as steepness affect the direction and magnitude of surface water flows, degree of soil erosion, and suitability for development. Land surface topography affects water quality as steeper slopes are more prone to overland flow and soil erosion resulting in a greater potential to generate pollutants in runoff. Soil slope data for the Loch Raven West watershed was obtained from the Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) database (USDA, 2015) and divided into the following five slope ranges, which were derived from slope classification definitions in the U.S. Department of Agriculture (USDA) *Soil Survey Manual* (USDA, 1993).

- Nearly level (0 to 3% slopes)
- Gently sloping, undulating (3 to 8% slopes)
- Strongly sloping, rolling (8 to 15% slopes)
- Moderately steep, hilly (15 to 25% slopes)
- Steep (> 25% slopes)

Table 2-1 provides a summary of the percent breakdown of soil slopes by watershed. The Loch Raven West watershed has a variety of slope classifications. Overall, the watershed leans towards the gently to

strongly sloping categories. Based on soil slope alone, the Loch Raven West watershed is prone to erosion by overland flow; however, the degree of erosion is also dependent on soil type and land use/land cover. The subwatershed with the flattest topography is Delaware Run with approximately 25% nearly level land. McGill Run has the highest percentage of steep slopes at 15% followed by Blackrock Run and Piney Run with a percentage of steep slopes of 14.6% and 14.5%, respectively. Soil slopes within Loch Raven West are shown in Figure 2-1.

Table 2-1: Loch Raven West Slope Classification by Subwatershed

	SLOPE CATEGORY %					
Subwatershed	**Nearly Level (0-3%)**	**Gently Sloping, Undulating (3-8%)**	**Strongly Sloping, Rolling (8-15%)**	**Moderately Steep, Hilly (15-25%)**	**Steep (>25%)**	**Water**
Piney Run	10.8	25.3	29.9	19.4	14.5	0.1
Blackrock Run	12.0	27.8	28.0	17.6	14.6	0.1
Little Piney Run	14.6	33.3	31.3	12.8	7.6	0.4
Indian Run	8.2	29.1	30.3	19.1	13.1	0.2
McGill Run	12.1	28.9	25.9	18.1	15.0	0.0
Western Run	15.2	32.5	25.9	18.0	8.3	0.1
Slade Run	14.8	28.7	29.7	20.2	6.5	0.1
Delaware Run	24.5	31.4	22.3	20.2	1.6	0.0
Councilman's Run	19.4	33.2	21.0	23.0	2.9	0.5
Waterspout Run	19.6	29.7	26.1	19.2	5.4	0.0
Deadman's Run	13.2	32.7	29.2	20.4	4.5	0.0
Total	***14.0***	***29.5***	***27.2***	***18.8***	***10.4***	***0.1***

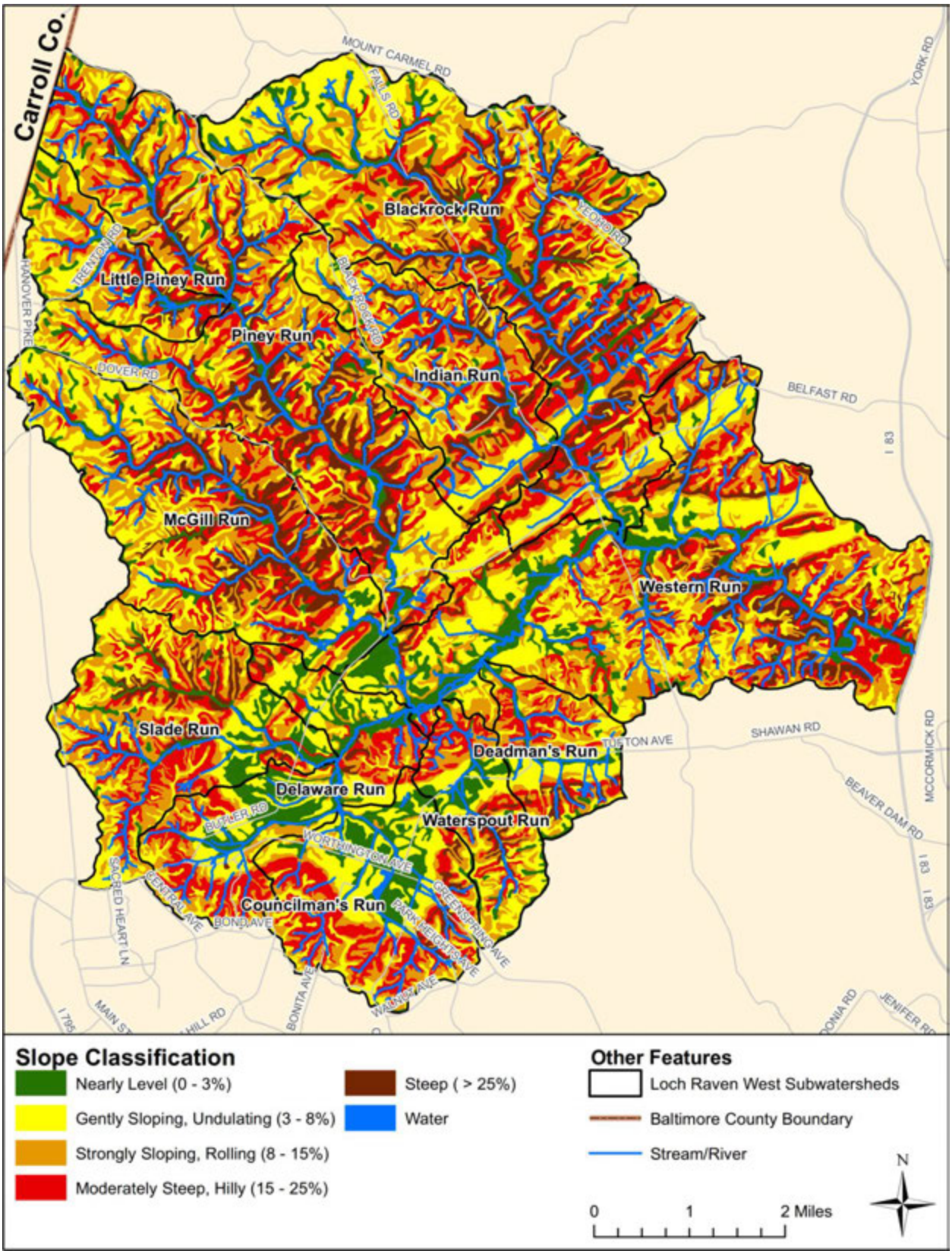

Figure 2-1: Loch Raven West Topography based on Soil Slopes

2.2.4 Geology

The geology of an area affects the chemical composition of surface water and groundwater, as well as groundwater and well recharge rates. It is also relevant to soil formation and influences the buffering capacity of pollutants to water bodies in developed areas. Consequently, geology often has a close correlation to water quality.

The Loch Raven West watershed is located in the Upland Section of the Piedmont Plateau Province of Maryland. Soils in this region consist of very deep, moderately sloping, well drained upland soils. The dominant piedmont soils in the Baltimore area consist of Ultic Hapludalfs. The region contains contrasting rock types, such as highly metamorphosed sedimentary and igneous rocks of volcanic origin as well as granitic plutons and pegmatites, which create a distinctive topography (MGS, 2016).

The majority of the watershed falls within the Harford Plateaus and Gorges Region of the Piedmont Plateau Province. The general physiographic characteristics of this region are gently rolling or moderately hilly landscapes. The Hampstead Upland District, which comprises most of the land area within this region, is characterized by rolling to hilly uplands interrupted by steep-walled gorges producing distinctive hills, valleys, and ridges, and the smaller tributary streams of the Gunpowder Falls within this district may have short segments of narrow, steep-sided valleys (MGS, 2008).

The eastern portion of the watershed falls within the Phoenix Dome Region of the Piedmont Plateau Province, which includes the Chattolanee Upland District. The general physiographic characteristics of this region and district are gently rolling uplands created by four interconnected dome-like terrain underlain mainly by Baltimore Gneiss, which are surrounded and separated by broad marble valleys. Steep (>15 degree) slopes separate the uplands from the lowlands, and are underlain by the Setters Formation (quartzite and schist). There is a small outlier of Loch Raven Schist resting on Cockeysville Marble that creates a ridge surrounded by a marble valley in the Western Run area of this region. (MGS, 2008).

2.2.5 Soils

Soil characteristics are an important consideration when evaluating water quantity and quality in streams and rivers. Soil type and moisture content impact how land may be used and its potential for vegetation and habitat. Soil conditions are also evaluated for projects aimed at improving water quality and habitat.

Soils data including hydrologic soil groups and soil erodibility for the Loch Raven West watershed was obtained from spatial data provided by the NRCS SSURGO database (USDA, 2015).

2.2.5.1 Hydrologic Soil Groups

The NRCS classifies soils into four hydrologic soils groups (HSG) based on their runoff potential and infiltration rates. Soils with high runoff potential have low infiltration capacity and tend to cause overland flow instead of allowing stormwater to infiltrate. Infiltration rates are highly variable among soil types and are influenced by disturbances to the soil profile such as land development activities. For example, urbanization on land composed of high infiltration soils (such as sands and gravels) will greatly increase

runoff from the pre-development runoff rate. Whereas development on land composed of low infiltration soils (such as silts and clays) will have less of an impact on runoff.

The four hydrologic soil groups range from A to D, lowest runoff potential to highest, respectively. Brief descriptions of each hydrologic soil group are provided below. Further explanation can be found in chapter 7 of the USDA/NRCS publication, *National Engineering Handbook- Hydrology Chapters* (NRCS, 2009).

- **Group A** soils include sand, loamy sand, or sandy loam types. These soils have low runoff potential when thoroughly wet and a high infiltration rate. This type of soil generally consists of sands and gravels, typically have less than 10 percent clay, and have gravel or sand textures. These soils have a high rate of water transmission.
- **Group B** soils include well aggregated loam, silt loam, or sandy clay loam. These soils have a moderately low runoff potential when thoroughly wet. These soils generally contain between 10 to 20 percent clay and 50 to 90 percent sand with a loamy sand or sandy loam texture. Water transmission through these soils is moderate.
- **Group B/D** soils are wet Group B soils, including well aggregated loam, silt loam, and sandy clay loam. These wet soils are placed in a dual category due to the presence of a water table within 24 inches of the surface. The first letter refers to the drained condition while the second letter describes the undrained condition. Only wet soils that can be adequately drained are placed into dual categories.
- **Group C** soils include silt loam, sandy clay loam, clay loam, and silty clay loam textures. These soils have a moderately high runoff potential when thoroughly wet. This soil typically contains between 20 to 40 percent clay and less than 50 percent sand. Water transmission through these soils is low and somewhat restricted.
- **Group C/D** soils are wet Group C soils, including silt loam, sandy loam, clay loam, and silty clay loam. These wet soils are placed in a dual category due to the presence of a water table within 24 inches of the surface. The first letter refers to the drained condition while the second letter describes the undrained condition. Only wet soils that can be adequately drained are placed into dual categories.
- **Group D** soils include clayey textures. These soils have high runoff potential when thoroughly wet. These soils generally contain greater than 40 percent clay and less than 50 percent sand. These consist mainly of clays with high swell potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. Water transmission through this soil is very restricting with very low infiltration rates.

As shown in Table 2-2 and Figure 2-2, all of the Loch Raven West subwatersheds possess similar hydrologic soil group characteristics in both the upland and bottomland areas. Nearly 70% of the Loch Raven West watershed falls into hydrologic soil group B which has a moderate infiltration rate and moderately low runoff potential. Approximately 28% of the watershed falls into soil group C exhibiting low infiltration rates and a moderately high runoff potential. The C soils group is generally found along the stream valley

and throughout the northwestern subwatersheds. The majority of D soils are located at two quarries in the Indian Run and Blackrock Run subwatersheds.

Table 2-2: Loch Raven West Hydrologic Soil Groups

Subwatershed	Hydrologic Soil Group (%)						Water
	A	B	B/D	C	C/D	D	
Piney Run	0.0	56.6	2.5	40.2	0.6	0.0	0.1
Blackrock Run	0.0	67.2	1.8	29.6	0.9	0.4	0.1
Little Piney Run	0.0	49.7	4.3	44.8	0.8	0.0	0.4
Indian Run	0.0	73.8	0.3	24.8	0.6	0.2	0.2
McGill Run	0.0	65.3	0.7	33.9	0.2	0.0	0.0
Western Run	0.0	74.0	2.7	21.2	1.6	0.3	0.1
Slade Run	0.0	71.4	1.7	26.7	0.1	0.0	0.1
Delaware Run	0.0	72.6	2.0	25.1	0.2	0.1	0.0
Councilman's Run	0.0	79.3	4.8	14.5	0.9	0.0	0.5
Waterspout Run	0.0	78.8	5.6	15.6	0.0	0.0	0.0
Deadman's Run	0.0	75.5	0.5	24.0	0.0	0.0	0.0
Total	***0.0***	***68.5***	***2.2***	***28.3***	***0.7***	***0.2***	***0.1***

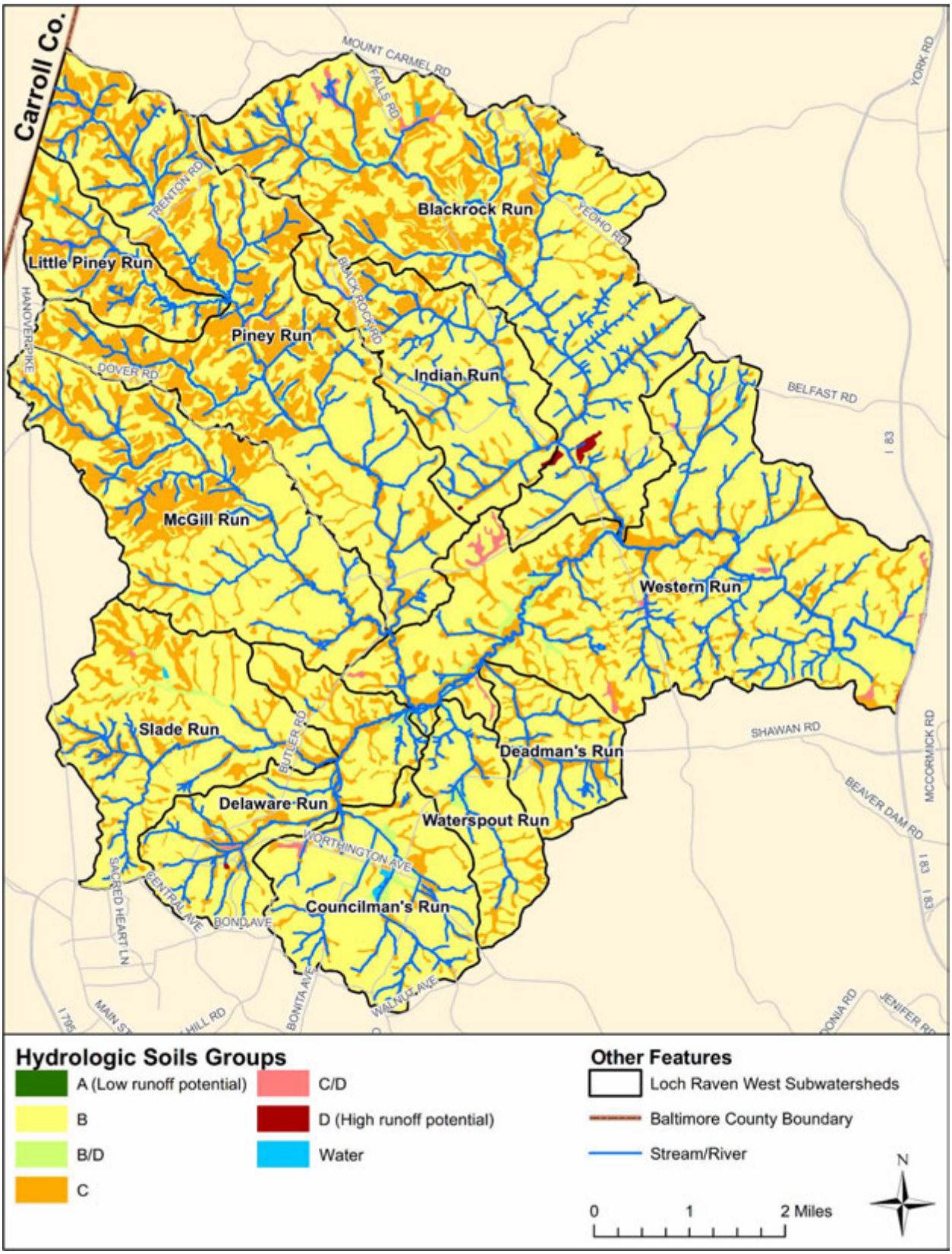

Figure 2-2: Loch Raven West Hydrologic Soils Groups

2.2.5.2 Erodibility

Erodibility is the susceptibility of soil to erosion. It is quantified by the K factor, which is used in the Universal Soil Loss Equation (USLE) developed by USDA's Agricultural Research Service to estimate the rate of erosion and soil loss for a particular site. Soil erodibility is determined based on the physical and chemical properties of the soil, which represent how strongly soil particles cohere to one another. Soils with low K factors indicate low erodibility or high resistance to detachment, and soils with high K factors indicate high erodibility potential. For example, soils high in clay content are the least erodible with K values of about 0.05 to 0.15, and soils with high silt content are the most erodible with K values often greater than 0.4 (IWR, 2002).

Table 2-3 summarizes soil erodibility values in the Loch Raven West watershed by subwatershed. Erodibility K factors range from 0 to 0.49 and were grouped into three categories as follows:

- Low Erodibility (0 ≤ K factor < 0.24);
- Medium Erodibility (0.24 ≤ K factor < 0.32); and
- High Erodibility (0.32 ≤ K factor)

A portion of the soils within the SSURGO data do not have a K factor associated with them; these areas are conveyed in the "N/A" category as seen in Table 2-3 and Figure 2-3.

As shown in Table 2-3 and Figure 2-3, there is a significant presence of highly erodible soils in the Loch Raven West watershed. These highly erodible soils are most evident in the Slade Run and Delaware Run subwatersheds making up 32% of the soils. Soils with low erodibility generally appear to correspond to soils with low and somewhat restricted infiltration rates (pertaining to hydrologic soil group C). The majority of the Loch Raven West watershed soils have moderate infiltration rates (hydrologic soil group B) resulting in higher erodibility. Moderate erodibility soils appear to correspond primarily with soils along the stream valleys with very low infiltration rates (hydrologic soil group D). In some areas, such as locations where mill dams were located along a stream, the soils along particular reaches of these stream valleys may actually exhibit a higher level of erodibility than mapped due to the dam breaching or being removed, as discussed further in Section 3.6. Less than 1% of the total watershed soils do not have an associated K factor in the SSURGO database.

Subwatersheds with larger percentages of highly erodible soils present the greatest potential for addressing soil conservation issues via best management practices (BMPs), such as minimizing bare soil and keeping topsoil in place. Soil erodibility data is also useful in combination with other information such as location of cropland, slope steepness, and distance from streams to determine where other BMPs, such as retirement of highly erodible cropland, are appropriate. High K factor values also serve as a warning for planning of urban activities near streams such as road construction and utility placements.

Table 2-3: Loch Raven West Soil Erodibility Categorization Based on K Factor

	Soil Erodibility Category (%)			
Subwatershed	**Low**	**Medium**	**High**	**N/A**
Piney Run	27.5	45.5	26.9	0.1
Blackrock Run	21.3	50.4	27.9	0.5
Little Piney Run	24.3	49.7	25.6	0.4
Indian Run	19.9	43.1	36.6	0.5
McGill Run	20.1	51.5	28.4	0.0
Western Run	20.0	45.2	34.0	0.8
Slade Run	16.7	39.8	43.4	0.1
Delaware Run	36.6	20.8	42.6	0.1
Councilman's Run	45.4	18.2	36.0	0.5
Waterspout Run	25.0	52.3	22.7	0.0
Deadman's Run	20.3	45.8	33.9	0.0
Total	***24.1***	***43.6***	***32.0***	***0.3***

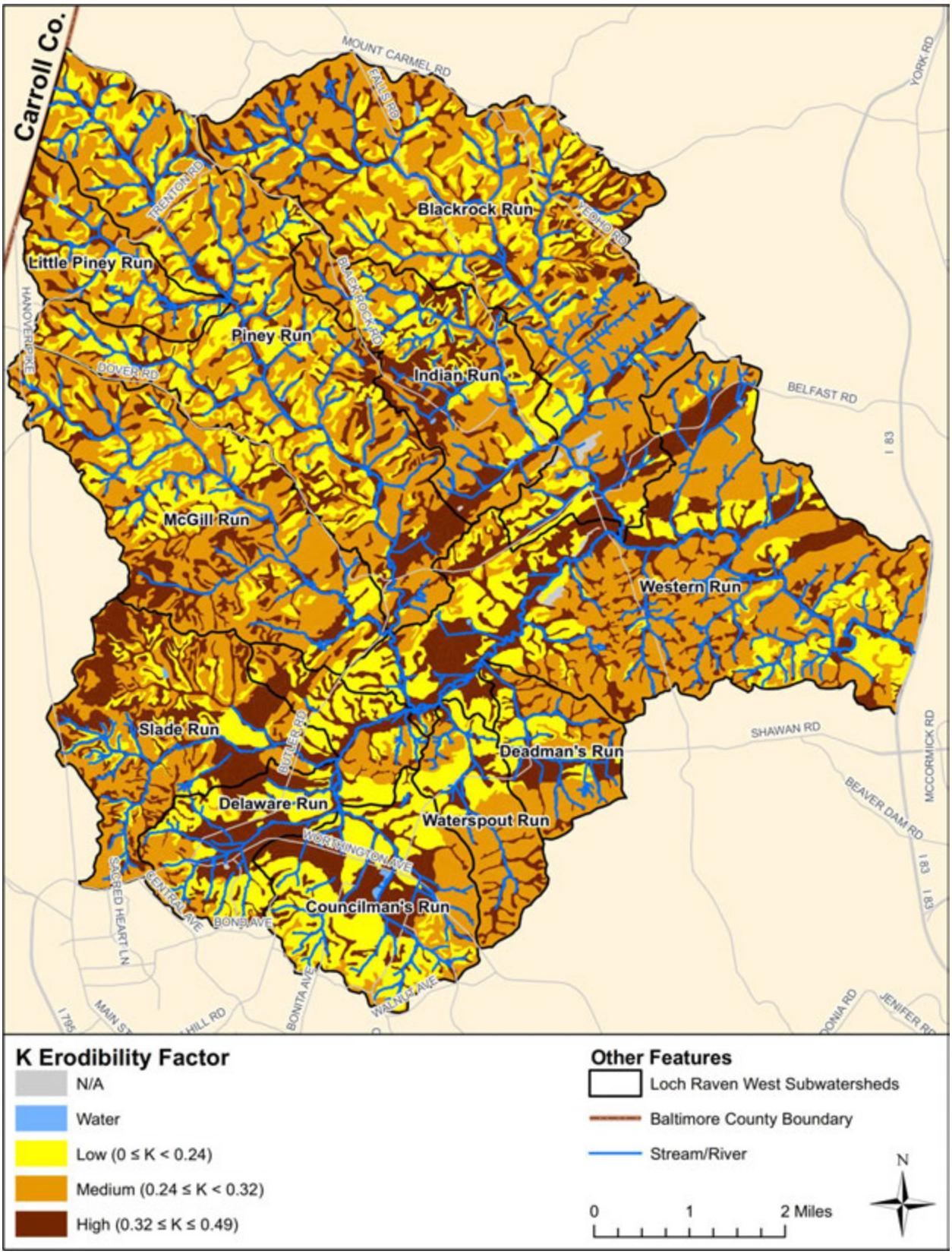

Figure 2-3: Loch Raven West Soil Erodibility Based on K Factor

2.2.6 Forest Cover/Forest Canopy

Forests provide the greatest protection among land cover types for water and soil quality. In pristine systems, forest and soils co-evolve, shaping the hydrologic cycle; these systems operate within a natural range of variability, assuring healthy habitat and water quality. The Loch Raven West watershed consisted mainly of old-growth forest prior to colonial settlement, as is true for the entire Chesapeake Bay basin. Although the watershed is relatively rural, deforestation has occurred, and even in developed systems, forest cover can still provide many benefits such as reducing erosion potential and protecting water quality if carefully planned and conserved.

For the Loch Raven West watershed, forest cover and forest canopy were both examined. Forest cover implies not only the presence of a tree canopy, but also understory vegetation with little or no impervious structures. Forest canopy indicates that a tree canopy is present, but the land use beneath the canopy may be pavement, homes, turf grass, agricultural land, etc.

Loch Raven West forest cover data was obtained from the Maryland Department of Planning (MDP) 2010 land use/land cover GIS shapefile. Forest cover included deciduous, evergreen, and mixed forest classifications. Table 2-4 lists the number of acres of forest cover for each subwatershed in the Loch Raven West watershed, along with the percent of the watershed that is forested. Figure 2-4 shows the distribution of forest cover within the watershed. The Loch Raven West watershed contains approximately 11,898 acres of forest cover, or 30.9% of the watershed. The highest forest cover percentages are found in Waterspout Run and Slade Run with 39.2% and 36.4% cover, respectively. The subwatersheds with the lowest forest cover percentages are Western Run and Delaware Run with 23.6% and 23.0%. These areas are located in subwatersheds with some of the highest combinations of residential and agricultural land use and may offer some potential opportunity for reforestation through land preservation.

Forest canopy data for the Loch Raven West watershed was obtained from 2007 Urban Tree Canopy Land Cover spatial data for Baltimore County. This data was created based on 2007 infrared aerial imagery and 2005 LiDAR data by the University of Vermont Spatial Analysis Laboratory. Using the Baltimore County Impervious area/NLCD data, forest canopy was superimposed to determine which land uses are covered by forest canopy. The land uses were divided into four major categories: forest (see Figure 2-4), agriculture, residential, and other. The other category consists of land uses such as commercial, industrial, institutional, bare ground, etc. that amount to a minor portion of the total watershed. Table 2-5 summarizes the different forest canopied areas in each subwatershed as well as the total percentage of tree canopy present in each subwatershed. Figure 2-5 shows the distribution of forest canopy by land use throughout the watershed. Approximately 45% of the Loch Raven West watershed is shaded with tree canopy. The majority of the canopy resides within the forest cover land use; however a significant portion of canopy is also present within the residential and agricultural land use.

Forest canopy adds between 9-25% of additional canopy coverage compared to forest cover alone. Notable differences are shown in Delaware Run and Deadman's Run, where the forest canopy increases by 23% and 25%, respectively. The subwatersheds with the least forest canopy increases are Piney Run and Indian Run with increases of only 9% and 10%, respectively. Table 2-5 shows that forest canopy is also

slightly higher across the agricultural land use than across the residential land use in the Loch Raven West watershed.

Table 2-4: Loch Raven West Forest Cover by Subwatershed

Subwatershed	Total Acres	Forested Acres	% Forested
Blackrock Run	7,117	2,433	34.2%
Councilman's Run	2,436	776	31.9%
Deadman's Run	1,098	267	24.3%
Delaware Run	2,283	524	23.0%
Indian Run	2,454	858	35.0%
Little Piney Run	1,257	346	27.5%
McGill Run	4,077	1,432	35.1%
Piney Run	6,244	1,998	32.0%
Slade Run	2,849	1,036	36.4%
Waterspout Run	1,163	456	39.2%
Western Run	7,510	1,773	23.6%
Total	***38,488***	***11,898***	***30.9%***

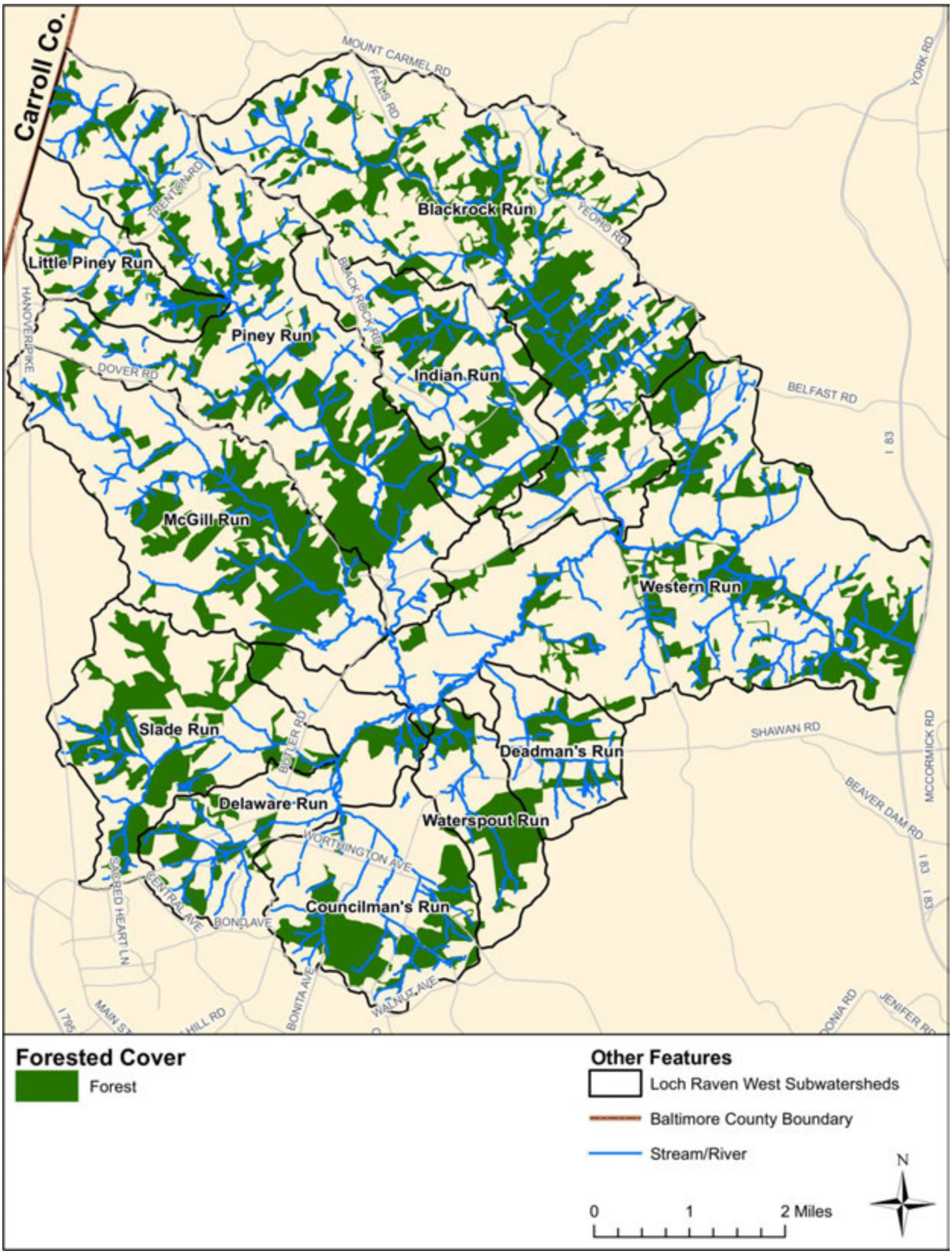

Figure 2-4: Loch Raven West Forest Cover

Table 2-5: Loch Raven West Acres of Forest Canopy per Land Use Classification

Subwatershed	Forest	Agriculture	Residential	Other	Total Forest Canopy	% Forest Canopy
Piney Run	1,794	615	164	7	2,580	41.3%
Blackrock Run	2,206	532	666	25	3,429	48.2%
Little Piney Run	318	96	99	53	565	44.9%
Indian Run	773	243	85	0	1,102	44.9%
McGill Run	1,290	382	180	24	1,877	46.0%
Western Run	1,564	786	651	44	3,045	40.6%
Slade Run	936	265	160	21	1,382	48.5%
Delaware Run	470	169	377	22	1,038	45.5%
Councilman's Run	700	113	395	1	1,208	49.6%
Waterspout Run	433	50	124	0	608	52.3%
Deadman's Run	235	105	168	38	545	49.7%
Total	***10,719***	***3,356***	***3,069***	***235***	***17,380***	***45.2%***

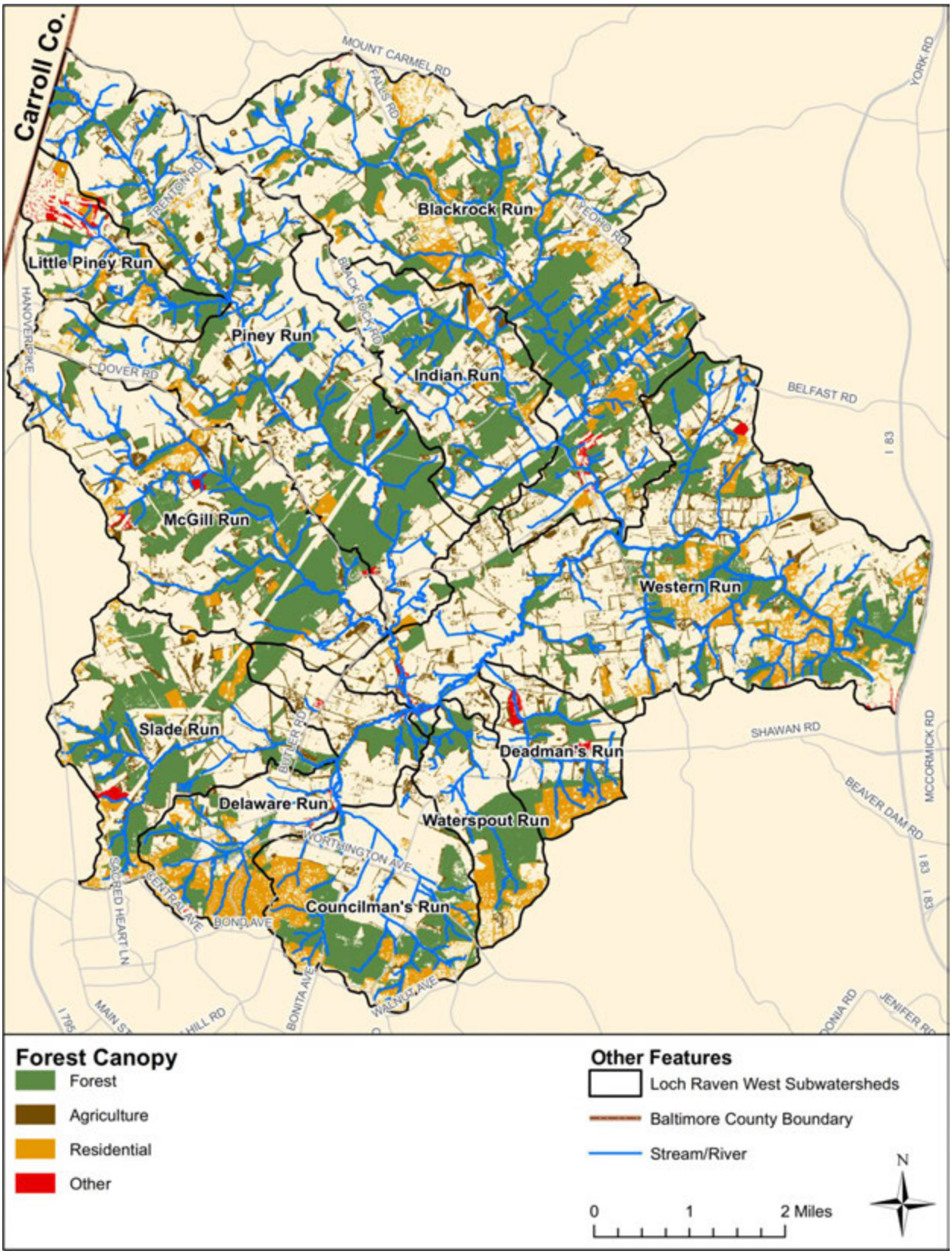

Figure 2-5: Loch Raven West Forest Canopy by Land Use Classification

2.2.7 Stream Systems

All of the streams within a watershed make up its stream system, the most visible part of the hydrologic cycle. Streams are the flowing surface waters of the watershed, and while they are separate from groundwater and standing surface water such as lakes, they are closely connected to both. The stream system is an intrinsic part of the landscape and closely reflects conditions on the land. Streams are a fundamental natural resource with numerous benefits for plants, animals, and humans. Maintaining a healthy stream system is a priority for many individuals and organizations and requires ensuring that stream flows and water quality closely mimic the conditions found in un-impacted watersheds.

2.2.7.1 Stream System Characteristics

The subwatersheds with the most stream miles include Piney Run, Blackrock Run, and Western Run, which together comprise approximately 57% of all the stream miles in the watershed. As previously mentioned, the Loch Raven West watershed was divided into a smaller series of 11 subwatersheds by Baltimore County. These subwatersheds were delineated based on the drainage areas contributing to major creeks and rivers as well as geographic/property considerations within the watershed. Figure 2-6 shows the system of streams and subwatersheds comprising the Loch Raven West watershed. Table 2-6 summarizes the number of linear stream miles in each subwatershed along with stream density, defined as miles of stream per square mile of subwatershed area. Comparing the stream density of each subwatershed gives an indication of how much the streams may have been altered, especially headwater streams. Headwater streams are the smaller tributaries that carry water from the upper reaches of the watershed to the main channel. As an area becomes urbanized, headwater streams are often filled in or incorporated into storm sewer systems (i.e. piped). This alters the hydrologic connectivity and physical habitat of the headwater streams and consequently, the watershed as a whole. Comparing the stream densities of each subwatershed in Table 2-6 with the land uses in Table 2-8 shows a correlation between stream density and percent cover of forest and agriculture. Although, generally, a higher percentage of forest land use corresponds to a higher stream density, in Loch Raven West, the two subwatersheds with the greatest stream density, Western Run and Delaware Run, have the lowest percentage of forest land. This departure from the normal correlation of forest land use to stream density may be due to the overall rural nature of the watershed and indicates that there has likely been less stream modification in the agricultural areas of this watershed than is seen in more urban watersheds. Compared to the 16 completed SWAPs in Baltimore County that calculated stream density, Loch Raven West has one of the highest overall stream density at 6.5 stream miles/sq. miles. Other watersheds have an average density between 0.9 and 7.0 steam miles/sq. miles, indicating that Loch Raven West has relatively unaltered stream channels.

There are nearly 393 miles of stream in the Loch Raven West watershed, all of which drain to the Gunpowder River, which then discharges into the Chesapeake Bay. Stream data for the watershed is provided by Baltimore County OIT based on the hydrology lines captured from 3D compilation processes using imagery captured in 2008.

Table 2-6: Loch Raven West Stream Mileage and Density

Subwatershed	Area (Sq. Miles)	Stream Miles	Stream Density (mi./sq. mi.)
Piney Run	9.76	63.51	6.51
Blackrock Run	11.12	70.30	6.32
Little Piney Run	1.96	9.67	4.92
Indian Run	3.83	19.91	5.19
McGill Run	6.37	42.82	6.72
Western Run	11.73	88.49	7.54
Slade Run	4.45	30.85	6.93
Delaware Run	3.57	25.32	7.10
Councilman's Run	3.81	20.58	5.41
Waterspout Run	1.82	9.27	5.10
Deadman's Run	1.72	11.81	6.89
Total	***60.14***	***392.52***	***6.53***

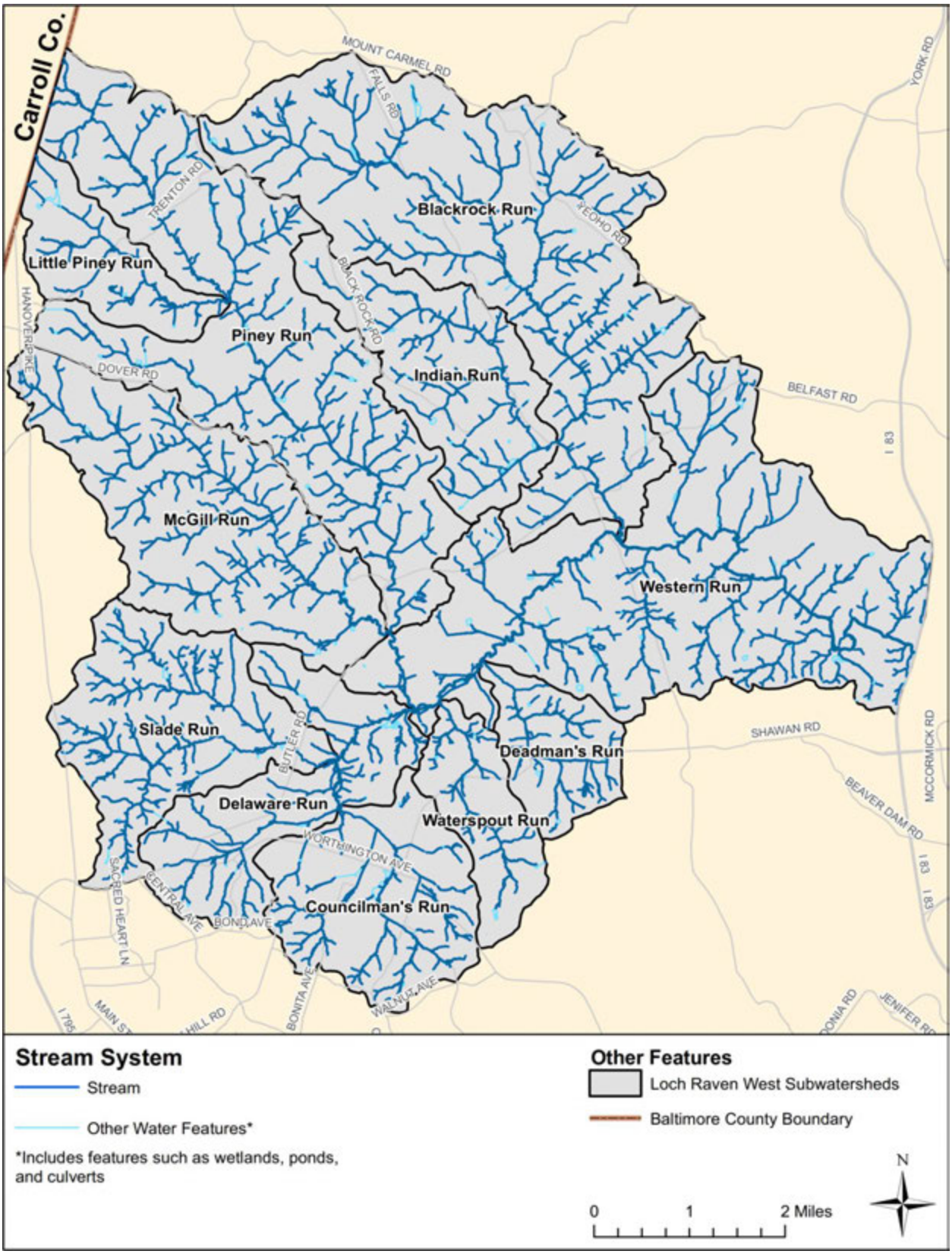

Figure 2-6: Loch Raven West Stream System

2.2.7.2 Stream Riparian Buffers

Riparian buffer refers to the vegetated area adjacent to streams and other water bodies that protect them from pollutant loads while also providing bank stabilization and habitat. Forested buffer areas along streams play a crucial role in improving water quality and flood mitigation as they can intercept and reduce surface runoff, stabilize stream banks, trap sediment, and provide habitat for various types of terrestrial and aquatic life. For example, tree roots capture and remove pollutants including excess nutrients such as nitrogen from shallow flowing water; the tree root structure also holds together the soil to reduce erosion potential and slows water flow which reduces sediment loads and flooding risk. Tree canopies provide shade that helps to maintain the cooler water temperatures preferred by many aquatic organisms, particularly cold-water species like trout, which are known to inhabit the streams of this watershed. In smaller tributaries, terrestrial plant material that falls into the stream is the primary source of food for aquatic life. While leaves provide seasonal food for stream life at the base of the food chain, fallen tree branches and trunks provide a more consistent, slow-release food source throughout the year. Tree roots and snags also offer habitat and spawning areas for fish and other aquatic species.

Maintaining healthy streams and forest buffers are important for reducing nutrient and sediment loads to the Loch Raven West watershed, and thus to the Chesapeake Bay. When stream riparian buffers are converted from forest to agriculture or urban development, many of these benefits are lost and stream health declines. Riparian buffer zones can be re-established or preserved as a BMP to reduce land use impacts by intercepting and controlling pollutants entering a water body.

The condition of stream riparian buffers in the Loch Raven West watershed was analyzed based on a 100-foot buffer on both sides of all streams. It should be noted that this 100-foot buffer is different than the regulated “forest buffer” mentioned in Article 33, Title 3 of the Baltimore County Code. The regulated forest buffer is used primarily as a setback when development is to occur near a stream. For this analysis, the condition of the riparian buffer was classified using three categories: impervious, open pervious, or forest. The stream data described in the previous section were used as a base to create the 100-foot buffer. The road and building data and the urban tree canopy data were overlain with the 100-foot buffer area along each stream to obtain the impervious and forested areas lying within the buffer zone, respectively. Remaining areas that were not impervious or forested were classified as open pervious. Table 2-7 summarizes stream riparian buffer conditions by subwatershed and the spatial distribution is shown in Figure 2-7.

The largest percentage of the riparian buffers falls under open pervious land cover (approximately 57%), corresponding to the high percentage of agricultural land in the watershed. In comparison, total impervious areas within the stream riparian buffer zones are reasonably low at approximately 1.2% for the watershed, which is indicative of the rural setting of the watershed. Councilman’s Run has the highest subwatershed percentage of impervious area in the buffer zone at approximately 2%. Western Run has the largest overall area of impervious land in the buffer zone at approximately 25 acres, equating to 0.3% of the total buffer for the subwatershed. Though relatively low values when compared with a more urban watershed, these areas may represent potential opportunities for impervious cover removal or buffer establishment. The subwatershed with the highest open pervious acreage in the buffer zone is Western Run with 972 acres and may present opportunities for potential buffer reforestation efforts.

The subwatersheds with the most significant acreage of forested riparian buffer are Blackrock Run and Western Run with approximately 622 and 543 acres, respectively. These areas may present potential preservation opportunities. It is noteworthy that approximately 42% of all subwatershed riparian buffers are forested. These buffers are maintained throughout the watershed, and offer preservation and public awareness opportunities.

Table 2-7: Loch Raven West Land Cover in the 100-ft Stream Buffer

	IMPERVIOUS		OPEN PERVIOUS		FOREST		Total	Total % of
Subwatershed	Acres	%	Acres	%	Acres	%	Acres	Watershed
Piney Run	9.6	0.8%	727.9	59.6%	484.0	39.6%	1,221.5	15.5%
Blackrock Run	14.7	1.1%	745.9	54.0%	621.6	45.0%	1,382.2	17.6%
Little Piney Run	2.3	1.0%	118.5	52.3%	105.6	46.7%	226.3	2.9%
Indian Run	6.6	1.4%	258.2	55.5%	200.1	43.0%	465.0	5.9%
McGill Run	6.0	0.7%	475.0	54.3%	394.4	45.1%	875.4	11.1%
Western Run	24.5	1.6%	971.5	63.1%	543.3	35.3%	1,539.3	19.6%
Slade Run	5.8	0.8%	334.5	47.5%	363.5	51.6%	703.7	9.0%
Delaware Run	7.9	1.6%	333.5	68.0%	149.3	30.4%	490.6	6.2%
Councilman's Run	9.4	2.0%	272.8	57.3%	193.6	40.7%	475.8	6.1%
Waterspout Run	1.1	0.5%	83.0	39.5%	126.0	60.0%	210.1	2.7%
Deadman's Run	4.5	1.7%	182.2	68.3%	79.9	30.0%	266.6	3.4%
Total	***92.5***	***1.2%***	***4,502.8***	***57.3%***	***3,261.2***	***41.5%***	***7,856.6***	***100.0%***

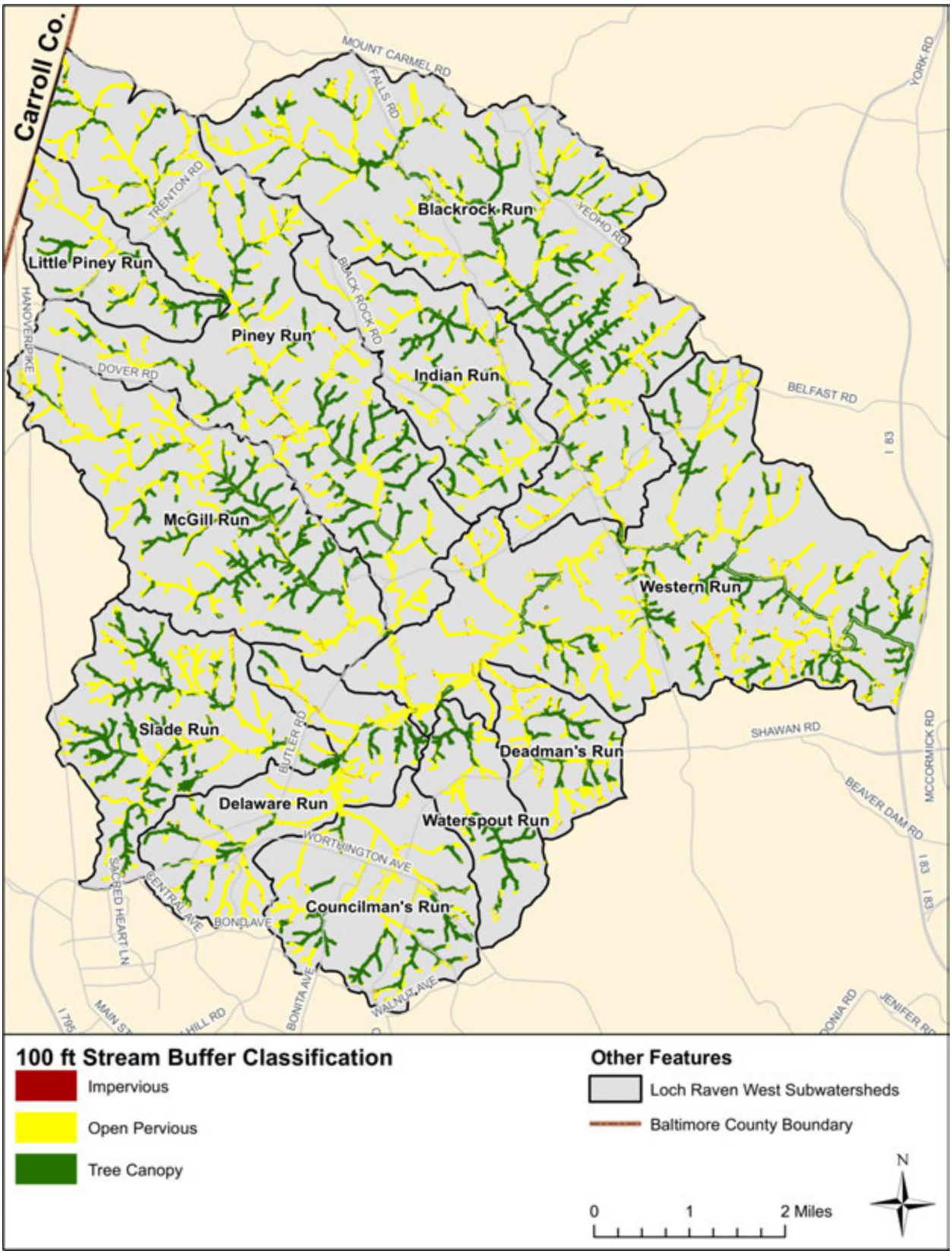

Figure 2-7: Loch Raven West 100-ft Stream Buffer Condition

2.2.7.3 Tier II High Quality Waters

The Clean Water Act requires regulations that set goals for and protect each States' waters. Maryland's anti-degradation policy has been promulgated to provide implementation of more restrictive planning efforts in areas where Tier II (high quality) waters have been designated. This implementation has the greatest immediate effect on local government planning due to higher standards for discharge into Tier II waters (MDE, Maryland's High Quality Waters (Tier II), 2014a). Catchments that drain to Tier II waters are under regulatory anti-degradation protection that exceeds minimum applicable water quality criteria and standards. Currently, Tier II streams are identified according to fish and benthic indices of biotic integrity. Streams listed as Tier II waters will always remain Tier II waters.

The Loch Raven West watershed contains two stream segments classified as Tier II waters located in the Blackrock Run and Delaware Run subwatersheds. The Tier II segment in Blackrock Run shares a Tier II catchment that encompasses Blackrock Run and Indian Run. This catchment is listed as having no assimilative capacity remaining, meaning that the stream is approaching or below water quality standards and any future source of pollution (i.e. land development) must be treated to prevent any further degradation to the stream. The Tier II segment in Delaware Run shares a Tier II catchment that encompasses Slade Run and Councilman's Run. This catchment is listed as having some assimilative capacity remaining, meaning the water body still has the natural capacity to dilute and absorb pollutants without exceeding predetermined water quality standards. Tier II streams where water quality standards have been exceeded are considered impaired. Figure 2-8 shows the location of Tier II stream segments in the watershed as well as their corresponding catchment areas.

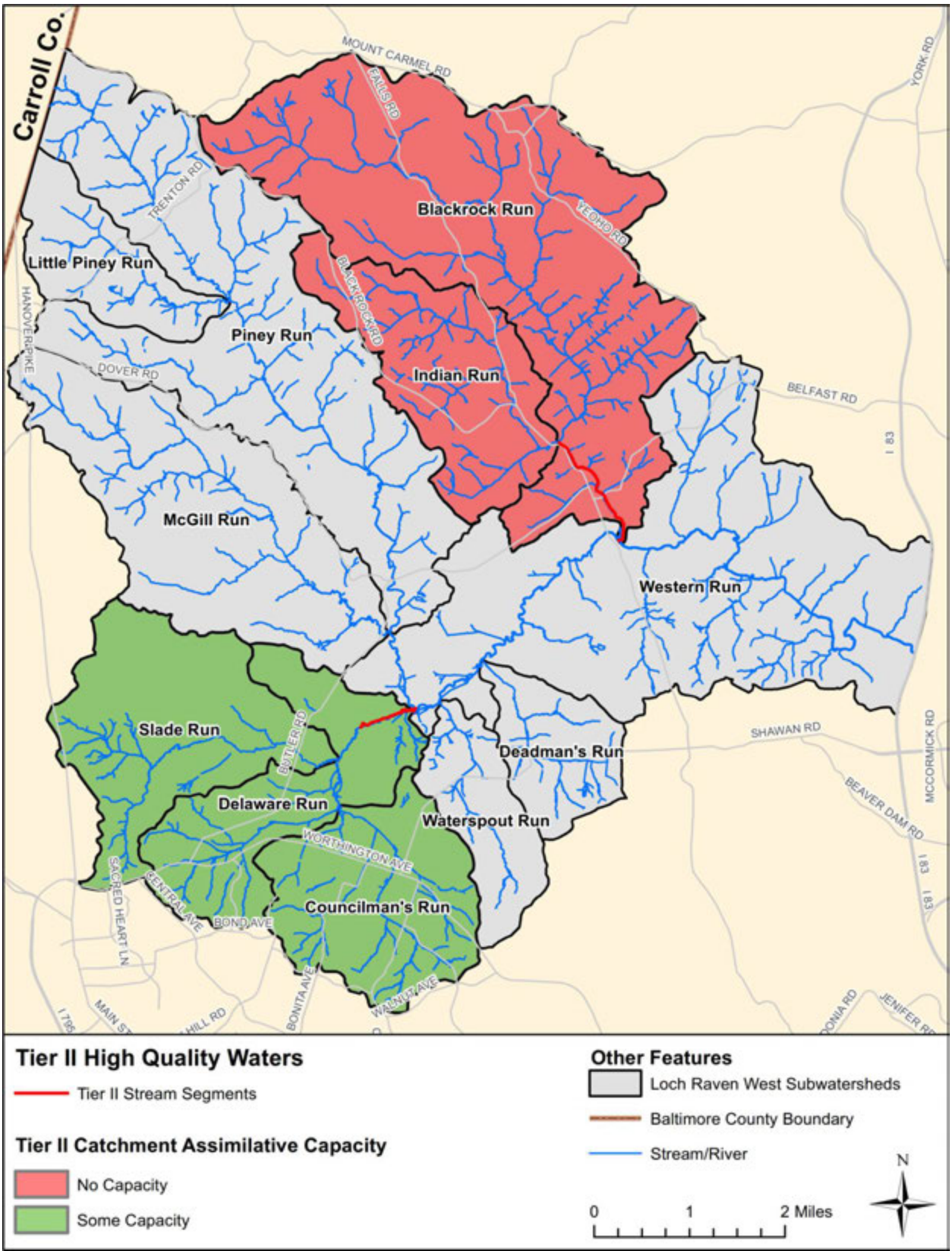

Figure 2-8: Tier II Waters within Loch Raven West

2.3 The Human Modified Landscape

Human activities have altered the natural landscape over time through the use of land and water resources. The intensity of development activities has increased since the colonization of Maryland in the 1600s, which has resulted in environmental impacts to both terrestrial and aquatic ecosystems. This section describes the characteristics of the human modified landscape and how it is associated with impacts to the natural ecosystem of the Loch Raven West watershed. This includes a description of land use and land cover, population, impervious cover, drinking water, wastewater, stormwater systems, discharge permits, and zoning.

2.3.1 Land Use and Land Cover

Land use represents the types of human activities taking place within a watershed and has pronounced impacts on water quality and habitat. The extent of these impacts, including types and amounts of pollutants generated, will vary depending on the land uses that are present in the watershed. As discussed previously, a forested watershed has the ability to absorb pollutants such as sediment and nutrients and to reduce the flow rate of runoff into streams. Developed areas have impervious surfaces that block the natural infiltration of precipitation into the ground. These impervious surfaces include roads, parking lots, roofs, and other man-made constructions. Unlike most natural surfaces, impervious surfaces tend to concentrate stormwater runoff, accelerate flow rates, and direct polluted stormwater to the nearest stream. This behavior can cause bank erosion and destruction of in-stream and riparian habitat of the receiving water body and also prevent infiltration from occurring that would otherwise filter pollutants and recharge groundwater aquifers that help to maintain base flow in a stream channel. For these reasons, undeveloped watersheds and those with smaller amounts of impervious surfaces tend to have better water quality in local streams than developed watersheds with larger amounts of impervious surfaces. In addition, agricultural land can contribute to increases in sediment, nutrients, pesticides/herbicides, and fecal coliform bacteria in streams if not properly managed.

MDP develops statewide land use/land cover spatial data to provide a general overview of predominant land cover and usage and to monitor development activities throughout the state. The land use/land cover delineations are based on high altitude aerial photography and satellite imagery. In this report, land use analyses were performed using 2010 MDP land use spatial data provided by Baltimore County OIT. Table 2-8 summarizes land use categories in the Loch Raven West watershed and their percent composition in each subwatershed. Figure 2-9 illustrates the land use/land cover distribution in the watershed.

The predominant land use types present within the Loch Raven West watershed are agriculture and forest, making up approximately 53.9% and 30.9% of the total watershed area, respectively. Additionally, very low and low density residential, combined, cover approximately 5,104 acres or 13.3% of the total watershed area. These four land use classifications equate to 98% of the total watershed area. The remaining 2% is divided between the remaining land use/land cover classifications (commercial, industrial, bare ground, etc.), each covering less than 1% of the total watershed area. Although a much smaller percentage compared to the more rural land use types, these areas cover approximately 728 acres of the watershed. Two golf courses contribute a large percentage of the total open urban land use in the watershed. The institutional areas such as schools, churches, medical facilities, and government offices

located in the watershed may present opportunities to initiate environmentally sensitive management of these properties and provide opportunities for public outreach and education that promotes an increased level of environmental awareness.

The distribution of predominant land use type (agriculture and forest) coverage varies between the subwatersheds within Loch Raven West. Waterspout Run contains the highest percentage of forest coverage at 39.2%. The subwatersheds with the highest percentages of residential areas include Deadman's Run, Councilman's Run, and Waterspout Run (22% to 24%). Residential areas present an opportunity for community involvement in restoration efforts, neighborhood pollutant source control, and environmental stewardship. Piney Run, Indian Run, McGill Run, Western Run, Slade Run, Delaware Run, and Deadman's Run are primarily agricultural, each containing more than 50% agricultural land use/land cover. These areas may indicate potential sources of agriculturally-based sediment and nutrient loading into the stream system. Little Piney Run contains the highest percentage of other land use/land cover classifications (commercial, industrial, open urban land, etc.) at 16%. The majority of this land is the Piney Branch Golf Course located in the western border of the subwatershed.

Table 2-8: Loch Raven West Land Use/Land Cover Classification (%)

Subwatershed	Very Low Density Residential	Low Density Residential	Medium/High Density Residential	Commercial	Industrial	Institutional	Open Urban Land	Agriculture - Cropland/Pasture/etc.	Deciduous/Evergreen/Mixed Forest	Brush	Water/Wetlands	Bare Ground	Transportation
Piney Run	2.4	2.9	0.2	0.0	0.0	0.1	0.2	62.2	32.0	0.0	0.0	0.0	0.0
Blackrock Run	7.7	8.0	0.4	0.4	0.0	0.3	0.0	48.7	34.2	0.0	0.0	0.3	0.0
Little Piney Run	7.2	7.1	0.1	0.0	0.0	0.0	15.9	42.2	27.5	0.0	0.0	0.0	0.0
Indian Run	2.7	3.6	0.0	0.0	0.0	0.0	0.1	58.7	35.0	0.0	0.0	0.0	0.0
McGill Run	2.6	5.1	0.5	0.4	0.0	0.1	0.1	55.4	35.1	0.7	0.0	0.0	0.0
Western Run	6.5	9.8	0.0	0.0	0.0	0.0	0.7	58.4	23.6	0.6	0.0	0.0	0.3
Slade Run	4.4	4.8	0.8	0.2	0.0	0.0	0.0	52.6	36.4	0.8	0.0	0.0	0.0
Delaware Run	4.0	17.5	1.1	0.5	0.0	0.2	0.0	51.5	23.0	0.3	2.0	0.0	0.0
Councilman's Run	2.4	21.6	0.0	0.0	0.0	0.0	0.0	43.9	31.9	0.0	0.2	0.0	0.0
Waterspout Run	1.0	21.0	0.0	0.0	0.0	0.0	0.0	38.9	39.2	0.0	0.0	0.0	0.0
Deadman's Run	16.0	1.5	0.0	0.0	0.0	0.0	0.0	54.1	24.3	4.2	0.0	0.0	0.0
Total % of SWAP Area	***5.0%***	***8.3%***	***0.3%***	***0.2%***	***0.0%***	***0.1%***	***0.7%***	***53.9%***	***30.9%***	***0.4%***	***0.1%***	***0.1%***	***0.0%***

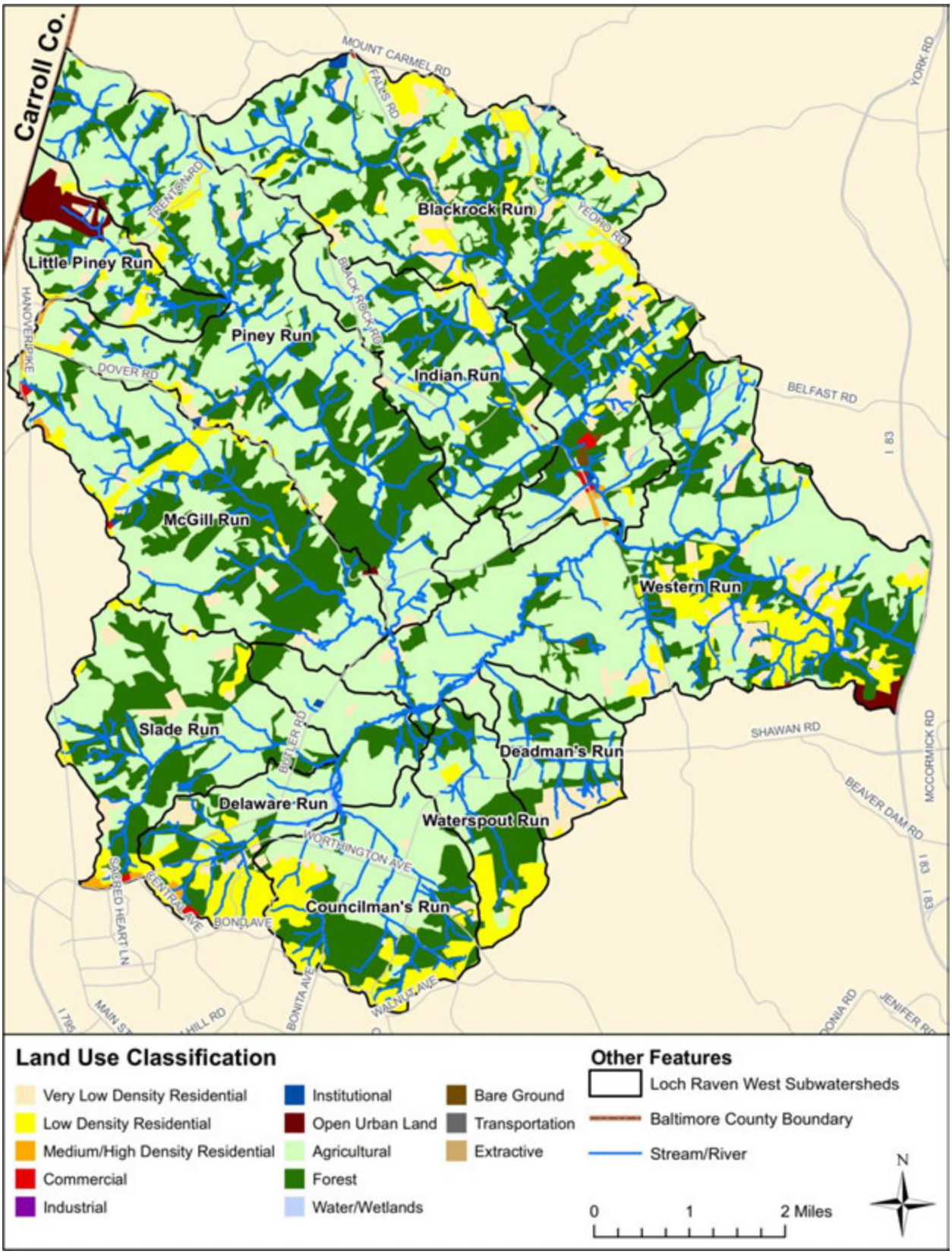

Figure 2-9: Loch Raven West Land Use/Land Cover

2.3.2 Population

Population data provides another method of evaluating the intensity of land use. Areas of concentrated population normally represent more intense use of the land and potential for environmental degradation. Much of the degradation from these locations (typically found in urban and suburban areas) is related to the extent of impervious cover and depletion of natural land covers such as forests that help to protect water resources. Smart growth principles are aimed at directing future growth to areas of existing services and locations where development has already begun. This strategy will result in less conversion of more natural land use categories such as forest and agriculture to residential and commercial land uses, thereby promoting conservation of land uses with less environmental impact.

Population data presented in this section are based on 2010 census blocks and population data from the U.S. Census Bureau. Table 2-9 summarizes total population and population densities with respect to total area and total impervious area for each subwatershed. Higher amounts of impervious area per person could indicate potential sprawl development (such as larger homes), whereas the greater the population density per impervious acre could be more reflective of better clustering and smarter growth patterns. Figure 2-10 shows the distribution of population density throughout the Loch Raven West watershed. Because this watershed is rural and is predominantly very low/low density residential, population density is relatively low compared to most other watersheds in Baltimore County. The subwatershed with the highest population density is Delaware Run. The total population of the Loch Raven West watershed is approximately 10,948 people, with a population density of 0.28 people/acre.

Table 2-9: Loch Raven West Population Data

Subwatershed	Total Population (2010 census)	Total Area (Acres)	Population Density (per acre)	Impervious Area (Acres)	Impervious Acres per person	Population Density (per impervious acre)
Piney Run	1,116	6,244	0.18	119	0.11	9.39
Blackrock Run	1,647	7,117	0.23	185	0.11	8.91
Little Piney Run	346	1,257	0.28	30	0.09	11.49
Indian Run	591	2,454	0.24	55	0.09	10.72
McGill Run	979	4,077	0.24	86	0.09	11.40
Western Run	1,601	7,510	0.21	230	0.14	6.96
Slade Run	914	2,849	0.32	77	0.08	11.92
Delaware Run	1,360	2,283	0.60	88	0.06	15.44
Councilman's Run	1,308	2,436	0.54	96	0.07	13.59
Waterspout Run	468	1,163	0.40	27	0.06	17.22
Deadman's Run	617	1,098	0.56	34	0.06	18.00
Total	***10,948***	***38,488***	***0.28***	***1,027***	***0.09***	***10.7***

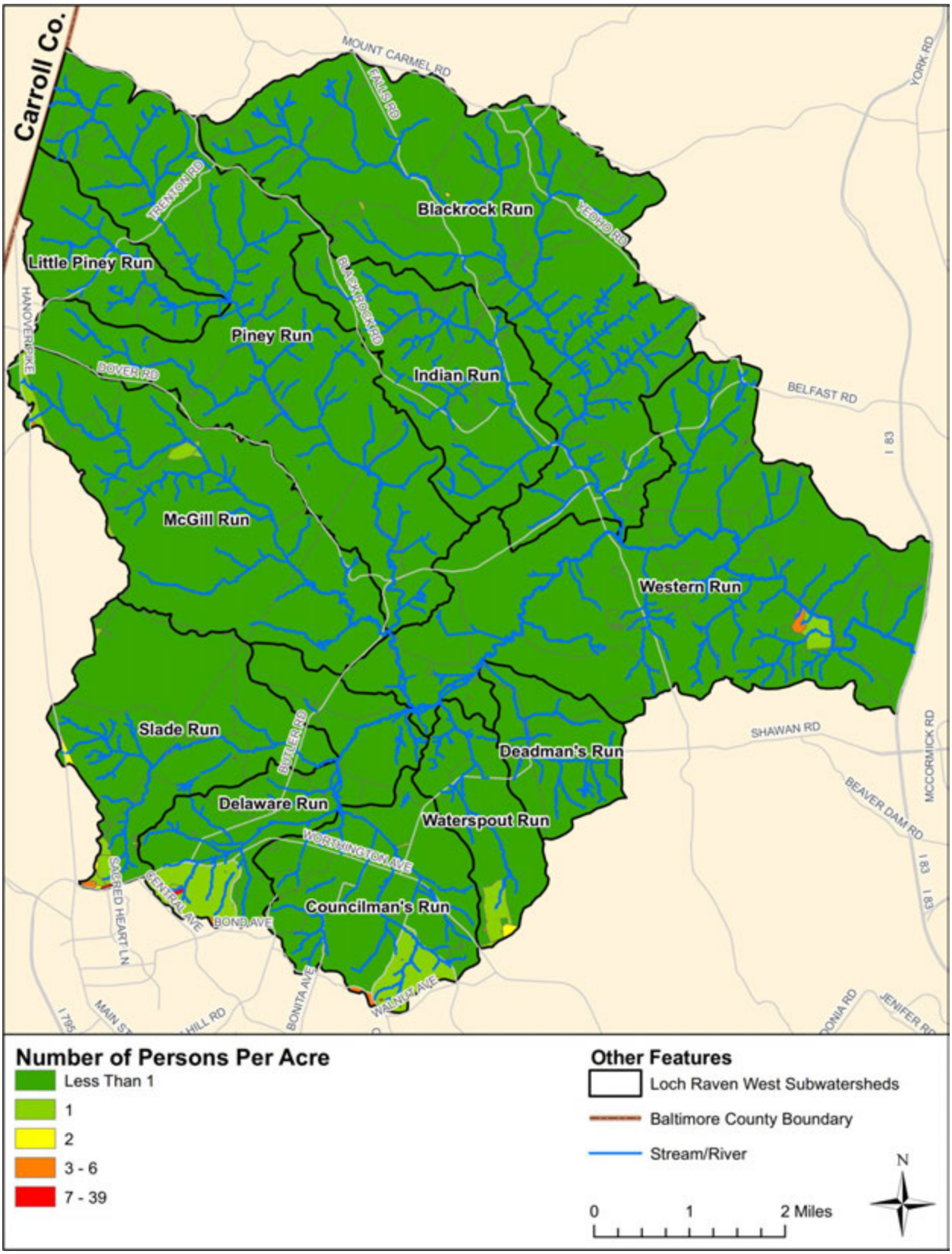

Figure 2-10: Loch Raven West Population Distribution

2.3.3 Impervious Surfaces

Impervious surfaces such as roads, parking lots, roofs, and other paved areas prevent precipitation from naturally infiltrating into the ground. Stormwater runoff from these areas becomes overland flow and is typically concentrated, accelerated, and conveyed directly to the nearest stream. Consequently, the high energy flows of stormwater runoff from impervious surfaces can cause stream erosion and habitat destruction. This runoff is also likely to be more polluted and at a higher temperature than runoff from pervious areas. In general, undeveloped watersheds with small amounts of impervious cover are more likely to have better water quality in local streams than urbanized watersheds with greater amounts of impervious cover.

Impervious cover is a primary factor when determining pollutant characteristics and quantities in stormwater runoff. Research has been conducted to link the degree of urbanization (typically measured by amount of impervious cover) with various watershed-based indicators of water quality such as diversity and abundance of aquatic and terrestrial life. The Center for Watershed Protection (CWP) compiled stream research conducted in various parts of the country and developed a simple model that relates a general description of stream quality to percentage of impervious cover in a watershed. Studies used to develop the impervious cover model measured stream quality based on a variety of indicators such as number of aquatic insect species, stream temperature, channel stability, aquatic habitat, wetland plant diversity, and fish communities present. CWP's impervious cover model is shown in Figure 2-11.

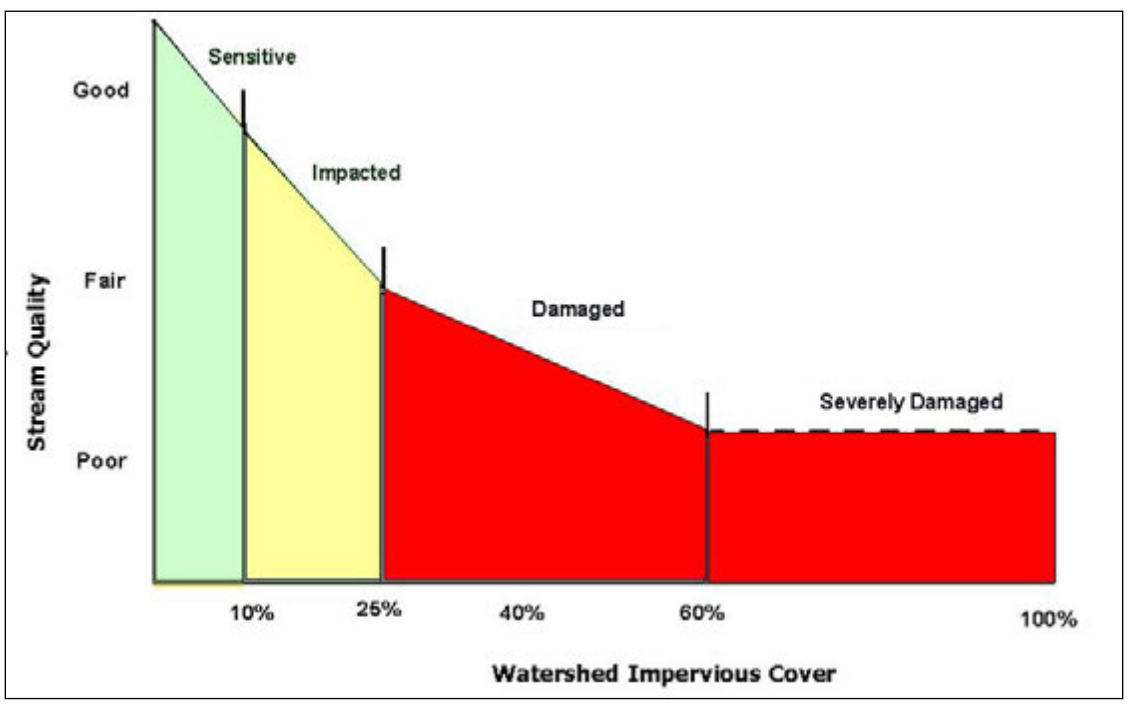

Figure 2-11: Impervious Cover Model (adapted from (CWP, 2003))

Based on the compiled research, CWP determined four classifications that predict stream quality based on watershed imperviousness: sensitive; impacted; damaged; or severely damaged. Watersheds with less than ten percent impervious cover are referred to as sensitive and typically have high quality streams with

stable channels, good habitat conditions, and good to high water quality. These watersheds are considered sensitive because they are susceptible to environmental degradation with increased urbanization and impervious cover. The model predicts that when a watershed reaches between 10 and 25 percent impervious cover, they become impacted and show clear signs of degradation such as erosion, channel widening, and a decline in stream habitat. There is potential to restore streams to a somewhat natural functioning system for watersheds that fall within this category. When a watershed has from 25 to 60 percent impervious cover, streams are classified as damaged and characterized by fair to poor water quality, with unstable or channelized stream channels, severe erosion, and an inability to support aquatic life and provide habitat; many streams in this category are typically channelized, or in some areas, may be piped beneath the impervious surfaces resulting in a lack of continuity between natural riparian areas along the stream corridor.

Figure 2-11 shows that when impervious cover exceeds 60 percent, a watershed is classified as severely damaged and means that most of the natural stream system has diminished. Management of damaged and severely damaged streams may focus on decreasing pollutant loads to downstream receiving waters (e.g., installing BMPs), but the ability to restore natural functions, such as habitat, is unlikely. Restoration efforts may also focus on making the remaining stream systems stable, aesthetically pleasing, and an amenity to the community. It should be noted that the impervious cover model is a simplified approach for classifying the potential stream quality. Although it is based on research, there are inherent model assumptions and limitations that should be considered such as regional variations and scale effects. In addition, while impervious cover is a relevant and significant indicator for watershed health, it is only one of many different factors affecting stream health and contributing to the cumulative impacts of development on water quality. For example, agricultural land uses may also contribute sediment and nutrient loads to receiving waters. Furthermore, the ability of BMPs to offset adverse impacts from urbanized areas is not specifically accounted for in the model (CWP, 2003).

Impervious cover data for the Loch Raven West watershed was obtained from 2015 road and 2015 building spatial data provided by Baltimore County OIT. Impervious area quantities shown in Table 2-10 are the sum of road and building areas. The table also shows the percentage of impervious cover within each subwatershed. It should be noted that parking lots are included in the roads column of Table 2-10, whereas sidewalks are not included. Figure 2-12 illustrates the location of impervious surfaces within the Loch Raven West watershed. The total impervious area calculated is approximately 1,042 acres or 2.7% of the watershed. Subwatersheds with the highest percentage of impervious cover include Delaware Run and Councilman's Run, which are 3.9% and 4.0%, respectively.

Table 2-10: Loch Raven West Impervious Area Estimates

Subwatershed	Total Area (Acres)	Roads (Acres)	Buildings (Acres)	Impervious Area (Acres)	% Impervious	CWP Impervious Rating
Piney Run	6,244	88	31	119	1.9%	Sensitive
Blackrock Run	7,117	138	47	185	2.6%	Sensitive
Little Piney Run	1,257	21	9	30	2.4%	Sensitive
Indian Run	2,454	43	12	55	2.2%	Sensitive
McGill Run	4,077	64	22	86	2.1%	Sensitive
Western Run	7,510	170	60	230	3.1%	Sensitive
Slade Run	2,849	56	20	77	2.7%	Sensitive
Delaware Run	2,283	60	28	88	3.9%	Sensitive
Councilman's Run	2,436	69	27	96	4.0%	Sensitive
Waterspout Run	1,163	18	9	27	2.3%	Sensitive
Deadman's Run	1,098	27	7	34	3.1%	Sensitive
Total	***38,488***	***755***	***272***	***1,027***	***2.7%***	***Sensitive***

Based on the CWP model (Figure 2-11), all of the subwatersheds within the Loch Raven West watershed fall into the sensitive range. For this reason, other watershed indicators can be tracked to determine their additional influence on stream quality such as forest or crop cover.

Figure 2-13 shows the impervious cover ratings for the subwatersheds in the Loch Raven West watershed based on the CWP model. As expected from the rural nature of the watershed and high percentages of forest and agricultural land use, the Loch Raven West watershed does not contain any impacted, damaged, or severely damaged subwatersheds. “Impacted” subwatersheds mainly correspond to those with high amounts of residential development, “damaged” subwatersheds have more commercial development associated with more impervious cover density, and “severely damaged” is correlated with vast development completely altering the natural system. These categories are associated with urbanization and high impervious cover, both of which are not prominent characteristics of the Loch Raven West watershed. Sensitive watersheds are susceptible to impacts from development and need to be protected and conserved to prevent future degradation. This is especially true for the subwatersheds with a comparatively high percentage of impervious area, including Delaware Run and Councilman’s Run, as they are closer to the 10% threshold.

While not a destination for recreational trout fishing, multiple streams in the watershed, including Blackrock Run, Indian Run, and Deadman Run are known to support native brook trout. The rural nature and limited development have left many of the streams habitable for native brook trout, a species that is not typically found in watersheds with more than 4% impervious surface (DNR, 2014b). Once the percentage of impervious surface approaches 5-10%, water temperatures rise, water quality declines, and brown trout begin to replace the more sensitive brook trout population. No trout can survive in streams where surface cover is greater than 10% impervious.

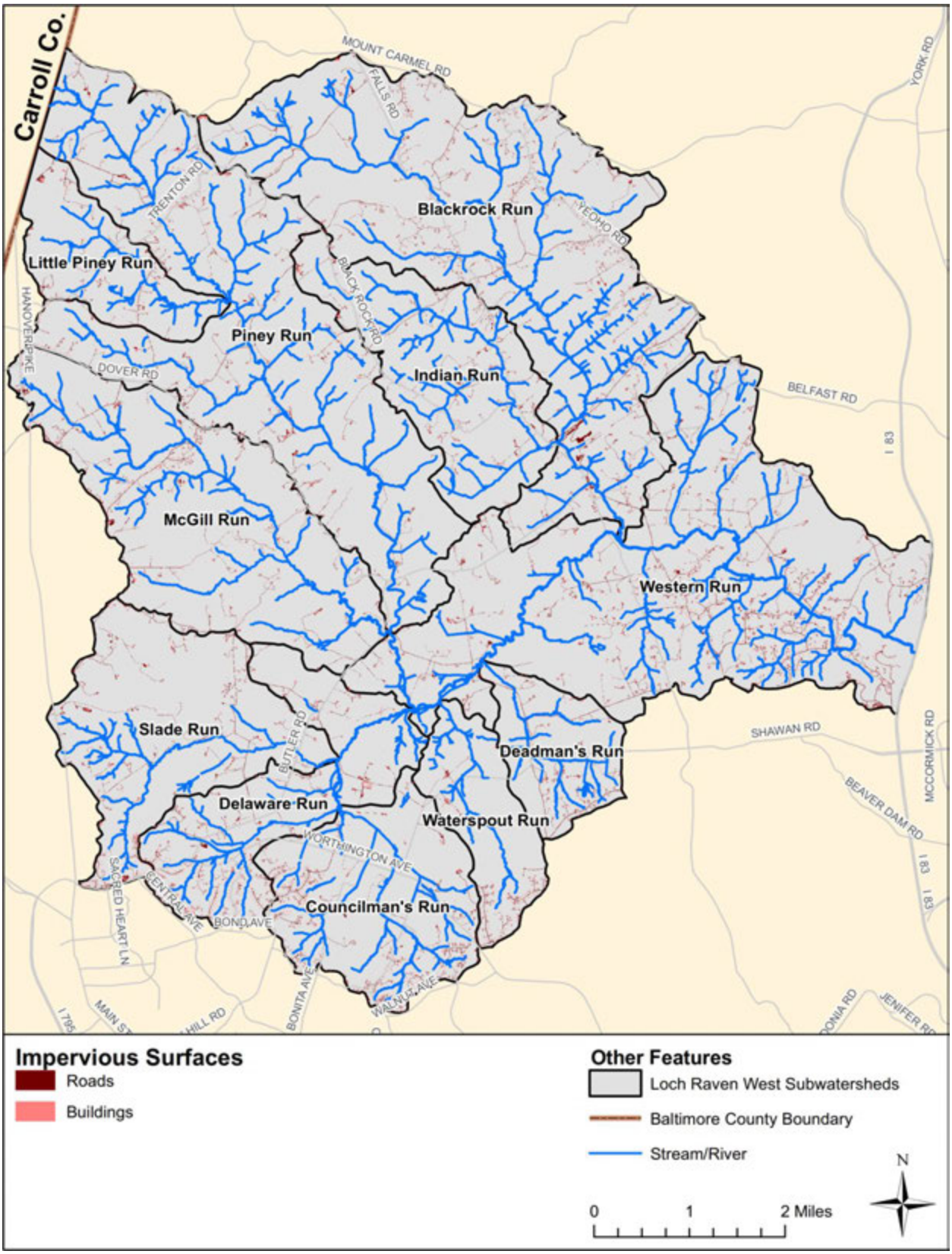

Figure 2-12: Loch Raven West Impervious Surfaces

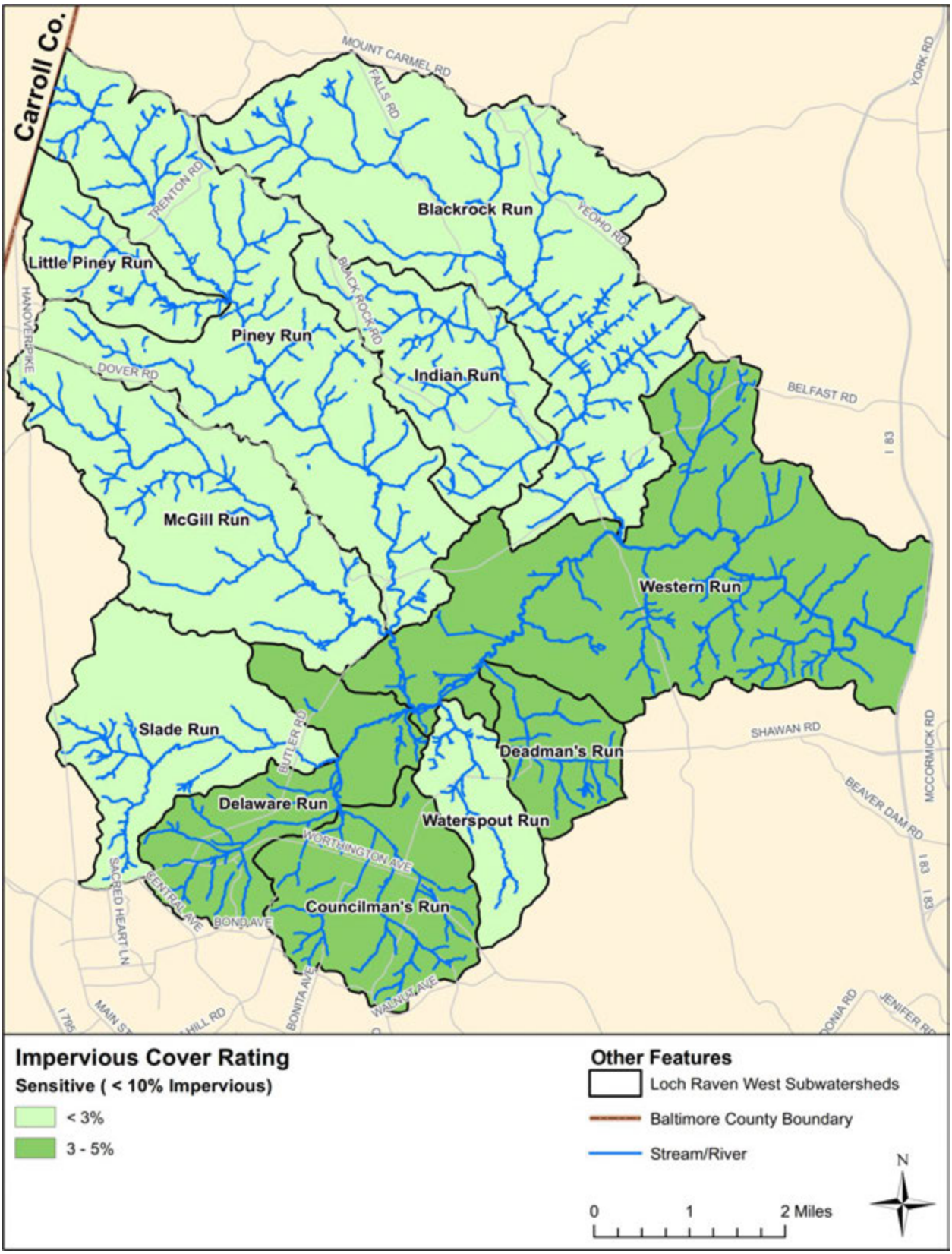

Figure 2-13: Loch Raven West Impervious Cover Ratings

2.3.4 Urban/Rural Demarcation Line

The majority of the Loch Raven West watershed lies outside of the Urban/Rural Demarcation Line (URDL) growth boundary. No public water or sewer services are offered to areas outside of the boundary. The URDL was established by the Baltimore County Planning Board in 1967 to limit growth and preserve natural and agricultural resources. Slade Run, Delaware Run, and Councilman's Run are the only subwatersheds within the Loch Raven West watershed that lie partially within the URDL growth boundary. Table 2-11 summarizes the acreage and percentage of subwatershed areas located within the urban section of the URDL for these three subwatersheds.

Table 2-11: Area of Watershed within Urban Rural Demarcation Line

	Area of Watershed within Urban Rural Demarcation Line		
Subwatershed	**Area within URDL (acres)**	**Area of Subwatershed (acres)**	**% within URDL**
Slade Run	46.4	2,848.6	1.6
Delaware Run	111.7	2,283.4	4.9
Councilman's Run	16.6	2,436.4	0.7
Total Loch Raven West Watershed	***174.7***	***61,435.9***	***0.3***

2.3.5 Drinking Water

Drinking water is a fundamental need for human development. It can be supplied either by public distribution systems or by wells associated with individual developed properties. Having an adequate supply of drinking water and a method for its conveyance is essential to the human population.

2.3.5.1 Public Water Supply

Environmental impacts associated with the public supply of water include the potential for increased residential development with the associated effects of increased impervious cover as discussed in the previous section, as well as the potential for leaks from the system. Leaks from public water supply systems introduce chlorine into the aquatic system which can result in the death of aquatic organisms. In addition, major leaks can cause erosion, which contributes to the sediment load in the stream channels; this can bury aquatic benthic communities and degrade habitat. As most of the Loch Raven West watershed is located outside the URDL, there is no public water supply for the majority of the residents and most rely on well water to meet their drinking water needs. However, the entire watershed is within the drainage area for the Loch Raven Reservoir, which supplies drinking water to the majority of the people residing in the Baltimore area.

The Loch Raven Reservoir is one of three reservoirs owned and managed by Baltimore City to supply drinking water to 1.8 million people in the Baltimore metropolitan area including all of Baltimore City and parts of Baltimore County, Harford County, Carroll County, Howard County, and Anne Arundel County (BMC, 2009). The Loch Raven West watershed encompasses 28% of the reservoir's total drainage area. Therefore, the activities and land uses in the Loch Raven West watershed have a direct impact on the

quality of water in the reservoir. All the tributaries in the watershed are designated as *nontidal cold water and public water supply* (Use III-P), which will be discussed further in Chapter three (COMAR, 2016b).

2.3.5.2 Private Well Supply

The majority of residents and businesses in the Loch Raven West watershed rely on private wells to supply their drinking water needs. The well water quality and quantity is affected by the region's crystalline-rock formations. The aquifers in the Piedmont portion of Baltimore County are susceptible to groundwater contamination because they lack a confining layer, and ground water contamination is generally caused by land use activities in the immediate vicinity of the well (Bolton, 1998). Historically, the overall quality of well water in the study area was found to be within drinking water standards, with limited elevated concentrations of nitrates, lead, pesticides, and chloride, although these concentrations rarely exceeded water quality standards (Bolton, 1998). Baltimore County has also designated areas underlain with Loch Raven Schist as "critical yield areas" as the lower degree of fracturing in the bedrock results in a lower flow of groundwater, and therefore a greater risk of drilling a dry well (EPS, 2011b).

2.3.6 Wastewater

Wastewater produced by human processes must be treated and disposed of properly. This is accomplished through public or private conveyance to a treatment facility or through on-site disposal systems such as septic systems. Residential wastewater consists of all water typically used by residents including wash water, bathroom water, and any other rinse water such as paint brush, floor washing, etc. Commercial and industrial wastewater can contain various contaminants such as metals, organic compounds, detergents, or synthetic compounds depending on the operation. All of these wastewater types have the potential to adversely impact the natural environment.

2.3.6.1 Septic Systems

Properly functioning septic systems provide treatment for nearly all the phosphorus present in wastewater but these systems can leak nitrogen in the form of nitrates into the groundwater. Depending on the location of the system, nitrates may be reduced or eliminated through de-nitrification as the treated water passes through riparian buffers, with forested buffers having a higher level of treatment over grassy buffers. Failing systems can release nitrogen, phosphorus, and other chemicals, contaminating the downstream aquatic environment. They can also result in increased bacterial contamination of nearby streams and therefore increase potential human health concerns. Table 2-12 summarizes the approximate number of septic systems present in the Loch Raven West watershed by subwatershed. Septic system data is based on the 2015 septic and public sewer spatial data from Baltimore County Department of Environmental Protection and Sustainability (EPS). Based on this data, the Western Run subwatershed contains the most septic systems of all subwatersheds, approximately 94% of which are residential. Figure 2-14 shows the distribution of residential and non-residential septic systems throughout the Loch Raven West watershed.

Table 2-12: Loch Raven West Septic Systems by Subwatershed

Subwatershed	Residential	Non-Residential	Total # of Septic Systems
Piney Run	208	26	234
Blackrock Run	454	39	493
Little Piney Run	69	6	75
Indian Run	79	11	90
McGill Run	225	15	240
Western Run	473	30	503
Slade Run	117	9	126
Delaware Run	241	12	253
Councilman's Run	318	6	324
Waterspout Run	93	0	93
Deadman's Run	40	1	41
Total	***2,317***	***155***	***2,472***

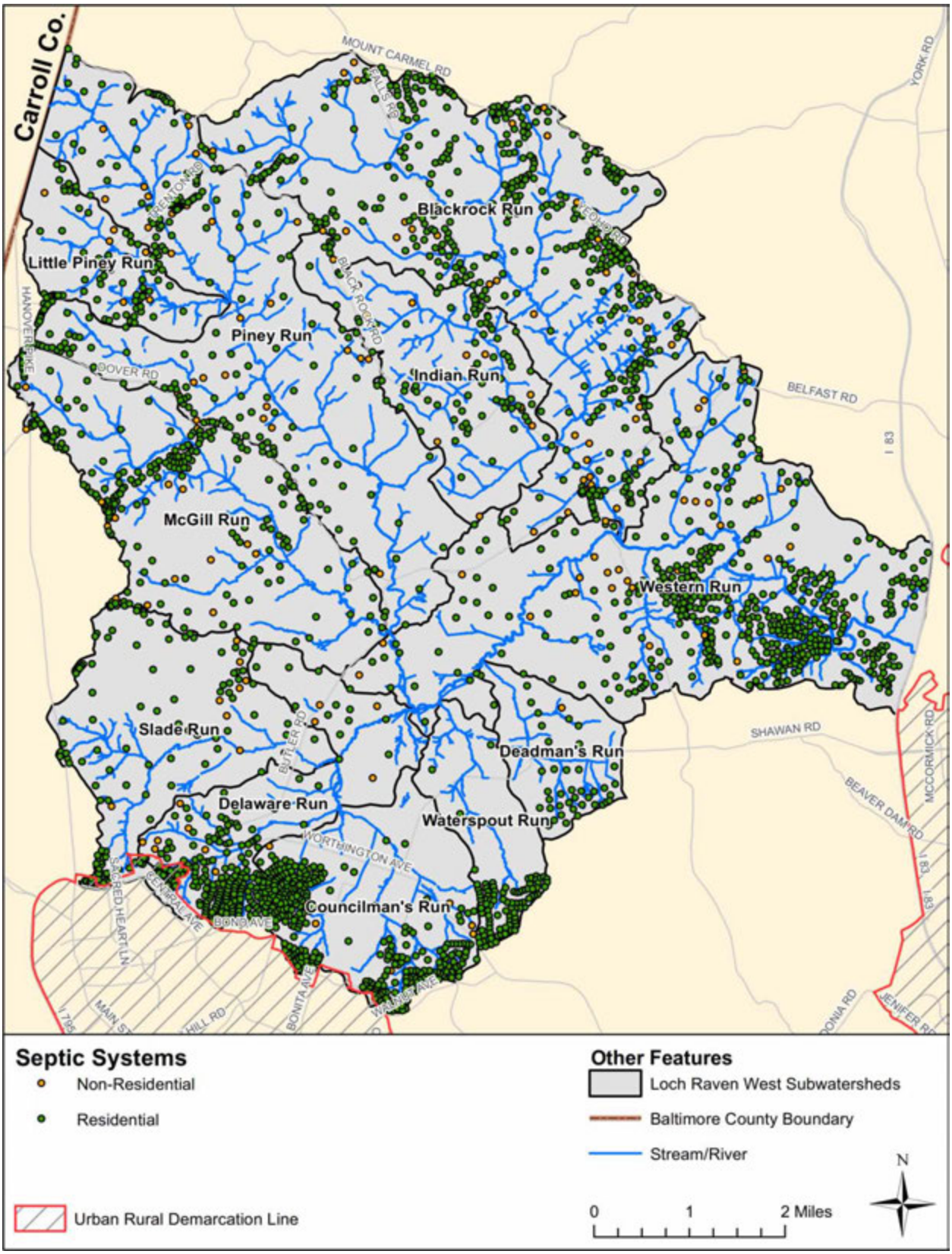

Figure 2-14: Location of Septic Systems in Loch Raven West Watershed

2.3.6.2 Public Sewer

The public sewer system conveys wastewater from individual households or businesses to a facility that treats the wastewater prior to discharge. It consists of the piping system within the public right-of-way and cleanouts on individual properties. Property owners are responsible for the maintenance of their individual cleanouts. The portion of the system within the public right-of-way is owned and maintained by the local government, including the gravity piping system, access manholes, pumping stations, and force mains.

Table 2-13 below summarizes the lengths of public sewer piping in the Loch Raven West watershed by type (gravity main or pressurized main). This data was compiled from gravity main, manhole, and force main spatial data provided by Baltimore County OIT. Table 2-14 summarizes public sewer piping density (length of sewer main per square mile of subwatershed area). As the majority of the Loch Raven West watershed lies outside of the URDL growth boundary, only portions of the Slade Run, Delaware Run, and Councilman's Run subwatersheds contain a public sewer system.

Table 2-13: Public Sewer Piping Length in Loch Raven West Watershed

Subwatershed	Pressurized Main (ft.)	Gravity Main (ft.)	Gravity Main Abandoned (ft.)	Total (ft.)
Slade Run	0	3,091	0	3,091
Delaware Run	0	851	0	851
Councilman's Run	0	230	0	230
Total	***0***	***4,172***	***0***	***4,172***

Table 2-14: Public Sewer Piping Density in Loch Raven West Watershed within the URDL

Subwatershed	Area within URDL (Sq. Miles)	Pressurized Main (ft./sq. mi)	Gravity Main (ft./sq. mi)
Slade Run	0.07	0	42,644
Delaware Run	0.17	0	4,880
Councilman's Run	0.03	0	8,853

Environmental impacts associated with the public sewers are usually the result of sewage overflows. Sanitary sewer overflows (SSOs) typically result from blockages in the sewage system, pumping station failure, or rainwater inflows exceeding pipe capacity. Contamination can also occur during dry weather due to leaks in the sewer system. Water quality concerns related to sewer overflows and leaks include high bacteria concentrations, release of nutrients, increased turbidity (cloudiness), and low dissolved oxygen concentrations.

2.3.6.3 Wastewater Treatment Facilities

There are no wastewater treatment facilities located in the Loch Raven West watershed; however, the Hampstead Wastewater Treatment Plant in Carroll County discharges to Piney Run, which flows into the

Loch Raven West watershed in Baltimore County. The wastewater from the Loch Raven West watershed that is conveyed through public sewers is sent to the Back River Wastewater Treatment Plant. This facility is scheduled for an enhanced nutrient removal (ENR) upgrade to be completed by 2017, which will aid in nitrogen removal for the watershed.

2.3.7 Stormwater

Stormwater is generated during and immediately after storm events. Precipitation that does not seep into the ground becomes stormwater runoff and flows directly to storm drain systems, stormwater treatment facilities, or receiving water bodies. The quantity and characteristics of stormwater runoff are affected by the quantity and intensity of rainfall, soil properties, land slope, and land use/land cover type. Concerns associated with stormwater include 1) volume and rate of runoff and 2) water pollution.

As previously discussed, larger volumes of stormwater runoff are generated from impervious areas than from undeveloped land and pervious surfaces; impervious surfaces prevent infiltration of runoff into the ground, conveying it to stream systems more swiftly and in larger quantities. The increase in runoff rate and volume can cause flooding and stream erosion, which results in destruction of habitat and natural stream functions such as nutrient reduction. In addition, there is less potential for groundwater recharge when there is little or no infiltration of stormwater.

Stormwater runoff can contain various contaminants depending on the land use characteristics and human activities that are taking place within a watershed. The contaminants that are carried by stormwater to the stream systems include pollutants deposited on impervious surfaces and other developed lands from daily human activity. Common pollutants found in impervious surface runoff (such as from highways and parking lots) are sediment, metals, bacteria, nutrients, petroleum, salt, and litter. These pollutants accumulate over time from sources such as road/parking lot maintenance activities (de-icing), vehicles (exhaust and leaks), and accidents or spills, and are washed off the impervious surfaces during storm events. While the runoff from other developed lands, for example agriculture and residential areas, may be moderate compared to highly impervious areas, it can still carry pollutants such as nutrients, bacteria, and chemicals to receiving water bodies. In addition, stormwater transports pollutants introduced by atmospheric deposition into receiving water bodies, most notably nitrogen and mercury.

2.3.7.1 Storm Drainage System

The storm drainage system consists of either drainage swales (roadside ditches) or a curb and gutter system including inlets, piping, and outfalls. Both conveyance methods are intended to prevent flooding and potentially hazardous situations by removing water quickly from roadways. However, the efficiency and watershed impacts associated with each method differ significantly. The curb and gutter system drains stormwater more rapidly from impervious surfaces and typically convey water directly into the stream system. In doing so, however, it conveys increased runoff volumes and more untreated pollutants to receiving water bodies. Currently, Baltimore County's storm drainage system is comprised of approximately 1,760 miles of storm drain pipe, over 72,000 inlet structures, and over 41,000 storm manhole structures.

Table 2-15 summarizes the curb and gutter system components in the Loch Raven West watershed by subwatershed. The summary includes estimates of major outfalls (greater than three feet in diameter) and minor outfalls (less than three feet in diameter), along with corresponding number of inlets and pipe length draining to those outfalls. Storm drain system data used to compile this information was created by Baltimore County EPS based on stormdrain plans and topographic data. This data provides a reasonable approximation of storm drain pipe lengths.

Table 2-16 provides a summary of the percentage of each subwatershed that is covered by the storm drain system, identified as the drainage areas of the storm drain system, divided by the total subwatershed area. It also shows the inlet density (number of inlets per square mile) of each subwatershed.

Table 2-15: Stormwater System Components in Loch Raven West Watershed

	MAJOR (> 3ft)			MINOR (< 3ft)			ALL OUTFALLS		
Subwatershed	Outfalls (#)	Inlets (#)	Pipe (ft.)	Outfalls (#)	Inlets (#)	Pipe (ft.)	Total Outfalls (#)	Total Inlets (#)	Total Piping (ft.)
Piney Run	0	0	0	0	0	0	0	0	0
Blackrock Run	0	0	0	1	2	230	1	2	230
Little Piney Run	0	0	0	1	2	214	1	2	214
Indian Run	0	0	0	0	0	0	0	0	0
McGill Run	0	0	0	0	0	0	0	0	0
Western Run	0	0	0	0	0	0	0	0	0
Slade Run	0	0	0	5	15	1,151	5	15	1,151
Delaware Run	0	0	0	8	15	3,065	8	15	3,065
Councilman's Run	0	0	0	21	48	11,110	21	48	11,110
Waterspout Run	0	0	0	3	9	2,095	3	9	2,095
Deadman's Run	0	0	0	5	9	580	5	9	580
Total	***0***	***0***	***0***	***44***	***100***	***18,445***	***44***	***100***	***18,445***

Table 2-16: Stormwater System Coverage in Loch Raven West Watershed

Subwatershed	Subwatershed Area (Acres)	Stormwater System Drainage Area* (Acres)	Area Covered by Stormwater System (%)	No. of Inlets (#)	Subwatershed Area (Sq. mi.)	Inlet Density (#/sq. mi)
Piney Run	6,244	0.0	0%	0	9.76	0.0
Blackrock Run	7,117	8.8	0%	1	11.12	0.1
Little Piney Run	1,257	6.3	1%	1	1.96	0.5
Indian Run	2,454	0.0	0%	0	3.83	0.0
McGill Run	4,077	0.0	0%	0	6.37	0.0
Western Run	7,510	0.0	0%	0	11.73	0.0
Slade Run	2,849	16.2	1%	5	4.45	1.1
Delaware Run	2,283	29.8	1%	8	3.57	2.2
Councilman's Run	2,436	90.3	4%	21	3.81	5.5
Waterspout Run	1,163	33.5	3%	3	1.82	1.7
Deadman's Run	1,098	45.7	4%	5	1.72	2.9
Total	***38,488***	***230.7***	***1%***	***44***	***60.14***	***0.7***

*Not all outfalls have delineated drainage areas

There are no major outfalls in the Loch Raven West watershed. The subwatershed with the highest number of total outfalls is Councilman's Run with 21 total outfalls. The majority of the Loch Raven West watershed is forest and agriculture, which explains the low number of inlets and outfalls in the storm drain system. Locations where inlets are present signify potential locations for management of pollution sources and community education measures such as storm drain marking.

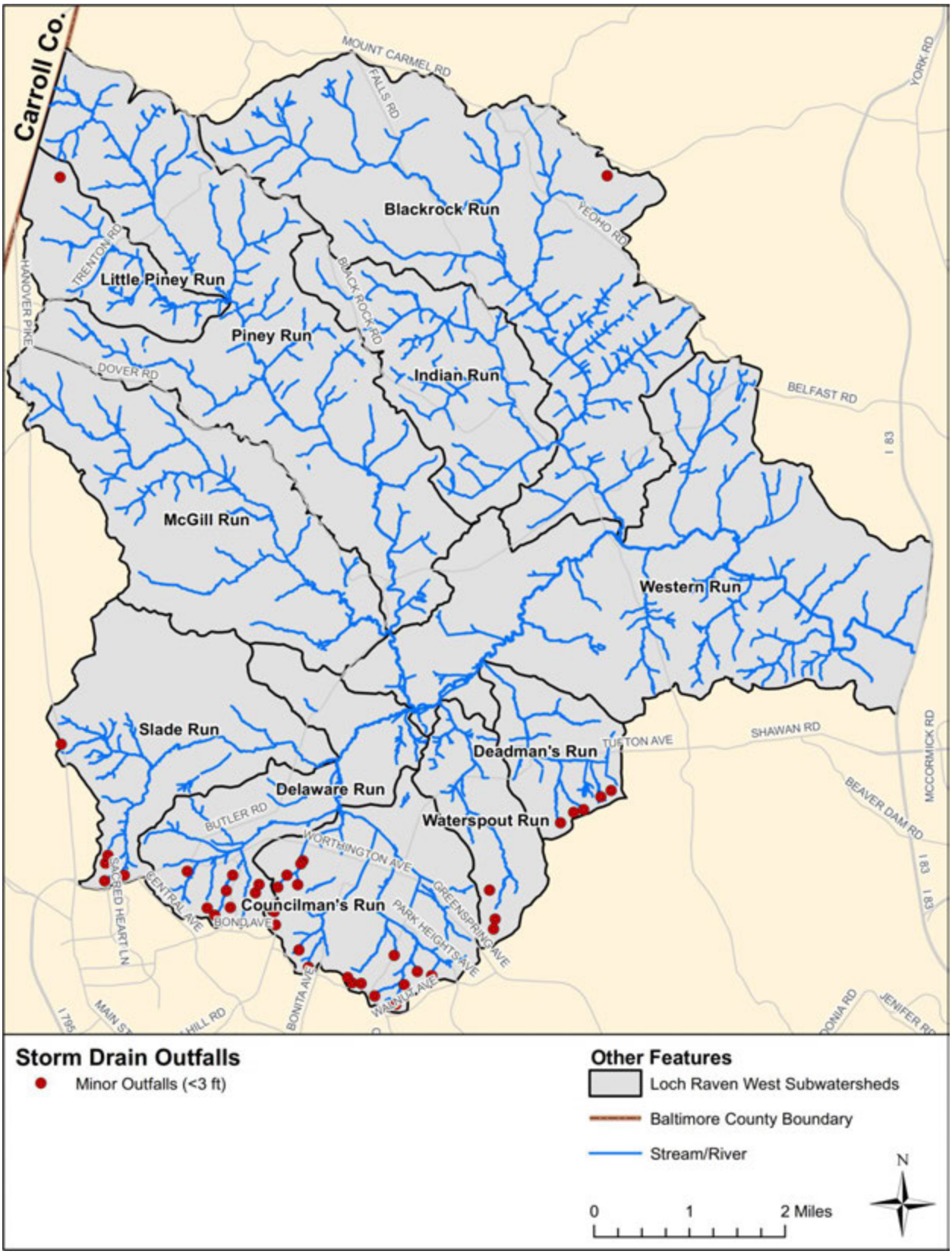

Figure 2-15: Loch Raven West Storm Drain Outfalls

2.3.7.2 Stormwater Management Facilities

The Maryland Department of the Environment (MDE) developed stormwater management (SWM) regulations over 25 years ago to control the quantity and quality of runoff. SWM practices have evolved since then, and will continue to progress as new technology and research are developed. SWM is a significant consideration for new development and redevelopment within Maryland. Per Title 4, Subtitle 2, of the Environment Article of the Annotated Code of Maryland, management of stormwater runoff is required to reduce erosion, sedimentation, pollution, and flooding. Increased importance of water quality and water resource protection has led to the development of the Maryland Stormwater Design Manual in 2000 (revised in 2009) to provide Best Management Practice (BMP) design standards and environmental incentives, and has promoted a general shift toward low-impact SWM practices that mimic natural hydrologic processes and achieve pre-development conditions. The latter is evident by the Maryland Stormwater Management Act of 2007 which requires that Environmental Site Design (ESD) be implemented to the maximum extent practicable via nonstructural BMPs and/or other innovative design techniques.

There are many types of BMP options for managing stormwater runoff and providing stormwater quality treatment. SWM facilities can target specific objectives depending on the BMP type selected, such as improving overall stormwater quality before it enters the stream, soil stabilization and erosion control, stormwater flow control or detention, and stream protection. In addition, different SWM facilities have different pollutant removal capabilities. For example, early pond designs for SWM have low pollutant removal efficiency compared to practices that filter stormwater or allow it to infiltrate into the ground or through plant roots. Considerations such as space requirements, constructability, maintenance needs, cost, and community acceptance are taken into account when selecting the appropriate stormwater treatment measures.

Table 2-17 summarizes the number of various types of public and private SWM facilities in the Loch Raven West watershed, including the sum of their drainage areas per subwatershed. The SWM facilities are categorized into detention ponds, wetlands, infiltration practices, filtration practices, extended detention, grassed swales and channels, and others. Figure 2-16 shows the distribution of these facilities throughout the watershed. Data for SWM facilities and their drainage areas were obtained from Baltimore County EPS.

Table 2-17: Stormwater Management Facilities in Loch Raven West Watershed

SWM Facility Type	Piney Run	Blackrock Run	Little Piney Run	Indian Run	McGill Run	Western Run	Slade Run	Delaware Run	Councilman's Run	Waterspout Run	Deadman's Run	Loch Raven West Subtotals
Dry Pond (#)	0	0	0	0	0	3	1	2	2	1	0	***9***
Drainage Area (acres)	0	0	0	0	0	4	6	36	95	107	0	***249***
Wetland (#)	0	1	0	0	0	0	0	1	0	0	0	***2***
Drainage Area (acres)	0	108	0	0	0	0	0	41	0	0	0	***149***
Infiltration (#)	1	1	0	0	2	2	0	0	2	1	0	***9***
Drainage Area (acres)	0	0	0	0	2	2	0	0	5	9	0	***19***
Filtration (#)	0	0	0	0	0	6	0	0	3	3	0	***12***
Drainage Area (acres)	0	0	0	0	0	26	0	0	2	36	0	***64***
Extended Detention (#)	0	1	0	0	0	1	1	0	1	0	1	***5***
Drainage Area (acres)	0	0	0	0	0	11	21	0	12	0	0	***44***
Grass Swales & Channels (#)	0	0	0	0	0	0	0	0	0	1	0	***1***
Drainage Area (acres)	0	0	0	0	0	0	0	0	0	2	0	***2***
Other (#)	1	0	0	0	0	0	0	2	2	0	1	***6***
Drainage Area (acres)	0	0	0	0	0	0	0	0	1	0	15	***17***
Total SWM Facilities (#)	***2***	***3***	***0***	***0***	***2***	***12***	***2***	***5***	***10***	***6***	***2***	***44***
Total Drainage Area Acres to SWM	***1***	***108***	***0***	***0***	***2***	***43***	***27***	***77***	***115***	***153***	***15***	***541***

SWM facilities are present in nine of the 11 subwatersheds that make up the Loch Raven West watershed. There are no documented SWM facilities in Blackrock Run and Little Piney Run. The most common SWM facility type is filtration practices followed by dry ponds and infiltration facilities. Subwatersheds with the most SWM facilities tend to be those with commercial and industrial land uses. SWM facilities are also more prevalent near areas with a residential land use. Filtration devices within the watershed include sand filters and check dams. Dry pond facilities represent the best opportunity for conversion to BMPs with higher pollutant removal capabilities, such as extended detention ponds. SWM facilities classified as “other” include environmentally sensitive development (ESD) techniques.

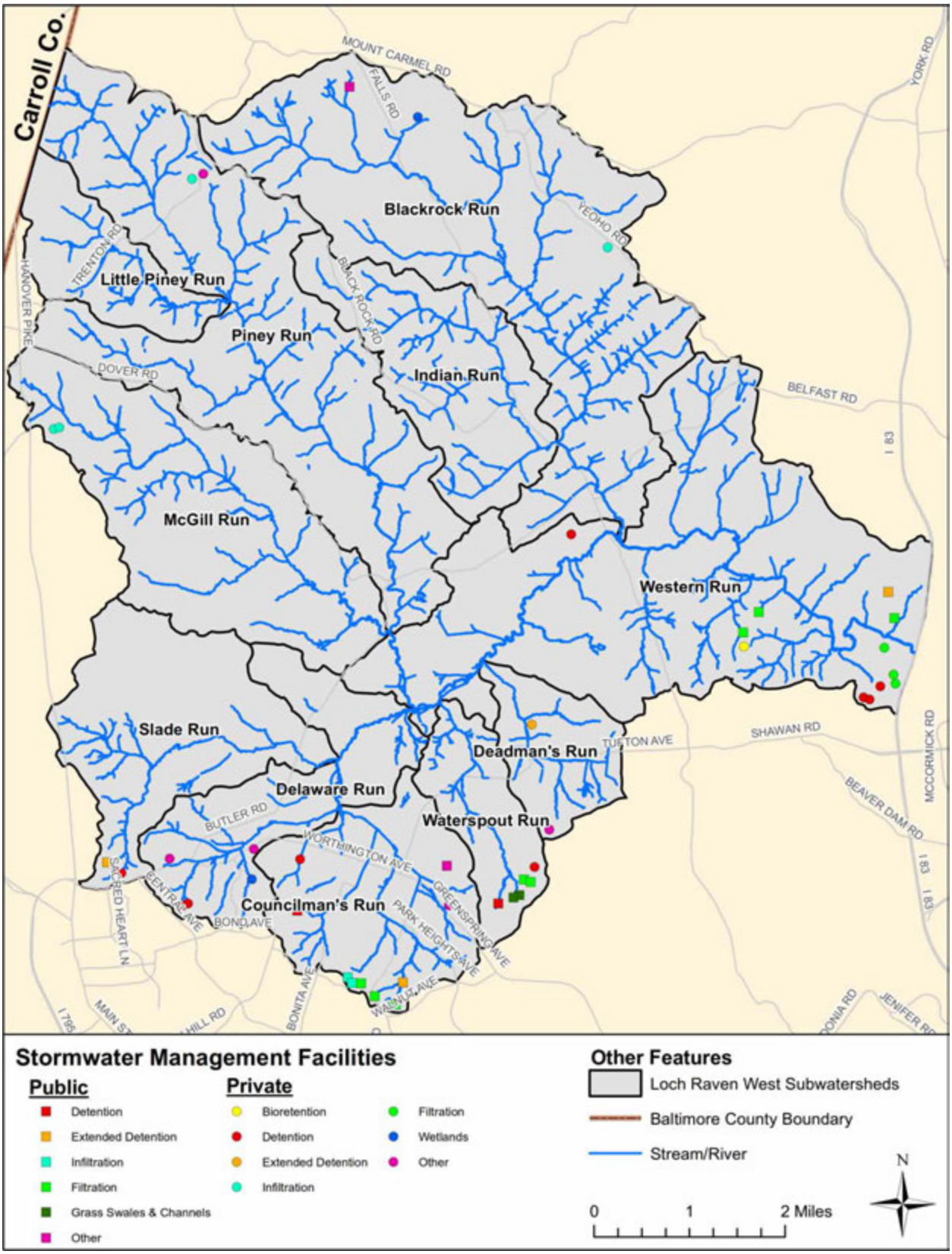

Figure 2-16: Distribution of Stormwater Management Facilities in Loch Raven West Watershed

Table 2-18 shows the total drainage area and the percentage of urban land treated by SWM facilities in each subwatershed. Urban land in this case refers to very low, low, medium and high density residential, commercial, industrial, institutional, open urban, and transportation land uses. This is important to evaluate because subwatersheds with high amounts of urban land but low SWM coverage percentages present opportunities for BMP implementation. BMPs can be implemented in existing developed areas with no current SWM practices or can be converted from facilities that are not providing adequate stormwater treatment. Approximately 15% of the watershed is classified as urban land (34% of which is very low density residential), and 10% of this area is treated by SWM facilities.

Table 2-18: Area Treated by Stormwater Management Facilities in Loch Raven West Watershed

Subwatershed	Area (Acres)	Urban Land Use (Acres)	Area Treated by SWM (Acres)	Urban Land Use Treated by SWM (%)
Piney Run	6,244	359	1	0%
Blackrock Run	7,117	1,196	108	9%
Little Piney Run	1,257	382	0	0%
Indian Run	2,454	156	0	0%
McGill Run	4,077	357	2	1%
Western Run	7,510	1,305	43	3%
Slade Run	2,849	292	27	9%
Delaware Run	2,283	532	77	14%
Councilman's Run	2,436	584	115	20%
Waterspout Run	1,163	256	153	60%
Deadman's Run	1,098	191	15	8%
Loch Raven West Total	***38,488***	***5,610***	***541***	***10%***

2.3.8 NPDES Discharge Permits

Businesses and other facilities that discharge municipal or industrial wastewater or conduct activities that can contribute pollutants to a waterway are required to obtain a National Pollutant Discharge Elimination System (NPDES) permit. The type of NPDES permit required depends on the nature of the activities conducted by the facility. Table 2-19 summarizes the number of facilities holding NPDES permits in the Loch Raven West watershed by subwatershed and permit type. Blackrock Run has two facilities, one with two permits; these permits are reported in the table.

Table 2-19: NPDES-Permitted Facilities in Loch Raven West Watershed

Subwatershed	# General Industrial Stormwater Permits	# Surface Industrial Discharge Permits	# Groundwater Municipal Discharge Permits	# General Permits	Total # of Permits in Subwatershed
Piney Run	0	0	0	0	0
Blackrock Run	0	0	0	3	3
Little Piney Run	0	0	0	0	0
Indian Run	0	0	0	0	0
McGill Run	0	0	0	0	0
Western Run	0	0	0	0	0
Slade Run	0	0	0	0	0
Delaware Run	0	0	0	0	0
Councilman's Run	0	0	0	0	0
Waterspout Run	0	0	0	0	0
Deadman's Run	0	0	0	0	0
Total	***0***	***0***	***0***	***3***	***3***

The federal NPDES permits listed above also function as MDE water management permits. Descriptions of each type of NPDES permit are provided as follows by MDE:

- **General Industrial Stormwater Permits** are required for industrial facilities discharging stormwater to storm drains or surface waters.
- **Surface Industrial Discharge Permits** are required for industrial facilities that discharge any wastewater to any place other than the sanitary sewer.
- **Groundwater Municipal Discharge Permits** are required for municipal facilities discharging any wastewater to the groundwater of the State.
- **General Permits** are required for facilities discharging wastewater or stormwater to any place other than a sanitary sewer, or for any manufacturing, fleet vehicle, or recycling facility.

NPDES permit data for the Loch Raven West watershed was estimated from spatial data provided by Baltimore County EPS, based on 2014 MDE records. As of 2014, there are a total of two facilities holding NPDES permits in the Loch Raven West watershed. The facilities holding NPDES permits are a variety of transportation facilities such as emergency services and industrial facilities such as material manufacturers. The only subwatershed with NPDES permitted facilities is Blackrock Run. Figure 2-17 shows the locations of NPDES-permitted facilities in the Loch Raven West watershed.

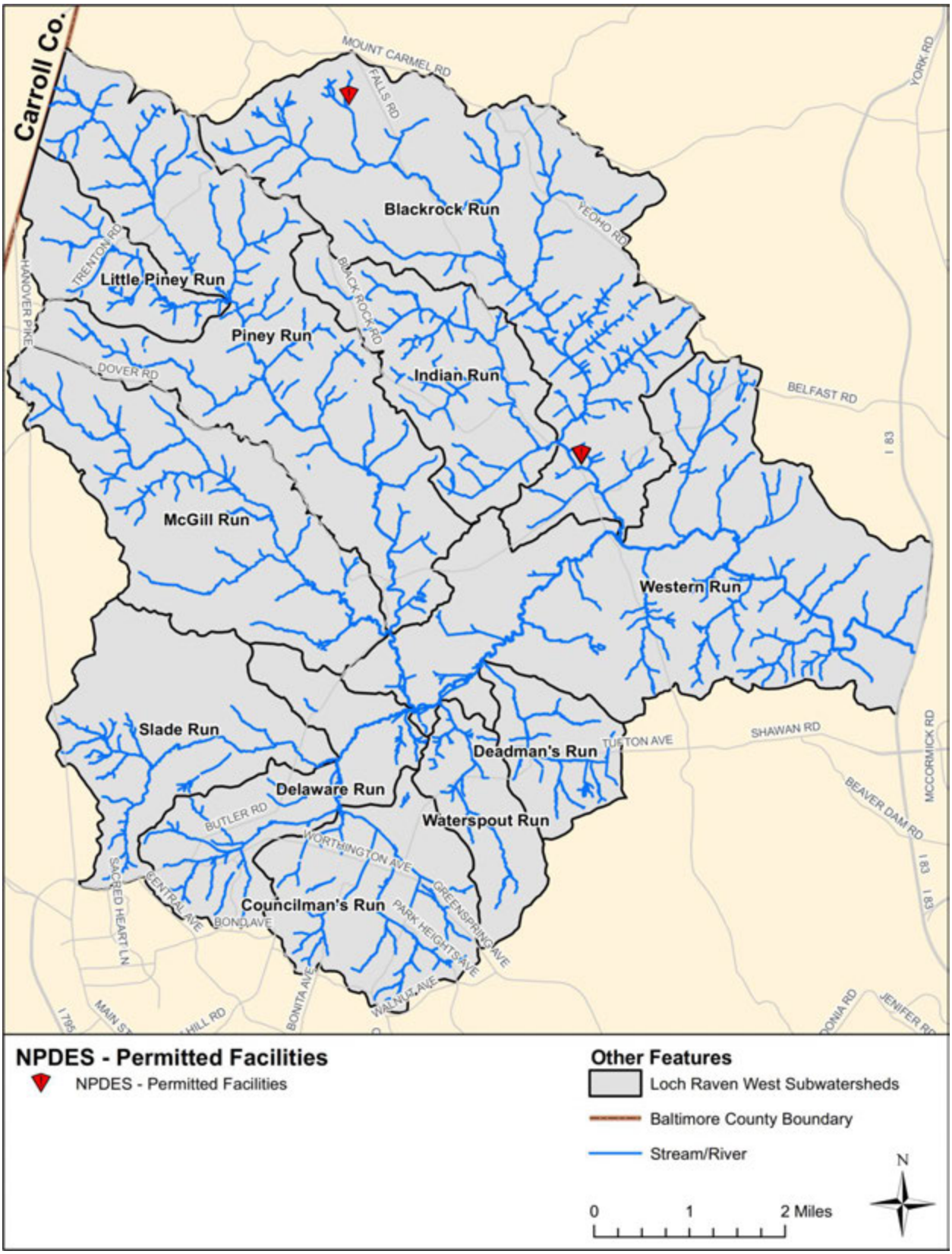

Figure 2-17: Location of NPDES-Permitted Facilities in Loch Raven West Watershed

2.3.9 Agricultural Best Management Practices (BMPs)

Current agricultural best management practices (BMPs) being used in the Loch Raven West watershed was available through the Baltimore County Soil Conservation District (SCD) on the 12-digit watershed scale. Loch Raven West is encompassed by three 12-digit watersheds as shown in Figure 2-18. As seen in the figure, portions of subwatersheds 021308050308 and 021308050303 extend beyond the Loch Raven West watershed. The Loch Raven West watershed boundary ends approximately 21,000 feet upstream of the southern end of the 021308050303 subwatershed, resulting in approximately 11% of the 12-digit watershed falling outside of the Loch Raven West watershed (Figure 2-18). In addition, subwatershed 021308050308 intersects both Baltimore and Carroll County. Due to the aforementioned watershed boundary overlaps, the total BMPs accounted for by SCD within this subwatershed are not strictly within the Loch Raven West watershed.

The agricultural BMPs provided by the SCD were divided and reported for the watershed based on their broader functions. The primary agricultural BMP functions within the watershed include waste storage, cover crops and land management activities, habitat improvement, animal control for waterways, erosion control, nutrient reduction, and water control. For a complete list of BMPs and their reclassification see Table 2-20. The agricultural BMPs for the three 12-digit subwatersheds encompassing Loch Raven West are summarized below in Table 2-21.

Table 2-20: Reclassification of BMPs to Functional Classifications for Loch Raven West Watershed

Waste Storage	Cover Crops/ Land Management	Habitat Improvement	Animal Control (to waterways)	Erosion Control	Nutrient Reduction	Water Control
Waste Storage Facility	Conservation Cover	Critical Area Planting	Fence	Grassed Waterway	Nutrient Management	Subsurface Drain
	Conservation Crop Rotation	Riparian Forest Buffer	Livestock Pipeline	Prescribed Grazing	Integrated Pest Management	
	Residue and Tillage Management	Wetland Wildlife Habitat Management	Streamside Fence (10'-34')	Heavy Use Area Protection		
	Residue Management and Tillage Management	Upland Wildlife Habitat Management	Non Streamside Fence	Diversion		
	Forage Harvest Management	Forest Strip/Stand Improvement	Spring Development	Access Road		
	Forage and Biomass Planting		Watering Facility	Windbreak/shelterbel t Establishment		
	Stripcropping			Roof Runoff Structure		
				Stream Crossing		

Table 2-21: Agricultural BMPs in the Loch Raven West Watershed

Subshed	Waste Storage (No.)	Cover Crops/ Land Management (Ac.)	Habitat Improvement (Ac.)	(Ac.)	Animal Control (to waterways) (Ft.)	(No.)	(Ac.)	Erosion Control (Ft.)	(No.)	Nutrient Reduction (Ac.)	Water Control (Ft.)
02130805**0303**	2	1,065.5	65.4	0.0	22,427.0	26	56.4	225.3	10	1,475.7	0.0
02130805**0307**	2	2,038.7	22.2	0.0	13,387.0	17	70.7	4,140.0	5	1,602.8	1.0
02130805**0308**	3	845.0	134.2	0.0	5,402.0	6	60.6	930.0	3	869.3	555.0
Total	***7***	***3,949.2***	***221.8***	***0.0***	***41,216.0***	***49***	***187.7***	***5,295.3***	***18***	***3,947.8***	***556.0***

*Multiple BMPs can be applied to the same area of land; totals do not take into account overlapping BMPs

Figure 2-18: Agricultural BMPs within 12-digit Subwatersheds and Loch Raven West Watershed

2.3.10 Zoning

The Baltimore County Office of Planning defines zoning as "a system of land use regulation that controls the physical development of land and a legal mechanism by which local government is able to regulate an owner's right to use privately owned land for the sake of protecting the public health, safety, and/or general welfare" (DP, 2016). In other words, zoning manages development patterns over time throughout the county. Table 2-22 shows the various zoning categories present in the Loch Raven West watershed.

As shown in Figure 2-19, a significant portion of Loch Raven West watershed is zoned agricultural. The watershed also has a noteworthy percentage of watershed protection, resource preservation, and rural residential zoning. These areas are located within the southern portion of the watershed.

Table 2-22: Baltimore County Zoning in Loch Raven West Watershed

Zoning Code	Zoning Description	Total Acres	% of Watershed Area
DR 1	Density Residential - 1 units/acre	100	0.3
DR 2	Density Residential - 2 units/acre	35	0.1
DR 3.5	Density Residential - 3.5 units/acre	13	0.0
RC 2	Agricultural	34,633	90.0
RC 3	Deferral of Planning and Development	18	0.0
RC 4	Watershed Protection	451	1.2
RC 5	Rural Residential	1,771	4.6
RC 6	Rural Conservation and Residential	92	0.2
RC 7	Resource Preservation	1,343	3.5
RC 8	Environmental Enhancement	2	0.0
RCC	Resource Conservation Commercial	3	0.0
Commercial	Office/Business	28	0.1
Industrial	Manufacturing	1	0.0
Total		***38,488***	***100.0***

As presented in Table 2-22, approximately 90% of the Loch Raven West watershed is zoned for agricultural use (zone RC 2). Areas zoned for protection, preservation, or rural residential cover approximately 9% of the watershed.

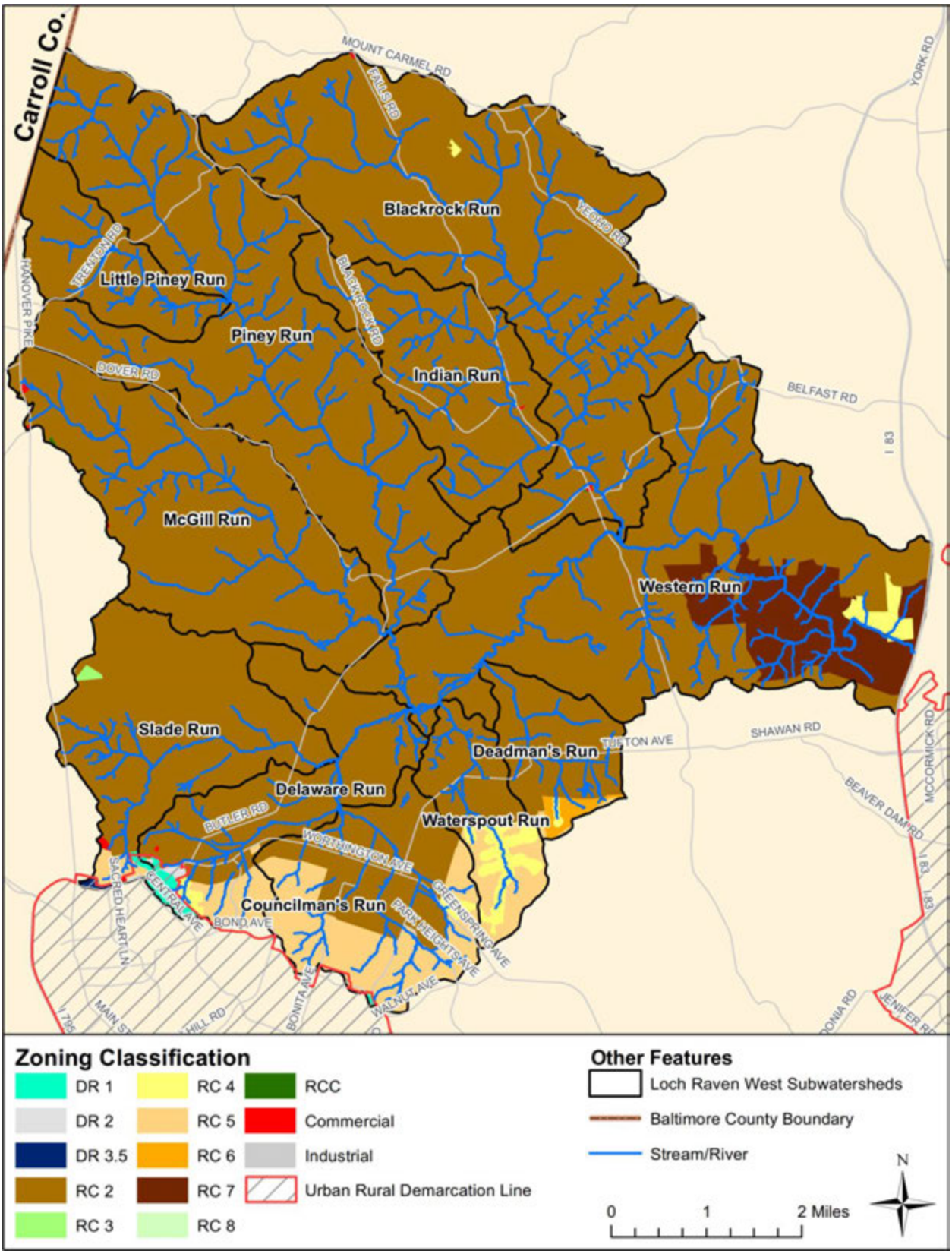

Figure 2-19: Loch Raven West Watershed Zoning

2.3.10.1 Resource Conservation Areas

There are multiple programs working to conserve land in the Loch Raven West watershed. Analysis of conservation areas within the watershed was conducted using GIS data provided by Baltimore County EPS. Overall, 67% of the watershed is located in a conservation area. Piney Run and Blackrock Run have the most land area in easements with 5,596 and 4,936 acres, respectively. While Piney Run, Indian Run, and McGill Run have the greatest percentage of land in easements, 90%, 83%, and 78%, respectively. Waterspout Run has the lowest percentage of land in easements with only 9% of the subwatershed protected. Table 2-23 summarizes the conservation easements located in each subwatershed, and Figure 2-20 illustrates the easement distribution in the watershed. Many properties are co-held under multiple easements; however the numbers reported do not reflect this.

Baltimore County has ten resource conservation zones, of which, seven are currently being applied to land within the County (Table 2-22). One of the ten resource conservation zones, RC 4, contains a resource conservation easement in the Loch Raven West watershed. Resource conservation zones are used to protect agricultural land, rural residential development, rural commercial development, and natural resources. The RC 4 (Watershed Protection) zoning requires 70% of the tract acreage be allocated as a conservancy area (DP, 2006). Less than one percent of the Loch Raven West watershed (280 acres) is in RC4 easements, with all of the conservation easements located in the Western Run subwatershed.

In addition to zoning conservation efforts, the Baltimore County Agricultural Land Preservation Program aims to create easements to preserve working family farms located within the Agricultural Preservation Protection Areas. The Loch Raven West watershed has 5,110 acres of county agricultural easements with the majority of the easements in Piney Run, Blackrock Run, and Western Run. County forest conservation easements protect 1,806 acres of forest land throughout the watershed as required by the Forest Conservation Act of 1991. The only subwatershed without county forest conservation easements is Waterspout Run, which has very few acres in easements.

The Federal Farm and Ranch Program is another program used to keep productive farm and ranchland in agricultural use. The watershed has nine easements under this program protecting 741 acres over four subwatersheds.

Local land trusts are another method of land conservation whereby the landowner may donate or sell part of their land to a land trust as a conservation easement. In the Loch Raven West watershed the only land trust operating is the Land Preservation Trust. Land trusts are non-profit organizations that focus on the preservation of farms, forests, and historical landmarks in the watershed, and currently have 1,249 acres in conservation easements in all eleven subwatersheds.

There are also multiple State led conservation efforts within the watershed. The Maryland Agricultural Land Preservation Foundation (MALPF) is a cooperative program of the county and Maryland Department of Agriculture (MDA) that protects agricultural land and woodland through the use of perpetual easements. This program accounts for the third largest percentage of protected land, 20% of all easements in the watershed.

The Maryland Environmental Trust (MET) is a statewide land trust whose goal is the preservation of open land, including farmland, forest land, and significant natural resources. This is achieved mainly through the use of conservation easements, which are perpetual agreements between the landowner and MET ensuring that the property shall not be developed beyond a limit agreed upon by both parties. Approximately 7,045 acres of land are under MET easements in the Loch Raven West watershed.

The Rural Legacy Program is a state program that was adopted and additionally funded by the county to protect Maryland's rural landscapes and natural areas through the purchase of land or conservation easements. The program emphasizes the protection of large blocks of rural agricultural and forested land. The Rural Legacy Program has the largest acreage under conservation in the Loch Raven West watershed at approximately 8,813 acres of land.

Table 2-23: Loch Raven West Conservation Easements (Acres)

Subwatershed	Forest Conservation	County Agricultural Land Preservation	Federal Farm & Ranch Protection	Transportation Enhancement Program	Local Land Trust	MD Ag. Land Preservation Foundation	MD Environmental Trust	RC4 (Watershed Protection Zoning)	Rural Legacy	Total*
Piney Run	322	16	30	0	121	1,025	1,844	0	2,239	5,596
Blackrock Run	240	46	0	0	294	782	841	0	2,734	4,936
Little Piney Run	32	0	0	0	1	1	100	0	547	681
Indian Run	66	0	0	0	15	418	645	0	897	2,040
McGill Run	215	253	0	0	11	544	472	0	1,682	3,177
Western Run	575	127	170	0	408	671	1,931	280	173	4,335
Slade Run	157	165	135	0	35	571	501	0	365	1,929
Delaware Run	109	0	0	0	149	378	382	0	177	1,194
Councilman's Run	78	0	405	0	134	596	169	0	0	1,381
Waterspout Run	0	0	0	0	43	4	55	0	0	101
Deadman's Run	14	30	0	0	39	122	105	0	0	310
Total*	***1,806***	***637***	***741***	***0***	***1,249***	***5,110***	***7,045***	***280***	***8,813***	**25,680**

*The total does not double count land that was included in multiple easements

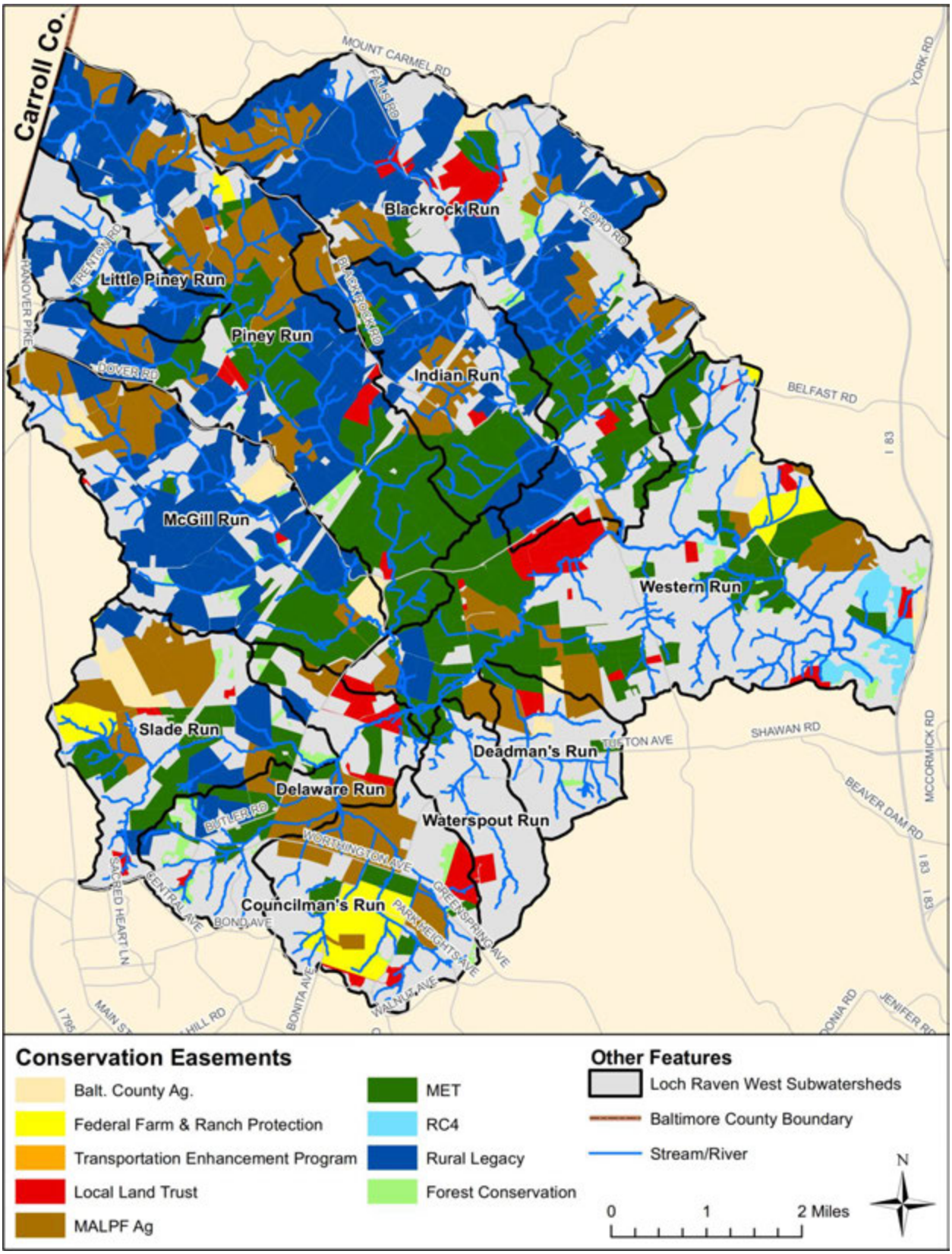

Figure 2-20: Resource Conservation Easements

2.3.11 Historical Development

Historical development within the Loch Raven West watershed began before the 1800s. There has been steady growth throughout the watershed with the peak of development in the 1980s. Using GIS tax parcel data provided by the Baltimore County OIT, the decade each parcel of land was built was derived for the watershed. A summary of these parcels and their build date are shown in Table 2-24 and Figure 2-21. Parcels constructed prior to 1920 were categorized on a broader time step as shown. Figure 2-22 illustrates the historical development throughout the Loch Raven West watershed. A significant portion of land parcels are undeveloped.

Table 2-24: Decade Built and Number of Parcels

Subwatershed	1700s	1800s	1900 to 1919	1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000 to 2009	2010 or after	Undeveloped
Piney Run	1	74	35	4	7	12	37	33	32	39	31	19	1	259
Blackrock Run	3	74	30	15	15	27	90	76	84	80	47	33	3	413
Little Piney Run	0	14	9	0	3	5	4	17	13	15	11	15	0	97
Indian Run	1	28	13	4	6	13	16	10	23	7	6	3	0	120
McGill Run	1	41	39	14	8	19	42	28	39	37	27	24	0	215
Western Run	2	62	16	9	20	8	38	24	110	96	63	81	5	389
Slade Run	3	33	28	25	6	8	46	18	15	23	51	15	0	169
Delaware Run	2	16	26	13	3	12	31	11	76	100	41	16	0	112
Councilman's Run	2	5	6	7	9	4	15	2	59	166	98	33	0	97
Waterspout Run	0	2	1	0	0	2	5	6	3	16	50	35	0	76
Deadman's Run	0	3	0	3	2	1	3	2	13	25	11	2	0	32
Total	***15***	***352***	***203***	***94***	***79***	***111***	***327***	***227***	***467***	***604***	***436***	***276***	***9***	***1,979***

*Parcels that cross subwatershed boundaries are counted in each subwatershed

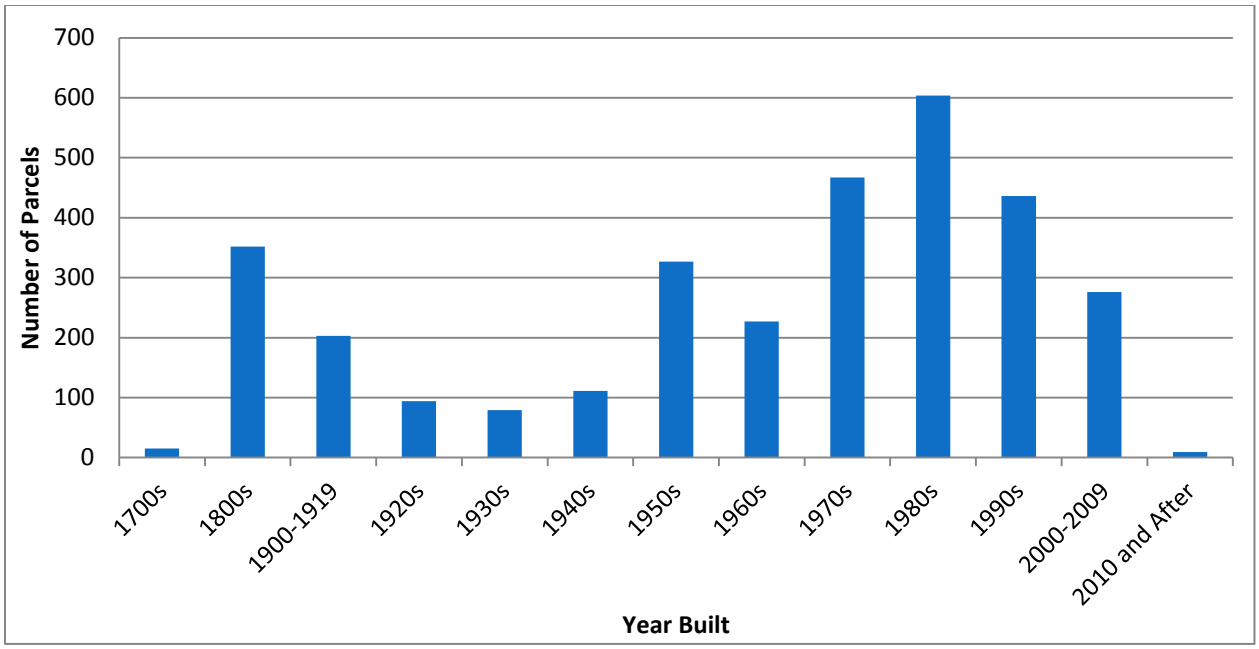

Figure 2-21: Number of Parcels Built Over Time

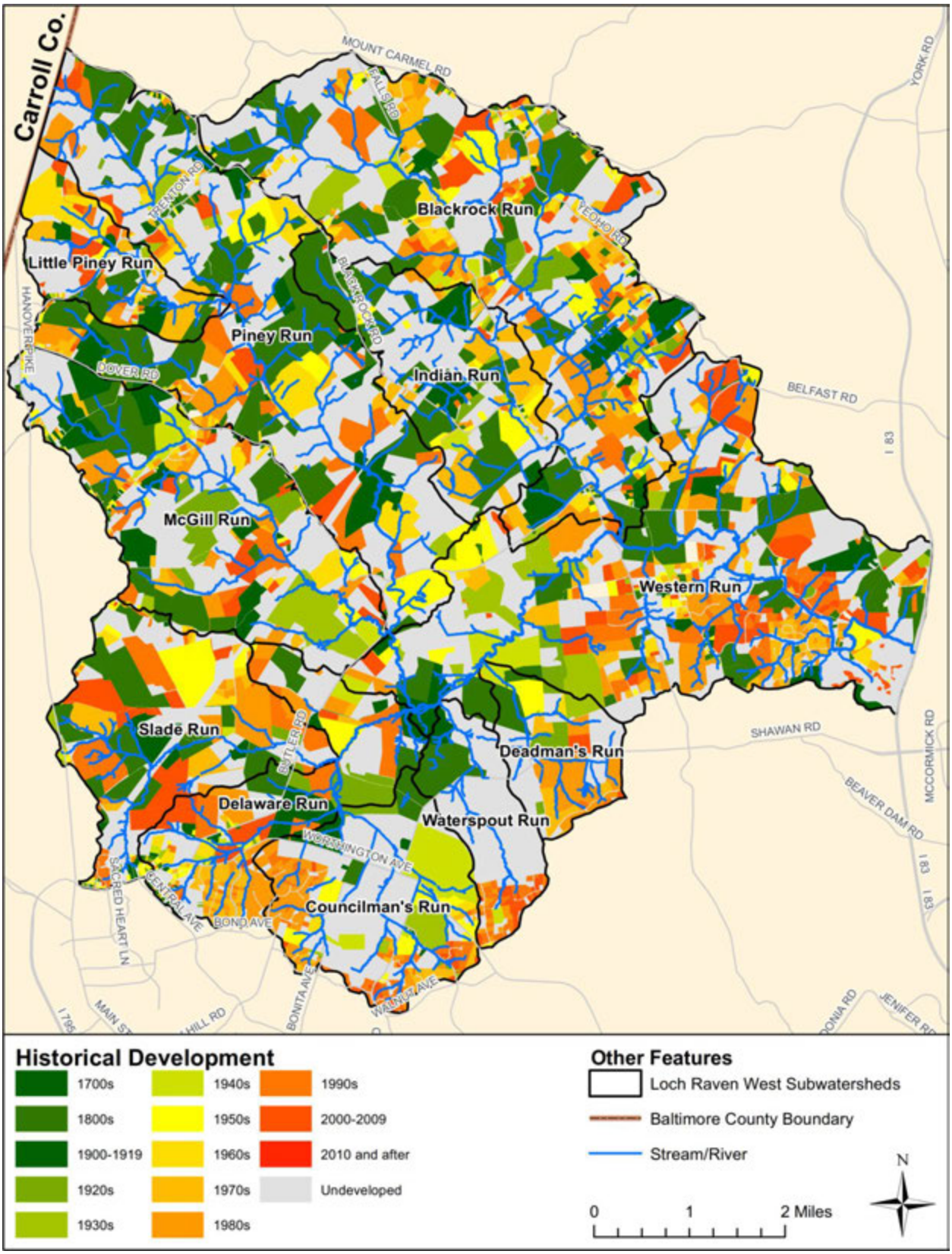

Figure 2-22: Historical Development throughout Loch Raven West Watershed

CHAPTER 3: WATER QUALITY AND LIVING RESOURCES

3.1 Introduction

Water is an integral part of all habitats. The SWAP goals for maintaining and improving water quality also aim to provide for flora, fauna, and their habitats. Because habitat conditions affect the ability of natural communities to find food and shelter and carry on natural processes, it is necessary to evaluate the state of existing land, water, and biological elements that provide for their needs. This chapter describes the water quality, living resources, and habitats for the Loch Raven West watershed based on existing conditions.

Living resources, including all plants and animals, require water for survival. They are intimately connected to and respond sensitively to water quality and habitat conditions. Their dependence on water quality can provide a gauge with which to measure and evaluate the status of water bodies and the effects that watershed characteristics and upland activities have on these water bodies. For example, in addition to taking direct measurements of a pollutant, water quality can be measured in terms of its ability to support living resources, such as trout or shellfish. Information on living resources is presented in this chapter to indicate water quality status and to evaluate habitat conditions in the Loch Raven West watershed. This information can help to determine if current watershed management practices are adequately providing for the needs of the natural communities.

The following sections include descriptions of the following with respect to the Loch Raven West watershed: impairments per Maryland state water quality standards, pollutant loading analysis for total nitrogen, total phosphorus and sediment, water quality monitoring data available to date, and mill dam assessments.

3.2 303(d) Listings and Total Maximum Daily Loads (TMDLs)

The Clean Water Act (CWA) requires states, territories, and authorized tribes to: develop water quality standards for all jurisdictional surface waters; monitor these surface waters; and identify and list impaired waters. More specifically, Section 305(b) of the CWA requires annual water quality assessments to determine the status of jurisdictional waters. Section 303(d) requires states to identify and periodically update a list of impaired waters that fail to meet applicable state water quality standards. States must also establish priority rankings and develop Total Maximum Daily Loads (TMDLs) for waters on the 303(d) list, which generally target pollutants including sediment, metals, bacteria, nutrients, and pesticides. According to USEPA, a TMDL is a calculation of the maximum amount of a pollutant that a water body can receive and still safely meet state water quality standards.

Water quality standards are developed from a combination of the designated use for a given water body and the water quality criteria designed to protect that use. Table 3-1 provides the definition for each designated class.

Table 3-1: Maryland's Designated Uses for Surface Waters (COMAR, 2016a)

Class	Definition
Use I	Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life
Use I-P	Water Contact Recreation, Protection of Aquatic Life, and Public Water Supply
Use II	Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting
Use II-P	Tidal Fresh Water Estuary – includes applicable Use II and Public Water Supply
Use III	Nontidal Cold Water
Use III-P	Nontidal Cold Water and Public Water Supply
Use IV	Recreational Trout Waters
Use IV-P	Recreational Trout Waters and Public Water Supply

Surface waters (e.g., streams) within the Loch Raven West watershed, including Western Run and all tributaries, are designated as Use III-P – nontidal cold water and public water supply (COMAR, 2016b). Downstream from the watershed, the Loch Raven Reservoir is designated as Use I-P – water contact recreation, protection of aquatic life, and public water supply (COMAR, 2016b). Below the reservoir dam, the main stem Big Gunpowder Falls receiving stream is designated as Use IV – recreational trout waters and public water supply and discharges into the Gunpowder River Oligonhaline (GUNOH), designated as Use II – tidal fresh water estuary (COMAR, 2016b).

Based on the water quality criteria associated with the above designated uses, the Loch Raven West watershed is listed in *Maryland's Final 2014 Integrated Report of Surface Water Quality* for various pollutants of concern. Each pollutant listing is applicable to the Loch Raven Reservoir (basin 02130805). Each listing within the Integrated Report is sorted by attainment status or category upon which a water body is placed. Table 3-2 provides the definition for each attainment status or listing category within the report (MDE, 2014).

Table 3-2: Maryland Integrated Report Listing Categories (MDE, 2014)

Listing Category	Definition
2	Waters meeting the standards for which they have been assessed
3	Waters that have insufficient data or information to determine whether any water quality standard is being attained
4a	Waters that are still impaired but have a TMDL developed that establishes pollutant loading limits designed to bring the waterbody back in to compliance
4b	Waters that are impaired but for which a technological remedy should correct the impairment
4c	Waters that are impaired but not for a conventional pollutant including pollution caused by habitat alteration or flow limitations
5	Water bodies that may require a TMDL

The water quality segments in Loch Raven Reservoir that are applicable to the current SWAP area contain the following listings in the 2014 Integrated Report: nutrients (phosphorus), sediments, sulfates, chlorides, fecal bacteria, and lack of riparian buffer. Impairment listings within categories 4a, 4b, 4c, or 5 reflect an inability to meet water quality standards. When a water quality segment is listed as impaired, action can be taken by developing and/or adhering to a TMDL or by submitting a Water Quality Analysis (WQA) to remove a specific pollutant from the impairment listing. TMDLs can be developed for a single pollutant or group of pollutants of concern. WQAs are performed to determine if the pollutant of concern is actually impairing the waters. If it is determined that the pollutant of concern is not contributing to water impairment, a report documenting the findings is submitted to the United States Environmental Protection Agency (USEPA) for concurrence. Maryland's 2014 Integrated Report (IR) of Surface Water Quality represents a fully combined 303(d) and 305(b) report approved by USEPA (MDE, 2014).

Table 3-3 summarizes the status of the current listings for portions of the Loch Raven West watershed that are applicable to the current SWAP area.

Table 3-3: Loch Raven West Water Quality Impairment Listings and Status

Impairment	Applicable Segment	Listing Category	Status	Approval Date
Fecal Bacteria	MD-02130805	4a	TMDL	12/3/2009
Lack of Riparian Buffer	MD-02130805	4c	Impaired	N/A
Phosphorus (Total)	MD-02130805	5	Impaired	N/A
Sulfates	MD-02130805	5	Impaired	N/A
Chlorides	MD-02130805	5	Impaired	N/A

As shown in Table 3-3, the Loch Raven West watershed has five listings applicable to the current SWAP area. The fecal bacteria listing was placed under category 4a, meaning a TMDL has been completed for this impairment. The lack of a riparian buffer listing was placed under category 4c, meaning the impairment is not caused by a pollutant. This is one of four listings that replaced the biological impairment caused by an unknown source, which was on the impairment list from 2002 to 2012. There are three impairments in the current SWAP area requiring the creation of a TMDL; they are phosphorus, sulfates, and chlorides. All three of these listings were added in 2014 as they were found to be major stressors affecting the biological integrity of the watershed and replace the biological impairment listing (MDE, 2014). Additionally, Councilman's Run has a temperature listing under category 3, meaning there is insufficient data available to determine if the water quality standard is being met. In this case, there was not a complete summer of temperature readings and additional summer readings are needed (MDE, 2014).

The Loch Raven Reservoir, which receives water from the Loch Raven West watershed, has four additional listings. Heavy metals were listed under Category 2, meaning the reservoir meets the criteria for heavy metals as documented in a Water Quality Analysis accepted in 2003 (MDE, 2003). Mercury, total phosphorus, and sediment were listed under Category 4a, and have completed TMDLs for each impairment. The total phosphorus TMDL is 54,941 lbs/yr (50% reduction), which includes nonpoint source

loads from agricultural and forest lands, and septic tanks. The urban stormwater load accounts for 15% of the total phosphorus TMDL. The sediment TMDL is 28,925 tons/yr (25%) reduction, which includes nonpoint source loads from agricultural and forest lands. The urban stormwater load accounted for 0% sediment loads at the time the TMDL was written (MDE, 2006). Since 2006, sediment loads from urban stormwater have increased by 358.3 tons/year above the TMDL baseline and must now be reduced by that amount (EPS, 2014). Based on the ratio of urban sediment loading from Loch Raven West compared to the entire Loch Raven Reservoir Watershed (12.8%), the Loch Raven West watershed must reduce its sediment loading by 46 tons/year or 1%. The mercury TMDL for the reservoir is 843.5 g/yr, which is expected to be met by reductions from atmospheric contributions (MDE, 2002).

3.2.1 Chesapeake Bay Nutrient and Sediment Impairment

The Chesapeake Bay Program (CBP) has developed the Phase 5 Watershed Model. This model, in conjunction with the Estuary Model, is used to determine the sources and reductions of nitrogen, phosphorus, and sediment needed to meet Chesapeake Bay tidal water quality standards. The Phase 5 model was used to develop a Chesapeake Bay-wide TMDL and to assign nutrient and sediment load reductions to individual states and ultimately local jurisdictions based on the segment loads. In Maryland, nutrient and sediment load reductions were assigned on a county basis for achievement by a 2025 timeframe. Table 3-4 lists the pollutant load reduction requirements updated to reflect 2010 reductions for Baltimore County, and in turn the Loch Raven West watershed, under the Chesapeake Bay TMDL.

Table 3-4: Baltimore County Stormwater Sector Pollutant Load Reductions (EPS, 2012a)

TMDL Pollutant	% Pollutant Load Reduction Requirements for Baltimore County by 2025
Nitrogen	32.2
Phosphorus	47.0

In developing the pollutant reduction strategy in Baltimore County's *Phase II Watershed Implementation Plan* (WIP), consideration was given to the relative delivery ratios for Baltimore County's fourteen 8-digit watersheds and the land use loading rates for urban impervious and urban pervious (EPS, 2012a). The Loch Raven West watershed has varying delivery to the bay for pollutants due to treatment factors in the reservoir and drinking water withdrawals. The delivery ratios to the Bay for nitrogen, phosphorus, and sediment are 25.9%, 36.0%, and 22.5%, respectively, for the Loch Raven Watershed (EPS, 2015). Therefore, any pollutant reduction actions that take place within the Loch Raven West watershed receive only partial credit toward Bay restoration.

3.2.2 Bacteria (*E. coli*)

Sampling from seven representative stations in the Loch Raven Reservoir watershed (one in the Loch Raven West watershed) was used to estimate a baseline load for *E. coli*. High flows and low flows for annual and seasonal conditions were then used to determine the TMDL load which is reported in the units of Most Probable Number (MPN) per day. The *E. coli* TMDL for the entire Loch Raven Reservoir watershed (including a portion located in Pennsylvania) is 513,894 billion MPN *E.coli* /year. The Loch Raven West

watershed portion of the TMDL (including a small portion of Carroll County) is 80,168 billion MPN *E.coli* /year. The TMDL allocations are split between load allocations (LA) for nonpoint sources and waste load allocations (WLA) for point sources including NPDES regulated stormwater (SW) and wastewater treatment plants (WWTP). Overall, Loch Raven West contributes 16% of the total load allocation. See Table 3-5 for the Loch Raven West baseline loads and TMDL allocations by type (MDE, 2009b).

Table 3-5: Fecal Bacteria Baseline Loads and TMDL Allocations (Billion MPN E. coli/year) (MDE, 2009b)

		TMDL Allocation					
Watershed	Baseline Load	LA_{PA}	LA_{LR}	SW-WLA_{LR}	WWTP-WLA_{LR}	Total Allocation	% Target Reduction
Loch Raven West*	307,744	-	76,920	1,681	1,567	80,168	74%
Loch Raven Reservoir	2,194,308	6,200	487,750	18,377	1,567	513,894	77%

* Includes a small portion of Carroll County

To meet the final TMDL, Loch Raven West must reduce 74% from its baseline load. The TMDL calls for implementation of maximum practical reductions to reduce fecal bacteria loads. In addition, other BMPs will be needed to meet reduction requirements including public awareness on pet waste, management of overpopulation of wildlife, and addressing failing septic systems in the watershed (MDE, 2009b).

3.3 Pollutant Loading Analysis

Pollutant loading analyses are intended to assess the impacts of current and future development on water quality. For the Loch Raven West watershed, a pollutant loading analysis was completed based on land-uses in the watershed along with the presence of septic systems and point sources within the watershed.

3.3.1 Land-Use Pollutant Loading

Land use analyses have been performed for each of the Maryland designated 8-digit watersheds located entirely or in part within Baltimore County. As part of these analyses, Baltimore County derived watershed-specific pollutant loading rates for nitrogen, phosphorus, and sediment based on the Chesapeake Bay Program October 2011 Watershed Model. The model derived segment-specific loading rates for urban and non-urban land uses. Pollutant loading rates corresponding to different land use types in the Loch Raven West watershed are summarized in Table 3-6.

Table 3-6: Annual Pollutant Loading Rates for Water Resources Element (WRE) Land Use Classifications (lbs/acre/yr)

WRE Land Cover	Nitrogen Per Acre	Phosphorus Per Acre	Sediment Per Acre
Impervious Urban	17.36	1.51	1,601.51
Pervious Urban	11.55	0.30	220.64
Cropland	23.08	1.32	1,111.18
Pasture	7.76	0.72	277.62
Livestock (AFO/CAFO)*	162.74	23.92	4,099.94
Forest	2.77	0.04	64.36
Water**	10.26	0.61	0.00
Extractive	16.30	2.59	2,966.60
Construction	32.30	5.15	8,193.36

*AFO/CAFO refers to animal feeding operations and concentrated animal feeding operations
**Nutrient loadings from water were not included in the analysis

To predict pollutant loading rates from the watershed, Baltimore County uses a combination of the National Land Cover Database 2011(NLCD 2011) and the Baltimore County 2014 impervious surfaces data. This combined dataset is referred to as the Baltimore County Land Cover Database (BCLCD). The NLCD 2011 is a nationwide land cover product based primarily on a classification of Landsat satellite data. The NLCD 2011 uses 16 land cover classifications that are applied at a 30 meter spatial resolution (Homer, 2015). The Baltimore County 2014 impervious surfaces data was derived from 2014 leaf-off orthophotography. The NLCD land cover classifications were consolidated to match the Bay Watershed Model land cover, because loading rates do not differ significantly between certain land use classes (e.g., various forest types). This methodology utilizes the most recent data available and is consistent with Baltimore County's methodology for conducting pollutant loading analysis in current County implementation plans and NPDES reports.

Total acreages of each BCLCD land use category were calculated for the Loch Raven West watershed. These were multiplied by the corresponding loading rates presented in Table 3-6 yielding annual pollutant loads for total nitrogen, total phosphorus, and total sediment from the watershed. The total annual land use pollutant loadings calculated for the Loch Raven West watershed are summarized in Table 3-7.

Table 3-7: Total Annual Pollutant Loads for Nitrogen, Phosphorus, and Sediment for Loch Raven West

		NITROGEN		PHOSPHORUS		SEDIMENT	
BCLCD Land Use	Area (acres)	Loading Rate (lbs/ac)	Load (lbs)	Loading Rate (lbs/ac)	Load (lbs)	Loading Rate (lbs/ac)	Load (lbs)
Water*	13	-	-	-	-	-	-
Pervious Urban	3,041	11.55	35,128	0.30	912	220.64	671,052
Impervious Urban	1,041	17.36	18,080	1.51	1,573	1601.51	1,667,967
Extractive	5	16.30	88	2.59	14	2966.60	16,082
Forest	15,557	2.77	43,093	0.04	622	64.36	1,001,261
Pasture	10,993	7.76	85,303	0.72	7,915	277.62	3,051,771
Cropland	7,837	23.08	180,877	1.32	10,345	1111.18	8,708,255
Total	***38,488***		***362,570***		***21,381***		***15,116,388***

*Nutrient loadings from water were not included in the analysis

Note that the pollutant loading rates developed for the Water land use category represent atmospheric deposition of nitrogen and phosphorus to water, and because this nutrient delivery system is not addressed in SWAPs, it is not typically included in the watershed pollutant loading analysis.

Total annual nitrogen and phosphorus loads estimated for the Loch Raven West watershed are 362,570 lbs TN/year and 21,381 lbs TP/year, respectively. Total annual sediment loading from land use sources into the Loch Raven West watershed is 15,116,388 lbs Sediment/year. Pollutant loadings were also calculated on a subwatershed basis using the same loading rates and land use classification. These estimates will provide baseline pollutant loads before implementation of restoration projects and will allow a better assessment of both progress made to date and further progress needed to meet watershed goals or anticipated TMDLs for urban nonpoint source reduction.

Table 3-8 summarizes the acreages of BCLCD land use categories by subwatershed in the Loch Raven West watershed. The resulting nitrogen, phosphorus, and sediment loads for the 11 subwatersheds are presented in Table 3-9, Table 3-10 and Table 3-11, respectively. These three tables also include annual nitrogen, phosphorus, and sediment loading rates per acre (lbs/ac/yr) calculated for each subwatershed. The tables show that the subwatershed generating the greatest pollutant load is Blackrock Run followed by Western Run and Piney Run. It is important to note that Western Run has the largest surface area of any subwatershed (20% of the total watershed) followed by Blackrock Run (18%), Piney Run (16%), and McGill Run (11%) compared to the remaining subwatersheds (see Table 1-1).

When evaluated based on predicted amount of annual pollutant loading per acre, McGill Run, Piney Run, and Blackrock Run generate the highest pollutant loading out of all the subwatersheds. These four subwatersheds contain the highest acreage of cropland, while McGill Run, Blackrock Run, Piney Run, and Indian Run contain the highest percentage of cropland coverage in the subwatershed with a quarter of their land uses as cropland, which has one of the highest pollutant loading rates. Impervious Urban and Extractive land uses also have high pollutant loading rates, but their percent coverage in these subwatersheds range between 0.1% to 2%. In general, the subwatersheds in the Loch Raven West are less urbanized but more heavily farmed compared to other areas in the county and pollutant loadings into

surface waters are consequently high. Subwatershed pollutant loadings and rates will be used to prioritize restoration efforts. Total planning level pollutant load estimates will be used to determine necessary reductions to meet watershed goals and any future TMDL reductions.

Table 3-8: Loch Raven West Baltimore County Land Cover Database (BCLCD) Land Use Acreages by Subwatershed

	BCLCD LAND COVER						
SUBWATERSHED	Water*	Pervious Urban	Impervious Urban	Extractive	Forest	Pasture	Cropland
Piney Run	1	228	119	0	2,286	2,084	1,526.2
Blackrock Run	3	615	186	2	3,024	1,405	1,881.4
Little Piney Run	2	223	30	0	475	293	233.6
Indian Run	0	126	55	3	1,026	683	560.9
McGill Run	0	150	86	0	1,748	904	1,189.2
Western Run	1	788	232	0	2,569	2,872	1,047.4
Slade Run	1	156	79	0	1,322	843	447.0
Delaware Run	0	201	93	0	920	753	317.4
Councilman's Run	4	321	98	0	1,104	483	426.7
Waterspout Run	0	148	28	0	572	363	52.5
Deadman's Run	0	86	36	0	510	310	154.7
Total	***13***	***3,041***	***1,041***	***5***	***15,557***	***10,993***	***7,837***

Table 3-9: Loch Raven West Annual Nitrogen Loads by Subwatershed Based on BCLCD Land Use (lbs/yr)

		BCLCD LAND COVER							
SUBWATERSHED	Total Area (acres)	Pervious Urban	Impervious Urban	Extractive	Forest	Pasture	Cropland	Total Nitrogen Load (lbs/yr)	Nitrogen Loading Rate (lbs/acre/yr)
Piney Run	6,244	2,628	2,064	0	6,333	16,169	35,225	62,419	10.0
Blackrock Run	7,117	7,098	3,228	35	8,378	10,904	43,422	73,065	10.3
Little Piney Run	1,257	2,575	522	0	1,316	2,276	5,392	12,081	9.6
Indian Run	2,454	1,454	957	54	2,842	5,300	12,946	23,552	9.6
McGill Run	4,077	1,734	1,485	0	4,841	7,015	27,446	42,521	10.4
Western Run	7,510	9,098	4,034	0	7,117	22,288	24,173	66,711	8.9
Slade Run	2,849	1,807	1,376	0	3,663	6,538	10,316	23,700	8.3
Delaware Run	2,283	2,318	1,610	0	2,548	5,842	7,325	19,643	8.6
Councilman's Run	2,436	3,709	1,695	0	3,058	3,746	9,847	22,056	9.1
Waterspout Run	1,163	1,710	486	0	1,584	2,817	1,213	7,809	6.7
Deadman's Run	1,098	996	624	0	1,414	2,408	3,571	9,013	8.2
Total	***38,488***	***35,128***	***18,080***	***88***	***43,093***	***85,303***	***180,877***	***362,570***	***9.4***

Table 3-10: Loch Raven West Annual Total Phosphorus (TP) Loads by Subwatershed Based on BCLCD Land Use (lbs/yr)

SUBWATERSHED	Total Area (acres)	BCLCD LAND COVER						Total Phosphorus Load (lbs/yr)	Phosphorus Loading Rate (lbs/acre/yr)
		Pervious Urban	Impervious Urban	Extractive	Forest	Pasture	Cropland		
Piney Run	6,244	68	180	0	91	1,500	2,015	3,854	0.62
Blackrock Run	7,117	184	281	6	121	1,012	2,483	4,087	0.57
Little Piney Run	1,257	67	45	0	19	211	308	651	0.52
Indian Run	2,454	38	83	9	41	492	740	1,403	0.57
McGill Run	4,077	45	129	0	70	651	1,570	2,465	0.60
Western Run	7,510	236	351	0	103	2,068	1,383	4,140	0.55
Slade Run	2,849	47	120	0	53	607	590	1,416	0.50
Delaware Run	2,283	60	140	0	37	542	419	1,198	0.52
Councilman's Run	2,436	96	147	0	44	348	563	1,199	0.49
Waterspout Run	1,163	44	42	0	23	261	69	440	0.38
Deadman's Run	1,098	26	54	0	20	223	204	528	0.48
Total	***38,488***	***912***	***1,573***	***14***	***622***	***7,915***	***10,345***	***21,381***	***0.56***

Table 3-11: Loch Raven West Annual Sediment Loads by Subwatershed Based on BCLCD Land Use (lbs/yr)

SUBWATERSHED	Total Area (acres)	BCLCD LAND COVER						Total Sediment Load (lbs/yr)	Sediment Loading Rate (lbs/acre/yr)
		Pervious Urban	Impervious Urban	Extractive	Forest	Pasture	Cropland		
Piney Run	6,244	50,211	190,407	15	147,157	578,450	1,695,883	2,662,123	426.4
Blackrock Run	7,117	135,590	297,833	6,325	194,651	390,088	2,090,562	3,115,049	437.7
Little Piney Run	1,257	49,185	48,145	0	30,576	81,436	259,583	468,925	372.9
Indian Run	2,454	27,769	88,244	9,742	66,029	189,607	623,299	1,004,690	409.4
McGill Run	4,077	33,126	136,951	0	112,484	250,974	1,321,371	1,854,905	455.0
Western Run	7,510	173,806	372,182	0	165,358	797,357	1,163,820	2,672,523	355.9
Slade Run	2,849	34,527	126,976	0	85,102	233,896	496,657	977,158	343.0
Delaware Run	2,283	44,284	148,487	0	59,192	209,014	352,666	813,643	356.3
Councilman's Run	2,436	70,855	156,350	0	71,063	134,026	474,101	906,395	372.0
Waterspout Run	1,163	32,671	44,807	0	36,794	100,780	58,383	273,435	235.1
Deadman's Run	1,098	19,029	57,586	0	32,856	86,143	171,929	367,543	334.8
Total	***38,488***	***671,052***	***1,667,967***	***16,082***	***1,001,261***	***3,051,771***	***8,708,255***	***15,116,388***	***392.8***

3.3.2 Septic Pollutant Loading

The majority of the Loch Raven West watershed relies on septic systems for waste treatment; public sewer systems only extend into the southernmost tip of the watershed. Septic systems are designed so that waste goes into a tank, enabling solids to settle at the bottom and liquids to flow through a septic field. While some phosphorus can become soluble in septic systems, it is assumed that only nitrogen is distributed to the septic field (CBP, 2009) for pollutant loading calculations.

The nitrogen load that passes into the septic field, through the soil, reaches the stream system through groundwater. Septic systems are classified based on their location in the watershed and their proximity to streams. For septic systems located in the Chesapeake Bay Critical Area, a loading rate of 16.44 lbs nitrogen/year is used. For systems outside the critical area, rates of 10.28 lbs nitrogen/year if the system is within 1,000 feet of a stream and 6.17 lbs nitrogen/year if the stream is located further than 1,000 feet of a stream are used. In the Loch Raven West watershed, there are no septic systems located within the Chesapeake Bay Critical Area.

As shown in Table 3-12, Loch Raven West has a high number of septic systems due to the rural nature of the watershed with the majority of the area located outside the URDL. The total estimated annual nitrogen load due to septic systems was calculated as 25,281 lbs/yr and is broken down by subwatershed in Table 3-12.

Table 3-12: Total Septic Systems and Population by Subwatershed

		# of Septic Systems		Nitrogen Load (lb N/year)		
Subwatershed	Total # of Septic Systems	<1000' from stream	>1000' from stream	<1000' from stream	>1000' from stream	Total Nitrogen Load
Piney Run	234	230	4	2,364	25	2,389
Blackrock Run	493	479	14	4,924	86	5,011
Little Piney Run	75	74	1	761	6	767
Indian Run	90	89	1	915	6	921
McGill Run	240	240	0	2,467	0	2,467
Western Run	503	497	6	5,109	37	5,146
Slade Run	126	126	0	1,295	0	1,295
Delaware Run	253	252	1	2,591	6	2,597
Councilman's Run	324	322	2	3,310	12	3,323
Waterspout Run	93	90	3	925	19	944
Deadman's Run	41	41	0	421	0	421
Total	***2,472***	***2,440***	***32***	***25,083***	***197***	***25,281***

3.3.3 Total Pollutant Loading

The total estimated pollutant loads based on land use and septic systems within the entire Loch Raven West watershed are summarized in Table 3-13.

Table 3-13: Total Annual Pollutant Loading for Loch Raven West

BCLCD Land Use	Total Nitrogen Load (lb/year)	Total Phosphorus Load (lb/year)	Total Sediment Load (lb/year)
Pervious Urban	35,128	912	671,052
Impervious Urban	18,080	1,573	1,667,967
Extractive	88	14	16,082
Forest	43,093	622	1,001,261
Pasture	85,303	7,915	3,051,771
Cropland	180,877	10,345	8,708,255
Septic Systems	25,281	-	-
Total	***387,850***	***21,381***	***15,116,388***

3.4 Water Quality Monitoring Data

Baltimore County and Maryland DNR have conducted chemical, physical, biological, and bacterial monitoring for the Loch Raven West watershed through various programs.

3.4.1 Flow Monitoring

The United States Geological Survey (USGS) currently operates two gage stations in the Loch Raven West watershed. The monitoring station on Western Run has been in operation since 1944 and the monitoring station on Piney Run has been in operation since 1982 (USGS, 2016). One additional USGS gage, Slade Run at Longnecker Road (near Glyndon), was operational for 34 years between 1947 and 1981 and then again for two years between 2009 and 2011. Table 3-14 shows historical flows for the three gage stations. Their locations within the watershed are shown in Figure 3-1. The Western Run monitoring station has also been measuring turbidity since September 2015 (USGS, 2016). An additional gage station was at one time stationed on a Western Run Tributary, but there is no flow data available for that station.

Table 3-14: Historical Flow Data for USGS Gage Stations in Loch Raven West Watershed (USGS, 2016)

Gage Station	Location	Drainage Area (Sq. mi)	# of Years of Monitoring Data	Daily Mean Discharge (cfs)	Maximum Instantaneous Discharge (cfs)	Date	Minimum Instantaneous Discharge (cfs)	Date
1583100	Piney Run at Dover	12.3	34	15.5	3,220	9/8/87	0.7	8/22-23/02
1583500	Western Run at Western Run	59.8	72	70.9	38,000	6/22/72	2.4	9/12/66
1583000	Slade Run at Longnecker Rd	2.1	36	2.4	515	6/22/72	0.0	8/25 - 9/11/66

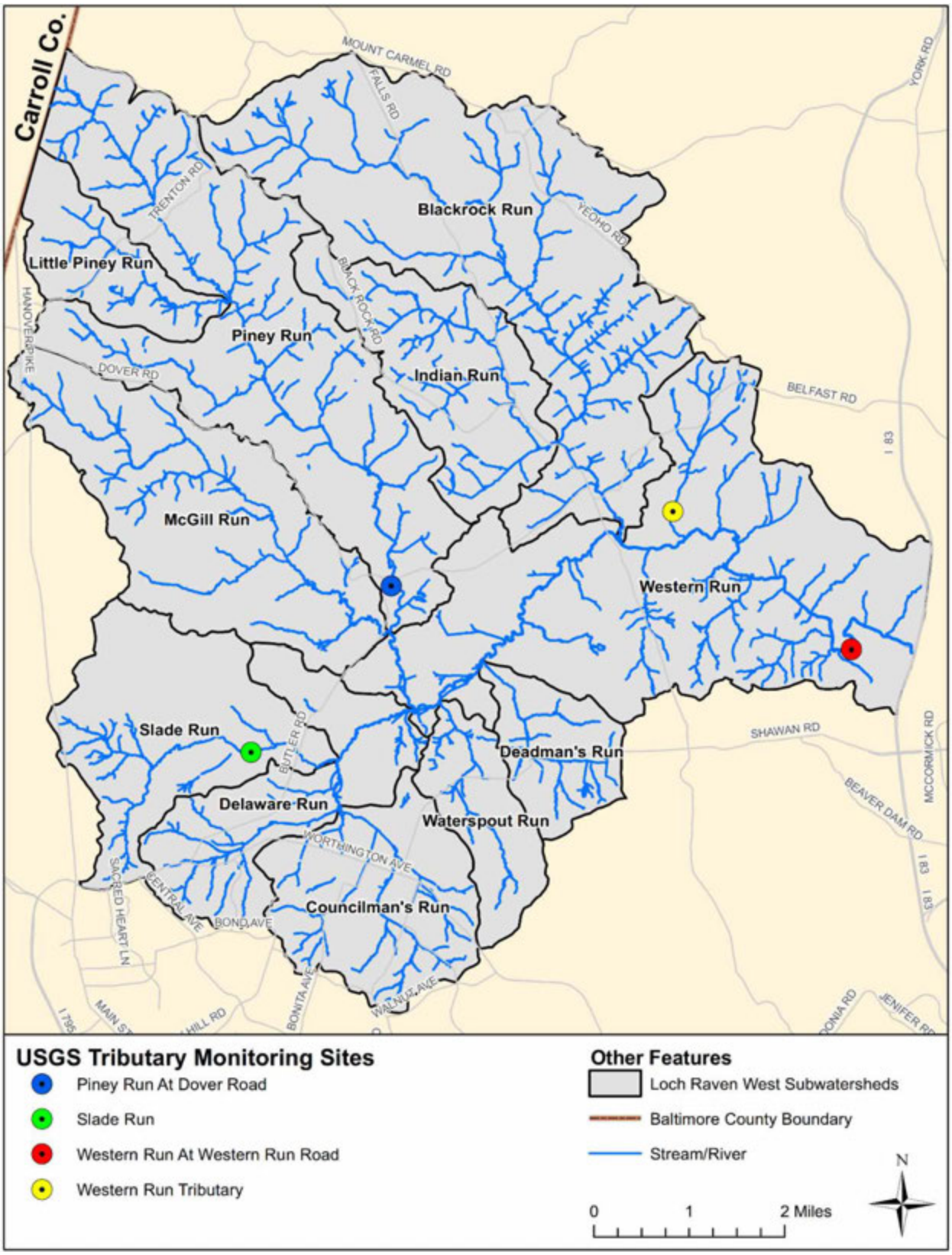

Figure 3-1: USGS Tributary Monitoring Stations within the Loch Raven West Watershed

3.4.2 Baltimore Countywide Monitoring

Baltimore County conducts several water quality monitoring programs across the county. The following subsections provide details on the chemical, biological, and bacterial monitoring that is currently in place. There is no geomorphologic monitoring for Loch Raven West.

3.4.2.1 Trend Chemical Monitoring

Baltimore County's Trend Chemical Monitoring Program observes ambient chemical conditions and determines trends in chemical concentrations and pollutant loads over time. This data is used to determine areas to target restoration, assess the impact of implemented restoration activities, and determine the amount of progress made towards meeting TMDLs and other restoration goals. The program was initiated in January 2011 and replaced Baltimore County's previous Baseflow Monitoring program. Sites are visited on the same day, once per month. In the Loch Raven West watershed, there are a total of three monitoring sites located in the Western Run, Piney Run, and Slade Run subwatersheds as shown in Figure 3-2.

Table 3-15: Chemical Monitoring Sites in Loch Raven West

Type of Monitoring	Monitoring Site*	Subwatershed
Trend	LR17**	Western Run
	LR35	Piney Run
	LR39	Slade Run

*All three sites are also USGS gage stations;
**Site is also sampled for bacteria.

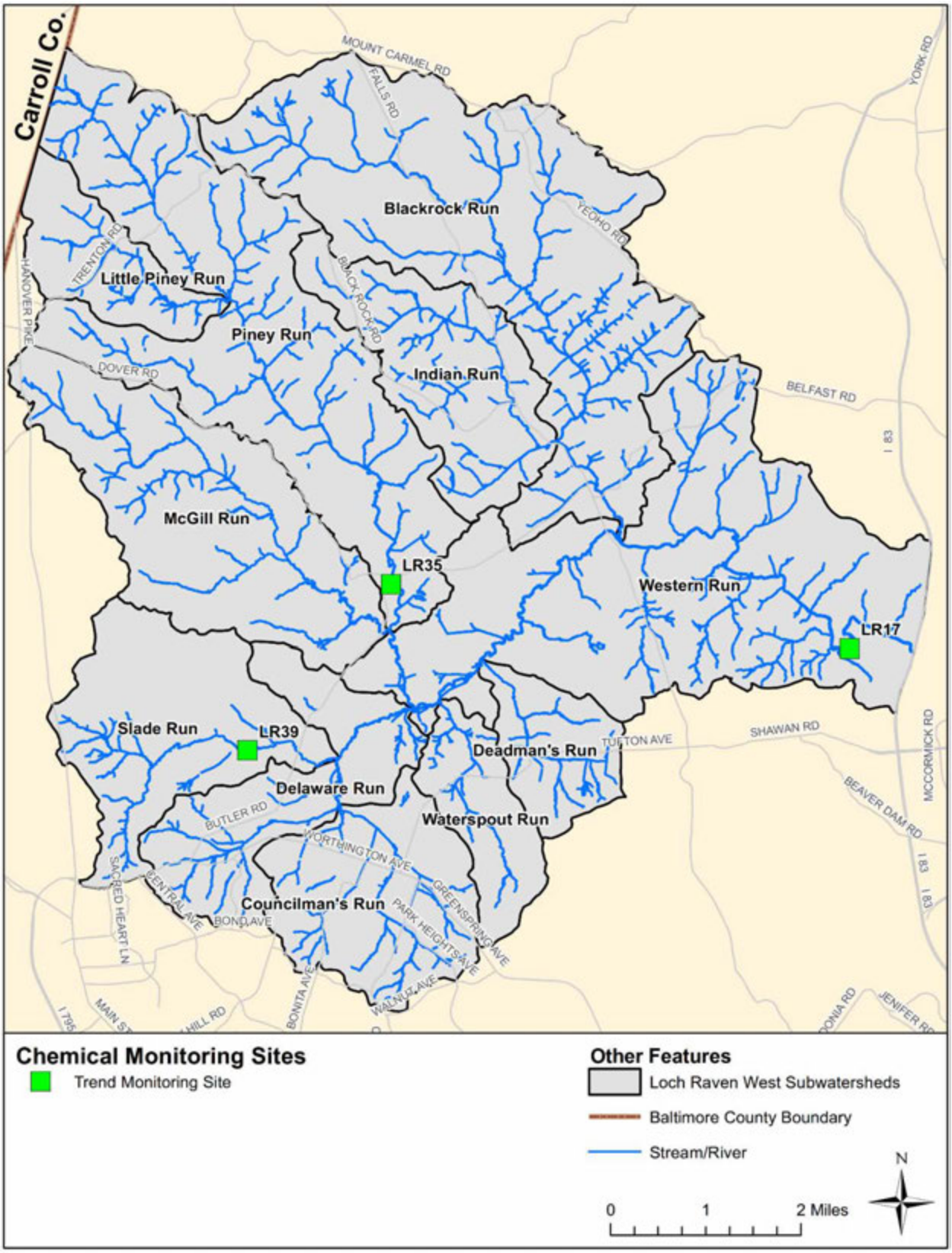

Figure 3-2: Chemical Monitoring Sites in Loch Raven West

Numerous water quality parameters were measured during the trend monitoring including total suspended solids (TSS), total solids (TS), total kjeldahl nitrogen (TKN), nitrate-nitrite, total phosphorus (TP), chloride (Cl^-), sodium (Na), biochemical oxygen demand (BOD), chemical oxygen demand (COD), hardness, magnesium, and calcium as well as water temperature and pH determined in situ. If water quality parameters registered below the equipment detection limit, they were given a value of half the detection limit.

Of particular importance were measurements for total suspended solids (TSS), nutrients (nitrogen and phosphorus), sulfates, chlorides, and temperature due to 303(d) listings and TMDLS as well as sodium due to the downstream impoundment's use as a water supply and temperature due to the Use III classification:

- Suspended Solids: Excessive suspended solids can adversely impact aquatic life as it affects the light available for photosynthesis by plants and visual capability of aquatic life. Decreased light can lead to a decrease in algae communities that may limit food supplies and reduce growth rates of invertebrate and fish communities. Suspended solids can inhibit the hunting capability of visual fish predators and cause gill damage. Excessive sediment can also negatively affect habitat structure, through the burial of space between the gravel in the stream bottom (called embeddedness). Embeddedness can kill incubating fish eggs/larvae and benthic macroinvertebrates and can trap bacteria and organics on the stream bottom causing oxygen depletion. Over the long term, excessive sediment can also reduce the storage volume available in the reservoir.
- Nutrients: Over-enrichment of water bodies by excessive nutrient input can cause excessive growth of aquatic plants (algal blooms) and bacterial consumption of dissolved oxygen when the plants decompose. This can lead to significant reductions in water quality as well as abundance and diversity of aquatic life communities.
- Temperature: Water temperature is the single most important factor that limits the geographic distribution of aquatic life. The fish may be found in waters with temperature ranges from 0 – 24°C; however, the temperature should not exceed 20°C (the water quality criteria for Use III Waters) for an optimal environment.
- Chlorides and Sodium: Natural stream systems can also be impaired by urban land use and its effects such as an increase in dissolved substances (including chloride and sodium) in runoff. Chlorides come from a variety of sources including industrial discharges, metals contamination, and road salt application. The most likely source of chlorides entering the Loch Raven Reservoir is from the storage and application of road salt (MDE, 2014b). Road salt has also been identified as a major contributor to sodium levels in the watershed and reservoir (ACEQ, 2009). Increased chloride and sodium levels are associated with degraded biological conditions by inversely impacting water quality, soil chemistry, and aquatic health.
- Sulfate: While sulfur is an essential plant nutrient, elevated levels of sulfates are able to form strong acids, which can lower the pH in surface waters. Sulfates can enter water bodies naturally, mostly through the breakdown of leaves that fall into streams and water flowing through

substrate containing gypsum. Excess sulfate can also enter waterbodies from urban runoff, agricultural runoff, acid mine drainage, atmospheric deposition, and wastewater discharges (MDE, 2009a).

Total suspended solids, total nitrogen, and total phosphorus were evaluated because the reservoir is 303(d) listed for sediment and total phosphorus and these are key Chesapeake Bay Program parameters. Temperature, sulfates, and chloride were evaluated because they are 303(d) listed as impairments affecting the biological community. Stream ratings were based on total nitrogen concentration established using data adapted from the Maryland Department of Natural Resources (DNR) using loading coefficients reported by Frink are shown in Table 3-16 (Frink, 1991). Ratings for total phosphorus were developed by evaluating non-tidal phosphorus data from the Chesapeake Bay Program, also shown in Table 3-16 (Belval & Sprague, 1999).

Table 3-16: Stream Ratings by Nutrient Concentration

Rating	Total Nitrogen (TN)	Total Phosphorus (TP)
Baseline	0.0 – 1.0	< 0.05
Slightly elevated	1.0 – 2.0	0.05 - 0.075
Moderate	2.0 – 3.0	0.075 – 0.10
High	3.0 – 5.0	0.10 – 0.20
Excessive	> 5.0	> 0.20

Three trend monitoring sites are located within the Loch Raven West watershed. The trend monitoring data from January 2011 through November 2015 are summarized in Table 3-17.

Table 3-17: Loch Raven West Trend Monitoring Summary by Site

Parameter (mg/L)		Site		
		LR17	LR35	LR39
Suspended Solids (SS)	No. Samples	59	59	61
	Max	155	2,596	706
	Min	0.50	0.00	0.50
	Median	4.00	0.50	0.50
	Mean	**12.08**	**55.37**	**17.20**
	Std. Dev	25.35	339.68	91.19
Total Nitrogen	No. Samples	25	29	31
	Max	4.17	13	6.87
	Min	1.99	2.79	0.87
	Median	3.10	4.91	1.77
	Mean	**3.07**	**4.91**	**1.90**
	Std. Dev	0.61	1.77	1.04
Total Phosphorus	No. Samples	57	55	57
	Max	0.51	4	1.44
	Min	0.03	0.03	0.03
	Median	0.03	0.03	0.03
	Mean	**0.05**	**0.15**	**0.08**
	Std. Dev	0.08	0.50	0.22
Sulfates	No. Samples	49	52	54
	Max	11.65	12	16.56
	Min	6.14	6.33	6.22
	Median	8.95	9.12	10.57
	Mean	**9.07**	**8.91**	**10.54**
	Std. Dev	1.18	1.14	1.47
Chloride	No. Samples	49	51	54
	Max	67.1	130	80.34
	Min	17.26	6.62	6.22
	Median	29.06	35.42	16.65
	Mean	**30.71**	**39.27**	**19.76**
	Std. Dev	8.25	18.31	12.89
Sodium	No. Samples	56	57	59
	Max	40	69	75.6
	Min	4.60	2.50	1.50
	Median	12.05	16.80	6.90
	Mean	**13.69**	**20.67**	**9.60**
	Std. Dev	6.68	12.83	10.28

Average total nitrogen concentrations were rated as “Slightly Elevated” (LR39) and “High” (LR17 and LR35). LR35 experienced one event registering as “Excessive”, while LR35 (Piney Run) experienced 13 events or 45% of samples registering as “Excessive”. Total phosphorus averages were rated as “Slightly Elevated” (LR17), “Moderate” (LR39), and “High” (LR35). LR17 experienced two events registering as “Excessive”, LR39 experienced 4 events registering as “Excessive”, while LR35 (Piney Run) experienced seven events or 13% of samples registering as “Excessive”.

Loch Raven West is 303(d) listed for sulfates and chlorides as the cause for biological impairment. Inorganic pollutants, such as sulfates and chlorides, are often found in contaminated runoff from roads, urban, and agricultural land (MDE, 2009a). Chlorides and sulfates were found in 26% and 23%, respectively, of streams with poor to very poor biological condition in the Loch Raven Reservoir watershed (MDE, 2009a). Site LR39 (Slade Run) had the highest average sulfate concentration (10.54 mg/L) and the maximum sampled concentration (16.56 mg/L). Site LR35 (Piney Run) had the highest average chloride concentration (39.27 mg/L) and the maximum sampled concentration (130.22 mg/L).

Natural stream systems can also be impaired due to the usage of road salt in the winters. Road salt (NaCl) enters the stream system as roadway runoff and dissolves in water into sodium and chloride ions, inversely impacting water quality, soil chemistry, and aquatic health. According to the Baltimore County Advisory Commission on Environmental Quality, Baltimore County and the State apply more road salts than other jurisdictions at a rate of approximately 1.2 tons of salt per lane mile per storm and 3.2 tons of salt per lane mile per storm, respectively (ACEQ, 2009). While there is currently no state water quality criterion for chlorides, MDE has recommended a future water quality standard be implemented (MDE, 2013). The EPA’s recommended water quality criterion for aquatic life for chloride is 860 mg/L for acute exposure and 230 mg/L for chronic exposure (USEPA, 2016b). Based on BSID methodology, MDE identified chloride threshold values indicating potentially significant biological degradation at 50.0 mg/L (MDE, 2009a). None of the measurements taken at the three sampling locations exceed the EPA 230 mg/L chronic exposure limit; however, all three sites had maximum samples above the 50.0 mg/L limit. Similarly, there is no water quality criteria established for sodium; however, the EPA warns that people under strict sodium diets not consume water with sodium concentrations exceeding 20 mg/L (USEPA, 2003). Only LR35 (Piney Run) exceeds this limit with an average concentration of 20.7 mg/L. While the current monitoring indicated relatively low chloride and sodium levels, increasing salinity levels have been observed in the Loch Raven Reservoir and Montebello Treatment Plant, which treats the reservoir water (ACEQ, 2009).

Brook trout have historically been found throughout the Gunpowder basin, which includes the Loch Raven West watershed. During MBSS sampling between 1995 and 2004, exotic trout were found in every subwatershed in Loch Raven West except Little Piney Run, while native brook trout were also found in Blackrock Run, Indian Run, and Deadman’s Run (DNR, 2006). Two of the most critical conditions for a healthy trout population are pH and water temperature (DNR, 2006). The optimal pH range for brook trout is 6.5 - 8.0, similar to the MDE threshold values, while the tolerance range is 4.0 – 9.5. All of the monitoring sites fall well within the tolerance range for brook trout. The threshold for pH was determined to range from 6.5 to 8.5; all of the trend monitoring sites averaged within the threshold range. LR17 and LR35 registered pH values over 8.5, while LR35 and LR39 registered pH values below 6.5 with a minimum

of 3.40 and 3.20, respectively. Monitoring site LR35 was either above or below the threshold value for 10% of the samples taken during the sampling period. Low pH can have many causes such as agricultural land use, organic sources, or atmospheric deposition resulting in high acidity and poor aquatic life. The trend monitoring sites record stream temperature and are shown in Table 3-18.

Water temperature is the single most important factor that limits the geographic distribution of brook trout. The fish may be found in waters with temperature ranges from 0 – 24°C; however, the temperature should not exceed 19°C for an optimal environment. The trend monitoring sites record stream temperature and are shown in Table 3-19. Although all of the stream monitoring sites have average water temperatures in the optimum condition range, all sites have maximum temperatures exceeding the 20°C limit for Use III waters and one site (LR17) has a maximum temperature above the 24°C limit. For all three sites, the optimal temperature is exceeded for multiple months every summer that measurements were taken.

Table 3-18: Water pH at Trend Monitoring Sites

Monitoring Site	Subwatershed	Average pH	Min. pH	Max. pH
LR17	Western Run	7.52	6.54	8.95
LR35	Piney Run	7.46	3.40	8.68
LR39	Slade Run	7.30	3.20	8.46

Table 3-19: Water Temperature at Trend Monitoring Sites

Monitoring Site	Subwatershed	Average Temp. (°C)	Max. Temp. (°C)
LR17	Western Run	13.88	24.80
LR35	Piney Run	12.28	22.30
LR39	Slade Run	12.36	21.80

3.4.2.2 Biological Monitoring

Biological monitoring for Loch Raven West is conducted by Baltimore County (since 2003) following the Maryland Biological Stream Survey (MBSS) probabilistic monitoring methods to assess ecological health in local streams. In even-numbered years, macroinvertebrate samples are taken in the Loch Raven West watershed during the spring index period and a Benthic Index of Biotic Integrity (BIBI) score is calculated. The BIBI scores are grouped and given a condition rating: “Very Poor” (1.00 – 1.99), “Poor” (2.00 – 2.99), “Fair” (3.00 – 3.99), and “Good” (4.00 – 5.00) (EPS, 2015). Table 3-20 provides the distribution of BIBI scores calculated for the entire Loch Raven West watershed between 2004 and 2014. A visual reference of the distribution of BIBI scores across all monitoring years is shown in Figure 3-3.

Table 3-20: Historical BIBI Scores in the Loch Raven West Watershed

Year	# of Samples	Very Poor (1.00 - 1.99)	Poor (2.00 - 2.99)	Fair (3.00 - 3.99)	Good (4.00 - 4.99)
2004	24	4%	13%	63%	21%
2006	21	5%	5%	48%	43%
2008	16	0%	0%	38%	63%
2010	28	0%	18%	68%	14%
2012	17	0%	6%	65%	29%
2014	16	6%	13%	44%	38%

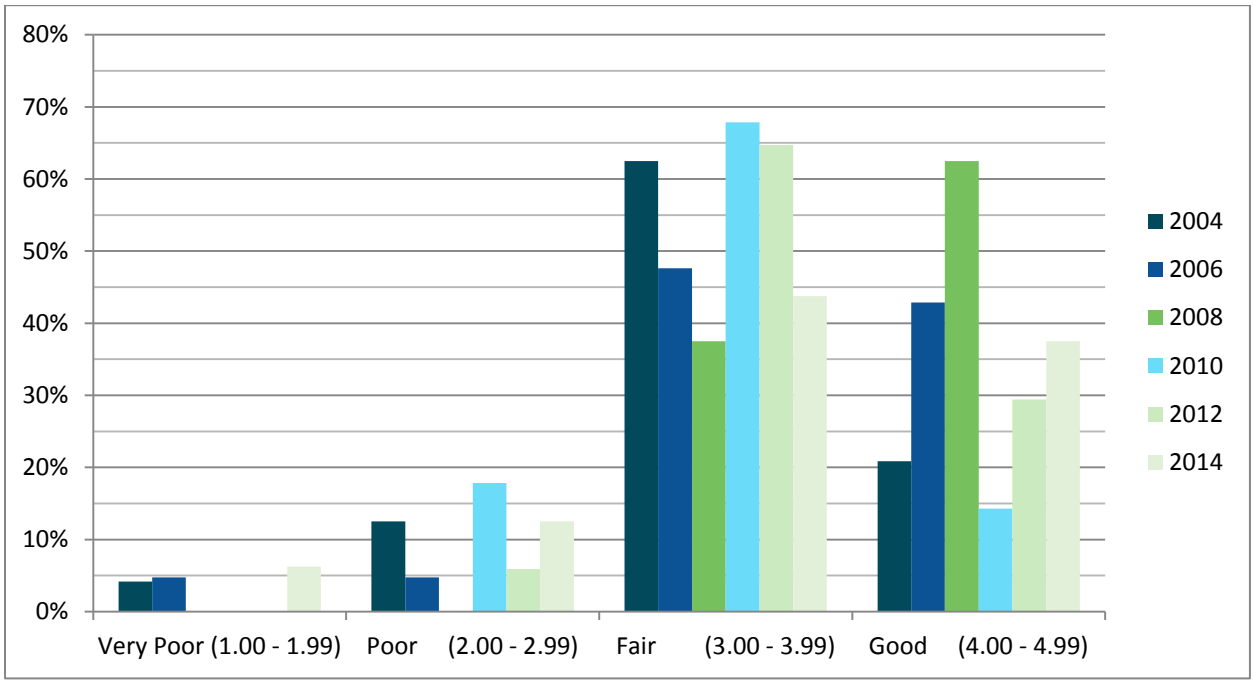

Figure 3-3: Distribution of BIBI Scores in the Loch Raven West Watershed over Time

Since monitoring began in 2004, the BIBI scores have leaned heavily towards the "Fair" to "Good" range. Only three of the sampling sites have ever registered a "Very Poor" rating (one in 2004, one in 2006, and one in 2014). A total of 12 sites registered a "Poor" rating with at least one site in every year except 2008. 2008 was the only year where all the sampled sites rated either "Fair" or "Good" with 63% falling under the "Good" score. Overall, there is a slight downward trend in the BIBI scores when evaluating the total of "Fair" and "Good" sites each year. The number and location of sampling sites vary year to year to provide unbiased estimates of stream conditions; the location of sampling sites within the Loch Raven West watershed and their corresponding conditions are shown in Figure 3-4.

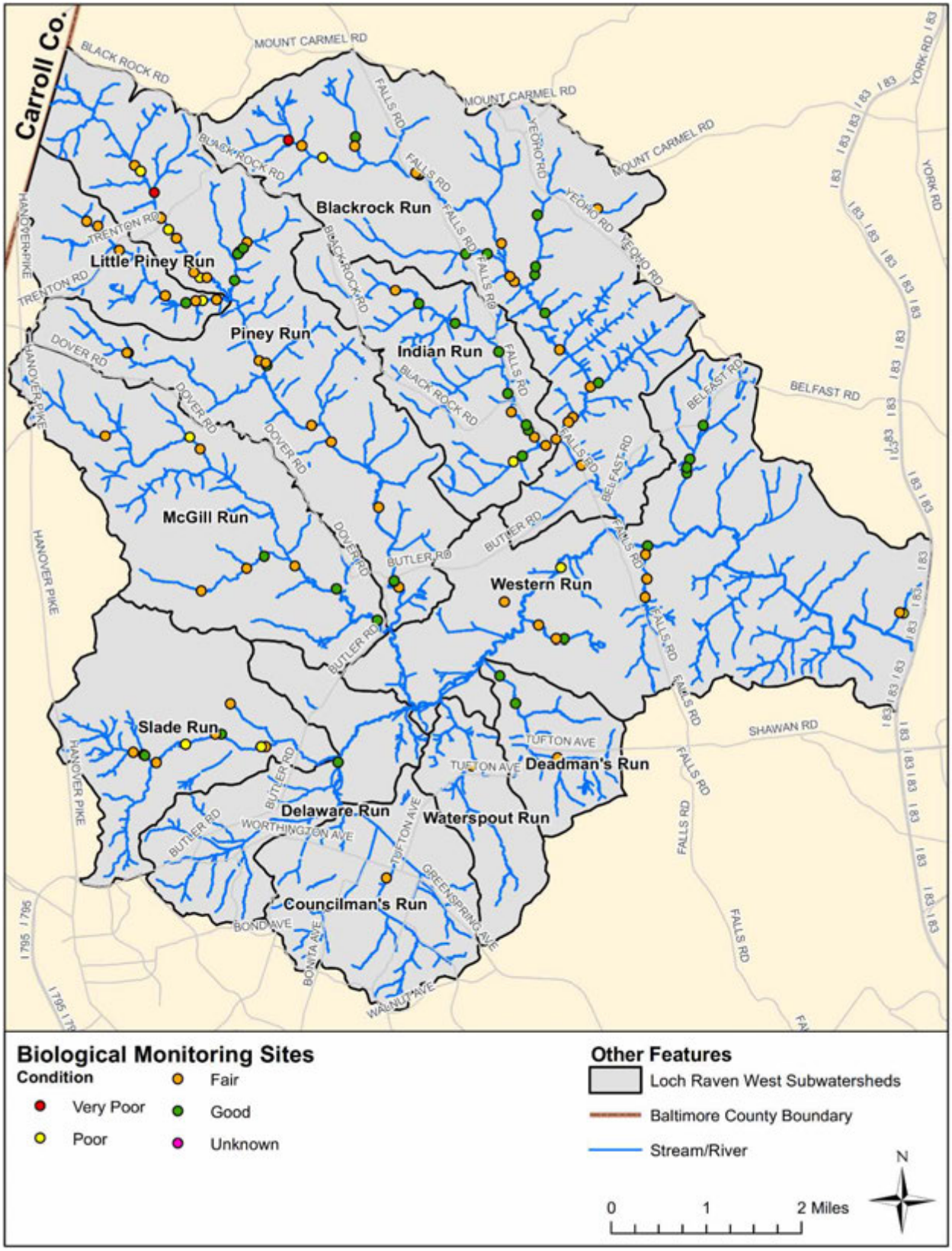

Figure 3-4: Biological Monitoring Sites from 2004-2014 in Loch Raven West

3.4.2.3 Bacterial Monitoring

In addition to chemical and biological monitoring, Baltimore County conducts bacteria water quality sampling for *Escherichia coli* (*E. coli*). Beginning in June of 2010, Baltimore County EPS has coordinated with the Baltimore City Surface Water Management Division to monitor bacteria trend levels over time at seven monitoring locations within the Loch Raven Reservoir watershed. This effort is part of the Bacteria Trend Monitoring Program that includes Baltimore County, Baltimore City, and Carroll County to monitor bacteria trends over time within six major watersheds in response to the development of bacteria TMDLs for these watersheds.

Of the seven monitoring sites within the Loch Raven Reservoir watershed, one is within the Loch Raven West watershed. As part of the TMDL implementation plan, the County performed additional bacteria monitoring to further identify which particular subwatersheds within the entire watershed may have higher bacteria concentrations. Figure 3-5 shows the locations of current bacteria monitoring sites.

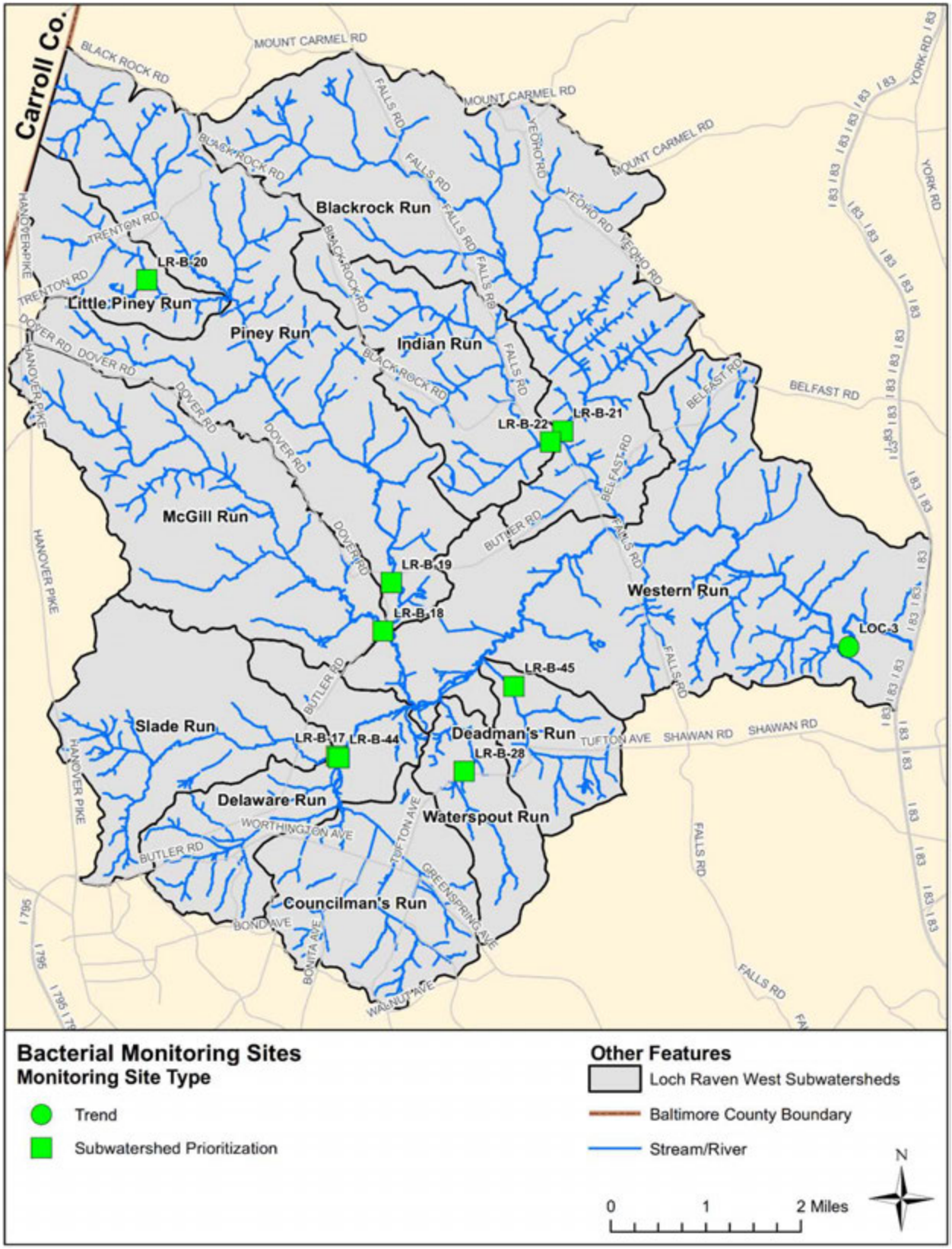

Figure 3-5: Bacteria Monitoring Sites in the Loch Raven West Watershed

Within the Loch Raven West watershed, the current monitoring site is located on the main stem of the Western Run on the eastern most boundary of the watershed (LOC-3). This sampling station is the same as chemical trend monitoring site LR17. Samples are collected on the first Thursday of every month. Table 3-21 shows annual average *E. coli* concentration and the seasonal (only those samples collected between May 1st and September 30th) average *E. coli* concentration. The table breaks down the results by high flow sample days and low flow sample days based on long term flow data, as more pollutants are likely washed into the water during high flow periods.

Table 3-21: Annual and Seasonal (May 1st - September 30th) *E. coli* Concentrations by Flow Regime for the Loch Raven West Watershed

			2010		2011		2012		2013		2014		2015		2016*	
Site	**Type**	**Flow Type**	**N**	**MPN**	**N**	**MPN**	**N**	**MPN**	**N**	**MPN**	**N**	**MPN**	**N**	**MPN**	**N**	**MPN**
LOC-3	**Annual**	High	2	**735**	4	**576**	4	**861**	3	**190**	4	**1,238**	5	**750**	1	**613**
		Low	5	**836**	8	118	8	**137**	9	63	8	**129**	12	**180**	1	77
		All	7	**806**	12	**200**	12	**253**	12	83	12	**275**	17	**274**	2	**217**
	Seasonal	High	0	**-**	2	**968**	2	**1,448**	1	**313**	2	**1,493**	1	**1,203**	0	-
		Low	4	**1,132**	3	**387**	3	**411**	4	112	3	**258**	9	**465**	0	-
		All	4	**1,132**	5	**558**	5	**680**	5	**138**	5	**521**	10	**512**	0	-

*Through February 2016 only; Bold numbers exceeded the water quality standard of 126 MPN (COMAR, 2016); Shaded cells have measurements that exceeded the maximum threshold of the instrumentation and may be under reporting.

In addition to analyzing the bacteria monitoring data for annual and seasonal geometric mean, the County also analyzed the data based on the single sample maximum allowable density for the seasonal period. The water quality criteria for single sample maximum allowable density are based on frequency of full body contact, ranging from infrequent (576 MPN) to frequent (235 MPN) (COMAR, 2016). The objective in the control of bacteria is to not only meet the geometric mean water quality standards, but also to meet the single sample water quality standards. This is particularly important for the low flow (dry weather) component of the flow regime, as this is when human recreational use of water is most likely to occur. Table 3-22 shows the percentage of single samples that exceeded the single sample water quality standards.

Table 3-22: Frequency of Single Sample Water Quality Exceedance by Flow Regime for the Loch Raven West Watershed

		N		Percent Single Sample Exceedance (MPN)							
		Flow Type		Infrequent Contact (576 MPN)		Occasional Contact (410 MPN)		Moderately Frequent Contact (298 MPN)		Frequent Contact (235)	
Site	Year	High	Low	High	Low	High	Low	High	Low	High	Low
LOC-3	2010	0	4	-	**100%**	-	**100%**	-	**100%**	-	**100%**
	2011	2	3	**50%**	0%	**50%**	**33%**	**100%**	**67%**	**50%**	**100%**
	2012	2	3	**100%**	0%	**100%**	**67%**	**100%**	**67%**	**50%**	**100%**
	2013	1	4	0%	0%	0%	0%	**100%**	**25%**	0%	**50%**
	2014	2	3	**100%**	0%	**100%**	**33%**	**100%**	**67%**	0%	**67%**
	2015	1	9	**100%**	**56%**	**100%**	**67%**	**100%**	**67%**	**200%**	**78%**

Bold numbers exceeded the water quality standard (COMAR, 2016)

Overall, LOC-3 fails to meet annual and seasonal standards for mean concentration at all flow regimes and shows no improvement in levels during the most recent sampling year. During 2013, LOC-3 had the fewest occurrences of exceeding water quality standards since sampling began. LOC-3 also failed to meet single sample exceedance for every year since sampling began. 2013 had the fewest occurrences of exceedance, and only exceeded water quality standards for Moderately Frequent and Frequent Contacts. In 2015, every water quality standard measurement was exceeded and this was the worse year to date for single sample exceedance. Additional subwatershed bacteria monitoring will help further identify areas of high bacteria concentrations.

In 2015, the County began performing additional seasonal bacteria monitoring in nine subwatersheds to further identify which particular subwatersheds may have higher bacteria concentrations. Table 3-23 shows the seasonal (May 1st - September 30th) *E. coli* concentrations for 2015 and the geometric mean for the season.

Table 3-23: Seasonal Single Sample *E. coli* Concentrations in 2015 for the Loch Raven West Watershed

Station Code	Subwatershed	Month						Geometric Mean
		May	June	July	August	Sept	Oct	
LR-B-17	Slade Run	**133**	**1,414**	**2420**	**201**	-	96	388
LR-B-18	McGill Run	**178**	**517**	**>2,419.6**	**365**	-	39	317
LR-B-19	Piney Run	**201**	**>2,419.6**	**>2,419.6**	**291**	**517**	-	708
LR-B-20	Little Piney Run	33	**548**	**1,300**	125	-	54	173
LR-B-21	Blackrock Run	66	**313**	**291**	**276**	-	96	174
LR-B-22	Indian Run	**161**	**276**	**1,120**	**185**	-	50	215
LR-B-28	Waterspout Run	80	**387**	**1,553**	105	-	19	157
LR-B-44	Delaware Run/ Councilman's Run	**488**	**1,733**	**1,733**	**365**	-	91	546
LR-B-45	Deadman's Run	**138**	**770**	**>2,419.6**	**866**	-	36	380

Bold numbers exceeded the water quality standard of 126 MPN (COMAR, 2016)

All of the subwatesheds sampled exceeded water quality standards in June and July, and the geometric mean for the season. Piney Run and Delaware Run/Councilman's Run had the greatest exceedance of water quality standards, with a geometric mean for the season of 708 and 545 MPN, respectively. Little Piney Run, Blackrock Run, and Waterspout Run had the lowest exceedance of water quality standards, with a geometric mean for the season of 173, 174, and 157 MPN, respectively. These three subwatersheds, were the only subwatersheds to have samples that were within the water quality standard of 126 MPN. While efforts to reduce bacteria still need to occur across all the sampled subwatersheds, efforts will likely be focused in the subwatersheds with the greatest exceedance concentrations of bacteria.

3.4.3 Illicit Discharge and Elimination Data

Baltimore County monitors illicit discharges from its storm sewer system through a program of routine outfall screenings. The program consists of three parts:

1. A quantitative analysis of the effluent that includes measuring the effluent flow rate, temperature and pH, and field testing for parts per million (ppm) of chlorine, phenols, copper, and ammonia using a specially configured LaMotte NPDES test kit;
2. A qualitative assessment of the effluent, outfall structure, and receiving channel noting conditions such as water color, odor, vegetative condition, sedimentation, erosion, damage, etc.; and
3. A visual inspection of each outfall that identifies any structural damage.

The County has an outfall prioritization system based on data from the outfall screenings. There are 68 outfalls documented through spatial data by Baltimore County EPS in the Loch Raven West watershed. Approximately 97 percent of these (66) are minor outfalls (less than three feet in diameter) which are not prioritized. The remaining two major outfalls (greater than three feet in diameter) have a prioritization rating. The prioritization system allows for a more streamlined approach in selecting outfalls to screen and provides a more efficient use of manpower.

Under the outfall prioritization system, outfalls that have not been screened at least twice are not prioritized. Prioritized outfalls, those screened two or more times, are assigned one of the following priority ratings:

- Priority 1 (Critical): Outfalls with major problems that require immediate correction and/or close monitoring, or outfalls with recurring problems. These outfalls are sampled four times each year.
- Priority 2 (High): Outfalls with moderate to minor problems that have the potential to become severe. These outfalls are sampled once per year.
- Priority 3 (Low): Outfalls with minor or no problems that do not require close monitoring. These outfalls are sampled on a 10-year cycle.
- Priority 0 (Not prioritized): Outfalls with insufficient data to determine a priority rating. This may be due to inaccessibility, or if there has been an insufficient number of screenings. Major outfalls need three visits and minor outfalls need one visit before being prioritized.

3.5 Additional Studies

Various reports and studies have been conducted by State, County, and municipal agencies pertaining to Loch Raven West and the watershed's water quality. The reports are summarized in the sections below.

3.5.1 Road Salt Management

The Maryland State Legislature passed two bills in 2010 requiring the establishment of a Statewide Salt Management Plan; the Maryland State Highway Administration (SHA) in conjunction with the Maryland Department of the Environment (MDE) developed the document to minimize adverse impacts of road salt runoff in the state of Maryland. The objective of the Statewide Salt Management Plan is to provide a framework for highway agencies to deliver safe, efficient roadways during winter storms cost effectively while also acknowledging their obligation to do so in the most environmentally sensitive manner practicable (SHA, 2013). The report highlights the importance of providing public safety and mobility during winter storm events, but highlights the importance of proper storage, handling, and distribution of salt and the significance of alternative de-icing methods to ensure minimal negative environmental impacts. The severity and duration of winter storms dictates the quantity of salt required to maintain levels of service along roadways; currently, salt is the primary snow and ice control material due to its low cost. SHA and other municipalities have begun investigating other ways to treat the roads, such as pretreatment with a salt brine, to decrease salt use and impacts to waterways (Yurek, 2016).

Over-salting can have significant environmental impacts. A report conducted by the Maryland Department of Natural Resources (DNR) directly links road salts to increasing levels of sodium in fresh water sources (DNR, 2013). Increased sodium levels result in poor aquatic habitat and a decrease in populations of fish, amphibians, and other macro invertebrates. Some research has found, that even after stream restoration, increased conductivity levels associated with road salt application are present and may inhibit the complete re-establishment of the biological community (Kashiwagi, 2016). Sodium and chloride concentrations have also been detected in groundwater; the number of cases of resident complaints of contaminated well water in Baltimore County has increased 20-fold from the 1980s to 2015 (Ensor, 2016). Currently, there are no water quality criteria for chloride or sodium in Maryland, although MDE is in the process of developing chloride criteria to address the chloride impairment of streams throughout the state (Fox, 2016).

3.5.2 Reservoir Management

The Reservoir Watershed Management Agreement was signed in 2005 to continue the review of problems and actions affecting the three Baltimore County water-supply reservoir watersheds and provide recommendations to protect the three reservoirs (RWPC, 2005). The agreement is signed by multiple government agencies including Baltimore County, Baltimore City, Carroll County, Maryland Department of the Environment, Maryland Department of Agriculture, Baltimore and Carroll Counties Soil Conversation District, Reservoir Watershed Protection Committee (RWPC) and Baltimore Metropolitan Council (BMC). The Loch Raven Reservoir is one of the three water-supply reservoirs and its watershed encompasses the entire Loch Raven West watershed.

The Action Strategy for the Reservoir Watersheds consists of actions to be completed by various entities in order to protect and maintain the quality of water draining to the three reservoirs. These actions include

monitoring the reservoirs and major tributaries, watershed modeling, issuing discharge permits (NPDES), promoting agricultural BMPs, continuing the implementation of stormwater management regulations, administering sewer and septic regulations and inspections, aiding urban nutrient reductions, and overall land management through conservation and strategic development (BRWMP, 2005).

A progress report regarding the Action Strategy was published in 2009 by the Baltimore Metropolitan Council summarizing the 93 original "actions" recommended and focuses on the status of these commitments (BMC, 2009). Many of the efforts were found to be ongoing. One key action pertaining to the Loch Raven West watershed was the commitment of seeking funding to study the contribution of nutrients from septic systems; the majority of the watershed is on septic systems and further studies need to be completed to accurately estimate the pollutant loads. Overall, the majority of the actions are being performed although no further progress reports have been published.

3.5.3 Baltimore County Master Plan

The Baltimore County Master Plan is a guiding document for future development within Baltimore County. The goal of the Master Plan is to protect the environment, preserve agriculture, and ensure safe and attractive places to live and work (DP, 2010). The plan aims to focus development and redevelopment within the Urban Rural Demarcation Line (URDL) to direct growth away from sensitive ecological features. The vast majority of proposed land use within the document for the Loch Raven West watershed is within the Rural Zone (T-2: rural). Land in this zone is open or cultivated and sparsely settled. Land uses include woodlands, agricultural lands, and grasslands while typical structures include farmhouses and agricultural buildings. The report also emphasizes the importance of resource conservation with the county's current goal for land preservation of at least 80,000 acres of land to protect agriculture and natural resources.

3.5.4 Maryland Brook Trout Management Plan

Brook trout are the only trout in Maryland for which a Fisheries Management Plan was written due to their valuable standing as Maryland's only native freshwater trout species and concerns of their current status (DNR, 2006). Brook trout require high quality waters for survival and cannot typically survive in waters where temperatures exceed 68°F. The Fisheries Management Plan aims to restore and maintain healthy brook trout populations in Maryland's freshwater streams and provide long-term social and economic benefits from a recreational fishery. In Maryland, the top five reasons for loss and degradation of brook trout populations are 1) high water temperatures, 2) agriculture, 3) urbanization, 4) exotics (brown trout), and 5) poor riparian habitat.

As of fall 2005, there were 151 streams in the state of Maryland supporting brook trout populations, 31 are located in the Gunpowder basin, which includes portions of the Loch Raven West watershed. The brook trout population in this region is confined to headwater streams with no connectivity to other populations due to physical (blockages, high water temperature, etc.), chemical (pH), and biological (brown trout competition) barriers. Brook trout extirpation is likely when human land use exceeds 18% of a watershed. Intact populations only occur where human land use (any human-caused change from pre-settlement habitat type) is less than 10% (DNR, 2006). An intact population means that more than 50% of all native habitats in the subwatershed support self-sustaining brook trout populations. The management plan includes recommendations to restore native brook trout populations ranging from collecting more

brook trout data to encouraging buffer habitat restoration and public outreach. As of 2005, self-sustaining brook trout populations were found on private land in Blackrock Run, Indian Run, and Deadman's Run (DNR, 2006).

3.5.5 White-tailed Deer Management

Overabundant deer populations have a negative impact on forest health as deer eat understory and ground vegetation limiting the regenerative ability of the forests. This limits the stormwater benefits attributed to a healthy forest system such as slowed surface water flow, prevention of soil erosion, ground water filtration, and nutrient reduction. The lack of native understory vegetation also eliminates food and habitat for other wildlife, reducing biodiversity, and can increase the presence of invasive plants. While the recommended deer density to prevent forest degradation is approximately 15 to 20 deer per square mile, the average deer density in Baltimore County is 95 deer per square mile, according to a 2009 study (EPS, 2016). A reported 5,413 deer were harvested in Baltimore County during the 2014-2015 hunting season; of that number, 206 were harvested from the Loch Raven Reservoir Watershed (DNR, 2015). DNR's initial report for the 2015-2016 hunting season indicate that only 4,970 deer were harvested in Baltimore County, an 8.2% decrease from the 2014-2015 hunting season (DNR, 2016).

3.5.5.1 County White-tailed Deer Management

Deer herd management in Baltimore County began with the City of Baltimore's efforts to control deer herds at the reservoirs, Liberty, Prettyboy, and Loch Raven, through public bow hunting and deer cooperator approaches. The Loch Raven Reservoir has been managed for deer since 2008. Between 2008 and 2012, a total of 1,312 deer were culled at the Loch Raven Reservoir through the deer herd management program. Forward-Looking Infra-Red (FLIR) surveys are used to survey deer populations and to estimate additional reductions necessary to reduce deer pressure on the forest (EPS, 2016).

3.5.5.2 Maryland White-tailed Deer Plan 2009-2018

A white-tailed deer management plan was created by the Maryland Department of Natural Resources (DNR) to document the history and current status of white-tailed deer in Maryland, describe the responsibilities of the DNR deer management program, and serve as a strategic plan for deer management through 2018. The plan provides a myriad of strategic management options for statewide use. DNR has increased assistance to public land managers to develop deer hunting programs outside of the regular deer hunting season to address population issues. DNR also employs deer biologists to work with communities and derive the best management strategy to meet their local interests and needs (DNR, 2009).

In the state of Maryland, deer hunters remove just under 100,000 deer a year at little or no financial burden to the general public. Additionally, Deer Management Permits (DMPs) are available for producers (i.e. farmers, arborists, etc.) in situations where the deer hunting season does not adequately regulate the population. Another regulation program is the Maryland Deer Cooperator Program that certifies private individuals to lethally remove deer for a profit from areas where hunting is not feasible; the cost for deer removal ranges from $150 to $450 per deer. DNR also authorizes managed deer hunting programs for hunts primarily on county and federally owned lands with favorable results. Finally, contraception has been experimentally tested in the white deer population control with mixed results. The State of Maryland

has also created the venison donation program to provide a way for hunters to make use of more deer than they normally would in a given year, encouraging more deer culling (DNR, 2009).

3.5.6 Previous Stream Stability Assessment and Analysis

Stream stability assessments have occurred in the Loch Raven West watershed as part of previous studies. The stream stability assessment results of these studies are summarized in the following section.

3.5.6.1 Water Quality Management Plan for Loch Raven Watershed

Stream stability assessments were conducted previously as part of the Water Quality Management Plan in one of the Loch Raven West subwatersheds: Blackrock Run (DEPRM, 1997). For this assessment, all second and third order streams were targeted for assessment. Stream stability ratings were given for each segment of stream walked and impaired reaches were determined from these results. Multiple indicators were used to assess the streams, including but not limited to, mass wasting, vegetative bank protection, bank cutting, bank deposition, bottom size distribution, and scouring and deposition. Each indicator has an associated weighted number, which were added together to score each reach with < 75 considered *Good/Excellent* and > 124 considered *Very Poor* condition. Additionally, an enhanced Rosgen Level I approach was used to classify the stream channel type. Stream types G and F are typically unstable. Reaches were also assessed for riparian habitat. The riparian indicators for the assessment included riparian vegetation type, riparian buffer width, and riparian buffer density and rated as either *Good, Fair, Poor,* or *Very Poor*. Results from each of the three assessments are summarized below.

A total of 5.68 miles of stream were walked in the Blackrock Run subwatershed. Overall, the subwatershed streams are in stable condition with 73.1% of the streams assessed ranking as either Good/Excellent or Fair; however, almost half of the reaches assessed had no or limited buffer areas. A summary of the results for the Blackrock Run is shown in Table 3-24, Table 3-25, and Table 3-26.

Table 3-24: Distribution of Stream Stability Ratings by Subwatershed (DEPRM, 1997)

Subwatershed	Total Length Assessed (ft.)	Good/Excellent to Fair Stability Rating (%)	Potentially Impaired Stability Rating (%)	Slightly Poor to Very Poor Stability Rating (%)
Blackrock Run	30,020	83.1%	11.7%	5.3%

Table 3-25: Number of Reaches Classified as F and G Streams (DEPRM, 1997)

Blackrock Run	Number of Reaches Classified	Number Classified as F	Number Classified as G
Blackrock Run	26	3	3

Table 3-26: Percentage of Assessed Reaches with Poor Riparin Zone Ratings (DEPRM, 1997)

Subwatershed	No Riparian Zone (% of assessed reaches)	Limited Buffer (% of assessed reaches)
Blackrock Run	30.3%	16.4%

3.6 Mill Dam Impacts

During the late 17th to 19th centuries, the eastern United States experienced intensive land clearing, agriculture, and milling that produced large amounts of sediment from upland slopes (PDEP, 2006a). Sediment and deposits, as a result of this early settlement, have accumulated in valley bottoms and are commonly known as 'legacy sediment' or post-settlement alluvium. Accumulation of legacy sediment was especially prominent behind the many low-head mill dams built along the streams within the region. These mill dams backed up the streams, creating ponds that trapped sediment over the next two to three centuries.

Although legacy sediment can be found beyond the locations of historic mill dam sites, the correlation between sediment deposition and mill dams is indisputable. Many abandoned mill dam sites have left behind entire stream and floodplain systems filled with layers of legacy sediment. When remobilized, legacy sediments released downstream carry varying amounts of total phosphorus and nitrogen, contributing to nutrient loads in downstream waterways. In the event of a dam breach, the local sediment input may be much larger than that of a typical stream reach. Many factors affect the degree of influence that mill dams and in turn legacy sediment have on downstream channels and water bodies including time after dam breach and initial dam height. Research conducted within the watershed has found that the presence of mill dams are not the most significant source of the overall sediment release in a large system, but they can elevate the localized erosion rate of the stream reach and act as an erosion 'hotspot' (Donovan, 2014).

Additional research on Mid-Atlantic mill dams has shown that rates of stream bank erosion in breached millponds remain relatively high for several decades post-breach and these high sediment loads contribute to the Chesapeake Bay (Merritts, Walter, & Rahnis, 2013). While the extent of sedimentation varies from site to site, historic mill dam locations are ideal investigation targets for restoration opportunity. Depending on the site, removal of legacy sediment and stream bank stabilization can allow natural wetlands to return, floodplain reconnection, reductions in nutrient and sediment loads, and overall improved wildlife habitats.

The Loch Raven West watershed was home to many mill dams built in the 1700-1800s. Due to the rural nature of the watershed, many of the mill dam locations have not been further developed. For this SWAP, mill dams were investigated for restoration opportunities that could potentially decrease pollutant loading and re-establish healthy, natural stream systems. The following subsections describe the methods used to identify and evaluate the restoration potential of mill dam sites.

3.6.1 Assessment Protocol

Initial mill dam locations were determined based on county provided GIS data for known historical mill dams within the Loch Raven West watershed. The historic mill dam location data was made available through the Historic Sediment and Geomorphology Research Group at Franklin and Marshall College. The County processed and added to this data using two separate atlases: Kaiser's 1863 military map of Baltimore County and J. C. Sidney's 1857 map of the city and county of Baltimore, Maryland. Any duplicate

dam sites were noted and mill dams identified outside of the county or submerged by reservoirs were queried out.

Mill dams were given IDs once they were assessed in the field. Using the Baltimore County 200 scale map grids, each mill dam was numbered sequentially as it was assessed according to the map grid on which it is located, for example "MD01_022A2", where 'MD01' denotes the first mill dam assessed on map '022A2'.

The field team located each mill dam site, walking along the stream looking for any remaining signs of historic mill dams, mill buildings, and mill races. The team walked at a minimum 1,000 feet upstream and 200 feet downstream of the presumed historic mill dam site. Landowner permission was required by mail for all private properties located along the proposed stream segment. Mill dams that were located on properties whose landowner denied permission for access were not assessed. To standardize the mill dam assessment process and consistently determine restoration potential at each site, data was collected at each location for five main source areas: site location, mill dam structure, fish passage, bog turtle impact, and headcut or erosion. These are each briefly described below.

Site Information

Information pertaining to the location of each mill dam was first assessed through a desktop analysis to determine land use, land ownership, any special area designations, and floodplain constraints. Once in the field, additional information was collected including accessibility and infrastructure constraints.

Mill Dam Structure

The sites were investigated for signs of the mill dam, the historic mill dam building, or the mill dam race. Any residual or lasting structures were identified and documented in the field. This included the present condition of any observed structures, constructed materials, the height of the dam (if applicable), and if it was still operational.

Fish Passage

Mill dams alter a stream's morphology by diverting the natural channel flow to a race. In the process, natural fish migration is obstructed. During the field investigation, it was noted whether or not the dam presented a fish passage barrier and the severity of the barrier based on the drop in water. A fish passage around the dam or the removal of the dam has the potential to restore natural conditions and promote the return of native aquatic species upstream.

Bog Turtle Impact

Bog turtles are a federally threatened species found in portions of northern Maryland including Baltimore County. During the mill dam investigation, it was noted whether or not the mill dam site was a known bog turtle habitat or had potential to be a bog turtle habitat. The historic mill dam sites were also verified with the Maryland DNR if known rare, threatened, and/or endangered species were supported in the vicinity.

Headcut

A headcut is a form of unstable erosion characterized by a sudden vertical drop in the stream bed. Evidence of headcuts, upstream or downstream of the mill dam location, were noted during the field investigation as their presence can lead to further instability of the stream and dam structure. The proximity of observed headcuts was recorded.

Recommended Actions

After assessing each mill dam site, specific actions were recommended for each mill dam location for restoration or enhancement based on field observations. Recommended actions for the Loch Raven West watershed mill dams included:

- Legacy sediment removal
- Stream stabilization and/or restoration
- Wetland creation
- Floodplain reconnection
- Fish passage establishment
- Buffer creation

3.6.2 Summary of Sites Investigated

A total of 19 mill dams were assessed throughout the Loch Raven West watershed (see Figure 3-6). The number of mill dams assessed within each subwatershed is summarized in Table 3-27. Not all subwatersheds have historic mill dams located within them. Additionally, three historic mill dam sites included in the county provided GIS layer were removed from consideration as they were located in close proximity to a mill dam site that was already assessed and based on field observations appeared to be duplicate points. Three mill dam sites could not be field assessed due to land owner permission responses. All mill dams were assessed by WSP/Parsons Brinckerhoff.

Table 3-27: Mill Dams Assessed Per Subwatershed

Subwatershed	# of Mill Dams Assessed
Piney Run	3
Blackrock Run	5
Little Piney Run	2
Indian Run	0
McGill Run	1
Western Run	6
Slade Run	2
Delaware Run	0
Councilman's Run	0
Waterspout Run	0
Deadman's Run	0
Loch Raven West Total	19

3.6.3 General Findings

Recommended actions for the Loch Raven West mill dams are summarized in Table 3-28. Of the 19 mill dams assessed, nine of them were recommended for at least one restoration action. The most common restoration action recommended was buffer creation along the stream. Each recommended action is further explained in the sections below. The locations of the historic mill dams are shown in Figure 3-6. Photos illustrating different sites for each recommended action at select mill dam locations are included in each subsection. Appendix A includes a more detailed summary of the data collected, photos, and a plan view of each individual mill dam site as well as guidelines for the mill dam field assessment.

Table 3-28: Mill Dam Recommended Actions in Loch Raven West

			Recommended Action					
Mill Dam ID	**Subwatershed**	**Action***	**Legacy Sediment Removal**	**Stream Stabilization/ Restoration**	**Wetland Creation**	**Floodplain Reconnection**	**Fish Passage**	**Buffer Creation**
MD01_025C1	Little Piney Run	-	-	-	-	-	-	-
MD01_025C2	Little Piney Run	-	-	-	-	-	-	-
MD01_026A3	Piney Run	X	-	-	-	-	-	X
MD01_026C1	Blackrock Run	X	X	X	-	X	-	X
MD01_027A2	Blackrock Run	-	-	-	-	-	-	-
MD01_027A3	Blackrock Run	-	-	-	-	-	-	-
MD01_032B3	McGill Run	X	X	X	X	X	-	X
MD01_032C3	Piney Run	X	-	-	-	-	-	X
MD01_033A1	Blackrock Run	-	-	-	-	-	-	-
MD01_033B2	Western Run	X	-	-	-	-	-	X
MD01_040C1	Western Run	X	X	X	X	X	-	X
MD01_042A1	Western Run	-	-	-	-	-	-	-
MD02_032B3	Piney Run	X	-	-	-	-	-	X
MD02_033B2	Western Run	X	-	-	-	-	-	X
MD02_040C1	Western Run	X	-	-	-	-	-	X
MD02_042A1	Western Run	-	-	-	-	-	-	-
MD01_033A2	Blackrock Run	n/a	-	-	-	-	-	-
MD01_039C2	Slade Run	n/a	-	-	-	-	-	-
MD01_040A2	Slade Run	n/a	-	-	-	-	-	-
Loch Raven West Total		9	3	3	2	3	0	9

*Mill dams with action of "n/a" were not field assessed due to landowner permission responses

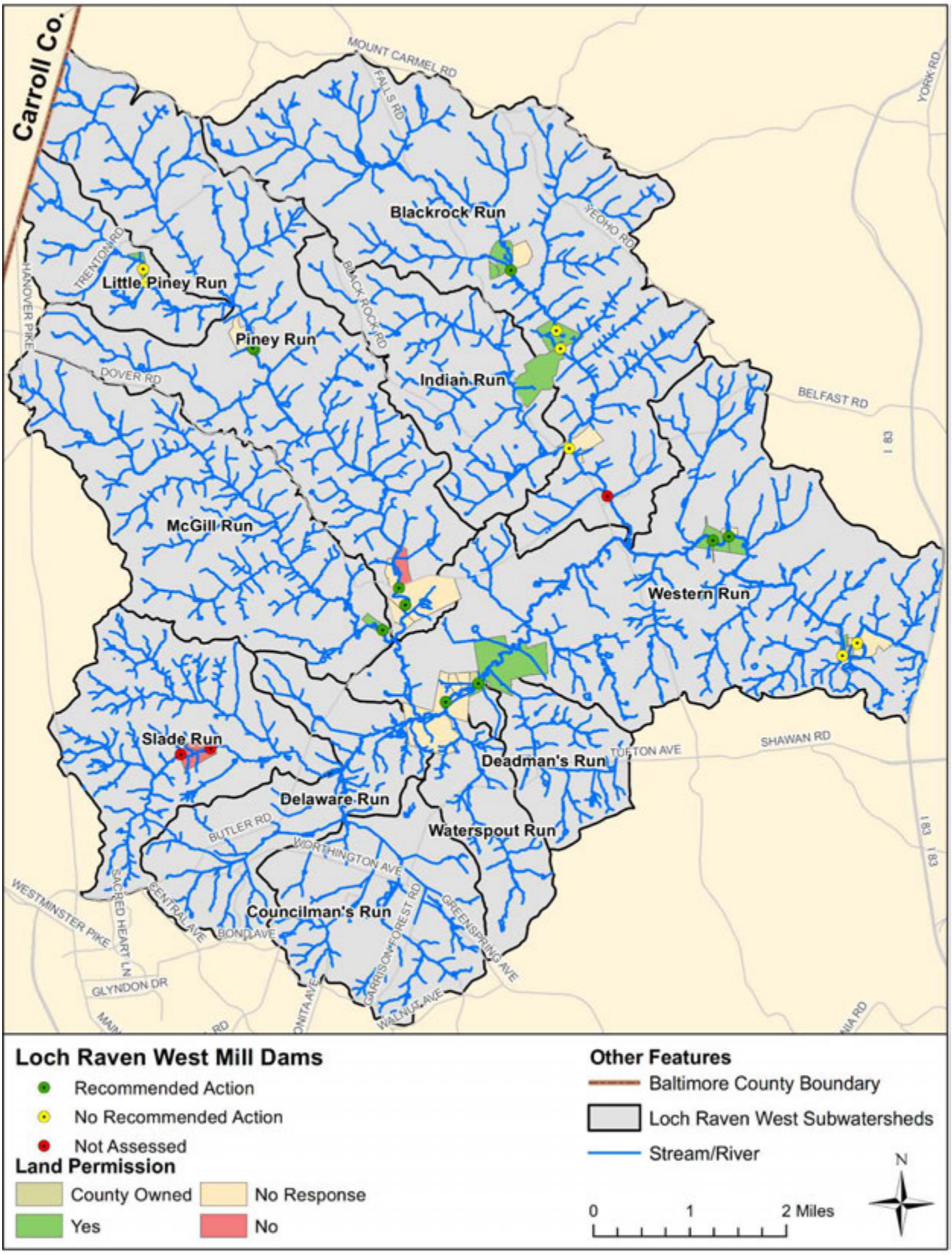

Figure 3-6: Location of Historic Mill Dams in Loch Raven West

3.6.3.1 Legacy Sediment Removal

Three of the mill dam sites were recommended for legacy sediment removal. Over multiple centuries, sediment from upstream has continuously been deposited and settled behind the dams creating a storage basin of sediment. If and when a dam is breached, large quantities of sediment are released downstream and the channel morphology can be drastically altered. The result is often an incised, unstable channel. The three sites listed for legacy sediment removal all have incised channels and limited floodplain access due to remaining sediment deposits. The legacy sediments are all in relatively flat areas that could be utilized for floodplain reconnection and/or wetland creation. Sites with mature buffers or existing wetlands growing in legacy sediment were not considered for legacy sediment removal due to impacts on the existing system. Removal would help stabilize the upstream channel to prevent potential future erosion and all three sites are also recommended for stream restoration.

Figure 3-7: Legacy Sediment Removal Recommended for MD01_026C1 (Left) and MD01_040C1 (Right)

3.6.3.2 Stream Stabilization and Restoration

One of the indicators of impaired streams due to legacy sediment is high banks with rapid rates of bank erosion (PDEP, 2006a). Stream restoration aims to return a stream corridor to its pre-disturbed condition in terms of physical, chemical, and biological characteristics. Stream stabilization aims to arrest erosion and improve stream function, while not returning it to pre-disturbed conditions. The level of stream restoration can vary based on the degree of impairment.

Three of the nine recommended sites were flagged for stream stabilization and/or restoration. Possible stream restoration actions for the Loch Raven West watershed range from stream bank terracing to channel realignment. The sites recommended have banks that are near vertical and show signs of active, ongoing erosion. Figure 3-8 shows two of the sites recommended for stream restoration and stabilization. A more detailed description of each site with photos and a plan view are available in Appendix A.

Figure 3-8: Bank Terracing Recommended at Site MD01_040C1 (Left) and Site MD01_032B3 (Right)

3.6.3.3 Wetland Creation

Prior to the 1970s, wetland draining and destruction were common practice to support agricultural uses or for other developmental purposes (NOAA, 2003). Since then, the value of wetlands has been recognized resulting in additional motivation for wetland restoration, enhancement, and creation. Some of the benefits of wetland creation are wildlife habitat, biological productivity, flood damage reduction, and improved water quality.

Of the nine sites recommended for restoration action, two sites were identified as having potential for wetland creation. The sites all contain large open, pervious banks for potential creation. An example of sites recognized for wetland creation potential are shown in Figure 3-9.

Figure 3-9: Potential Wetland Creation Upstream of Mill Dam MD01_040C1

3.6.3.4 Floodplain Reconnection

Natural floodplains have the ability to store, slow, and filter water which protects property, improves water quality, and minimizes erosion and overall runoff. Areas lacking adequate stormwater management experience high storm flows resulting in degraded stream systems and disconnection between riparian

root zones and groundwater flows. Floodplain restoration is an effective means of improving water quality and quantity, preventing an increase in riparian problems, and reducing erosive flow forces (PDEP, 2006b).

Three of the nine recommended mill dam sites were identified for floodplain reconnection. As shown in Figure 3-10, the channels are no longer connected to the floodplain due to high vertical banks. The entrenched channels no longer allow overflow into the floodplain during high flow events. Reconnection will aid in flood control, increase recharge to groundwater, improve natural habitats, and reduce erosive velocities.

Figure 3-10: Mill Dam Sites with High, Vertical Banks Recommended for Floodplain Reconnection at MD01_040C1 (Left) and MD01_032B3 (Right)

3.6.3.5 Fish Passage

The drop and rapid flows between intact dams and the downstream channel can significantly interfere with the upstream movement of fish. Unobstructed movement along a stream is important for various species of fish during their life cycle for events such as spawning. The Loch Raven West watershed is recognized as a prime location for trout fishing, thus the unimpeded passage of trout is essential for preserving recreational fishing in the area.

As no remaining or remnant dam structures were found, none of the mill dam sites were recommended for fish passage improvement.

3.6.3.6 Buffer Creation

Adding forest buffer will improve water quality, stabilize banks, and improve aquatic habitats. Many of the sites investigated had large open, pervious stream buffers that were unforested and unshaded. Ideally, all stream segments within the Loch Raven West watershed should have a 100 foot forested buffer on each stream bank as they are Use III-P waters (Baltimore County, 2015). Due to land ownership and infrastructure constraints this is not always possible.

Buffer creation was the most recommended action for mill dam sites. Nine different mill dam locations were proposed for buffer creation along the stream. Figure 3-11 and Figure 3-12 show examples of sites

selected for buffer creation. Most of the sites possessed pervious buffers; however, the banks are unshaded and unforested for a significant length of stream.

Figure 3-11: Buffer Creation Recommended for MD01_026A3 (Left) and MD01_026C1 (Right)

Figure 3-12: Buffer Creation Recommended for MD01_040C1 (Left) and MD02_040C1 (Right)

3.6.3.7 Prioritization of Mill Dam Restoration Sites

The nine sites recommended for restoration actions were ranked based on their restoration potential derived from the field observations and probable construction constraints associated with each site. A detailed evaluation of each location documenting the potential constraints and location of restoration activities is available in Appendix A.

Construction constraints were documented based on specific characteristics pertaining to the site that would limit accessibility and restrict certain restoration activities. Some of the constraints that could potentially limit the opportunity for restoration are the presence of utilities, private land ownership, overall site accessibility, and adjacent infrastructure. The construction constraint rating for each site can range from 0 to 13, where 0 would imply no foreseeable constraints and 13 would denote the maximum

number of constraints. The Loch Raven West mill dam sites that are recommended have construction constraint ratings that range from 4 to 7.

Restoration potential for each site was recorded and derived based on observations in the field and opportunities recommended based on these observations. Restoration opportunities included sediment removal, stream stabilization and/or restoration, wetland creation, floodplain reconnection, fish passage, and buffer creation. The restoration rating has a range from 0 to 9, where 0 indicates no restoration potential and a 9 would denote maximum restoration potential. The restoration potential ratings range from 0 to 5 for the 17 mill dam sites assessed in the Loch Raven West watershed. All 19 of the sites and their corresponding ratings are shown in Table 3-29. They are ranked and listed from highest potential to lowest potential based on both construction constraints and overall restoration potential.

Table 3-29: Loch Raven West Mill Dam Restoration Priority

Recommended sites	Priority Ranking	Restoration Potential Rating	Construction Constraints Rating
MD01_040C1	1	5	4
MD01_032B3	2	5	5
MD01_026C1	3	4	9
MD01_032C3	4	2	4
MD02_033B2	4	2	4
MD01_033B2	6	2	5
MD02_040C1	6	2	5
MD01_026A3	8	2	6
MD02_032B3	8	2	6
MD01_033A1	10	0	4
MD01_042A1	10	0	4
MD01_025C1	12	0	6
MD01_025C2	12	0	6
MD02_042A1	12	0	6
MD01_027A2	15	0	7
MD01_027A3	15	0	7
MD01_033A2	-	n/a	n/a
MD01_039C2	-	n/a	n/a
MD01_040A2	-	n/a	n/a

The mill dam sites were first ranked using the restoration potential, where a high score equates to the highest potential. The sites were then ranked based on their construction constraints where a low score equates to the least amount of constraints. Mill Dam sites MD01_040C1 and MD01_032B3 ranked as having the highest priority. MD01_040C1 is located partially on County land and partial on private land, while MD01_032B3 is located on private property. Both sites could potentially benefit from all the restoration recommendations except fish passage. Six sites ranked the lowest priority with a restoration potential of two and the only recommendation at these sites is forest buffer planting. Seven sites did not have any recommended actions.

CHAPTER 4: UPLANDS ASSESSMENT

4.1 Introduction

Upland areas were assessed according to the Unified Subwatershed and Site Reconnaissance (USSR) Manual developed by the Center for Watershed Protection (CWP) to identify potential pollution sources influencing water quality and to evaluate restoration project opportunities (CWP, 2005). The USSR manual is the last manual in a series of 11 regarding techniques for restoring urban watersheds. It provides detailed guidance for field survey techniques and was developed to help watershed groups, municipal staff, and consultants to quickly identify major stormwater pollution sources and assess subwatershed restoration potential for source controls, pervious area management, and improved municipal maintenance such as education, retrofits, street sweeping, inlet cleaning, and open space management. Upland areas within the Loch Raven West watershed were assessed by WSP/Parsons Brinckerhoff, Inc. and NMP Engineering, Inc.

The field survey of upland areas in the Loch Raven West watersheds included three major components:

- Neighborhood Source Assessment (NSA)
- Hotspot Site Investigation (HSI)
- Institutional Site Investigation (ISI)

Each of the above components is described in detail in the following sections.

4.2 Neighborhood Source Assessment (NSA)

NSAs describe pollution source areas, stewardship behaviors, and restoration opportunities within individual neighborhoods. Each neighborhood has unique characteristics which determine the ability to implement restoration projects, source controls, and stewardship practices. The sections below describe the methods used to delineate and assess individual neighborhoods in the Loch Raven West watershed.

4.2.1 Assessment Protocol

Prior to conducting NSAs in the field, neighborhoods were delineated in the office using GIS data such as tax parcels, historical development information, and aerial photography provided by Baltimore County OIT. A neighborhood was delineated based on a group of homes with similar characteristics including lot sizes, setbacks, and year houses were built. Neighborhoods defined in the office using available information were verified in the field. Adjustments were made as necessary in the field to group similar neighborhoods or separate dissimilar neighborhoods.

Unique ID numbers were assigned to NSAs using the classification scheme “NSA_W_1000”, where ‘W’ denotes the Loch Raven West watershed and the first two digits correspond to a specific subwatershed. Subwatersheds were assigned unique numbers summarized in Table 4-1 for the purposes of NSAs, HSIs, and ISIs.

Table 4-1: Subwatershed ID Numbers

ID	Subwatershed
01	Piney Run
02	Blackrock Run
03	Little Piney Run
04	Indian Run
05	McGill Run
06	Western Run
07	Slade Run
08	Delaware Run
09	Councilman's Run
10	Waterspout Run
11	Deadman's Run

The field team drove through every street in a defined neighborhood to identify potential pollution sources and restoration opportunities. To standardize the NSA process and be able to prioritize potential restoration efforts, data was collected in each neighborhood for four main source areas: yards and lawns; driveways, sidewalks, and curbs; rooftop runoff; and common areas. These are each described briefly below.

Yards and Lawns

Yards and lawns typically represent a significant portion of the pervious cover in a neighborhood and therefore can be a major source of nutrients, pesticides, sediment, and runoff. Maintenance behaviors tend to be similar within individual neighborhoods and certain activities can impact subwatershed quality such as fertilization, pesticide use, water use, landscaping, and waste management. Potential pollution sources evaluated under the yards and lawns category include grass cover and management status (fertilization and irrigation methods), bare soil, swimming pools, and junk or trash. The field team also identified the proportions of impervious cover, grass cover, landscaping, and bare soil within each neighborhood. The amount of existing tree cover and landscaping was then compared to the other cover types to evaluate potential for increasing these features and providing water quality benefits through interception and filtration of stormwater runoff.

Driveways, Sidewalks, and Curbs

Driveways, sidewalks, and curbs are common in neighborhoods and convey runoff to a storm drain system or directly into stream channels. Activities such as car washing, de-icing, and improper chemical storage can contribute pollutants such as nutrients, oil, sediment, and chlorides, into the storm drain system and stream channels. While driving through neighborhoods, data was collected for potential pollution sources including: pet waste (source of bacteria); long-term car parking (unused old cars with potential to leak chemicals, oil, and/or grease); and amount of sediment, organic matter, and/or trash present along curbs. Potential for street tree planting and street sweeping was also evaluated based on some of these factors.

Rooftops

Rooftop runoff is another contributor to stormwater runoff and pollutants in neighborhoods. Downspout retrofits can help reduce runoff and pollutants introduced to local streams. The field team identified whether downspouts discharged rooftop runoff to pervious areas, rain barrels, impervious surfaces (driveways, street), and/or directly to the storm drain system and the proportion of each within a neighborhood. The potential for disconnecting and redirecting downspouts from impervious surface or the storm drain system was also evaluated.

Common Areas

Common areas such as community parks (homeowners open space and/or local open space) and parking lots are good opportunities to observe community behaviors such as pet waste disposal, stormwater management, storm drain marking, and how natural areas or buffers are managed. Good maintenance of these areas indicate that residents or a homeowner's association are active in caring for the neighborhood and may represent opportunities for restoration projects. Data was collected on the condition of storm drain inlets (whether they were clean or filled with debris) and presence of pet waste or dumping in common areas to identify potential pollution sources in a neighborhood. The potential for storm drain marking, stormwater management practices, and stream buffer planting was also evaluated.

Other NSA Information

In addition to these four source areas, basic information was collected in individual neighborhoods to help rate restoration potential. This information included lot size, house types, and whether a homeowners' association exists for the community. Presence of sewer service was also identified for additional potential pollution sources. After surveying the entire neighborhood and completing the basic information and four major source area sections, any major pollutants that are potentially being generated by the neighborhood are indicated on the field form in the following categories: nutrients; oil and grease; trash/litter; bacteria; and sediment. For example, if a neighborhood had several long-term parked vehicles, oil and grease would be flagged as a potential major pollutant being generated in that neighborhood. The presence of trash in yards, dumping in common areas, or overflowing/uncovered dumpsters would be a significant indicator for trash/litter generated in a neighborhood. Sediment was

flagged as a major pollutant source if erosion or bare soil was observed, and/or a considerable portion of the curb and gutters were covered with sediment.

Recommended Actions

After evaluation of an entire neighborhood, specific actions were recommended for neighborhood restoration or retrofits based on initial field observations. Recommended actions included in the Loch Raven West watershed NSAs included:

- Downspout disconnection
- Rain barrels
- Rain gardens
- Storm drain marking
- Bayscaping
- Lot canopy improvement
- Fertilizer reduction
- Trash management
- Stream buffer improvement

The last step of the NSA involved rating the overall neighborhood pollution severity and restoration potential. The severity of pollution generated by a neighborhood is denoted by the Pollution Severity Index (PSI) based on benchmarks and scoring system in the USSR manual. An NSA PSI is rated as severe, high, moderate, or none. A neighborhood's potential for residential restoration projects is rated as high,

moderate, or low according to the Restoration Opportunity Index (ROI). The USSR also provides benchmarks and guidelines to establish NSA ROI ratings.

4.2.2 Summary of Sites Investigated

A total of 29 neighborhoods were assessed throughout the Loch Raven West watershed (Figure 4-1). The number of neighborhoods within each subwatershed is summarized in Table 4-2. Some neighborhoods may overlap multiple subwatersheds; in this case, the neighborhood is counted once for each subwatershed in which it falls. Analyses of acres of land or miles of road addressed by recommended actions, however, are based on the actual proportion of the neighborhood that falls within each watershed. This is explained further in subsequent sections.

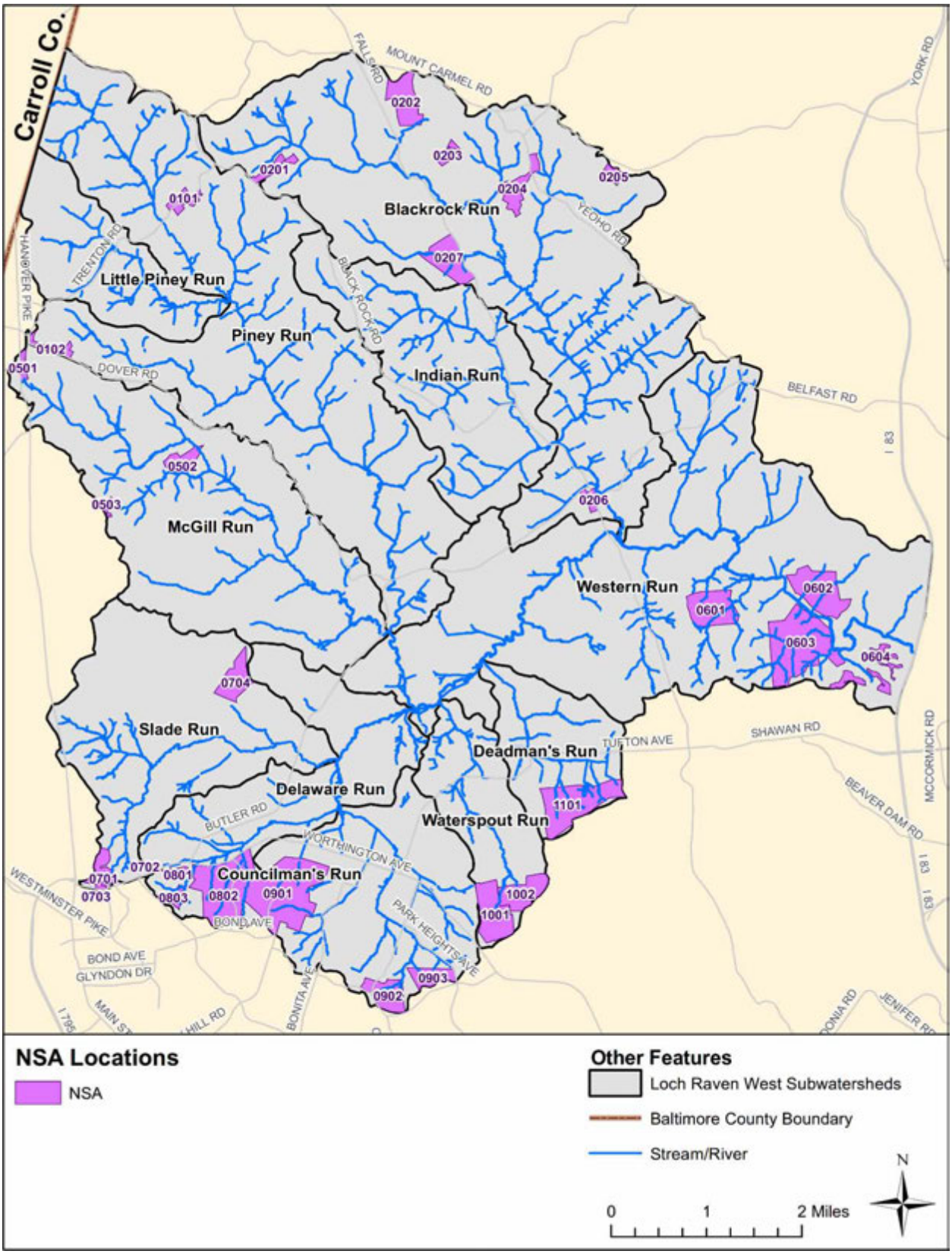

Figure 4-1: Locations of NSAs in the Loch Raven West Watershed

Table 4-2: Neighborhoods Surveyed per Subwatershed

Subwatershed	# of NSAs
Piney Run	3
Blackrock Run	7
Little Piney Run	0
Indian Run	1
McGill Run	4
Western Run	4
Slade Run	4
Delaware Run	4
Councilman's Run	4
Waterspout Run	2
Deadman's Run	1

Of the neighborhoods assessed, approximately 14% (4 of 29) were rated as having both high PSI and high ROI. Overall, six neighborhoods were rated as having high PSI and 14 neighborhoods were considered to have moderate PSI. Four neighborhoods were considered as having high ROI and 16 neighborhoods were rated as having moderate ROI. The remaining neighborhoods had either a low PSI or ROI rating. The 4 neighborhoods with high PSI and high ROI ratings represent the best areas to target for restoration initially. The distribution of PSI and ROI ratings among the Loch Raven West NSAs are shown in Figure 4-2.

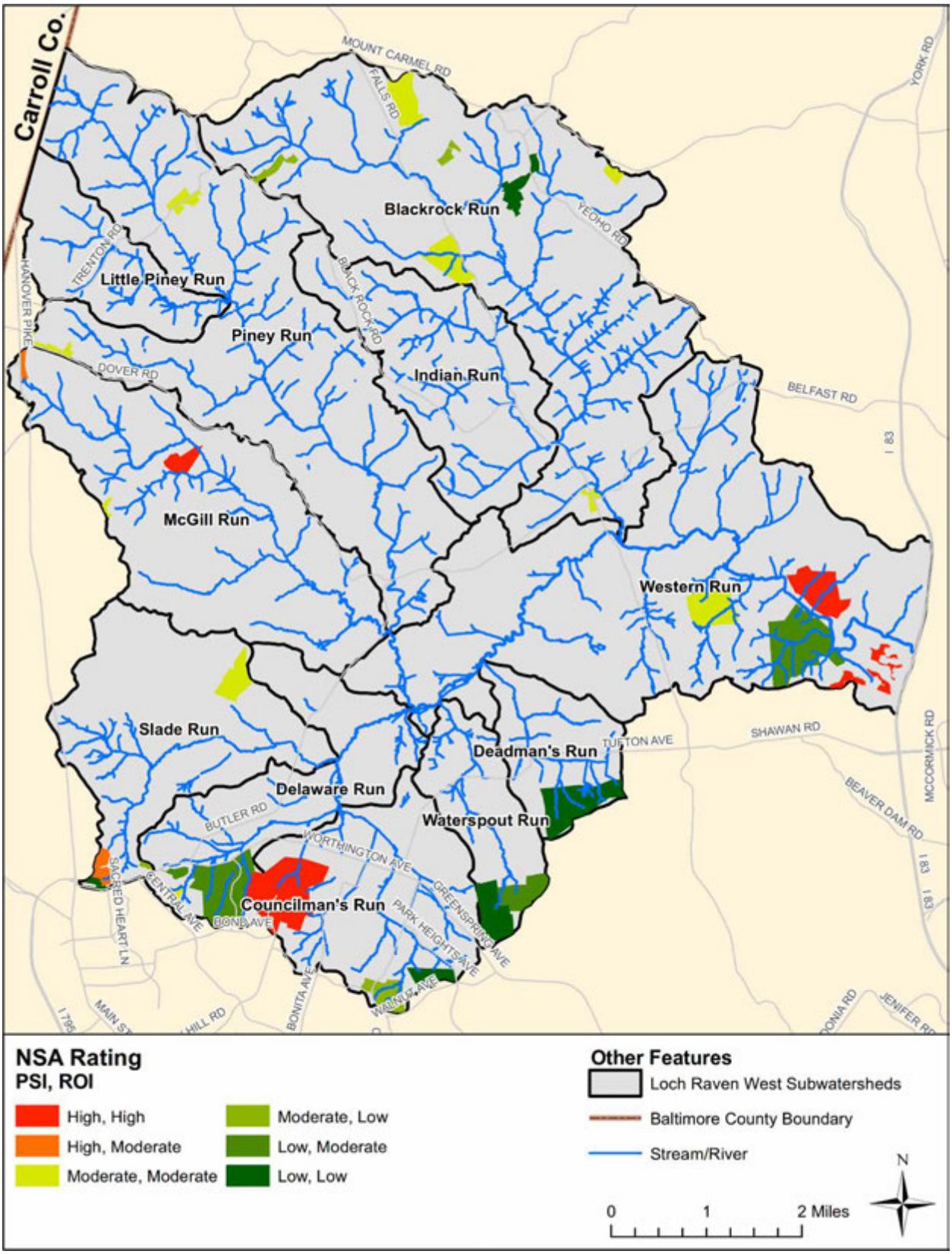

Figure 4-2: NSA Pollution Severity and Restoration Opportunity Indices in the Loch Raven West Watershed

4.2.3 General Findings

The following subsections describe the actions recommended based on evaluation of the NSAs. This includes an explanation of the methodologies and criteria used to evaluate the potential for recommended actions, as well as results expected if these actions were applied. Figures showing general locations of NSAs recommended for specific actions are included in each subsection. Some actions such as pet waste management, impervious retrofit, street sweeping, and common area tree planting identified in other Small Watershed Action Plans were not identified in the Loch Raven West SWAP area and therefore, were not recommended in the Loch Raven West subwatersheds. Appendix B includes a summary of NSA data collected and recommended actions by individual neighborhoods. Calculations supporting estimates of results for recommended actions are included in Appendix C.

4.2.3.1 Downspout Disconnection

Rooftop runoff is managed via downspouts which are classified as either connected or disconnected. Directly connected downspouts extend underground, discharging directly to the storm drain system without treatment. Indirectly connected downspouts drain to impervious surfaces, such as paved driveways, sidewalks, or curb and gutter systems with little or no treatment. Disconnected downspouts allow rooftop runoff to infiltrate into the ground and enter streams through the groundwater system in a slower more natural fashion. Downspout disconnection is desirable because it decreases flow to local streams during storm events, helping prevent erosion and reducing pollutant loads to streams. Disconnection involves redirecting connected downspouts from the storm drain system or impervious areas onto pervious areas such as lawns. This requires a minimum of 15 feet of pervious area down gradient from the downspout for filtration to occur. Rain barrels and rain gardens are alternative disconnection options. Rain barrels can be used to store rooftop runoff for irrigation if there is limited pervious area for disconnection. Rain gardens are a disconnection option if several hundred square feet of lawn area is available down gradient of the downspout. In the event a downspout is directed onto an impervious area that drains to a pervious area, for example a driveway that slopes towards the lawn, the downspout is considered disconnected.

Downspout redirection is recommended for neighborhoods where at least 25% of downspouts are directly connected to storm drains or indirectly connected to impervious area with at least 15 feet of pervious area available down gradient of the connected downspout for redirection. Table 4-3 includes a summary of the number of neighborhoods recommended for downspout redirection and the acres of rooftop addressed if downspout redirection were implemented by subwatershed. Table 4-3 also lists the percent of total impervious rooftop area in each subwatershed that would be addressed if downspout redirection were implemented; total impervious rooftop area per subwatershed was calculated using 2015 buildings spatial data provided by Baltimore County OIT.

Table 4-3 Rooftop Acres Addressed by Downspout Redirection

Subwatershed	# of NSAs Recommended for Downspout Redirection*	Rooftop Acres Addressed	% of Subwatershed Rooftop Area Addressed
Piney Run	3	1.39	55.3%
Blackrock Run	3	0.59	7.9%
Little Piney Run	0	0.00	0.0%
Indian Run	0	0.00	0.0%
McGill Run	3	0.65	31.9%
Western Run	1	0.95	7.1%
Slade Run	3	1.45	43.8%
Delaware Run	3	1.58	15.6%
Councilman's Run	1	2.32	17.9%
Waterspout Run	1	0.90	14.2%
Deadman's Run	0	0.00	0.0%
Loch Raven West Total	***18***	***9.83***	***3.3%***

*If a neighborhood overlaps multiple subwatersheds, it is counted for each watershed it encompasses.

Figure 4-3 illustrates the location of neighborhoods recommended for downspout redirection. Out of the 29 neighborhoods assessed, 18 have the potential for downspout disconnection through redirection (three of the recommended NSAs intersect two or more subwatersheds). If implemented, the redirection could address approximately 3% of the total impervious rooftop area in the Loch Raven West watershed. Downspout disconnection was not evaluated at one NSA in the watershed as the majority of the downspouts in these neighborhoods could not be seen from the road.

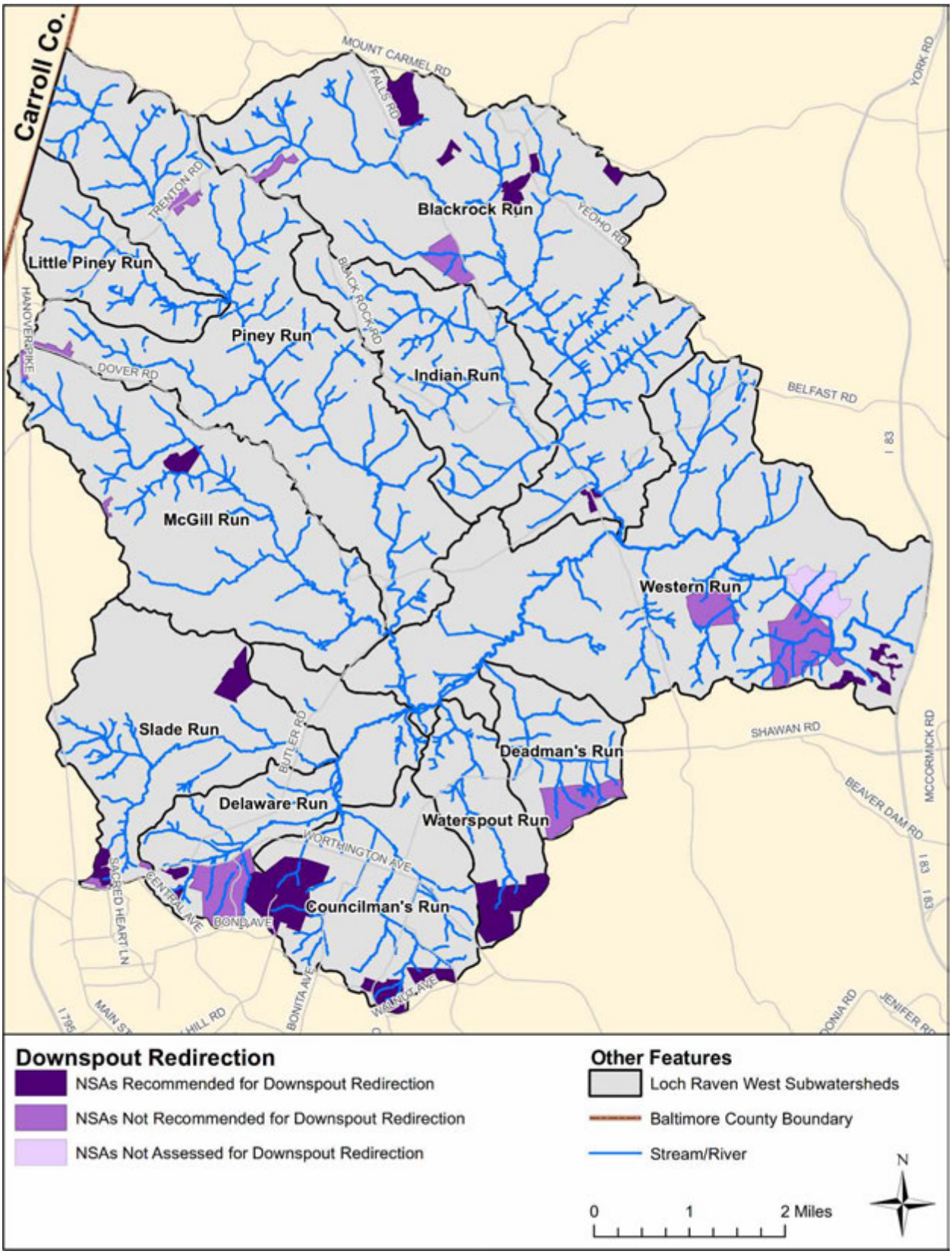

Figure 4-3: Neighborhoods Recommended for Downspout Disconnection

4.2.3.2 Bayscaping

Bayscaping refers to the use of plants native to the Chesapeake Bay watershed for landscaping. When plants are native to a region, they require less irrigation, fertilizers, and pesticides to maintain as compared to non-native or exotic plants. This results in fewer chemical pollutants and lawn maintenance requirements. Bayscaping is also beneficial to wildlife.

Typically, all neighborhoods could use more bayscaping; however, the benefits and feasibility of this action are limited by the space available for landscaping. Bayscaping was identified for implementation in neighborhoods where the lots were at least ¼ acre in size, where less than ten percent of the lots were already landscaped, and where there was sufficient open grass area available for implementation. Table 4-4 includes a summary by subwatershed of the number of neighborhoods recommended for bayscaping based on these criteria and the area of available lawn addressed if this action were initiated. Table 4-4 also lists the percent of the total subwatershed area that would be addressed by implementing bayscaping in the recommended neighborhoods.

Table 4-4: Acres of Land Addressed by Bayscaping

Subwatershed	# of NSAs Recommended for Bayscaping*	Acres of Land Addressed	% of Subwatershed Area Addressed
Piney Run	3	24.13	0.5%
Blackrock Run	7	103.38	0.3%
Little Piney Run	0	0.00	0.0%
Indian Run	1	0.04	0.2%
McGill Run	4	27.38	0.5%
Western Run	4	251.18	0.5%
Slade Run	3	32.92	0.3%
Delaware Run	4	80.54	0.3%
Councilman's Run	4	101.17	0.3%
Waterspout Run	2	63.42	0.3%
Deadman's Run	1	16.42	0.1%
Loch Raven West Total	***33***	***700.60***	**0.3%**

*If a neighborhood overlaps multiple subwatersheds, it is counted for each watershed it encompasses.

Figure 4-4 illustrates the location of neighborhoods recommended for bayscaping. Out of the 29 neighborhoods assessed, 28 (97%) met the criteria and were recommended for bayscaping. Many of the homes within the watershed have large lots and high percentages of lawn. Table 4-4 shows that 700.60 acres or 0.3% of the total watershed could be addressed through bayscaping.

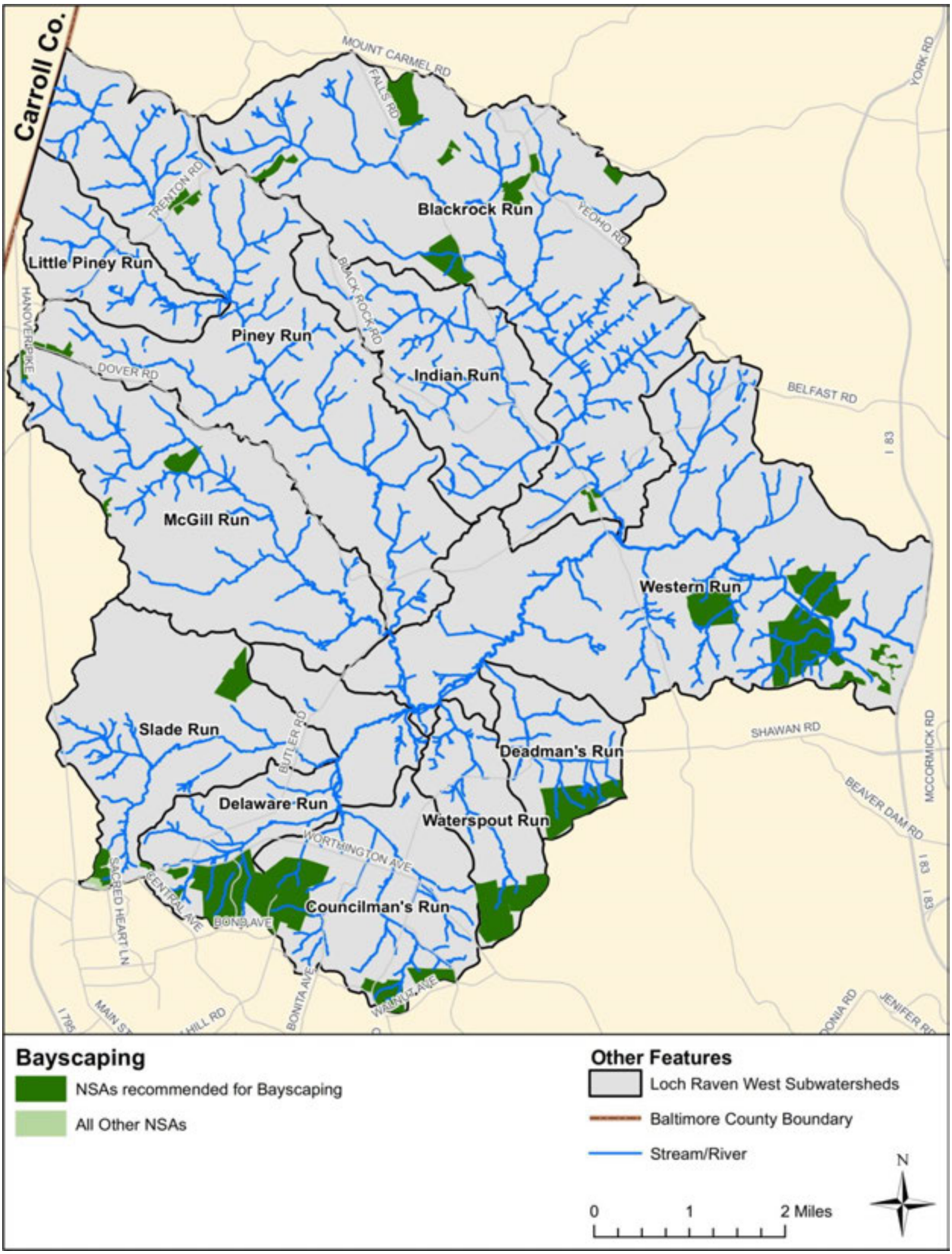

Figure 4-4: Neighborhoods Recommended for Bayscaping

4.2.3.3 Fertilizer Reduction and Awareness Outreach

Lawn maintenance activities often involve over-fertilization, poor pest-management, and over-watering. Lawns with a dense, uniform grass cover or signs designating application of lawn chemicals indicate high lawn maintenance activities. The result is often polluted stormwater runoff that drains to local streams. Neighborhood lawn care assessment was conducted in the spring.

Neighborhoods where 20 percent or more of the homes employ high lawn maintenance practices are identified for a fertilizer reduction and outreach program. Table 4-5 summarizes the total number of neighborhoods identified for fertilizer reduction and the acres of lawn addressed if this were implemented. The acres of lawn addressed are based on the percentage of high maintenance lawns present in each neighborhood for which fertilizer reduction is identified. The area treated in each neighborhood is based on the amount of lawn area. The average percentage of grass cover on each lot is estimated during the NSA, as well as the percentage of high maintenance lawns in the neighborhood area.

Table 4-5: Acres of Lawn Addressed by Fertilizer Reduction

Subwatershed	# of NSAs Recommended for Fertilizer Reduction*	Acres of Land Addressed	% of Subwatershed Area Addressed
Piney Run	2	3.0	0.05%
Blackrock Run	1	1.6	0.02%
Little Piney Run	0	0.0	0.00%
Indian Run	0	0.0	0.00%
McGill Run	1	0.0	0.00%
Western Run	1	29.7	0.40%
Slade Run	1	9.2	0.32%
Delaware Run	2	5.2	0.23%
Councilman's Run	2	20.1	0.83%
Waterspout Run	0	0.0	0.00%
Deadman's Run	0	0.0	0.00%
Loch Raven West Total	***10***	***68.9***	***0.18%***

* If a neighborhood overlaps multiple subwatersheds, it is counted for each subwatershed it encompasses

Of the 29 neighborhoods assessed, seven were identified for fertilizer reduction based on high percentages of high maintenance lawn. However, implementation of fertilizer reduction/outreach will only address approximately 0.18% of the total watershed. Many of the large, grass lawns were classified as medium maintenance. These neighborhoods may also be a significant target for fertilizer reduction and outreach. Figure 4-5 shows the neighborhoods in the Loch Raven West watershed with high lawn maintenance.

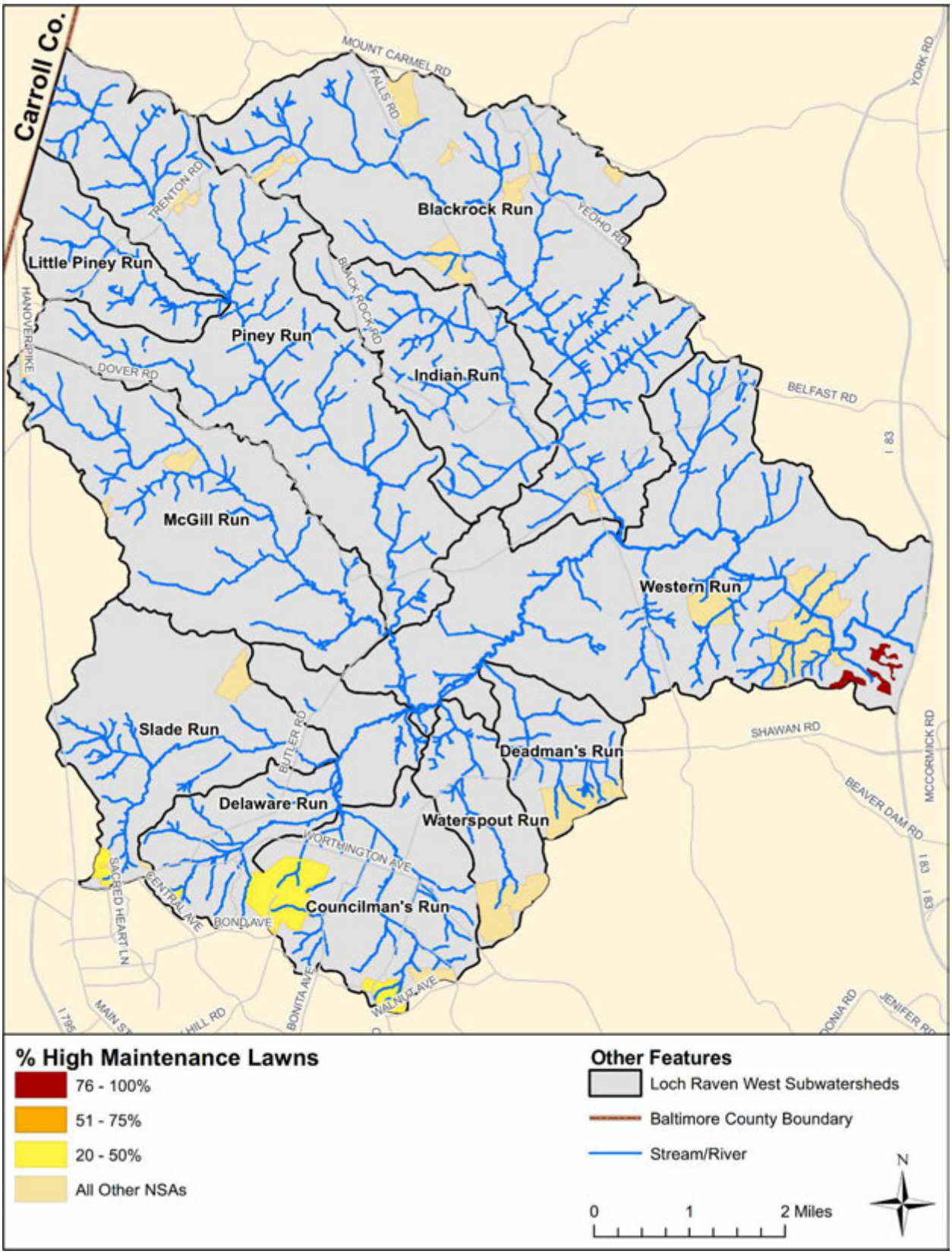

Figure 4-5: Percentage of High Maintenance Lawns in Neighborhoods

4.2.3.4 Storm Drain Marking

Of the assessed neighborhoods in the Loch Raven West watershed, 18 have a storm drain system with inlets. Of those NSAs, 16 have roads with curb and gutter systems that convey stormwater runoff quickly and directly to the stream system and ultimately to the Chesapeake Bay. The majority of the neighborhoods with inlets do not have storm drain markings nor indicate that the inlets eventually drain to the Chesapeake Bay. These markings are a way to educate residents that anything collecting along the curbs and gutters such as trash and lawn clippings (potential for nutrient pollution) will be washed away after a storm event and end up in the nearest stream and eventually the Chesapeake Bay.

Neighborhoods recommended for storm drain marking have storm drain systems with inlets appropriate for marking and where less than ten percent of the existing inlets were already marked and legible. Table 4-6 includes a summary of the number of neighborhoods recommended for storm drain marking and the number of inlets addressed if this action were initiated by subwatershed. The number of inlets addressed is estimated based on the total number of inlets observed per NSA during the uplands assessments. Table 4-6 also lists the percent of the total neighborhood inlets in each subwatershed that would be addressed if storm drain marking was implemented in the recommended neighborhoods. This value was calculated based on the total inlets observed in neighborhoods assessed in Loch Raven West during the uplands assessment.

Table 4-6: Number of Inlets Addressed by Storm Drain Marking

Subwatershed	# of NSAs Recommended for Storm Drain Marking*	Approximate # of Inlets Addressed	% of Inlets in Subwatershed Addressed**
Piney Run	1	11	100.0%
Blackrock Run	2	5	100.0%
Little Piney Run	0	0	0.0%
Indian Run	0	0	0.0%
McGill Run	1	2	100.0%
Western Run	3	15	93.8%
Slade Run	2	21	100.0%
Delaware Run	4	29	100.0%
Councilman's Run	3	29	100.0%
Waterspout Run	2	24	100.0%
Deadman's Run	1	10	100.0%
Loch Raven West Total	***19***	***146***	***99.3%***

*If a neighborhood overlaps multiple subwatersheds, it is counted for each subwatershed it encompasses
**based on the total number of inlets observed in neighborhoods during the upland assessments

Of the 29 neighborhoods assessed, 15 (79%) met the criteria for storm drain marking. Figure 4-6 shows the neighborhoods in the Loch Raven West watershed recommended for storm drain marking.

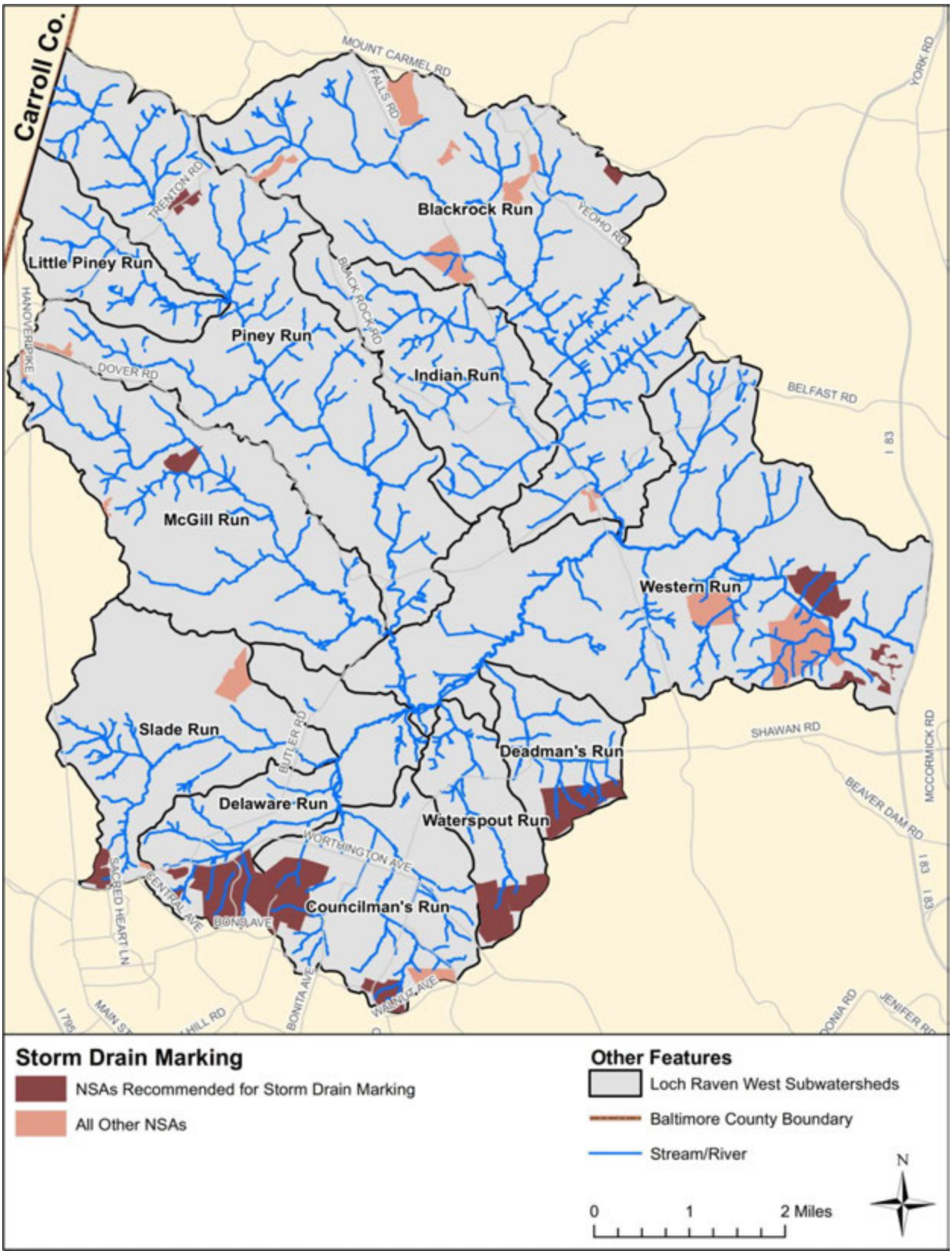

Figure 4-6: Neighborhoods Recommended for Storm Drain Marking

4.2.3.5 Street Trees and Shade Trees

Street trees and shade trees are not only an asset to a neighborhood aesthetically, but they also provide air and water quality improvement as they intercept precipitation with their leaves and absorb precipitation and nutrients through their root systems. This infiltration of precipitation through leaves or the root systems slows surface flow rates and provides some treatment before storm water reaches the stream system.

The criteria for recommending street trees includes neighborhoods with a minimum of four feet of green space between the sidewalk and curb with less than 75% of these areas already having trees. Only one assessed neighborhood had sidewalks, and it did not meet the criteria for street trees. Open space shade trees are recommended for open pervious areas in neighborhoods where the space has no apparent current use. The number of open space shade trees is estimated based on spacing of approximately 100 trees per acre for larger areas. These estimates are based on the Baltimore County Policy and Guidelines for Community Tree Planting Projects (EPS, 2013c). Of the 29 neighborhoods assessed, none of the neighborhoods met the requirements for street trees or open space shade trees.

4.2.3.6 Lot Canopy Improvement

Increasing lot canopy is an effective way of reducing runoff and peak flows, improving filtration and water quality, and increasing shaded areas to reduce stream temperatures from excessive solar heating. Reforestation works with bayscaping and rain gardens to improve runoff infiltration and provide terrestrial habitat. Reforestation of stream buffers are especially important for maintaining healthy streams as roots stabilize banks, leaves contribute to the stream's food web, and trees also help reduce nutrient loading to downstream waters.

Lot canopy improvement was recommended for neighborhoods where existing canopy coverage was on average less than 40 percent of the lot. Table 4-7 summarizes the neighborhoods identified for lot canopy improvement in each subwatershed and the estimated acres of land addressed. It also shows the percentage of the total watershed area addressed through the implementation of lot canopy improvement. Pervious lot area is found by taking the total acreage in each neighborhood and subtracting out the acres of impervious roadway and buildings. This area is multiplied by the difference in percent between the recommended 40 percent and the existing percentage of canopy cover estimated during the NSA. NSAs recommended that encompass multiple subwatersheds were counted in each corresponding subwatershed; however, the total acres of land were determined based on the proportion of NSA within each subwatershed.

Table 4-7: Acres of Land Addressed by Lot Canopy Improvement

Subwatershed	# of NSAs Recommended for Canopy Improvement*	Acres of Land Addressed	% of Subwatershed Area Addressed
Piney Run	1	6.1	0.10%
Blackrock Run	3	5.7	0.08%
Little Piney Run	0	0.0	0.00%
Indian Run	0	0.0	0.00%
McGill Run	2	4.7	0.11%
Western Run	2	53.9	0.72%
Slade Run	1	6.9	0.24%
Delaware Run	0	0.0	0.00%
Councilman's Run	0	0.0	0.00%
Waterspout Run	0	0.0	0.00%
Deadman's Run	0	0.0	0.00%
Loch Raven West Total	***9***	***77.3***	***0.20%***

*If a neighborhood overlaps multiple subwatersheds, it is counted for each subwatershed it encompasses

Of the 29 neighborhoods assessed, nine (31%) were recommended for lot canopy improvement. Of those nine recommended neighborhoods, seven were also recommended for better stream buffer management due to encroachment. Enhancing stream buffers through reforestation in these NSAs will also increase the lot canopy. Figure 4-7 shows the NSAs recommended for lot canopy improvement in the Loch Raven West watershed.

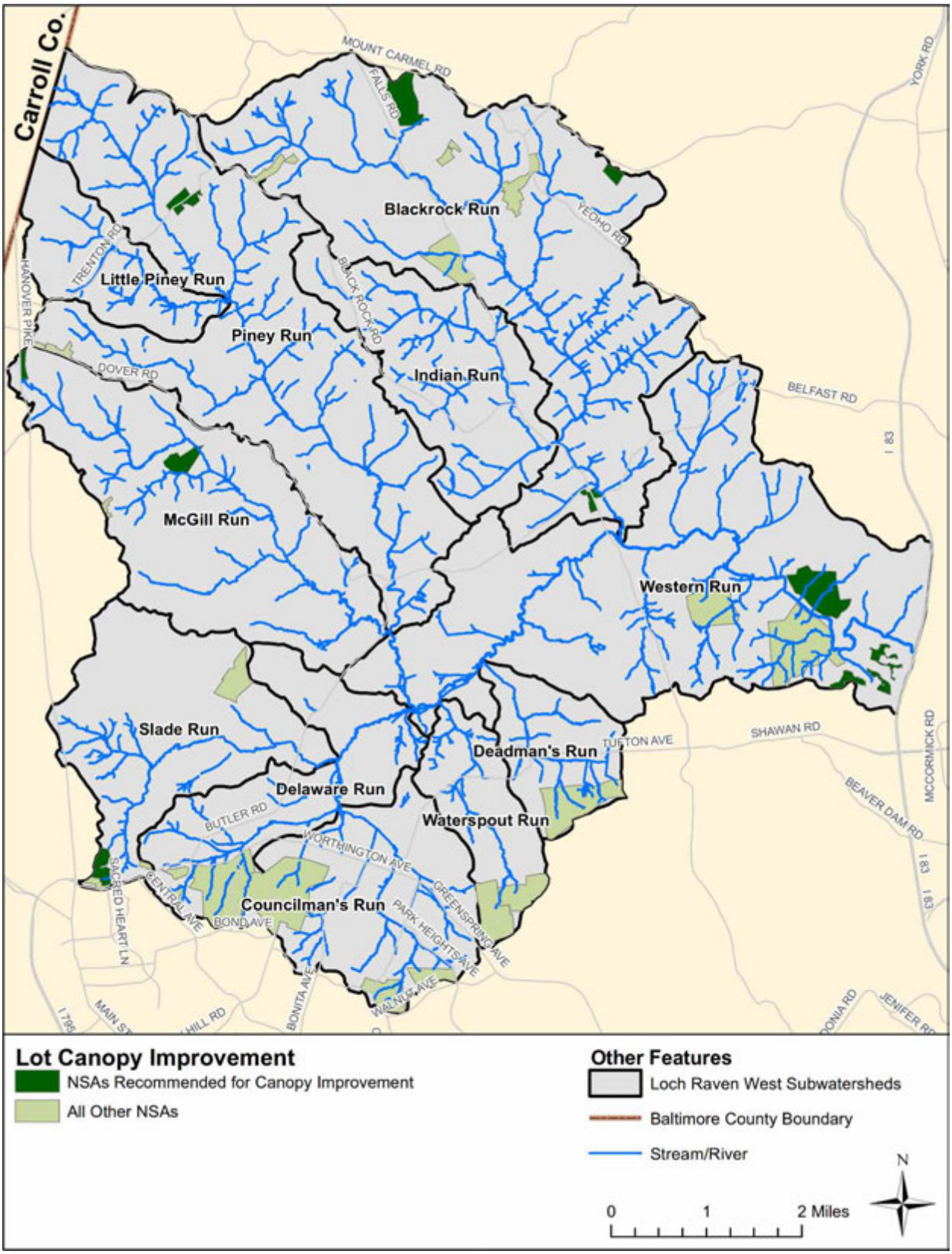

Figure 4-7: Neighborhoods Recommended for Lot Canopy Improvement

4.2.3.7 Neighborhood Trash Management

Trash can be a major neighborhood pollutant. The uplands survey revealed that a few locations within the study area may benefit from trash management initiatives such as community cleanups and trash management education. Neighborhoods where junk or trash was observed in ten percent or more of yards were recommended for trash management initiatives. Table 4-8 includes a summary of the number of neighborhoods recommended for trash management initiatives and the acres of land addressed if it was implemented by subwatershed. Table 4-8 also includes a summary of the percent of the total subwatershed area addressed by initiating trash management.

Table 4-8: Acres of Land Addressed by Trash Management

Subwatershed	# of NSAs Recommended for Trash Management*	Acres of Land Addressed	% of Subwatershed Area Addressed
Piney Run	2	33	0.53%
Blackrock Run	1	22	0.31%
Little Piney Run	0	0	0.00%
Indian Run	0	0	0.00%
McGill Run	2	46	1.14%
Western Run	0	0	0.00%
Slade Run	0	0	0.00%
Delaware Run	0	0	0.00%
Councilman's Run	0	0	0.00%
Waterspout Run	0	0	0.00%
Deadman's Run	0	0	0.00%
Loch Raven West Total	***5***	***102***	***0.26%***

*If a neighborhood overlaps multiple subwatersheds, it is counted for each subwatershed it encompasses

Figure 4-8 illustrates the location of neighborhoods recommended for trash management initiatives. Out of the 29 neighborhoods assessed, 4 neighborhoods (14%) were recommended for trash management. If initiated, this would address approximately 0.3% of the Loch Raven West watershed. Overall, the Loch Raven West watershed is relatively clear of neighborhood trash.

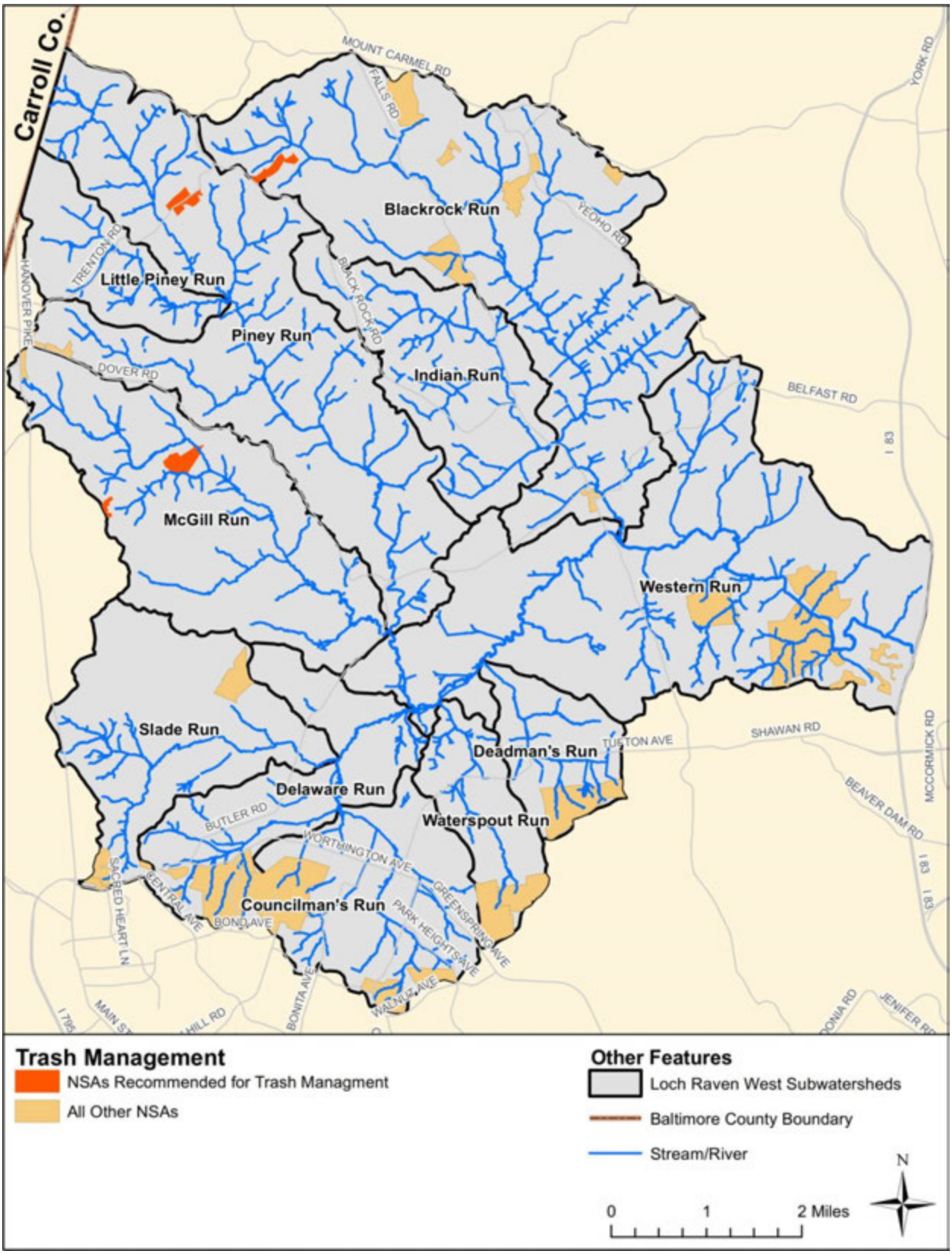

Figure 4-8: Neighborhoods Recommended for Trash Management

4.3 Hotspot Site Investigation (HSI)

Stormwater hotspots are areas that have potential to generate higher concentrations of stormwater pollutants than typically found in urban runoff and/or have a higher risk of spills, leaks, or illicit discharges due to the nature of their operations (CWP, 2005). These generally include commercial, industrial, municipal, or transport-related operations. Hotspots are either regulated or unregulated. Regulated hotspots are known sources of pollutions that abide by applicable federal or state laws (e.g., NPDES permits). The nature of unregulated operations makes them likely to be potential pollutant sources. Stormwater pollutants generated as a result of hotspot operations depend on the specific site activities but typically include nutrients, hydrocarbons, metals, chloride, pesticides, bacteria, and trash.

Commercial hotspots include a range of businesses and activities but are normally grouped together in subwatersheds. Operations characteristic of commercial hotspots include waste or wash water generation, outdoor material storage, fuel handling, and auto/boat repair. Common commercial hotspots include but are not limited to auto repair shops, car dealers, car washes, parking facilities, gas stations, garden centers, construction equipment and building material lots, swimming pools, and restaurants. Industrial operations utilize, generate, handle, and/or store pollutants that can be washed off with stormwater, spilled, or mistakenly discharged into the storm drain. Many industrial hotspots are regulated under NPDES industrial discharge permits and include various manufacturing operations such as metal production, chemical manufacturing, and food processing. Municipal hotspots typically refer to local government operations such as solid waste, wastewater, road and vehicle maintenance, and yard waste. Like industrial operations, many municipal hotspots are subject to NPDES stormwater permits. Transport-related hotspots normally include areas of significant impervious cover and extensive private storm drain systems. Many are regulated and include uses such as airports, ports, highway construction, and trucking centers.

The purpose of the HSIs is to evaluate pollution potential from hotspot operations and identify potential restoration practices that may be necessary. The following subsections describe the methods used to identify and assess a sample of hotspots in the Loch Raven West watershed.

4.3.1 Assessment Protocol

There are few operations in the Loch Raven West watershed that qualify as stormwater hotspots. The County preselected eight hotspots, which were included in the assessments; one additional site was identified and selected through a desktop assessment or identified in the field during the upland assessment. Commercial/industrial areas within the watershed were identified using GIS tax parcel information, land use data, NPDES locations and aerial photographs in the office.

One objective of the HSIs was to examine a variety of hotspot operations and select sites to represent common types of hotspots found in the watershed. HSIs were also focused on unregulated hotspots since access to regulated hotspots is often limited, and regulated hotspots are previously documented and known pollutant sources. Regulated hotspots are already subject to NPDES permit regulations which normally require strict effluent concentration limits and periodic monitoring. Obvious sources of pollution

observed during the upland assessment were revisited for hotspot potential. Problem areas identified by community members during the upland assessment were also scouted for hotspot potential.

While hotspots have unique operations, drainage systems, and pollutant-related risks, stormwater quality problems can be characterized and evaluated by operations and activities common to most hotspots. Per the USSR manual, the HSI involved an evaluation of six common operations at each potential hotspot: vehicle operations, outdoor materials, waste management, physical plant, turf/landscaping, and stormwater infrastructure. The field team aimed to survey the entire property of each potential hotspot selected for an HSI to determine water quality impacts and restoration opportunities.

These six categories were used to standardize the HSI process and prioritize potential restoration efforts. Parameters evaluated within each operation category are described briefly below.

Vehicle Operations

Vehicle operations include maintenance, repair, recycling, fueling, washing, or long-term parking. The presence of any of these activities was noted for each site since they can be a major source of metals, oil and grease, and hydrocarbons. Outdoor activities including vehicle storage, repair, fueling, and washing were also noted as potential pollution sources. Connections between vehicle operations and the storm drain system are the main focus of this category. The following were noted during the HSI as potential pollution sources: vehicle spills/leakage, lack of runoff diversion methods from storage/repair areas, directly connected fueling areas, and direct discharges to the storm drain from vehicle washing.

Outdoor Materials

Stormwater quality issues result from improper handling or storage of outdoor materials at hotspots. Locations where materials were loaded or unloaded were examined to see if materials were uncovered and draining to a storm drain inlet. Storage areas were also evaluated for types of materials stored outdoors and their potential for entering the storm drain system. Uncovered materials and stained storage areas were used as indicators of poor outdoor storage practices and potential pollution sources. The field team also looked for improperly labeled storage containers, lack of secondary containment for liquids, and whether the storage area was directly or indirectly connected to the storm drain system. If any of these were observed, they were marked as potential pollution sources.

Waste Management

Every hotspot generates waste as a result of daily operations which can be potentially hazardous or a source of stormwater pollution depending on the type of waste and how it is stored. The field team noted the type of waste generated (e.g., hazardous, garbage, etc.) and the condition of dumpsters. Dumpsters with no cover or open lids, with leaks, damaged or in poor condition, and/or overflowing were noted as potential pollution sources. Dumpsters located near storm drain inlets and lacking runoff diversion methods were also recorded as potential pollution sources.

Physical Plant

Common physical plant practices include cleaning, maintaining, or repairing the building, outdoor work areas, and parking lots. These activities can be a source of sediment, nutrients, paints, and solvents in stormwater runoff. For each hotspot, the condition around the building was evaluated. Staining or

discoloration around the building, which is evidence that maintenance activities (e.g., painting, power-washing, resealing, etc.) discharge to storm drains, were noted as potential pollution sources. Similarly, parking lots that were stained, dirty, breaking up, or had excessive impervious cover were recorded as potential pollution sources. Downspouts connected to impervious surfaces or directly to the storm drain system were also recorded as pollution sources at a hotspot site. A stain leading to storm drains denoted poor cleaning practices (e.g., for construction activities).

Turf/Landscaping

Ground maintenance activities for turf/landscaped areas were also evaluated at hotspot sites. High turf management and improper irrigation practices were noted since they are potential sources of nutrient, fertilizer, and pesticide pollution. The field team also determined whether landscaped areas drained directly to storm drains or if organics (leaves, grass) accumulated on impervious surfaces. More than 20 percent of bare soil in turf/landscaped areas was flagged as a sediment pollution source.

Stormwater Infrastructure

If stormwater treatment practices were not present, this was flagged as a potential pollution source. Private storm drains were also evaluated for pollution and illicit connection potential. Storm drains with considerable amounts of sediment, organics, and/or trash were identified as potential pollution sources.

Recommended Actions

For each operation on the HSI field form, there is an observed pollution source box which was checked when there was clear evidence of pollution problems at the time of the investigation. After surveying the entire property and evaluating hotspot operations, one or more of the follow-up actions listed below may be recommended based on initial field observations:

- Refer for immediate enforcement
- Follow-up on-site inspection
- Test for illicit discharge
- Future education effort
- Check to see if hotspot is an NPDES non-filer
- On-site non-residential retrofit
- Pervious area restoration
- Schedule a review of stormwater pollution prevention plan

4.3.2 Summary of Sites Investigated

Of the nine potential hotspots within the Loch Raven West watershed, two were unable to be assessed. The hotspot candidates included as part of the upland survey are listed in Table 4-9 including site ID, subwatershed, type, and category. All assessed hotspots were given an initial hotspot designation based on the severity of pollution potential observed in the field. Hotspots were categorized as either severe, confirmed, potential, or not a hotspot. Locations and initial hotspot status designations are shown in Figure 4-9. These hotspot candidates were selected as a representation of common types of hotspot

operations throughout the watershed. While based on this sample assessment, the overall watershed strategy should also encompass all hotspot operations occurring in the watershed.

Throughout the Loch Raven West watershed, two commercial facilities, two industrial facilities, and three municipal facilities were investigated.

Table 4-9: Summary of Hotspot Sites Investigated in Loch Raven West Subwatersheds

Site ID	Subwatershed	Type	Category
HSI_W_0201	Blackrock Run	Construction Maintenance Yard	Industrial
HSI_W_0202	Blackrock Run	Stone Quarry	Industrial
HSI_W_0203	Blackrock Run	Quarry	Industrial
HSI_W_0204	Blackrock Run	Fire Station	Municipal
HSI_W_0205	Blackrock Run	Store	Commercial
HSI_W_0301	Little Piney Run	Meeting Place	Municipal
HIS_W_0701	Slade Run	Petroleum Pipeline Management	Industrial
HSI_W_0702	Slade Run	Shopping Center	Commercial
HSI_W_0703	Slade Run	Fire Station	Municipal

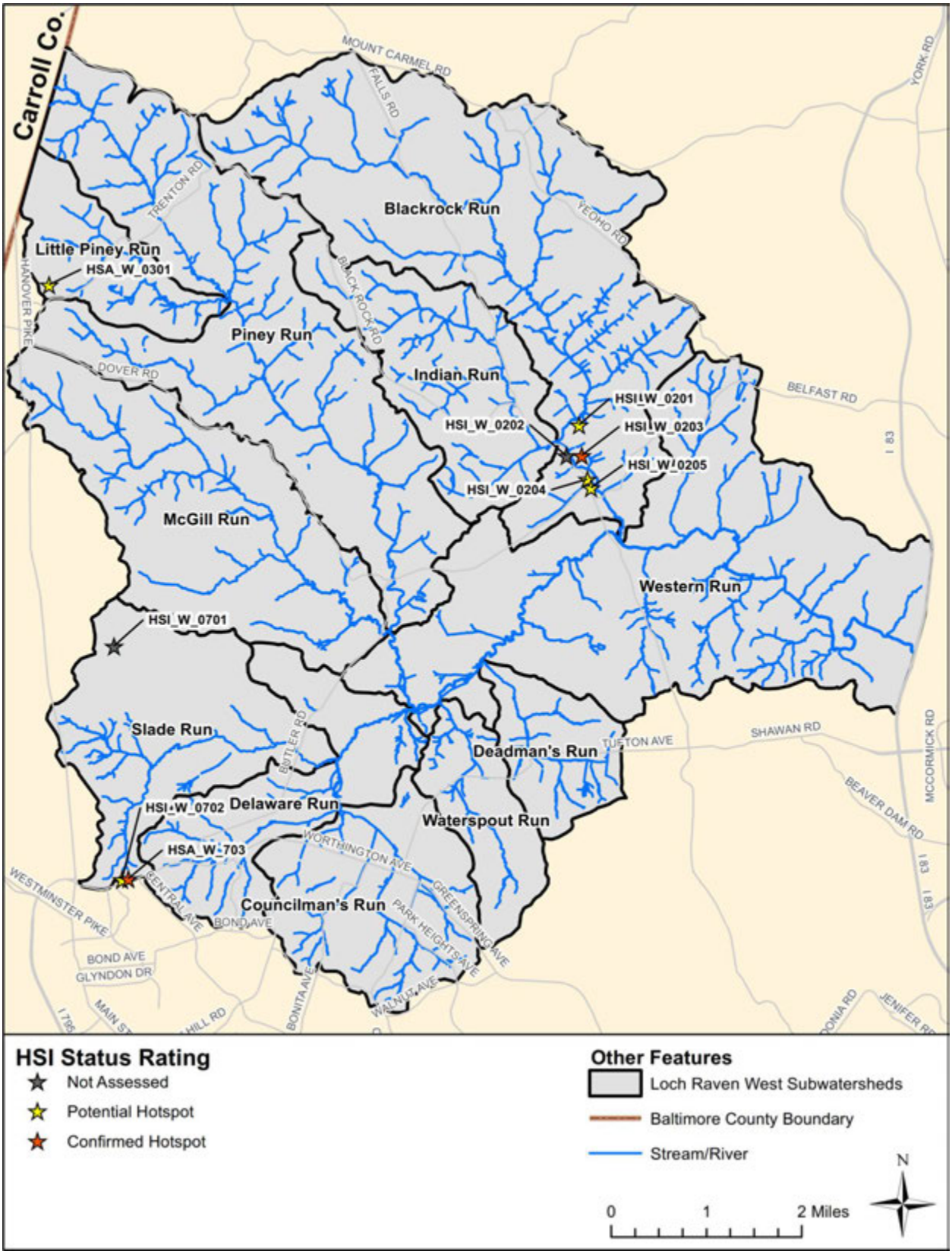

Figure 4-9: HSI Locations in the Loch Raven West Watershed

4.3.3 General Findings

A summary of HSI results is presented in Appendix B including hotspot status, category, pollution sources, and comments regarding hotspot observations. Two hotspots could not be assessed due to access restraints (no trespassing signs). Two confirmed hotspots and five potential hotspots were identified among this sample of hotspot categories including commercial, industrial, and municipal operations. Waste management (i.e., open and overflowing dumpsters, dumpsters stored near stormwater inlets, trash/litter, etc.) and physical plant (i.e., downspouts that discharge to impervious surface or are directly connected to the storm drain, parking lots that are breaking up, etc.) were the most common potential pollutant sources observed in the watershed. Another common potential pollutant source observed throughout the Loch Raven West watershed was vehicle operations such as vehicle fueling and storage. A brief description of the various hotspot categories assessed and general findings are provided in the subsequent subsections. This includes a description of how the pollution potential for specific sites can be ranked within a specific category.

4.3.3.1 Commercial

Two commercial areas were investigated within the Loch Raven West watershed, each with unique operations and pollution sources. Both of the commercial hotspots fall into the shopping centers, garden centers, and offices category with one being a store and one being a shopping center.

<u>Shopping Centers/ Garden Centers/ Offices</u>

Common potential pollutant sources from these HSIs included outdoor materials, waste management, and physical plant management. Commercial areas sometimes have outdoor shopping or stockpile areas where materials are stored outside. If materials are uncovered and on impervious surfaces, runoff from these areas can go directly into the storm drain system along with certain pollutants depending on the type of materials (See Figure 4-10). Waste management issues at shopping centers are often associated with the condition and location of dumpsters. Dumpsters at commercial HSIs in the Loch Raven West watershed were located close to a stream, on a parking lot that drains to a stream, or close to an inlet (See Figure 4-10).

Figure 4-10: Potential Pollution Source from Waste Management (Left) and Proper Trash Management (Right)

At shopping centers and stores, large amounts of impervious surfaces are present to accommodate parking needs of these businesses. As mentioned previously, impervious surfaces create increased runoff into storm systems and local surface waters, creating erosion problems and carrying nutrients and oil-based pollutants. When impervious surfaces break up, additional pollutants in the form of sediments are added to the runoff, further degrading downstream waters. Downspouts that discharge onto impervious surfaces or directly to the storm drain system increase the potential for pollutants to reach bodies of water. Figure 4-11 shows examples of pollution sources from impervious surfaces and downspouts at commercial hotspots in the Loch Raven West watershed.

Figure 4-11: Impervious Surface Breaking Up (Left) and Downspouts Discharging to an Inlet (Right)

Commercial Hotspot Summary

Pollution potential from commercial hotspots including auto-related facilities, shopping centers, and offices can be ranked as high, medium, or low based on the following example criteria:

- *High pollution potential*: Staining of impervious surfaces leading to storm drain inlets or stream; dumpsters in poor condition (leaking, overflowing, uncovered, next to storm drain or stream without diversion); improper disposal of hazardous materials or wash water; uncovered or lack of runoff diversion methods for repair/fueling areas or outdoor materials storage
- *Low pollution potential:* Proper disposal methods; good housekeeping (well maintained parking lot, waste management); stormwater management practices.

4.3.3.2 Industrial

Industrial sites generally include manufacturing sites, maintenance yards for construction companies, and distribution centers. As discussed in Section 2.3.10, only 0.002 % of the watershed is zoned industrial. Despite the small percentage of cover, industrial areas have the potential to contribute a significant release of illicit pollutants into nearby storm drains and surface waters.

Four industrial facilities were investigated in the Loch Raven West watershed: a construction maintenance yard, a petroleum pipeline management site, and two quarries. A quarry and the petroleum pipeline site

could not be accessed due to fencing and 'no trespassing' signs; therefore, these sites were not assessed. Potential pollutant sources observed at the two assessed facilities were related to vehicle operations, outdoor materials, waste management, physical plant, and turf/landscaping. Specifically, vehicles were being stored and repaired outside and uncovered fueling stations were observed. Broken down vehicles were observed at one of the facilities. Another common potential pollutant source came from the presence of uncovered outdoor material storage. Sand and stone were observed at both of the facilities. Stored improperly, outdoor materials can wash into waterways and loose trash can be washed or blown into drainage systems and streams. Both of the industrial sites that were assessed are recommended for a follow-up on-site inspection as part or all of the sites could not be assessed by the field teams. See Figure 4-12 and Figure 4-13 for examples of outdoor storage, waste, and vehicle operations observed at industrial hotspots.

Figure 4-12: Improper Outdoor Materials Storage Due to Lack of Cover (Left) and Long-Term Storage/Trash (Right)

Figure 4-13: Improper Outdoor Materials Storage (Left) and Vehicle Operations (Right)

Industrial Hotspot Summary

Pollution potential from industrial hotspots including construction companies, material distribution centers, and equipment storage can be ranked as high, medium or low based on the following example criteria:

- *High pollution potential*: Staining of impervious surfaces leading to storm drain inlets or stream; dumpsters in poor condition (leaking, overflowing, uncovered, next to storm drain or stream without diversion); improper disposal of hazardous materials or wash water; uncovered or lack of runoff diversion methods for repair/fueling areas or outdoor materials storage
- *Low pollution potential:* Proper disposal methods; good housekeeping (well maintained parking lot, waste management); stormwater management practices

4.3.3.3 Municipal Operations

Municipal properties tend to consist of storage yards, maintenance yards and fueling center and these sites usually have large impervious areas. Municipal areas can also include offices and recreational facilities.

Three municipal facilities were examined during the HSI assessments. They included two volunteer fire departments and a meeting place on the property of a volunteer fire department. There was a wide range of observed potential pollutant sources for the municipal sites; a few of the most common were vehicle storage and washing areas, impervious surfaces breaking up, and downspouts discharging to impervious surfaces (see Figure 4-14). Overall, these facilities were well maintained, but could benefit from education efforts related to tree planting and downspout disconnection (see Figure 4-14 and Figure 4-15). One site was recommended for immediate enforcement and a follow-up on-site inspection due to improper waste management (see Figure 4-15).

Figure 4-14: Impervious Surface Breaking Up (Left) and Area Available for Tree Planting (Right)

Figure 4-15: Downspouts Discharging to Impervious Surface (Left) and Improper Waste Management (Right)

Municipal Hotspot Summary

Pollution potential from municipal hotspots include maintenance yards, storage yards, and equipment storage and can be ranked as high, medium or low based on the following example criteria:

- *High pollution potential*: Staining of impervious surfaces leading to storm drain inlets or stream; improper disposal of hazardous materials or wash water; uncovered or lack of runoff diversion methods for repair/fueling areas or outdoor materials storage
- *Low pollution potential:* Proper disposal methods; good housekeeping (well maintained parking lot, waste management); stormwater management practices

4.4 Institutional Site Investigation (ISI)

The USSR manual does not treat institutional sites as a separate component of the uplands survey; instead, institutions can be assessed using HSI protocols. Consistent with recently completed county watershed studies, a modified version of the HSI field form was used to assess institutional sites since HSI protocols do not exactly match conditions encountered on institutional properties. The ISI method was first developed and implemented for the Upper Back River watershed study and was also used for the Tidal Back River, Middle River/Tidal Gunpowder, Bear Creek/Old Road Bay, Middle Gwynn Falls, Loch Raven North, and Liberty Reservoir watershed studies. Institutions surveyed as part of this study include the following types of community-based facilities: schools, faith-based facilities, and golf courses. The following subsections describe the methods used to identify and evaluate pollution sources and restoration potential at institutional facilities.

4.4.1 Assessment Protocol

The County had preselected seven institutions, which were included in the assessments. One additional site was identified in the field during the field assessment. These sites were shown and labeled on field maps created for the upland assessments and on larger base maps showing the entire watershed. Institutions were surveyed as encountered in the field using these maps and a list of institutions as guidance. Unique ID numbers were assigned to ISIs using the classification scheme “ISI_W_0101”, where

'W' denotes the Loch Raven West watershed and the first two numbers correspond to a specific subwatershed. As previously described, subwatersheds were assigned the unique numbers summarized in Table 4-1 for the purposes of NSAs, HSIs, and ISIs. Institutional sites were then numbered sequentially within a particular subwatershed. For example, ISIs in Western Run would be identified as 0601, 0602, etc.

The entire property of an institutional site was walked by the field team to collect necessary data and take photographs. Basic information was filled out first including type of institution, address, and ownership (public or private). Ownership is important as different approaches may be used to contact private versus public institutions. For example, a message may be received differently coming from the government as opposed to a non-profit group. Strategies for individual institutions will incorporate these different approaches. The ISI field form includes many of the pollution source categories used on the HSI form. Some of the restoration opportunities and recommended actions from the NSAs are also incorporated into the ISI. The focus of ISIs is to identify potential restoration opportunities, to educate the community, and to provide water quality benefits. The information collected for each of the pollution source and restoration categories are briefly described below.

Tree Planting

Potential tree planting locations at an ISI site were marked on aerial photographs while walking the property. After walking the entire site, the total number of trees that could be planted at the site was estimated based on 40-foot spacing between trees for narrow sites and based on an estimate of 100 trees per acre for larger open areas. More accurate numbers can be determined during the post-fieldwork desktop analysis after restoration opportunities have been selected and prioritized.

Exterior

The exterior category is similar to the physical plant category in the HSI, except it also includes restoration opportunities. The condition of the building(s) and parking lot(s) were noted. Stained, dirty, damaged, or breaking up surfaces were noted as potential pollution sources for both of these components. If no stormwater management was provided for impervious parking areas this was also considered as a potential pollution source. Exterior storm drain inlets were inspected for evidence of maintenance or wash water dumping and poor erosion/sediment control, cleaning, or material storage practices for construction activities. Any observations of staining, discoloration, or mop threads around a storm drain inlet indicated a potential pollution source as a result of these activities. Building downspouts that were directly connected to the storm drain system or indirectly connected to impervious surfaces were also recorded as potential pollution sources.

Potential restoration opportunities evaluated in the exterior category included impervious cover removal and downspout disconnection. Locations where excess impervious cover could be removed were marked on aerial field maps. Examples include unused or underutilized parking areas and abandoned athletic courts and foot paths.

Waste Management

Every institution generates waste as a result of daily operations, but unlike hotspots, it is typically just garbage. One exception to this could be health care facilities that have the potential to generate medical waste. The field team noted the type of waste generated (e.g., hazardous, garbage, medical, etc.) and the condition of dumpsters. Dumpsters with no cover or open lids, with leaks, damaged/in poor condition, and/or overflowing were noted as potential pollution sources. The field team also observed whether trash was present that could leave the site with wind or rain. Dumpsters located near storm drain inlets or lacking runoff diversion methods were also recorded as potential pollution sources.

Vehicle Operations

Vehicle operations include maintenance, repair, recycling, fueling, washing or long-term parking. The presence of any of these activities was noted since they can be a source of metals, oil and grease, and hydrocarbons. Outdoor activities including vehicle storage, repair, fueling, and washing were also noted as potential pollution sources. For the most part, it appeared that the institution likely only stored vehicles on-site.

Outdoor Materials

Materials such as mulch piles, storage drums, and de-icing salt are sometimes stored on institution grounds. Locations where materials were loaded or unloaded were examined to see if materials were uncovered and draining to a storm drain inlet. Storage areas were also evaluated for types of materials stored outdoors and their potential for entering the storm drain system. Uncovered materials and stained storage areas were used as indicators of poor outdoor storage practices and potential pollution sources.

Turf/Landscaping

The percentage of forest canopy, turf grass, landscaping, and bare soil covering the pervious area of a site was recorded on the field form. Sites with more than 20 percent of bare soil were noted as a potential source of sediment pollution. Ground maintenance activities for turf/landscaped areas were also evaluated. High turf management and improper irrigation practices (non-target/over-watering) were noted since they are potential pollution sources of nutrients, fertilizer, and pesticides. The field team also determined whether landscaped areas drained directly to storm drains or if organics (leaves, grass) accumulated on impervious surfaces. Evidence of buffer encroachment and whether buffers were adequately planted was also recorded for evaluating restoration potential.

Stormwater Infrastructure

The field team checked whether storm drains were marked and whether stormwater treatment practices were present. These were evaluated for potential pollution sources and restoration potential. In addition,

field teams also noted opportunities for the installation of stormwater retrofits to treat existing impervious areas.

Recommended Actions

After walking the entire property and evaluating the categories discussed above, one or more of the follow-up actions listed below were recommended based on initial field observations:

- Tree planting
- Stormwater retrofit
- Downspout disconnection
- Trash management
- Storm drain marking
- Stream buffer improvement
- Education (e.g., lawn care, outdoor materials storage)
- Landscaping improvement
- Nutrient management

4.4.2 Summary of Sites Investigated

A total of eight institutions were investigated throughout the Loch Raven West watershed. The number and type of institutions assessed within each subwatershed are summarized in Table 4-10. Several of the institutions overlap multiple subwatersheds. For this analysis, institutions which overlap watershed boundaries counted towards the subwatershed in which the majority of the area falls within. For example, Piney Branch Golf and Country Club encompasses portions of the Piney Run and Little Piney Run subwatersheds. Since the majority of the ISI area falls within the Little Piney Run, it was counted toward this subwatershed for analysis purposes. Figure 4-16 shows the distribution of the various types of institutions assessed throughout the watershed.

Table 4-10: Types of Institutions Assessed by Subwatershed

Subwatershed	Public Schools	Private Schools	Faith-Based	Golf Course
Piney Run	-	-	1	-
Blackrock Run	1	-	-	-
Little Piney Run	-	-	-	1
Indian Run	-	-	-	-
McGill Run	-	-	1	-
Western Run	-	-	1	1
Slade Run	-	-	1	-
Delaware Run	-	1	-	-
Councilman's Run	-	-	-	-
Waterspout Run	-	-	-	-

Deadman's Run	-	-	-	-
Loch Raven West Total	***1***	***1***	***4***	***2***

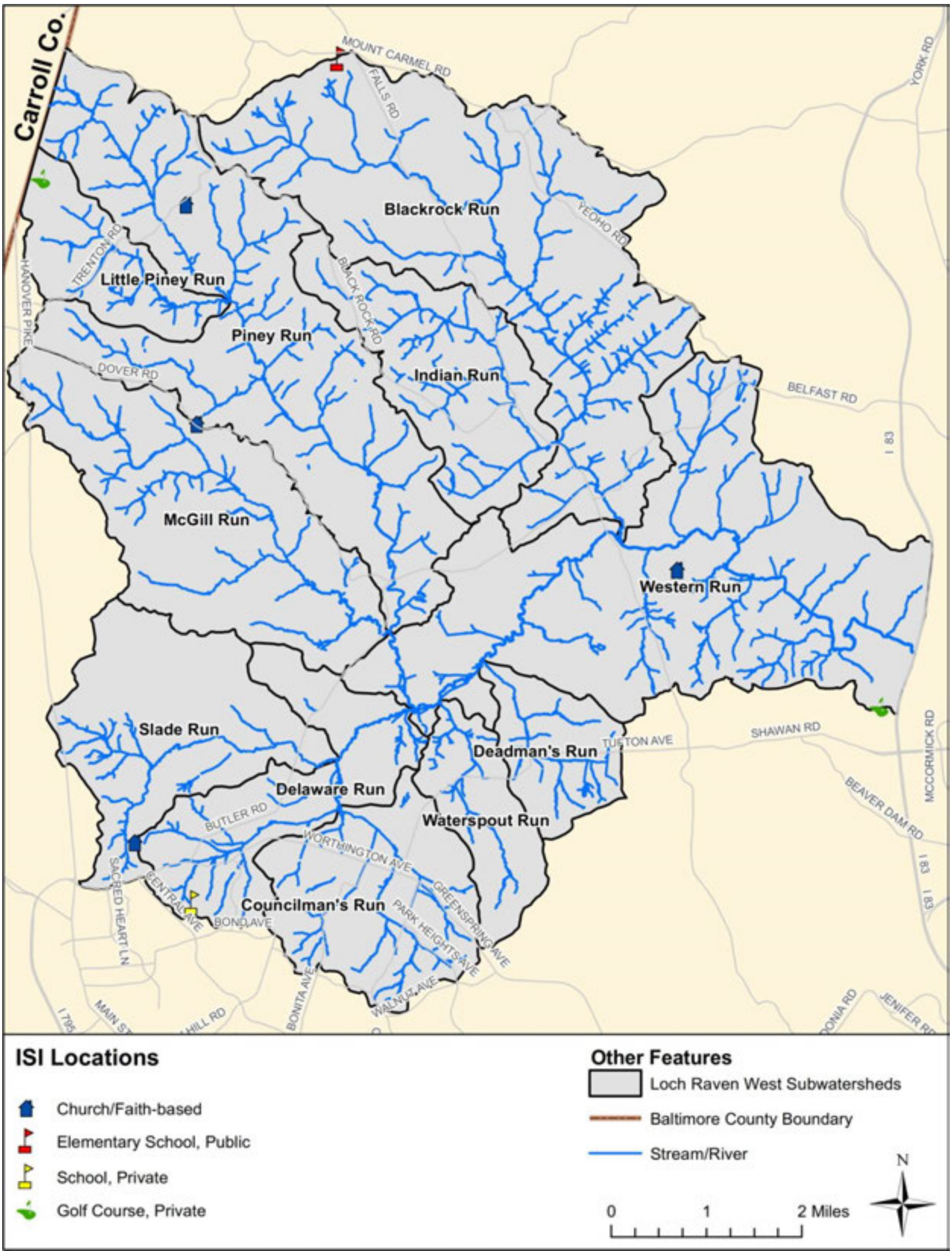

Figure 4-16: ISI Locations in the Loch Raven West Watershed

4.4.3 General Findings

The number and different types of recommended actions for ISIs are summarized in Table 4-11 by subwatershed. The most common potential pollution sources observed at the ISI locations were buffer improvement and nutrient management.

Table 4-11: ISI Recommended Actions by Subwatersheds

Subwatershed	# of Trees	SW Retrofit	Downspout Disconnection	Impervious Cover Removal	Trash Management	Storm Drain Marking	Buffer Improvement	Education	Landscaping Improvement	Nutrient Management
Piney Run	0	0	1	0	0	0	0	0	1	0
Blackrock Run	55	0	0	0	0	0	0	0	0	1
Little Piney Run	381	0	1	0	1	0	1	1	1	1
Indian Run	0	0	0	0	0	0	0	0	0	0
McGill Run	128	1	0	0	0	0	1	0	0	1
Western Run	1,946	1	0	0	1	1	1	1	0	0
Slade Run	0	0	0	0	0	0	0	0	0	0
Delaware Run	0	0	0	0	0	1	0	0	0	0
Councilman's Run	0	0	0	0	0	0	0	0	0	0
Waterspout Run	0	0	0	0	0	0	0	0	0	0
Deadman's Run	0	0	0	0	0	0	0	0	0	0
Loch Raven West Total	***2,510***	***2***	***2***	***0***	***2***	***2***	***3***	***2***	***2***	***3***

4.4.3.1 Tree Planting

It was estimated that a total of 2,510 trees could be planted at institutions located within the Loch Raven West subwatershed. Trees were recommended for four of the institutions assessed. Tree planting sites were identified in the field and noted on field maps. The table above represents planning level estimates which would be refined through follow-up site investigations if a site is selected for a restoration/improvement project(s). Like street trees, open space shade trees are not only an asset aesthetically but they also provide air and water quality improvement since they intercept precipitation with their leaves and can absorb precipitation and nutrients through their root systems. This infiltration of precipitation through leaves or the root systems slows flow input and provides some treatment before stormwater runoff reaches the stream system.

4.4.3.2 Stormwater Retrofits

As shown in Table 4-11, two stormwater retrofits were recommended at two sites, while storm drain marking was also recommended at two sites. Downspout disconnection was recommended for one public and one private institution where sufficient pervious area was available to redirect rooftop runoff. All of

these actions present an opportunity to educate the community about the connection between the storm drain system, Loch Raven West watershed, and how their actions can impact or improve water quality.

Stormwater retrofits were recommended at one public institution and one private facility (two faith-based locations). Stormwater retrofit opportunities included treating runoff from parking lots and conversion of existing SWM facilities. Sites where sufficient pervious area was available to treat a portion of the runoff from an impervious parking lot could implement infiltration or filtration practices such as bio-retention that incorporate vegetation and filter media through which stormwater infiltrates for pollutant removal prior to groundwater recharge or entering the stream system.

ISI_W_0501 is a site where impervious areas could potentially be treated by a bioretention facility (see Figure 4-17). Bioretention facilities are nonlinear infiltration facilities that usually, but not always, receive concentrated flows. They incorporate landscaping plants that are planted in a special soil mixture, which promotes the removal of pollutants through filtration and the uptake of excess nutrients by the plants. As runoff filters through the soil mixture it infiltrates into the ground. The soil mixture is kept dry with an under drain system. The under drain either discharges into an existing stormdrain system or daylights to a vegetated area. There is a potential stormwater management facility at the back of the parking lot at site ISI_W_0602, but it could not be accessed during field investigation.

Figure 4-17: Potential Location for Bioretention Facility (Left) to Treat Impervious Parking Lot (Right) at ISI_W_0501

4.4.3.3 Downspout Disconnection

Downspout disconnection was a recommended action for one private golf course and one faith-based institution. ISI_W_0101 is a church with downspouts directly connected to the storm drain. There is enough down gradient grass for the downspouts to be disconnected and discharged to. The second site, ISI_W_0301, is a golf course where downspouts discharge to impervious surface and directly connect to the storm drain system. Again, there is adequate open, pervious area surrounding the facility for disconnection to take place.

4.4.3.4 Trash Management

Trash management is an area in need of improvement throughout various areas of the watershed including institutions. A total of two private institution sites were recommended for trash management

action. Waste management education is recommended to address open or uncovered dumpsters where trash can leave the site and dumpsters in poor condition. Examples of poor waste management conditions such as open dumpster lids and poor dumpster conditions were found at ISI_W_0602 and at ISI_W_0301 (see Figure 4-18).

Figure 4-18: Trash Management Opportunities at ISI_W_0602 (Left) and ISI_W_0301 (Right)

4.4.3.5 Storm Drain Marking

Two of the institutional sites were identified for storm drain marking: one school and one golf course. All of the recommended sites possess storm drain inlets that are currently unmarked.

4.4.3.6 Buffer Improvement

Forested buffer areas along streams are important for improving water quality and flood mitigation since they can reduce surface runoff, stabilize stream banks (root systems), shade streams, remove pollutants such as nutrients and sediment from runoff, and provide habitat for various types of terrestrial and aquatic life including fish. Several institutions have streams that run through the property which is a potential opportunity for improving an inadequate stream buffer by introducing native vegetation and trees. Buffer improvement options, however, must be sensitive to property uses while striking a balance with protecting water resources. For example, a narrow buffer consisting of native vegetation might be an alternative to 50-foot wide, wooded buffers on either side.

Buffer improvement was identified as a recommended action for three out of the eight institutions assessed. These three sites include two golf courses and one church. Buffer planting could be performed by a church congregation in conjunction with a stream cleaning and/or restoration project.

Figure 4-19: Buffer Improvement Opportunity at ISI_W_0501 (Left) and ISI_W_0601 (Right)

4.4.3.7 Educational Efforts

Educational efforts can have widespread benefits when implemented at institutions. The efforts can include waste management, property management (i.e. downspout disconnection, landscaping practices, invasive removal, etc.), proper material storage, and an overall increased awareness between community actions and water quality. Education efforts have been recommended for two institutional sites.

4.5 Pervious Area Assessment (PAA)

The Pervious Area Assessment or PAA was used as a component of the USSR to identify and evaluate sites within the study area with potential for land reclamation, reforestation, or revegetation. The following subsections describe the methods used to identify and evaluate restoration potential of pervious areas.

4.5.1 Assessment Protocol

The areas being assessed were preselected by Baltimore County EPS. Although there are many open spaces in the Loch Raven West watershed, assessment sites primarily consist of publicly owned fields and farmland. Additionally, two privately owned fire department properties were also assessed. If additional tree planting is needed to obtain water quality standards, other pervious areas will be investigated.

Unique ID numbers were assigned to PAAs using the classification scheme “PAA_W_0101”, where “W” denotes the Loch Raven West watershed and the first two digits correspond to a specific subwatershed. As previously shown in Table 4-1, each subwatershed was assigned a two digit number. The pervious areas were then numbered sequentially in the order they were surveyed within a particular subwatershed. For example, PAAs in the Blackrock subwatershed would be identified as 0201, 0202, etc.

A new desktop analysis method for pervious area assessment, first utilized for the Loch Raven East SWAP, was also utilized for the Loch Raven West watershed. Using this method, open pervious areas were evaluated and rated using current aerial photography available through Baltimore County (2011). The parameters considered in the assessment are briefly described below. For each parameter, the PAA was evaluated, rated for restoration potential, and prioritized.

Stream Buffer

If the PAA site contained a stream with no forest buffer, it received a high score for reforestation potential. Adjacent properties were also examined for inadequate forest buffers (<100') that could potentially be expanded. As discussed in Section 2.2.7.2, stream buffers play an important role in improving water quality. For this analysis, a stream buffer with forest cover or natural vegetation was desired for at least 100 feet on either side to protect the stream environment and downstream conditions.

Length of Stream

If the PAA site contained a stream with no forest buffer, an approximate linear distance of stream that required a buffer and reforestation was recorded. The greater the length of stream in need of forest cover protection, the higher the priority given for tree planting.

Proximity to Forest Interior

Forest interior is defined as forested areas located more than 500 feet from any forest edge. Many forest dwelling plants and animals benefit from having a continuous forest condition. It protects the ecosystem from invasive plant and animal species, which tend to thrive in edge habitats and disturbed conditions. Sites that have the potential to increase forest interior acreage were given the highest rating, while sites that have the potential to increase contiguous forests without the potential to expand interior forest were given a lower rating. Sites without existing continuous forest cover were given the lowest rating.

Exterior Forest Gap

An exterior forest gap is an unforested area located along the edge of a forest patch that would be enclosed by the outline of the outermost edge of the forest patch when connected by a line. In other words, if there is a clear area located on the edge of the forest that extends into the forest that could be planted to create a continuous forest edge. Only exterior forest gaps with edges less than 500 feet apart were included. Similar to forest interior, it is beneficial to close forest gaps in order to increase the area of contiguous forest. Forest edges are subject to colonization pressure from invasive plants and non-native animals. Sites that have the potential to close exterior forest gaps were given a higher rating than those that did not.

Planting Area

The size of land available for planting was also used to score the restoration potential of a site. The larger the area available for planting, the higher the rating given to the site as the environmental benefit will be greater. Smaller planting sites are also valuable and present potential opportunities for community-based projects and were still rated.

Ownership

Restoration projects are typically easier to accomplish on publicly owned land than on privately owned land. While projects on privately owned land are sometimes possible, they require additional coordination with the landowner, which often makes them more time consuming and costly. Thus, publicly owned lands are given a higher rating than privately owned lands since the environmental benefit will likely be greater.

Stormwater Retrofit Potential

In addition to rating the sites for restoration potential, the analysis also involved evaluating potential stormwater retrofit opportunities. Stormwater retrofits implement management controls to improve water quality by capturing, slowing, and treating runoff to receiving water bodies where previous

practices do not exist. The type of stormwater retrofit selected is based on several considerations including available land, cost, ecological benefit, and specific objectives.

4.5.2 Summary of Sites Investigated

A total of seven pervious areas were pre-selected by the county and assessed within the Loch Raven West watershed. All of the sites are publicly owned with the exception of two volunteer fire department sites (PAA_W_0203, PAA_W_0301), which are privately owned. Potential planting sites ranged from 0.10 to 2.00 acres. Figure 4-20 shows the location and size of PAAs within the watershed.

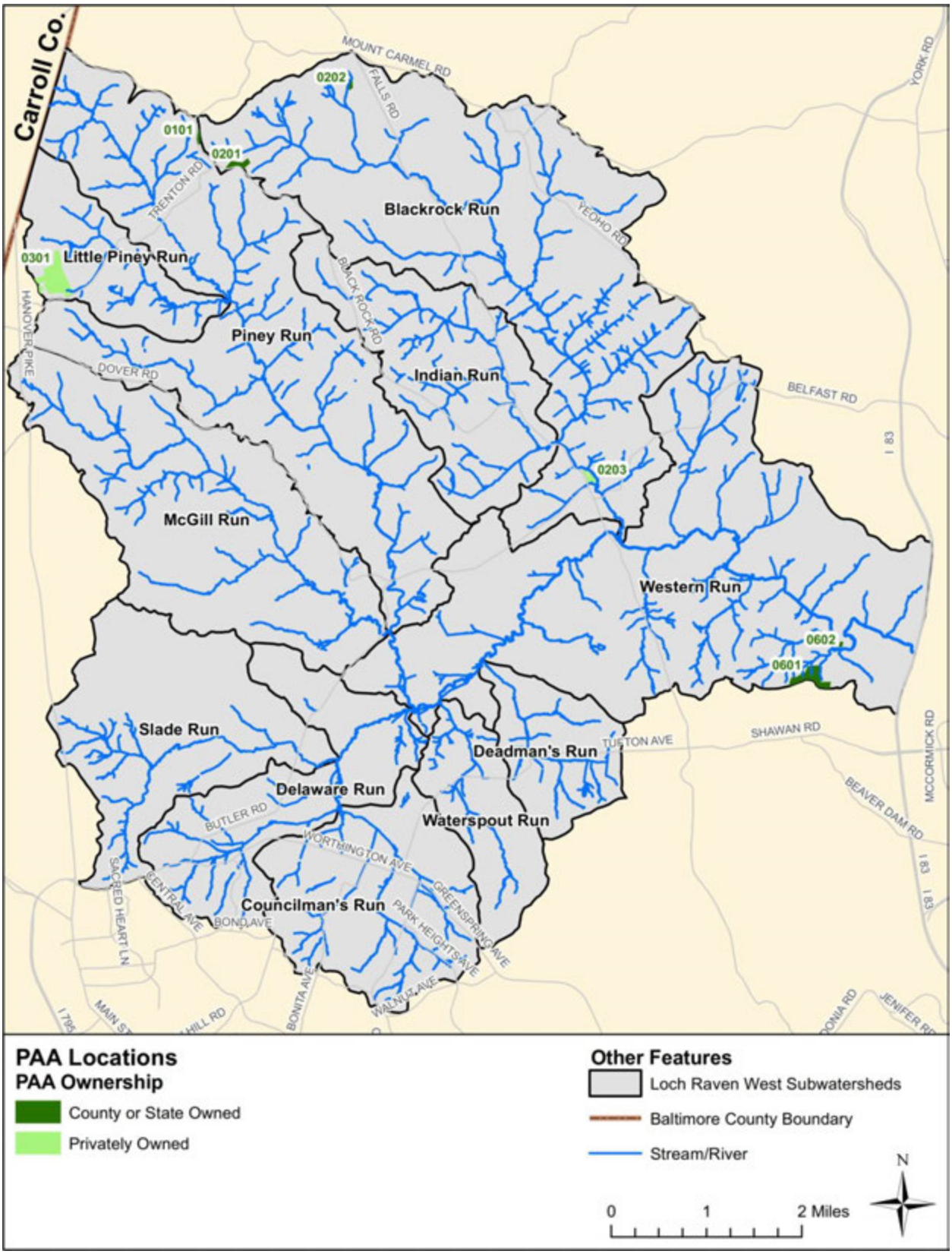

Figure 4-20: Pervious Area Assessment (PAA) Locations in Loch Raven West

4.5.3 General Findings

A summary of the selected PAAs and their results including area available for potential tree planning, presence of stream buffer, length of stream that can be planted, potential to expand forest interior acreage, presence of exterior forest gap, ownership, and stormwater retrofit potential is provided in Table 4-12.

Table 4-12: Loch Raven West PAA Summary

PAA	Planting Area (ac)	Stream Buffer Present	Length of Stream for Planting (linear ft.)	Expand Forest Interior	Exterior Forest Gap	Ownership	Restoration Score	SW Retrofit Potential
PAA_W_0101	0.0	Yes	0	No	No	Public	25	No
PAA_W_0201	1.36	No	N/A	No	No	Public	20	No
PAA_W_0202	0.75	Yes	672	No	No	Public	30	No
PAA_W_0203	2.14	Yes	1,577	No	No	Private	40	Yes
PAA_W_0301	1.27	Yes	510	No	No	Private	30	Yes
PAA_W_0601	0.50	Yes	560	Yes	No	Public	50	No
PAA_W_0602	1.26	Yes	318	No	No	Public	35	No

PAA_W_0101

Located in the Piney Run subwatershed, PAA_W_0101, is a 4.00 acre lot owned by Baltimore County near the Blackrock Road and Pleasant Meadow Road intersection. The parcel is currently being utilized as farmland that is adjacent to the end of a stream. While the ten feet of land adjacent to the stream has the potential to act as a stream buffer, the land is currently being used as farmland and there are overhead powerlines in the area. Thus, there is no recommended tree planting for this parcel at the current time.

Figure 4-21: PAA_W_0101

PAA_W_0201

Located in the Blackrock Run subwatershed, PAA_W_0201 is a 9.00 acre lot owned by Baltimore County that is southeast of the Blackrock Road and Trenton Road intersection. This parcel is being used as farmland and does not border any streams. In the northeast portion of the parcel, there is approximately 1.36 acre of land that is currently being used as farmland by an adjacent property. It is recommended that this 1.36 acre of land be planted with trees since it is contiguous to existing forest.

Figure 4-22: PAA_W_0201

PAA_W_0202

PAA_W_0202 is a Baltimore County owned, 2.00 acre parcel that is located in the Blackrock Run subwatershed near the intersection of Ridge Road and Falls Road. There is 0.75 acre available for tree planting along the Western portion of the site, which would help to create a continuous stream buffer on-site. It appears that this land is not currently being utilized and that it would be beneficial to plant in this area. There is an existing stormwater BMP located on-site.

Figure 4-23: PAA_W_0202

PAA_W_0203

The majority of PAA_W_0203 is located in the Blackrock Run subwatershed and is owned by the Butler Volunteer Fire Company. This site, which is 8.00 acres, is near the intersection of Falls Road and Butler Road. There is a stream adjacent to the site that does not currently have a contiguous buffer. This presents a tree planting opportunity of about 2.14 acres that would ensure a stream buffer for 1,577 feet of stream. The suggested tree planting area does not appear to currently be in use by the fire company, while the other open areas of the parcel seem to be utilized for training activities. There is a stormwater retrofit opportunity to capture sheet flow runoff from the large impervious parking area.

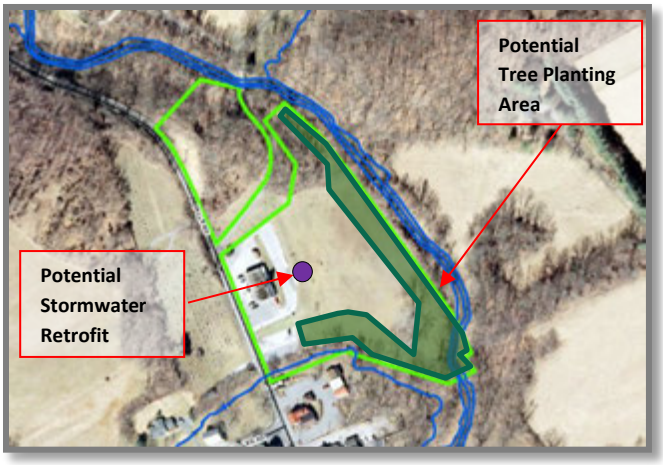

Figure 4-24: PAA_W_0203

PAA_W_0301

PAA_W_0301 is located in the Little Piney Run subwatershed along Carnival Avenue north of the intersection with Arcadia Avenue. The PAA site is owned and operated by the Arcadia Volunteer Fire Company and is used to host many events like music festivals and demolition derbies. The area that is not actively used for community events is farmland. There is tree planting potential in the parcel of about 1.27 acres that would enhance the buffer for 510 feet of stream. The tree planting sites were chosen so that there was as little infringement upon existing farmland as possible while still enhancing the stream buffer. The fire department station, which is not included in the PAA, is located off of Hanover Pike.

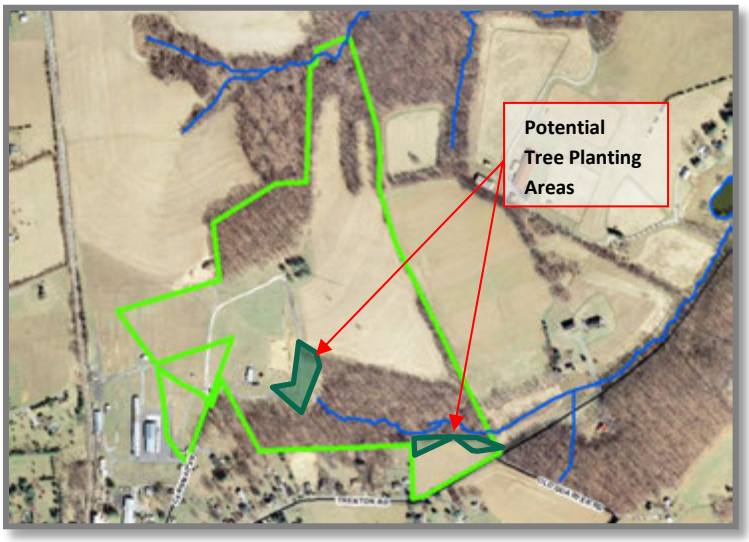

Figure 4-25: PAA_W_0301

PAA_W_0601

Located off of Shawan Road near the intersection of Greencroft Lane and Spring Green Lane, this parcel is in the Western Run subwatershed. PAA_W_0601 is a site owned by Baltimore County that is primarily used as farmland. This parcel is located on the southern border of the watershed, and presents 0.50 acre of tree planting potential. These tree planting areas present the potential to enhance the stream buffers for 560 feet of stream, and would only impact a small area of the existing farmland.

Figure 4-26: PAA_W_0601

PAA_W_0602

This PAA is located in the Western Run subwatershed along Western Run Road about 1/3 mile south of the intersection with Western Road. PAA_W_0602 is a 1.26 acre open lot along the forest edge, owned by Baltimore County. It is recommended that the whole parcel is planted with trees in order to enhance the buffer of the adjacent stream.

Figure 4-27: PAA_W_0602

Prioritization of Tree Plantings on Pervious Areas

Each site was given a Restoration Score derived by a point system of the parameters discussed in Section 4.5.1. The maximum score is 100 (greatest restoration benefit), while the minimum score is 5. Restoration scores for Loch Raven West PAAs range from 20 to 50. The highest scores go to the large lands with streams and adjacent forests, while the lowest scores go to small farmland without surrounding forest. To comply with the Loch Raven Reservoir and Chesapeake Bay TMDLs, Baltimore County must plant trees in stream buffer areas to decrease nutrient and sediment transport to the waterways, making sites with streams a higher priority. Decreasing forest fragmentation is also paramount in protecting the populations of native species, including neo-tropical migrating birds. See Table 4-13 for prioritization results.

Table 4-13: Loch Raven West PAA Restoration Priority

PAA	Restoration Score	Priority
PAA_W_0601	50	Medium
PAA_W_0203	40	Low
PAA_W_0602	35	Low
PAA_ W_0301	30	Low
PAA_ W_0202	30	Low
PAA_ W_0101	25	Low
PAA_ W_0201	20	Low

4.6 Other Upland Areas

4.6.1 Agricultural Land

The most prominent land use within the Loch Raven West watershed is agriculture, making up 54% of the area or approximately 20,700 acres. Agricultural land was not evaluated during the upland assessments, but it should be noted that if improperly managed, activity from agricultural land can lead to poor water quality through nonpoint source (NPS) pollution. These activities include but are not limited to plowing too often or at inappropriate times seasonally, mismanaged animal feeding operations, overgrazing, and improper, excessive, or poorly timed application of fertilizers, pesticides, and irrigation water (USEPA, 2016). Storm water runoff from agricultural lands can have high levels of nutrients, sediments, pesticides, salts, and metals, but there are BMPs that can be employed to minimize runoff pollution. Some examples of agricultural BMPs are conservation tillage to minimize soil disruption and cover crops which help decrease nutrient runoff after harvest. BMPs currently in use in the Loch Raven West watershed are summarized in Chapter 2 of this document.

4.6.2 Forested Land

The Loch Raven West watershed is comprised of approximately 31% forest (deciduous, evergreen, and mixed) equating to roughly 11,900 acres. Forested land was not included in the upland assessments but it has a large impact on stream health and water quality. Forest buffers along streams prevent pollution from entering receiving waters, stabilize stream banks, provide habitat and food for wildlife, and help keep water temperatures cool. The most beneficial management practice for forested lands is conservation, ensuring that the ecological advantages provided by forest and canopy are preserved.

CHAPTER 5: RESTORATION AND PRESERVATION OPTIONS

5.1 Introduction

This chapter presents an overview of the key management practice recommendations for the Loch Raven West watershed based on the information collected during both the office/desktop analysis and field assessments. There is a distinct difference between developed, residential and undeveloped, agricultural and their runoff characteristics. This difference also extends to the choice and effectiveness of stormwater best management practices (BMPs). For that reason, the management practices recommended in this chapter are geared toward the rural nature of the Loch Raven West watershed, including residential, agricultural, and forested areas. The chapter is divided into five sections: Municipal Capital Programs; Municipal Management Programs; Volunteer Restoration Programs; Neighborhood, Business, and Institutional Initiatives; and Citizen Awareness Activities. The sections were outlined based on the entity controlling and performing the activities along with their funding and schedule requirements.

5.2 Municipal Capital Programs

Municipal capital programs are characterized as projects and purchases that Baltimore County can undertake in the short term to improve water quality in the Loch Raven West watershed.

5.2.1 Stormwater Management Upgrades

The application of stormwater management practices varies according to various physical characteristics such as impervious cover and land use makeup of the site or subwatershed. The most efficient method to augment stormwater treatment is to convert existing stormwater facilities to a design with greater pollutant removal capability, for example a dry detention pond to an extended detention pond or wetland. This is referred to as a stormwater pond conversion. If enough land is available, the greatest benefit would be to construct a new facility, designed with current state of the art technology, to reduce pollutants to the maximum extent practicable. However, a developed subwatershed seldom has sufficient open space. Instead there are options available to put treatment systems directly in the storm drain system. Many packaged systems are available through the retail market and are explained further below. Additional sites adjacent to parking lots can offer treatment of large amounts of impervious surface. Also, new research in porous concrete and asphalt may offer the potential for additional reductions in impervious cover on public and private properties.

Most of the Loch Raven West watershed was developed prior to the passage of the Stormwater Act of 2007 in Maryland requiring more robust environmental site design. Stormwater retrofitting involves implementing stormwater BMPs and/or treatment devices in existing developed areas where previous practices did not exist or were ineffective to help improve water quality. Stormwater retrofits improve water quality by capturing and treating runoff before it reaches receiving water bodies. Retrofits target specific objectives depending on BMP type including stormwater quality, soil stabilization, stormwater flow control, and stream restoration. Several considerations must be taken into account to select appropriate stormwater treatment measures such as space requirements, cost, and community acceptance. Based on initial field and desktop evaluations, the following stormwater retrofit categories are recommended for addressing water quality issues in the Loch Raven West watershed through

municipal capital programs: stormwater management retrofit, storm drain inlet and outfall retrofits, and public parking retrofits. Each of these categories is described briefly in the sections below.

5.2.1.1 Stormwater Facility Conversion and Retrofit

The majority of the Loch Raven West watershed is largely undeveloped consisting of agricultural cropland and forest. Many of the developed regions, were constructed prior to the Stormwater Act of 2007 and do not include stormwater management facilities to treat stormwater runoff. This produces an excellent opportunity to introduce new stormwater facilities to treat and manage runoff in developed areas. Due to the rural nature of the Loch Raven West watershed, there are few existing stormwater management facilities. No existing stormwater facilities were evaluated in the Loch Raven West watershed. However, during the upland assessment, four sites (two ISI and two PAA) were identified as having potential for new or retrofit stormwater management facilities.

5.2.1.2 Storm Drain Inlet and Outfall Retrofits

Baltimore County's curb and gutter system consists of numerous inlets, pipes, and outfalls. While the curb and gutter system removes stormwater quickly from roadways, it often delivers increased runoff volumes and untreated pollutants to receiving water bodies. One way to address these potential water quality issues is to install proprietary BMPs at selected storm drain inlets. Various structural BMPs are commercially available and include catch basin inserts, water quality inlets, oil/grit separators, filtering devices and hydrodynamic devices. Proprietary BMPs are designed to address specific pollutants such as floatables and solid waste, nutrients, metals, sediment and oil/grease. Most are helpful for removing a portion of pollutants for pretreatment when used in conjunction with another BMP type such as an infiltration trench or a grassed swale for filtering pollutants upstream of an inlet.

While proprietary devices can be costly, they are water improvement alternatives for areas where there is inadequate space for other stormwater management options. Inlets selected for proprietary devices can be prioritized based on the county's outfall screening program.

Where space exists between an outfall and the stream channel, other BMPs can be considered such as floodplain wetlands and energy dissipation devices. Floodplain wetlands can provide treatment of storm flows prior to entering the stream channel. Energy dissipation devices can reduce stream power and thus erosive forces of storm flows prior to entering the stream channel.

5.2.1.3 Parking Lot Retrofits

The potential for installing new stormwater retrofits for treating runoff from existing developed areas is often limited by space availability. However, BMPs that require less space for treating runoff from portions of impervious surfaces can be an alternative to larger storage facilities such as wetlands and extended detention ponds. In areas where insufficient space is available for basin-scale retrofits, other infiltration/filtration practices such as bioretention can be incorporated into the parking lot layout. Bioretention involves open space combined with vegetated areas where stormwater is temporarily stored and passed through vegetation and a filter bed of sand, organic matter, soil, or other suitable media. Filtered stormwater is collected and returned to the storm drain system or allowed to partially exfiltrate from the system into the soil. A few private facilities were identified as having sufficient open space for

bioretention areas to treat runoff from parking lots. Another retrofit option for treating runoff from large impervious surfaces with limited open space is underground stormwater retention/infiltration systems. Underground stormwater retrofits help address sediment and nutrient inputs to the stream system as well as standing water.

5.2.2 Stream Corridor Restoration

Stream corridor restoration practices are used to enhance the appearance, stability, and aquatic function of stream corridors. These types of practices can range from simple stream clean-ups and localized bank stabilization to comprehensive repairs such as channel re-design and re-alignment. Stream restoration practices are often combined with stormwater retrofits and riparian management practices to meet subwatershed restoration objectives. Primary recommended practices for Loch Raven West stream corridors include buffer restoration and stream stabilization.

5.2.2.1 Forest and Buffer Improvement

Forests are the best land use for the protection of water quality. The Loch Raven West watershed is covered with over 30% forest and may provide opportunities for planting. Forested buffers are linear wooded areas along rivers, streams, and shorelines which help stabilize banks, prevent erosion, filter pollutants such as sediment and nutrients, and provide wildlife habitat. Many areas within the Loch Raven West stream system have inadequate buffers as a result of human development activities and agricultural clearing. A significant amount of the watershed has been altered and as a result, the original forested stream buffer has been replaced by cropland, pasture, mowed lawn areas, and impervious cover.

The main restoration strategy proposed for the Loch Raven West watershed is to conserve and enhance forests and impacted stream buffers. This can be accomplished by a variety of methods including:

- Planting on residential and open space properties with native vegetation – Institutions and residential communities should reduce the amount of mowed grass and plant additional native trees.

- Land Preservation – Forest protection is one reason for pursuing a property as part of the county's land preservation programs. Benefits to water quality are a part of the evaluation criteria in determining the most important parcels for protection.

- Targeted reforestation and education – Agencies and other watershed partners should seek to work cooperatively with landowners to help them plant buffers where possible. Increase landowner awareness (farmers, residents, businesses, and institutions) regarding the benefits of stream buffers that are forested or planted with native vegetation. In addition to providing water quality benefits, natural buffers help to protect property from erosion. There is a need for attention in this area, as it was observed that many landowners mow their lawns directly to the stream edge.

- Invasive species control – Invasive and non-native plant species such as bamboo and Japanese knotweed were identified in various locations within the watershed. Invasive species concerns

can be addressed through public education, training of county grounds maintenance staff, and developing a volunteer group dedicated to controlling invasive species in the watershed.

5.2.2.2 Stream Stabilization

Natural channel design techniques are utilized to stabilize eroded, degraded stream banks and to protect infrastructure such as private property, buildings, and utilities. Stabilizing the stream channel improves water quality by preventing eroded soils, and the pollutants contained in them, from entering the stream. In addition, protecting infrastructure such as water and storm drain pipes reduces and/or eliminates water quality impacts associated with leaking pipes. Where conditions allow, reconnecting the stream channel to its floodplain provides additional water quality benefits. When considering stream repair, it is important to take into account what is occurring upstream in the watershed. The hydrology and stormwater management practices upstream of a restoration site will dictate the quantity and speed runoff will reach a site. In addition, the sediment supply of the upstream channel is also an important consideration during the design of stream restoration repairs.

5.2.2.3 Wetland Creation

Wetlands are highly valuable lands in terms of their abilities to both improve water quality and as important habitat for many species. Wetlands are defined as areas that are inundated or saturated by surface or groundwater at a frequency sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands are often called swamps, marshes, or bogs. This strategy entails the creation or enhancement of existing wetlands that have been lost or impaired in the past. The County often undertakes wetland restoration on public lands where wetlands have been destroyed or impaired as well as partnering with businesses and institutions where wetland restoration is a viable option.

5.2.2.4 Floodplain Reconnection

Floodplains provide not only flood control, but have stormwater management and water quality benefits. Flooding is a natural process in stream systems and a functioning floodplain enables runoff to be slowed, stored, and gradually released along a vegetated surface. This promotes shallow groundwater recharge, increases pollutant reduction, and reduces the velocity and volume of water to the downstream channel. With a reduction in storm flow velocities, floodplains also aid in erosion control. This strategy involves reconnecting floodplains in areas where development has resulted in disconnection. The County aims to restore natural stream and floodplain function on an individual project basis focusing on urban stream problems.

5.2.2.5 Legacy Sediment Removal

Many historic mill dam sites provide the opportunity to remove legacy sediments that have deposited within the past 200 years. The overall sediment load to receiving waters decreases by removing the legacy sediment upstream of mill dams while also presenting opportunities for wetland, stream, and floodplain restoration. This process will reduce nutrient and sediment loads and improve wildlife habitats. Franklin and Marshall College is a lead partner with the US EPA in legacy sediment removal, and the University of Maryland, Baltimore County (UMBC) has conducted local mill dam research in the watershed.

5.2.3 Pervious Area Restoration

Pervious areas offer a good opportunity for restoration in subwatersheds since they can be used to restore natural infiltration properties, enhance stream buffers, and provide wildlife habitat. These areas also present an opportunity for reforestation in the watershed, which is a high priority in terms of improving infiltration and recharge functions. Other techniques can also be used to improve natural functions including soil aeration, amendments, and establishing native plants and meadows. Sites prioritized for pervious area restoration should require minimal preparation for reforestation or regeneration with little evidence of soil compaction, invasive plant species, and trash/dumping. Five of the seven pervious areas assessed are publicly owned.

5.3 Municipal Management Programs

Municipal management programs are longer-term or continuous actions that Baltimore County can take to improve water quality in the Loch Raven West watershed.

5.3.1 Best Management Practices for Developed Land

Development throughout the watershed is largely responsible for increased pollutant loads and storm flow rates. Best management practices can be adopted in order to reduce the impacts of development and restore the quality of receiving waters.

5.3.1.1 Trash Management/Education

Long-term outdoor storage of waste material was noted during the upland assessments. Existing trash initiatives include Adopt-A-Road, inmate roadside cleanups, and Clean Green 15. Watershed associations organize many stream cleanups throughout the county. Project Clean Stream, the Alliance for the Chesapeake Bay's annual region-wide stream clean up event engaged 7,500 volunteers at over 250 sites at its 2014 event. Implementing more municipal practices and programs related to trash management/education in the Loch Raven West watershed would improve water quality and aesthetics of the watershed.

A Trash Reduction Strategy was developed by EPS in conjunction with other county departments to address litter on a county wide scale. It will be used as a guide to litter reduction efforts and to inform any future trash Total Maximum Daily Load (TMDL) Implementation Plans for specific areas of the county. There is currently no trash TMDL for the Loch Raven Reservoir watershed, however a Trash and Litter TMDL Implementation Plan was developed by EPS as a plan to address the specific trash and debris pollution issue in the Jones and Gwynns Falls watersheds of Baltimore County.

5.3.1.2 Street Sweeping

Baltimore County has an active street sweeping program to remove debris, dirt and pollutants from streets before it can enter the storm drain system. Mechanical broom sweepers are operated on a schedule that takes into account seasonal changes such as leaf litter in the fall and more frequent lawn care activities in the spring and summer months. Currently, Baltimore County has nine street sweepers sweeping over 2,600 miles of roadway annually. Main thoroughfares, business districts, and industrial areas are swept on a regular basis throughout the year, while residential neighborhoods are swept by

request. Given the rural nature of the watershed and the lack of curb and gutter, street sweeping is not recommended in the Loch Raven West watershed.

5.3.1.3 Tree Planting

Several opportunities for reforestation and buffer improvement were identified during the field assessments, including open pervious areas, stream buffers, and institutions throughout the watershed. For smaller planting projects, citizens can purchase trees at low cost through the MD DNR's Tree-mendous Maryland program for planting on community open spaces and public lands, or through the county's Big Trees program for planting on private residential yards. For planting on larger properties, especially for reforestation greater than one acre, citizens can contact EPS about opportunities for reforestation "turf-to-trees" projects. These projects cover site preparation, planting, deer shelters, and monitoring and maintenance for three years.

5.3.1.4 Inlet Cleaning

Over time, solids in stormwater runoff collect in storm drains and inlets. As solids accumulate in an inlet, they are susceptible to downstream transport during larger storm events, contributing to pollution in the Loch Raven West watershed. A study conducted by the University of Maryland, Baltimore County (UMBC) and the Center for Watershed Protection as part of the U.S. EPA Chesapeake Bay Program concluded that annual or semi-annual cleaning of storm drain inlets can significantly increase solids removal rates (18-35%) while also contributing to nitrogen and phosphorus removal (Law, 2008). The Department of Public Works cleans inlet grates on a routine basis (EPS, 2015). Inlet boxes and pipes are cleaned as needed. Inlet cleaning at regular intervals can reduce pollutant loads in the watershed, reduce flooding and help locate illicit discharges in the storm sewer system.

5.3.1.5 Erosion and Sediment Control

Construction activities in or near streams were not observed during the field assessments; however, erosion and sediment controls are vital to prevent soil and other pollutants from entering the storm drain system or nearby streams. Follow-up inspections and improvements to substandard erosion and sediment control practices at construction sites are implemented and enforced by the Baltimore County Department of Permits, Approvals, and Inspections to prevent sediment and other pollutant inputs from entering into the storm drain system and stream network.

5.3.1.6 Dry Weather Discharge Prevention

Baltimore County’s illicit connection detection and elimination program targets dry weather flows into the storm drain system which contain significant pollutant loads. Examples include illicit discharges, sewage overflows, or industrial and transportation spills. Dry weather discharges can be continuous, intermittent, or transitory. Resulting water quality problems can be extreme depending on the volume and type of discharge. For example, sewage discharges include bacteria and can directly affect public health while other discharges such as oil, chlorine, pesticides, and trace metals can be toxic to aquatic life. Dry weather discharge prevention focuses on four major sources that can occur in a subwatershed as described briefly below:

- Illicit Sewage Discharge: When septic systems fail or when sewer pipes are mistakenly or illegally connected to the storm drain pipe network, sewage can get into streams. Sometimes sewage is directly discharged to a stream or ditch without treatment or illegally dumped into the storm drain system from boats or RVs.
- Commercial and Industrial Illicit Discharge: Some businesses mistakenly or illegally dispose of liquid wastes that can adversely impact water quality into the storm drain system. Examples include hotspots where materials such as oil, paint, and solvents are improperly disposed, where businesses' drains are directly connected to the storm drain system, or where untreated wash water or process water is dumped into the storm drain system.
- Industrial and Transport Spills: Pollutants can enter the storm drain system as a result of ruptured tanks, pipeline breaks, accidents/spills, or illegal dumping. These events are more likely to occur in urban subwatersheds and may result in potentially hazardous materials reaching streams through the storm drain system.
- Failing Sewage Lines: Sewer lines often follow the stream corridor. If they leak, overflow, or break, sewage will be discharged directly into the stream. The frequency of failure depends on the age, condition, and capacity of the existing sanitary sewer system. This is not a major concern for the Loch Raven West watershed as the majority of the watershed falls outside the Urban Rural Demarcation Line (URDL) and does not have access to sanitary sewer lines.

5.3.2 Land Preservation

Land preservation compliments the implementation of BMPs by insuring the specific non-urban land uses remain intact over time on specific parcels of land. Land preservation includes area such as parks and watershed protection zones where non-extractive uses are prevalent, as well as areas that are intensively managed for agriculture.

These parcels may be large, such as parks, or small, protecting a single farm. Land preservation reflects societal priorities and decisions to limit urban and residential development, and provides broad benefits. However, by themselves, they do not assure that certain environmental goals, such as good water quality, will be met.

"Protected land" includes any land with some form of long-term limitation on conversion to urban/developed land use. This protection may be in various forms: public ownership for natural resource or low impact recreational intent (i.e. park), private ownership where a third party acquired the development rights or otherwise required the right to limit use through the purchase of an easement (i.e. conservation easement). The extent of "protection" varies greatly from one situation to the next. Therefore, for some protected land, it may be necessary to explore the details of land protection parcel-by-parcel through the local land records office to determine the true extent of protection.

For purposes of watershed management, an understanding of existing protected lands can provide a starting point in prioritizing potential protection and restoration activities. In some cases, protected lands may provide opportunities for restoration projects because owners of these lands may value natural

resource protection or enhancement goals. A summary of current conservation easements is provided in Chapter 2, Section 2.3.10.1.

Maryland and County Rural Legacy Program

Baltimore County participates in the State Rural Legacy Program which was developed in 1997 to protect large, continuous tracts of valuable cultural and natural resource lands through grants made to local applicants. Baltimore County's Rural Legacy Program aims to protect large blocks of forest, wetlands, farms, and other open spaces that are of significant ecological value as habitat for rare, threatened, and endangered species and to preserve the environmental benefits that these areas provide to the Chesapeake Bay.

Maryland Environmental Trust (MET) and Local Land Trusts

Created by the Maryland General Assembly in 1967 to protect Maryland's natural environment, the Maryland Environmental Trust (MET) seeks donated easements on farms and forestlands, wildlife habitats, waterfront acreages, natural areas, historic sites, and other valuable and scenic features. In 1974, a landowner in Baltimore County was one of the first to protect their property through this program. Today, Baltimore County remains a leader in the state, with county landowners preserving over 12,000 acres through donations. Although both MET and local land trusts prefer to accept donations on lands greater than 50 acres, local land trusts are often willing to work with smaller property owners. Donations are accepted throughout the year. Landowners may qualify for a significant tax deduction and/or credit. MET also provides loans to qualified groups for the purchase of land for preservation.

Baltimore County Agricultural Land Preservation Program

The Baltimore County Agricultural Land Preservation Program was developed in 1994 to preserve working family farms. The County has used innovative and collaborative funding mechanisms for land preservation. Eligible farms must be at least 50 acres in size or 20 acres if contiguous to an existing easement and meet certain soil criteria. Currently, approximately 3,300 acres of land are preserved through this program.

Maryland Agricultural Land Preservation Foundation (MALPF) Easements

This program is a joint effort between the state and the county and is the main agricultural land easement program in Baltimore County. The program has been in existence since 1977 and aims to preserve sufficient agricultural land to maintain a viable local base of food and fiber protection for the present and future citizens of Maryland and protect and enhance the environmental quality of wildlife habitat and the Chesapeake Bay. MALPF also preserves forested properties. Development on the easements (both forest and farm) is restricted.

DNR Land Conservation Easements

The Department of Natural Resources holds conservation easements over land including the state park service. There are no DNR conservation easements in the Loch Raven West watershed. However, the DNR does maintain land in the larger Loch Raven Reservoir watershed including the Gunpowder Falls State Park – Hereford location which is 3,620 acres and preserved under State Wildlands Status for nature appreciation and outdoor adventures and the Torey C. Brown Rail Trail (formerly the Northern Central Railway) extending from Ashland, Maryland to the Maryland-Pennsylvania line.

Local Land Trusts

Local land trusts are another method of land conservation whereby the landowner may donate or sell part of their land to a land trust as a conservation easement. Many of the lands held by local land trusts are co-held with one of the aforementioned programs. In the Loch Raven West watershed the only land trust operating is the Land Preservation Trust, which has 1,249 acres in the watershed in preservation.

5.3.3 Best Management Practices for Agricultural Land

Agricultural land makes up approximately 54% of the Loch Raven West watershed. The Maryland Agricultural Water Quality Cost-Share (MACS) Program encourages implementation of agricultural BMPs by providing farmers with grants that cover up to 87.5 percent of the installation cost. Approximately 30 different BMPs are eligible for MACS grants. Funding is also available through various federal programs. Eligibility of the grants requires the practice to address and treat NPS pollution related to agricultural sources and be located on a farm.

5.3.3.1 Farm Conservation Plans

Farm conservation plans are agronomic, management, and engineered practices that protect and improve soil and water quality. They also aim to prevent the deterioration of natural resources on a farm. Plans include best management practices to manage the farm's resources, control soil erosion, and protect water quality. The Maryland Department of Agriculture refers to these plans as Soil Conservation and Water Quality Plans (SCWQP). These plans are required by the Federal Food Security Act on all highly erodible lands and farmland enrolled in the Maryland Agricultural Land Preservation Foundation Program. A number of the BMPs considered in conservation plans are listed below.

Cover Crops

Implementation of cover crops improves water quality by recycling unused plant nutrients and protecting fields against wind and water erosion. This practice also increases the productivity of farmland and improves the soil for the next season's crops. Maryland nutrient management regulations require farmers to plant cover crops when organic nutrient sources are applied to field in the fall. Grants are available to offset the costs of seed, labor, and equipment through the Maryland Agricultural Water-Quality Cost-Share (MACS) Program and are funded by the Chesapeake Bay Restoration Fund and Chesapeake Bay 2010 Trust Fund. For 2015, MACS allocated approximately $24 million towards the cover crop program (MDA, 2015). Guidelines and conditions determine the amount of incentive payments to be paid and applications must be submitted during specified times at soil conservation district offices statewide to be considered.

Conservation Tillage

Conservation tillage entails planting and growing crops with minimal disturbance to the surface soil. One form of conservation tillage is no-till farming where the crop is seeded directly into vegetative cover or crop residue with very little disturbance of the surface soil. Additionally, minimum tillage farming involves some soil disturbance, but uses tillage equipment that leaves much of the vegetation cover or crop residue on the surface. Conservation tillage requires two components: a minimum 30% residue coverage at the time of planting and a non-inversion tillage method. There are no cost-share measures for conservation

tillage; however, the State of Maryland offers income tax subtraction modification to offset the costs associated with buying certain types of conservation tillage equipment.

Agricultural Riparian Forest/ Grass Buffers

Riparian forest buffers are wooded areas along streams that help filter nutrients, sediments and other pollutants from upland areas and help remove nutrients from groundwater. Forest buffers also help control flooding and reduce erosion while creating habitat for wildlife. Mature forested buffers can help remove up to 90 percent of nutrients running off the land. Ideally, forested buffers extend 100 feet along each bank but 35 feet at a minimum.

Like forest buffers, riparian grassed buffers are linear strips of maintained grass or other non-woody vegetation between the edge of field and streams. Grass buffers help filter nutrients, sediments, and other pollutants from runoff and remove nutrients from groundwater.

Cost-share grants are available for planting riparian forest and/or grassed buffers through the MACS program and USDA's Conservation Reserve Enhancement Program (CREP).

Animal Waste Management

Animal waste management programs are designed to ensure the proper handling, storage, and utilization of wastes generated from animal operations. This requires collecting, scraping or washing wastes and contaminated runoff from confinement areas into appropriate facilities. Controlling runoff from these areas is an integral part of the management system.

The Maryland Department of Agriculture (MDA) promotes a manure transport and matching program that helps livestock producers with excess manure comply with their nutrient management plans and transport the excess manure in an environmentally safe manner. There is a cost-share assistance program to help farmers cover the cost of transporting the manure. This helps protect water quality in streams, river, and ultimately the Chesapeake Bay.

Stream Protection with Fencing

Under Maryland's new nutrient management regulations, as of January 1, 2014, livestock access to streams is to be restricted by a minimum ten foot setback. Fencing is not required under this regulation, however it may be the only option. Stream protection with fencing limits livestock access to streams and protects the stream buffer which may be planted. Cost-share grants are available for planting riparian forest and/or grassed buffers through the MACS program and USDA's Environmental Quality Incentives Program (EQIP).

Off Stream Watering

Creating alternative watering facilities for livestock through permanent or portable water troughs placed away from stream corridors improves water quality and prevents stream bank erosion. By removing livestock from the stream corridor, vegetative cover along the stream is protected, preventing erosion and pollution from nutrients, sediments, and animal wastes. Cost-share for watering facilities is available through the MACS program.

5.3.3.2 Nutrient Management Plans

As a result of 1998 legislation and the Water Quality Improvement Act, all Maryland farmers grossing $2,500 or more annually or raising 8,000 pounds or more of live animal weight are required to produce and operate using a nutrient management plan that addresses nitrogen and phosphorus inputs (MDA, 2016). These plans aim to specify the amount of nutrient sources (fertilizer, manure, etc.) that can safely be applied to farmland in order to achieve yields and prevent excess nutrients from entering waterways. The Maryland Department of Agriculture (MDA) currently monitors the implementation of these plans and issues penalties and fines for violations. Currently, there are no cost-sharing opportunities from MDA for nutrient management plans.

5.3.3.3 Federal Financial Assistance

A number of funding opportunities are available through the Natural Resources Conservation Service (NRCS) to manage natural resources in a sustainable manner (NRCS, 2016). Under the 2014 Farm bill, there are currently three different programs for financial assistance to help agricultural producers make and maintain conservation improvements on their land. The former Wildlife Habitat Incentive Program (WHIP) is now part of the Environmental Quality Incentives Program (EQIP) that provides financial and technical assistance to agricultural producers to implement conservation practices and deliver environmental benefits. There is also the Agricultural Management Assistance (AMA) program that helps agricultural producers use conservation to manage risk and solve natural resource issues. This program is available in 16 states including Maryland. Finally, there is the Conservation Stewardship Program (CSP) that helps agricultural producers maintain and improve their existing conservation systems. CSP payments are earned based on conservation performance – the higher the performance, the higher the payment. All of these programs must be applied for through the USDA.

5.4 Volunteer Restoration Programs

Volunteer restoration programs include activities or projects conducted by volunteers and volunteer organizations such as a watershed improvement group.

5.4.1 Stream Cleanups

Stream clean-ups are a simple practice used to enhance the appearance of the stream corridor by removing unsightly trash, litter, and debris. These are usually performed by volunteers and are one of the most effective methods for generating community awareness and involvement in watershed activities. Public outreach tools should be used to encourage and inform residents about organizing stream clean-ups.

5.4.2 Tree Planting

As previously mentioned, a number of open space planting opportunities are present in the Loch Raven West watershed, offering an opportunity to apply for municipal tree planting programs including SHA's "Partnership Program" and DNR's "Tree-mendous Maryland" program to help reforest public lands within the watershed. These types of programs also provide an opportunity to involve volunteers from various neighborhoods, businesses, and schools to help plant trees throughout the watershed while educating the community about the importance of trees for air and water quality benefits.

5.4.3 Storm Drain Marking

Some of the developed areas in the Loch Raven West watershed consist of curb and gutter systems including storm drain inlets that convey stormwater runoff quickly and directly to the stream system and ultimately to the Chesapeake Bay. Some inlets have grates with storm drain marking but many inlets do not have any indicators that they drain to the Chesapeake Bay. Since there is little or no infiltration of stormwater in a curb and gutter system, there is more potential for pollutants to be carried to the stream system. Storm drain marking is a way to educate residents that anything building up along the curbs and gutters such as trash and lawn clippings will be washed away after a storm event and end up in the Chesapeake Bay.

5.5 Business and Institutional Initiatives

Business and institutional initiatives include activities that are available for commercial businesses and institutions to undertake in order to improve water quality in the area.

5.5.1 Impervious Cover Removal

Impervious surfaces including roads, parking lots, roofs, and other paved surfaces prevent precipitation from naturally seeping into the ground. Stormwater runoff from impervious surfaces is often concentrated, accelerated, and discharged directly to the storm drain system or nearest stream. This can result in erosion, flooding, habitat destruction, and increased pollutant loads to receiving water bodies. Subwatersheds with high amounts of impervious cover are more likely to have degraded stream systems and be significant contributors to water quality problems in the watershed than those that are less developed.

Limited unused or unmaintained impervious surfaces with the potential for removal were identified in Loch Raven West. Some institutions may have parking areas that are not frequently used (e.g., cemeteries) and could be suitable for conversion to permeable pavement which allows some infiltration of stormwater runoff while providing support for less frequent traffic/vehicle use. Several neighborhoods have unpaved driveways, which allow some infiltration of stormwater runoff. However, completely paved driveways were more common in the neighborhoods assessed during this study. Education and outreach tools could be used to inform residents of the water quality impacts associated with large impervious driveways or patios and options available for conversion to or incorporation of more permeable surfaces such as grass strips, gravel, or permeable pavers.

5.5.2 Potential Redevelopment of Urban Areas

Natural areas that are developed into impervious urban landscapes result in an increase in runoff and pollutant loading. Redeveloping these urban areas back into a more natural setting can provide nutrient load reductions. In the Water Resources Element of its Master Plan 2020, Baltimore County has analyzed redevelopment scenarios and identified potential land for redevelopment in each of its watersheds.

Urban watersheds developed prior to modern stormwater regulations have fewer or no stormwater management facilities to capture and treat stormwater runoff. As businesses and property owners choose to redevelop properties that already have high amounts of impervious cover, they must meet redevelopment regulations in Baltimore County requiring a 50% reduction in impervious surface or

inclusion of equivalent stormwater quality management facilities. Limited opportunity for redevelopment exists in Loch Raven West.

5.5.3 Pervious Area Restoration

Some of the institutions assessed in Loch Raven West had opportunities for reforestation which would also require less ground maintenance than mowed lawn and improve energy efficiency. Parcels meeting these criteria are good candidates for follow-up investigations and landowner contact.

5.5.4 Stormwater Retrofits

The following represent stormwater retrofits that can be undertaken by private entities to positively affect water quality.

5.5.4.1 Parking Lot

Two institutions were identified as having sufficient open space for bioretention areas to treat runoff from impervious areas. Stormwater retrofits would help address sediment and nutrient inputs to the stream system.

5.5.4.2 Downspout Disconnection

Downspouts directly connected to the storm drain system or draining to impervious surfaces such as parking lots, sidewalks, or the curb and gutter system increase the volume and flow rate of pollutant-laden runoff reaching streams. Disconnected downspouts allow rooftop runoff to infiltrate into the ground and enter streams through the groundwater system in a slower more natural fashion. This decreases flow to local streams during storm events and helps prevent erosion and reduces pollutant loads to streams. Disconnecting downspouts in commercial corridors is an inexpensive way to improve water quality in the Loch Raven West watershed.

5.5.5 Open Space Planting

Several opportunities for reforestation and buffer improvement were identified during the field assessments including open space shade tree plantings in various open pervious areas and institutions throughout the watershed. This presents an opportunity to apply for municipal tree planting programs including SHA's Partnership Program and DNR's Tree-Mendous Maryland program to help reforest areas of the watershed.

Tree-Mendous Maryland coordinates the free delivery of trees to citizens and community groups, and provides an inexpensive way to obtain trees and shrubs for planting on public lands and within community open spaces. These types of programs also provide an opportunity to involve volunteers from various neighborhoods, businesses and schools to help plant trees throughout the watershed while also educating the community about the importance of trees for air and water quality benefits.

5.5.6 Pollution Source Control

Hotspots are commercial, industrial, municipal, or transport-related operations in the watershed that tend to generate higher concentrations of stormwater pollutants and/or have a higher risk of spills, leaks, or illicit discharges. Pollution prevention practices can significantly reduce hotspot pollution problems. Local government agencies must adopt pollution prevention practices for their operations and lead by

example. This should be followed by inspection and incentive-based educational efforts for privately operated sites with enforcement measures as a backstop. The ability to conduct such inspections and enforcement actions should be clearly articulated in local codes and ordinances and through education programs. As previously noted, some industrial/commercial sites are required to have NPDES permits for stormwater and/or wastewater discharges. While the County assists with the identification of these sites, MDE is responsible for regulating industrial/commercial sites that are required to have NPDES permits. Another potential program is to host workshops for local businesses that detail the permit requirements and how to prepare pollution prevention plans.

5.6 Citizen Awareness Activities

Citizen awareness activities are actions that any resident or citizen in the Loch Raven West watershed can take that would provide a benefit to water quality.

5.6.1 Pollution Prevention/Source Control Education

Residents often engage in behaviors that can adversely impact water quality. Some of these behaviors observed during the assessment of neighborhoods in the watershed include over-fertilizing lawns, excessive use of pesticides, improper storage of potentially hazardous materials (e.g., household cleaners, paints, automotive fluid, etc.), and dumping into storm drains (e.g., wash water). Pollution prevention/source control education efforts should also target waste management activities in the watershed to address dumpsters located near storm drain inlets or streams without diversion methods, poor dumpster conditions (leaking, overflowing, and uncovered), and the occurrence of trash dumping in the watershed. Positive behaviors were also observed such as tree planting, disconnected downspouts, and picking up pet waste which can help improve water quality. A pollution prevention program can be designed to discourage negative behaviors and/or encourage positive behaviors. Either way, the goal is to deliver a specific message through targeted education to promote behavior changes. Local watershed organizations can help influence these changes using pollution prevention education and outreach to teach citizens how to properly care for the watershed.

5.6.2 Trash and Recycling

Educating the public about the trash issues and impacts to water quality in the watershed through a trash campaign is one way to address trash and dumping problems. Baltimore County has implemented a Clean Green 15 initiative to encourage voluntary litter pickups. Clean ups can be dedicated to a local school to help the school win money and other prizes through the BCPS Clean Green 15 Challenge. A county wide anti-litter campaign is also in progress, which will encourage county residents to participate in anti-litter events in their watershed.

Recycling is an ongoing program, which is overseen by the Baltimore County Department of Public Works. The County's Single Stream Recycling program, launched in 2010, allows residents to set out all their recyclables for once-a-week collection. Residents are encouraged to recycle "all that they can". Area recycling rates can be found on bcrecycles.com. Here, residents can see their area's progress to the Baltimore County recycling goal: an average residential recycling rate of 50%.

5.6.3 Environmental Awareness and Education

Community-based facilities present good opportunities for educating the public about water quality issues and improvement methods for the watershed. This can be accomplished by implementing water quality BMPs such as rain gardens and bioretention facilities at these sites. In addition to environmental education, these BMPs have water quality and aesthetic benefits for property users. There is also potential for involving the community through BMP installation and maintenance. Environmental education can also be accomplished through water quality sampling and monitoring of stormwater management measures such as wetlands and extended detention ponds at schools, for example. Buffer and tree planting activities also present an opportunity for combining community involvement and environmental education.

5.6.4 Bayscaping

A "Bayscape" is a landscape using native plants to provide habitat for local and migratory animals, improve water quality, and reduce the need for chemical pesticides and herbicides. Bayscaping plants, such as trees, shrubs and perennials, are able to make better use of rain water than typical lawn grasses, and so require less watering once established. They are also better at trapping and removing nitrogen and pollutants from rain water so that it is not released into nearby water bodies. A Bayscape is also valuable for the gardener or landowner because it offers greater visual interest than lawn, reduces the time and expense of mowing, watering, fertilizing and treating lawn and garden areas, and can address areas with problems such as erosion, poor soils, steep slopes or poor drainage.

5.6.5 Lot Canopy Improvement

Implementing programs that promote tree planting in residential yards and commercial open space can increase overall tree canopy, slowing runoff rates and allowing greater infiltration of stormwater into the ground. Tree roots also stabilize soils and provide wildlife habitat. Many of the neighborhoods assessed in the Loch Raven West watershed had large lots with space available for tree planting.

Currently, Baltimore County hosts a Big Trees Sale in the fall and spring of each year featuring a selection of native trees intended to be planted on private residential properties. The sale provides species such as oaks and maples that grow taller and cast shade over a wider area than smaller trees. The trees help with stormwater infiltration, erosion control, and pollutant reduction. The State of Maryland also has a program called "Marylanders Plant Trees" that encourages citizens to plant and register trees. The program provides $25 off coupons for trees on a recommended tree list valued at or above $50 at participating nurseries and garden centers.

5.6.6 Downspout Disconnection

Approximately half of the neighborhoods assessed in the Loch Raven West watershed were recommended for downspout disconnection. This is because many of the downspouts were directly connected to the storm drain system or indirectly connected, draining to impervious surfaces such as driveways, sidewalks, or the curb and gutter system. Disconnected downspouts allow rooftop runoff to infiltrate into the ground and enter streams through the groundwater system in a slower more natural fashion. By using pervious ground to intercept and infiltrate runoff prior to its entering a conveyance system (i.e. gutter, inlet, and pipe), neighborhoods can be altered to mimic the predevelopment hydrology

of the area to a greater extent. This decreases flow to local streams during storm events and helps prevent erosion and reduce pollutant loads to streams. Many of the typical lots in the Loch Raven West watershed have sufficient room for rain gardens and can be implemented with homeowner outreach. Alternatively, redirecting downspouts to pervious areas such as yards or lawns or to rain barrels were also viable options for neighborhoods recommended for downspout disconnection.

Rain gardens are the most desirable option in terms of water quality because they consist of native plants that capture and treat runoff. The majority of homes in the Loch Raven West watershed can accommodate these gardens as there were several hundred square feet of open pervious area available down gradient from the downspout in most cases. Rain gardens may also be an option for disconnecting downspouts at institutional sites with sufficient space available. Redirecting downspouts to pervious areas or rain barrels is also an option for institutional sites as well as individual homeowners.

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APPENDIX A:

MILL DAM ASSESSMENT DATA

Mill Dam Assessments

Mill dams were assessed by two person teams using historical site locations provided by the County. Each site was assessed for possible construction constraints as well as restoration opportunities. The rating criteria for mill dam assessments are explained below. A copy of the field form used in the assessment is at the end of the document along with the field guide used to assess each site.

1. Construction Constraints Rating

Construction constraints were documented for each mill dam site based on specific characteristics that would limit accessibility or restrict certain restoration activities. The construction constraints were both evaluated in the office via a desktop analysis and in the field during the assessment. During the desktop analysis, land ownership, special area designations, and floodplain constraints were evaluated. Factors that could increase the construction constraint rating were private land ownership, one or multiple special area designations, and woods or improved properties located in the 100-yr floodplain.

During the field assessment, other factors were noted such as overall accessibility, physical constraints, and possible bog turtle habitats. Specifically, the construction constraint rating would increase if a site is difficult to access and must be accessed through private land, if there are utilities or other infrastructure present (i.e. culverts, bridges), if the dam is still in operation, and if the area is a known or potential bog turtle habitat.

The total construction constraints for each site were calculated and totaled. The ratings had a possible score of 0 to 13 where 0 would equate to no construction constraints and a rating of 13 would denote all foreseeable constraints are present. The construction constraint ratings were used to aid in prioritization of mill dam sites; the lower the construction constraint rating, the higher priority a site was ranked.

2. Restoration Potential Rating

The restoration potential for each mill dam site was based on observations made during the field assessment. Some factors that would lend themselves to restoration included the presence of open space or agricultural land in the floodplain, the presence of a fish blockage, an incised channel, and bank erosion. To address these issues, multiple restoration options could be recommended: legacy sediment removal, stream stabilization/restoration, wetland creation, floodplain reconnection, fish passage, and buffer creation. The more restoration opportunities recommended the higher restoration potential rating a site was given.

The restoration potential rating has a possible range from 0 to 9, where 0 would translate to no restoration potential and 9 would denote maximum restoration potential. The restoration potential ratings were used to aid in prioritization of mill dam sites; the higher the restoration potential rating, the higher priority a site was designated.

3. Priority Ranking

Each mill dam site recommended for restoration activities was given a priority ranking based on its restoration potential rating and its construction constraints rating. The sites were first sorted based on their restoration potential rating; the highest scores were given higher priority. Sites with the same restoration potential ratings were then sorted using the construction constraint ratings; the lowest construction constraints scores were given higher priority. For example, sites MD01_040C1 and MD01_032B3 both have restoration potential ratings of 5, but because MD01_040C1 has a lower construction constraint rating, it is given a higher priority ranking.

Table 1: Loch Raven West Mill Dam Restoration Priority

Sites Recommended	Priority Ranking	Restoration Potential Rating	Construction Constraints Rating	Location in Appendix
MD01_040C1	1	5	4	Page A-3
MD01_032B3	2	5	5	Page A-6
MD01_026C1	3	4	9	Page A-9
MD01_032C3	4	2	4	Page A-12
MD02_033B2	4	2	4	Page A-15
MD01_033B2	6	2	5	Page A-17
MD02_040C1	6	2	5	Page A-20
MD01_026A3	8	2	6	Page A-22
MD02_032B3	8	2	6	Page A-24
Sites Not Recommended				
MD01_033A1				Page A-26
MD01_042A1				Page A-29
MD01_025C1				Page A-31
MD01_025C2				Page A-34
MD02_042A1				Page A-37
MD01_027A2				Page A-40
MD01_027A3				Page A-43
Sites Not Assessed				
MD01_033A2				
MD01_039C2				
MD01_040A2				

4. Mill Dam Site Summaries – Recommended Sites

The data pertaining to each mill dam site assessment for sites with recommended actions are summarized below. The Information includes location data, access concerns, recommended restoration activities, ratings, and general notes and photos. Each site also includes a plan view showing assumed dam location and potential restoration opportunities and construction constraints.

Table 2: Assessment Summary for Mill Dam Site MD01_040C1

Mill Dam ID	**MD01_040C1**
Subwatershed:	Western Run
Nearest Cross Roads:	Mantua Mill Rd and Green Rd
Land Ownership:	Private/County
Dam Intact:	No
Access Concerns/Notes:	The site is accessible through Baltimore County land on Mantua Mill Rd and Green Rd.

Restoration Recommendations:	Legacy Sediment Removal	**X**
	Stream Restoration	**X**
	Wetland Creation	**X**
	Floodplain Reconnection	**X**
	Fish Passage	**-**
	Buffer Creation	**X**
Construction Constraints Rating:	4	
Restoration Potential Rating:	5	
Priority Ranking:	1	

General Notes:

Located in the Western Run subwatershed between private property and County property off of Mantua Mill Road, mill dam site MD01_040C1 had no observed mill dam or mill building. The mill race is still in existence and runs from the upstream mill dam site of MD02_02040C1 to the remains of the wheel housing just before the Mantua Mill Road bridge. Additionally, a mill stone has been installed as a decorative part of the stone wall surrounding the private property. The mill race is grassed, and water was not flowing during the site visit (Figure 1). While not listed as a sensitive species area with DNR, there is an area shown as National Wetlands Inventory-wetlands near a natural seep that could potentially be bog turtle habitat. There is no fish blockage along this section of Western Run.

The stream itself is incised, mostly unshaded, and appears to be somewhat unstable. The lawn is mowed to the edge of the stream along much of its length. In addition to buffer creation, this site could benefit from bank stabilization and given the lack of constraints in the floodplain, legacy sediment removal as well. These restoration actions could be utilized in conjunction with floodplain reconnection and wetland creation and could expand and enhance the existing wetlands. Also, near the culvert crossing at Mantua Mills Road, there is a patch of Japanese Stilt Weed that should be removed as part of invasive species control. This could likely be accomplished from Mantua Mills Road.

Figure 1: Ruins of wheel housing at the downstream end of the race (left) and the mill race (right)

Figure 2: Potential areas for stream stabilization/restoration due to erosion and legacy sediment removal

Figure 3: Potential for forest buffer creation (left) and invasive Japanese Stilt Weed (right)

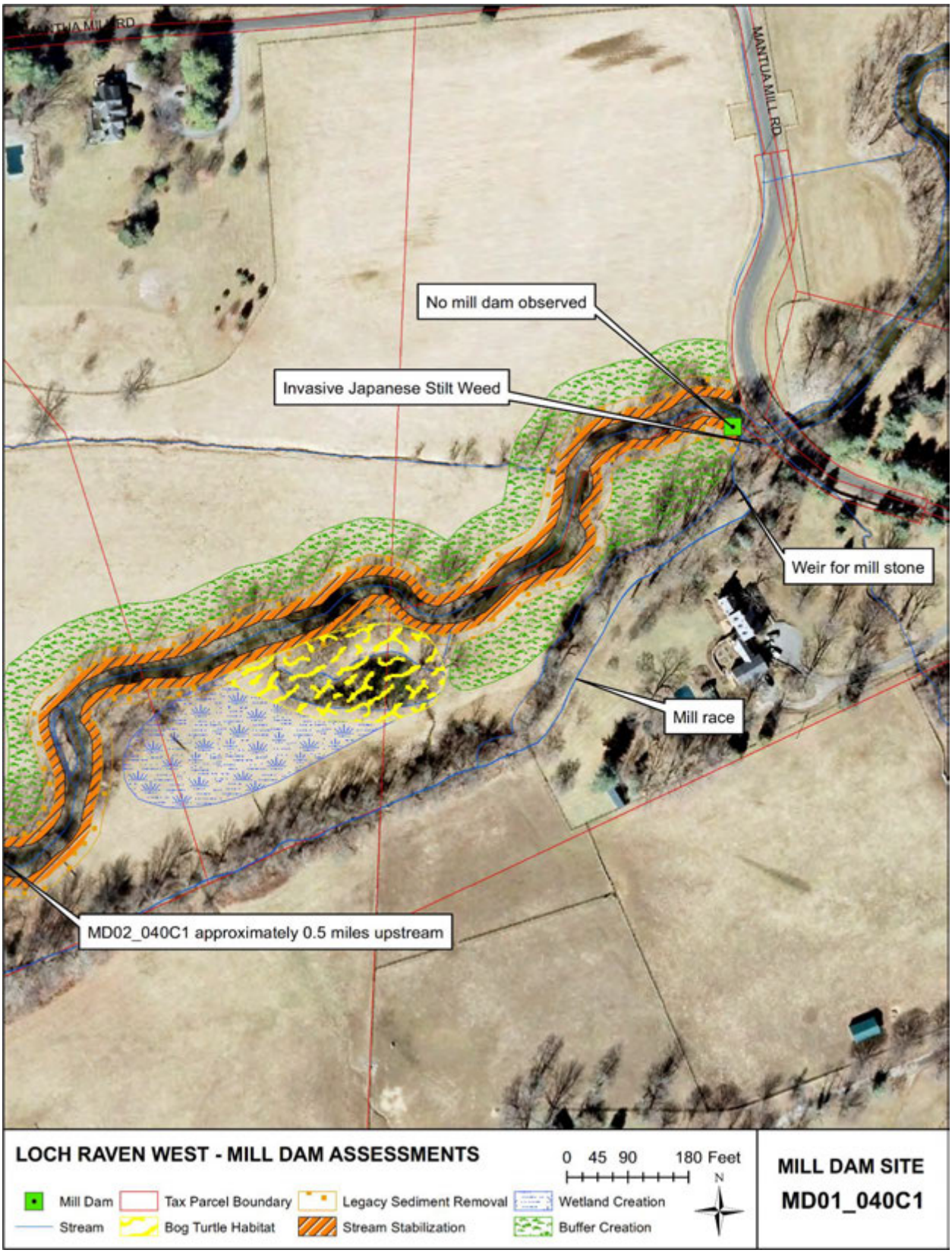

Figure 4: Plan view of mill dam site MD01_040C1

Table 3: Assessment Summary for Mill Dam Site MD01_032B3

Mill Dam ID	**MD01_032B3**
Subwatershed:	McGill Run
Nearest Cross Roads:	Butler Rd and Mantua Mill Rd
Land Ownership:	Private
Dam Intact:	No
Access Concerns/Notes:	The site is accessible through private property on Butler Road

Restoration Recommendations:	Legacy Sediment Removal	**X**
	Stream Restoration	**X**
	Wetland Creation	**X**
	Floodplain Reconnection	**X**
	Fish Passage	**-**
	Buffer Creation	**X**
Construction Constraints Rating:	5	
Restoration Potential Rating:	5	
Priority Ranking:	2	

General Notes:
Mill dam site MD01_032B3 is situated in the McGill Run subwatershed on private, mostly undeveloped property. A portion of the site is listed on the National Wetlands Inventory for palustrine wetlands. While not listed as a sensitive species area with DNR, there is an open, wet area with sedges that could potentially be bog turtle habitat (Figure 5, left). Additionally, approximately 2.5 acres of the northern parcel has been recently reforested (Figure 5, right). No remains of the dam or race were found. An area with stacked stone and bedrock was observed near a residential home, it is unclear if this was part of the dam. There is no fish blockage. The channel is incised with 4-5 foot vertical banks and appears to be widening. The stream is partly unshaded. Immediately upstream of the Butler Road culvert, the stream makes an oxbow and approaches the culvert at a 45 degree angle. The culvert appears to be designed to take the angled flow, although there is bank erosion on the outside of the bend. The site has overhead utilities that cross the steam at multiple locations.

It is recommended that the site be treated with stream bank stabilization. This will likely include terracing the banks to create a floodplain bench. Some legacy sediment removal will occur as part of the stream bank terracing and floodplain reconnection. Wetland and buffer creation should be included as part of the stream bank stabilization work.

Figure 5: Wet area with open canopy and sedges is possible bog turtle habitat (left) and recently planted reforestation area (right)

Figure 6: Areas along stream with 4-5 foot vertical banks have the potential for restoration including stream stabilization and forest buffer creation

Figure 7: Outside bend of oxbow shows signs of erosion (left) and overhead utilities located in the floodplain are a construction constraint (right)

Figure 8: Plan view of mill dam site MD01_032B3

Table 4: Assessment Summary for Mill Dam Site MD01_026C1

Mill Dam ID	**MD01_026C1**
Subwatershed:	Blackrock Run
Nearest Cross Roads:	Benson Mill Rd and Dubbs Rd
Land Ownership:	Private
Dam Intact:	No
Access Concerns/Notes:	The site is accessible through private property off of Benson Mill Rd.

Restoration Recommendations:	Legacy Sediment Removal	**X**
	Stream Restoration	**X**
	Wetland Creation	**-**
	Floodplain Reconnection	**X**
	Fish Passage	**-**
	Buffer Creation	**X**
Construction Constraints Rating:	9	
Restoration Potential Rating:	4	
Priority Ranking:	3	

General Notes:
Mill dam site MD01_026C1 is located in Blackrock Run just upstream from the Benson Mill Road bridge. The site is located on private property, and the homeowner has knowledge about the original dam and mill location. According to the landowner, the dam was originally located approximately 1,400 feet upstream of the bridge and the mill was located along Benson Mill Road. The dam has been completely breached and could not be located in the field, and the mill is no longer in existence. However, the race is still present and verifies the homeowner's account of the historic locations. The right bank floodplain is mostly active horse pasture (Figure 10, left). There are springs, wetlands, and according to the homeowner, bog turtle habitat throughout the pasture (Figure 10, right). The left bank floodplain is mostly forested; however, the majority of the stream is unshaded. The stream has 3-6 foot vertical or sloughing banks and there is significant fine sediment in the streambed mixed in with pebbles and cobbles (Figure 11).

This site is recommended for stream restoration as well as legacy sediment removal to prevent additional bank lost and to create floodplain reconnection. One factor that will affect the viability of legacy sediment removal at this site is the amount of floodplain available for excavation. Legacy sediment removal tends to have a large footprint and will impact land available for horse pasture and impacts to bog turtle habitat will need to be considered. If legacy sediment removal is determined to have too a great an impact on the property, stream bank terracing and stabilization with bioengineering is another option as a way to stabilize the stream within a smaller footprint. Buffer creation should also be considered at this site to help stabilize the banks, act as a buffer between the pasture and the water, and to add shade to the stream.

Figure 9: Downstream limit of proposed restoration at Benson Mill Bridge (left) and the remains of the race, which passes by the existing house (right)

Figure 10: Looking downstream at horse pasture (left) and existing spring with wetland vegetation (right)

Figure 11: Actively eroding streams banks could benefit from legacy sediment removal or streambank restoration

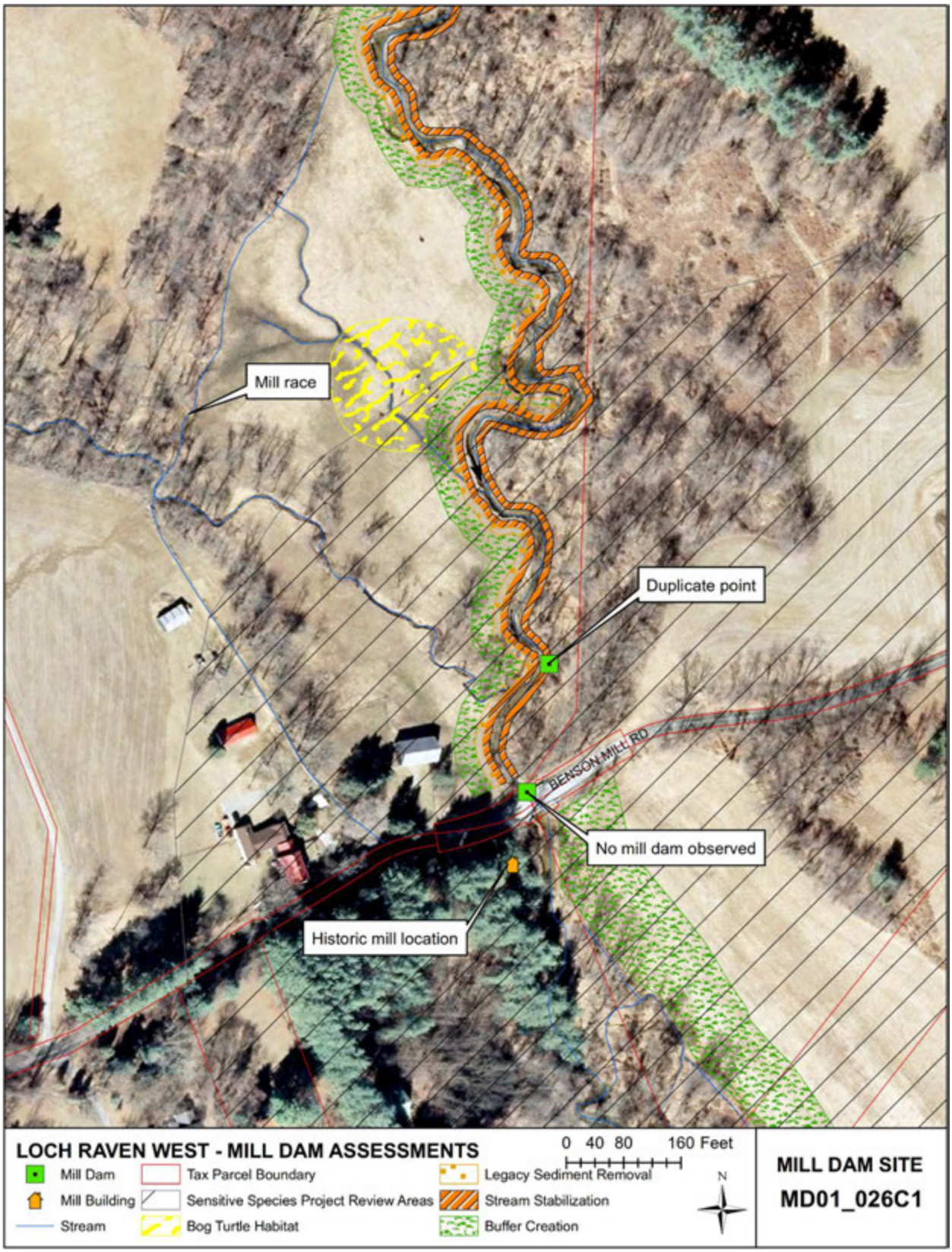

Figure 12: Plan view of mill dam site MD01_026C1

Table 5: Assessment Summary for Mill Dam Site MD01_032C3

Mill Dam ID	MD01_032C3
Subwatershed:	Piney Run
Nearest Cross Roads:	Butler Rd and Dover Rd
Land Ownership:	Private
Dam Intact:	No
Access Concerns/Notes:	The site is accessible through private property off of Butler Rd.

Restoration Recommendations:	Legacy Sediment Removal	-
	Stream Restoration	-
	Wetland Creation	-
	Floodplain Reconnection	-
	Fish Passage	-
	Buffer Creation	**X**
Construction Constraints Rating:	4	
Restoration Potential Rating:	2	
Priority Ranking:	4	

General Notes:
Mill dam site MD01_032C3 is located on private property in the Piney Run subwatershed, immediately southeast of the intersection with Dover Road and Butler Road and is in a Maryland Environmental Trust easement. No mill dam, race, or building was observed at this site. The stream is sparsely buffered with trees, but at the time of the field assessment the field was un-mowed and the grasses were waist high.

This site is recommended for buffer creation only. While the stream does benefit from the un-mowed 3-4 foot high grasses in the floodplain, it could also benefit from the planting of shade trees along the banks to help alleviate thermal impacts on the stream. Although maintaining the un-mowed buffer also has water quality benefits. Any work performed on the property must be done with landowner permission. The extent of the buffer will depend on the permission of the landowner.

Figure 13: Piney Run appears stable and benefits from the currently unmowed buffer, but the stream could benefit from additional shade trees.

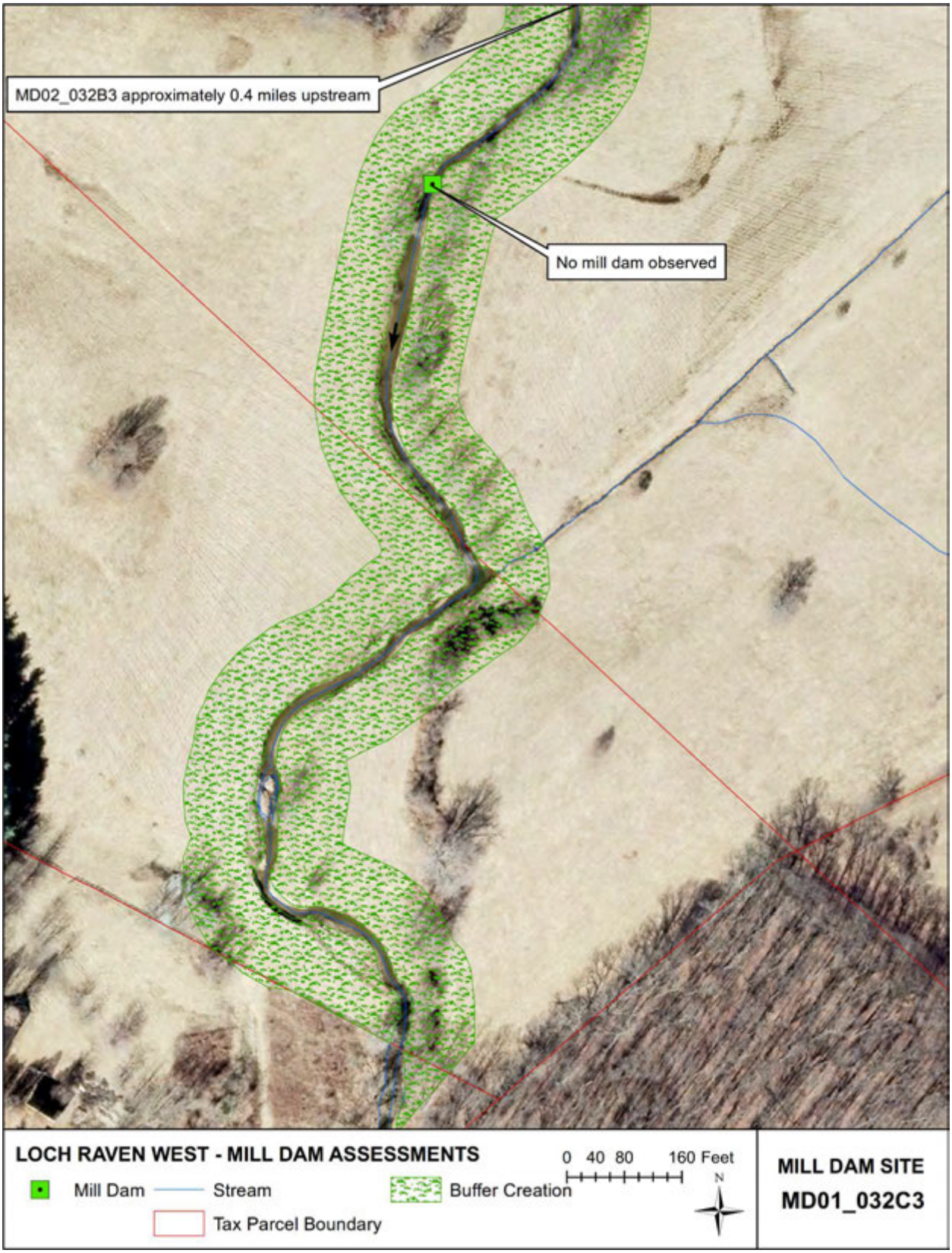

Figure 14: Plan view of mill dam site MD01_032C3

Table 6: Assessment Summary of Mill Dam Site MD02_033B2

Mill Dam ID	MD02_033B2
Subwatershed:	Western Run
Nearest Cross Roads:	Western Run Rd and Tanyard Rd
Land Ownership:	Private
Dam Intact:	No
Access Concerns/Notes:	The site is accessible through private property off of Western Run Rd

Restoration Recommendations:	Legacy Sediment Removal	-
	Stream Restoration	-
	Wetland Creation	-
	Floodplain Reconnection	-
	Fish Passage	-
	Buffer Creation	**X**
Construction Constraints Rating:	4	
Restoration Potential Rating:	2	
Priority Ranking:	4	

General Notes:
Located along Western Run in the middle of the subwatershed, mill dam site MD02_033B2 showed no evidence of a mill dam or mill race. The residential home on the property was constructed in 1813 but could not be verified as the mill building. The property is in a Maryland Environmental Trust easement. While the stream did have some spots of tall vertical banks, overall it appeared stable.

The stream is partially buffered with an average buffer width of 10 feet, and there have been recent plantings along one bank (Figure 15, right). However, the lawn is being mowed to the top of bank and could benefit from an improved forest buffer and a wider un-mowed buffer. Any work performed on the property must be done with landowner permission. The extent of the buffer will depend on the permission of the landowner.

Figure 15: The stream is in relatively stable condition with spots of vertical banks (left) and could benefit from additional tree plantings to supplement the recent tree plants and a greater un-mowed buffer (right)

Figure 16: Plan view of mill dam site MD02_033B2

Table 7: Assessment Summary for Mill Dam Site MD01_033B2

Mill Dam ID	**MD01_033B2**
Subwatershed:	Western Run
Nearest Cross Roads:	Western Run Rd and Tanyard Rd
Land Ownership:	Private
Dam Intact:	No
Access Concerns/Notes:	The site is accessible through private property off Western Run Rd.

Restoration Recommendations:	Legacy Sediment Removal	-
	Stream Restoration	-
	Wetland Creation	-
	Floodplain Reconnection	-
	Fish Passage	-
	Buffer Creation	**X**
Construction Constraints Rating:	5	
Restoration Potential Rating:	2	
Priority Ranking:	6	

General Notes:
Mill dam site MD01_033B2 is located approximately 1,200 feet upstream of MD02_033B2 on Western Run. No mill race or mill building was observed. The homeowner communicated that previously there was a stone bridge that crossed the stream that has since fallen apart (Figure 18, right). The ruins of the bridge are located at the site of MD01_033B2 and if a dam was originally part of the bridge, the homeowner was unaware of it. The stream has a partial buffer an average of 10 feet wide, and the lawn is mowed to the top of bank.

The only restoration treatment recommended at this site is buffer creation to extend the existing tree buffer and created an un-mowed buffer. This will require permission from the private landowner.

Figure 17: Western Run appears stable (left) with a partial buffer (right)

Figure 18: Stone bridge remains at MD01_033B2

Figure 19: Plan view of mill dam site MD01_033B2

Table 8: Assessment Summary for Mill Dam Site MD02_040C1

Mill Dam ID	MD02_040C1
Subwatershed:	Western Run
Nearest Cross Roads:	Mantua Mill Rd and Green Rd
Land Ownership:	Private
Dam Intact:	No
Access Concerns/Notes:	The site is accessible through private property on Mantua Mill Rd.

Restoration Recommendations:	Legacy Sediment Removal	-
	Stream Restoration	-
	Wetland Creation	-
	Floodplain Reconnection	-
	Fish Passage	-
	Buffer Creation	**X**
Construction Constraints Rating:	5	
Restoration Potential Rating:	2	
Priority Ranking:	6	

General Notes:
Mill dam site MD02_040C1 is located in the Western Run subwatershed along Mantua Mill Road approximately 2,600 feet upstream of MD01_040C1. No mill dam or mill building was observed. However, the mill race from MD01_040C1 appears to originate just upstream of MD02_040C1 suggesting that these two sites may have historically been part of one mill. The channel banks appeared stable with no signs of active erosion (Figure 20, left) with the exception of a vehicle crossing (Figure 20, right). Overall, the channel banks are vegetated with grass, shrubs, and small trees.

The only restoration treatment recommended for site MD02_040C1 is stream buffer creation; although there is a partial buffer, the channel is partly unshaded and would benefit from an improved buffer to decrease runoff from the fields and shade the stream. This will require permission from the private landowner.

Figure 20: The stream banks appear vegetated and stable (left) with the exception of a vehicle crossing (right).

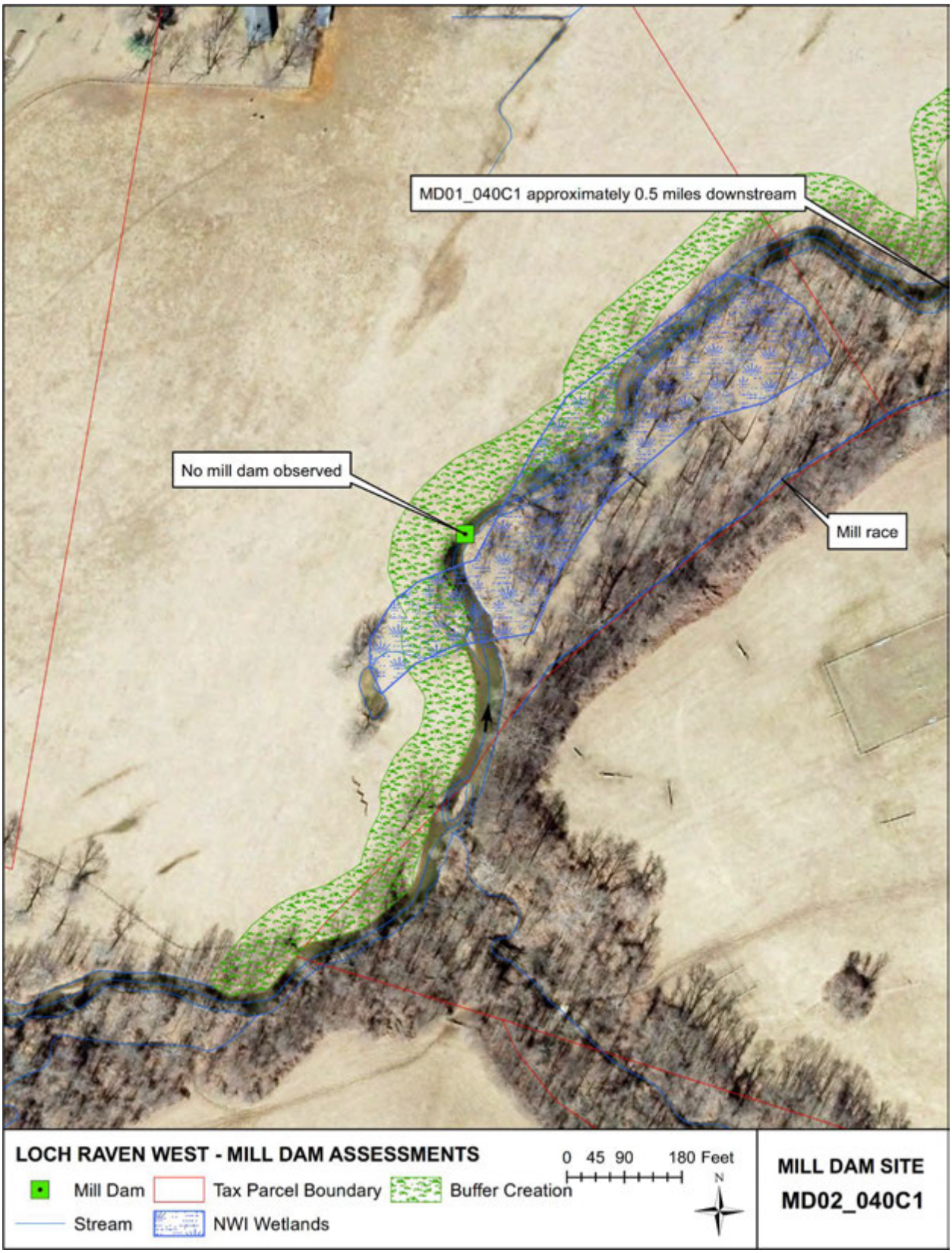

Figure 21: Plan view of mill dam site MD02_040C1

Table 9: Assessment Summary for Mill Dam Site MD01_026A3

Mill Dam ID	**MD01_026A3**
Subwatershed:	Piney Run
Nearest Cross Roads:	Mount Zion Rd and Dover Rd
Land Ownership:	Private
Dam Intact:	No
Access Concerns/Notes:	The site is accessible through private property (Piney Run Farm) on Mount Zion Rd.

Restoration Recommendations:	Legacy Sediment Removal	-
	Stream Restoration	-
	Wetland Creation	-
	Floodplain Reconnection	-
	Fish Passage	-
	Buffer Creation	**X**
Construction Constraints Rating:	6	
Restoration Potential Rating:	2	
Priority Ranking:	8	

General Notes:
Mill dam site MD01_026A3 is located in the Piney Run subwatershed on Mount Zion Road. No sign of a mill dam, building, or race were observed at the historic site location. This reach is unshaded with a pervious, but unforested, buffer on each bank.

It is recommended that both banks be planted to reestablish a buffer to decrease runoff from the fields and shade the stream. This will require permission from the private landowner. Additionally, an educational campaign should be implemented to educate homeowners about the benefits of leaving an un-mow buffer along the stream.

Figure 22: MD01_026A3 had no visible remnants of a mill building, dam, or race and could benefit from an improved stream buffer

Figure 23: Plan view of mill dam site MD01_026A3

Table 10: Assessment Summary for Mill Dam Site MD02_032B3

Mill Dam ID	MD02_032B3
Subwatershed:	Piney Run
Nearest Cross Roads:	Butler Rd and Dover Rd
Land Ownership:	Private
Dam Intact:	No
Access Concerns/Notes:	The site is accessible through private property on Butler Rd.

Restoration Recommendations:	Legacy Sediment Removal	-
	Stream Restoration	-
	Wetland Creation	-
	Floodplain Reconnection	-
	Fish Passage	-
	Buffer Creation	**X**
Construction Constraints Rating:	6	
Restoration Potential Rating:	2	
Priority Ranking:	8	

General Notes:
Located in the Piney Run subwatershed, mill dam MD02_032B3 is located just south of Butler Road approximately 2,000 feet upstream of MD01_032B3. No mill dam, building, or race was observed at the historic site location. The area upstream of Butler Road and mill dam site MD02_032B3 falls within a wetland protection area (Figure 24) and has an estimated 50 feet forested buffer on both banks. No recommendations are suggested upstream of Butler Road. Downstream of Butler Road, the stream buffer becomes less consistent and narrower, with limited trees on the right bank and an approximate 30 foot buffer on the left bank.

It is recommended that stream buffer be improved downstream of Butler Road to provide continuous shading and increase the stream buffer. This will require permission from the private landowner.

Figure 24: Upstream of site MD02_032B3, the stream is well buffered and has a wetland protection area on the left bank.

Figure 25: Plan view of mill dam site MD02_032B3

5. Mill Dam Site Summaries – Other Sites

The data pertaining to each mill dam site assessment for sites with no recommended actions are summarized below. The Information includes location data, access concerns, recommended restoration activities, ratings, and general notes and photos. Each site also includes a plan view showing assumed dam location and potential restoration opportunities and construction constraints.

Table 11: Assessment Summary of Mill Dam Site MD01_033A1

Mill Dam ID	**MD01_033A1**
Subwatershed:	Blackrock Run
Nearest Cross Roads:	Falls Rd and Springtown Rd
Land Ownership:	Private
Dam Intact:	No
Access Concerns/Notes:	The site is accessible through private property on Falls Rd.

Restoration Recommendations:	Legacy Sediment Removal	-
	Stream Restoration	-
	Wetland Creation	-
	Floodplain Reconnection	-
	Fish Passage	-
	Buffer Creation	-
Construction Constraints Rating:	-	
Restoration Potential Rating:	-	
Priority Ranking:	-	

General Notes:

There was no mill dam or mill race observed at the MD01_033A1 location, but the existing residence and remains of a structure were located next to the stream and either could be the historic mill but this was not verified (Figure 26, left). There were multiple places along the stream where natural rock created a pinch point in the stream or stone crossing that may have been part of a dam but no definitive dam was observed (Figure 26, left) The majority of the walked stream appeared stable, there is significant visible bedrock holding the stream grade, and some concrete toe protection, which appears necessary given the steepness of the slopes and the nearby infrastructure (Figure 26, right). The stream has a good buffer and no observed fish passage barriers. There was some observed bank erosion where the stream doglegs at the approach of an old concrete bridge that is in a state of disrepair (Figure 27, left). Multiple piles of pet waste were observed along the banks of the stream near the residence (Figure 27, right).

No restoration actions are recommended at this site; however, it is recommended the County perform education outreach to the residence regarding proper pet waste management.

Figure 26: Residence or ruins could be historic mill but was not verified, natural rock and concrete crossing stream could be historic mill dam but was not verified (left), and minor rubble toe protection below road

Figure 27: Minor stream bank erosion on outside bend of stream at bridge (left), and pet waste on the banks of the stream (right)

Figure 28: Plan view of mill dam location MD01_033A1

Table 12: Assessment Summary for Mill Dam Site MD01_042A1

Mill Dam ID	MD01_042A1
Subwatershed:	Western Run
Nearest Cross Roads:	Western Run Rd and Ford Rd
Land Ownership:	Private
Dam Intact:	No
Access Concerns/Notes:	The site is accessible through Baltimore County land on Western Run Rd.

Restoration Recommendations:	Legacy Sediment Removal	-
	Stream Restoration	-
	Wetland Creation	-
	Floodplain Reconnection	-
	Fish Passage	-
	Buffer Creation	-
Construction Constraints Rating:	-	
Restoration Potential Rating:	-	
Priority Ranking:	-	

General Notes:
Mill dam site MD01_042A1 is located in the Western Run subwatershed off of Western Run Road and is approximately 2,300 feet upstream from mill dam MD02_042A1. No mill dam or building was observed at this location. However, the mill race from MD02_042A1 appears to originates just downstream of MD01_042A1 and then crosses under Western Run Road suggesting that these two sites may have historically been part of one mill (Figure 29). This section of Western Run appears to be in stable condition. The banks are well buffered and there was no observed erosion or fish passage barrier (Figure 29).

No actions are recommended at this site.

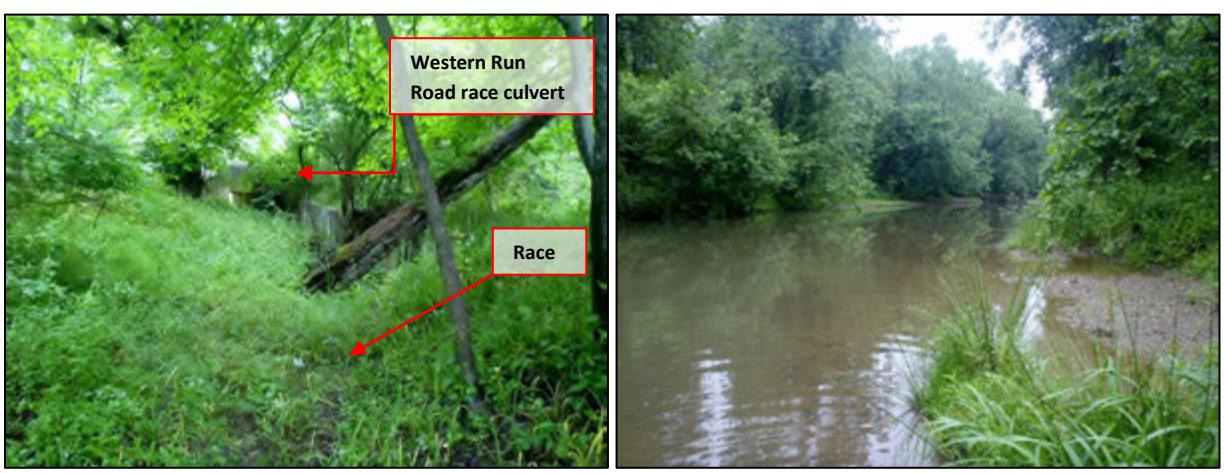

Figure 29: The race for MD02_042A1 originates at MD01_042A1 and passes under Western Run Road (left). MD02_042A1 appears stable and no restoration actions are recommended (right)

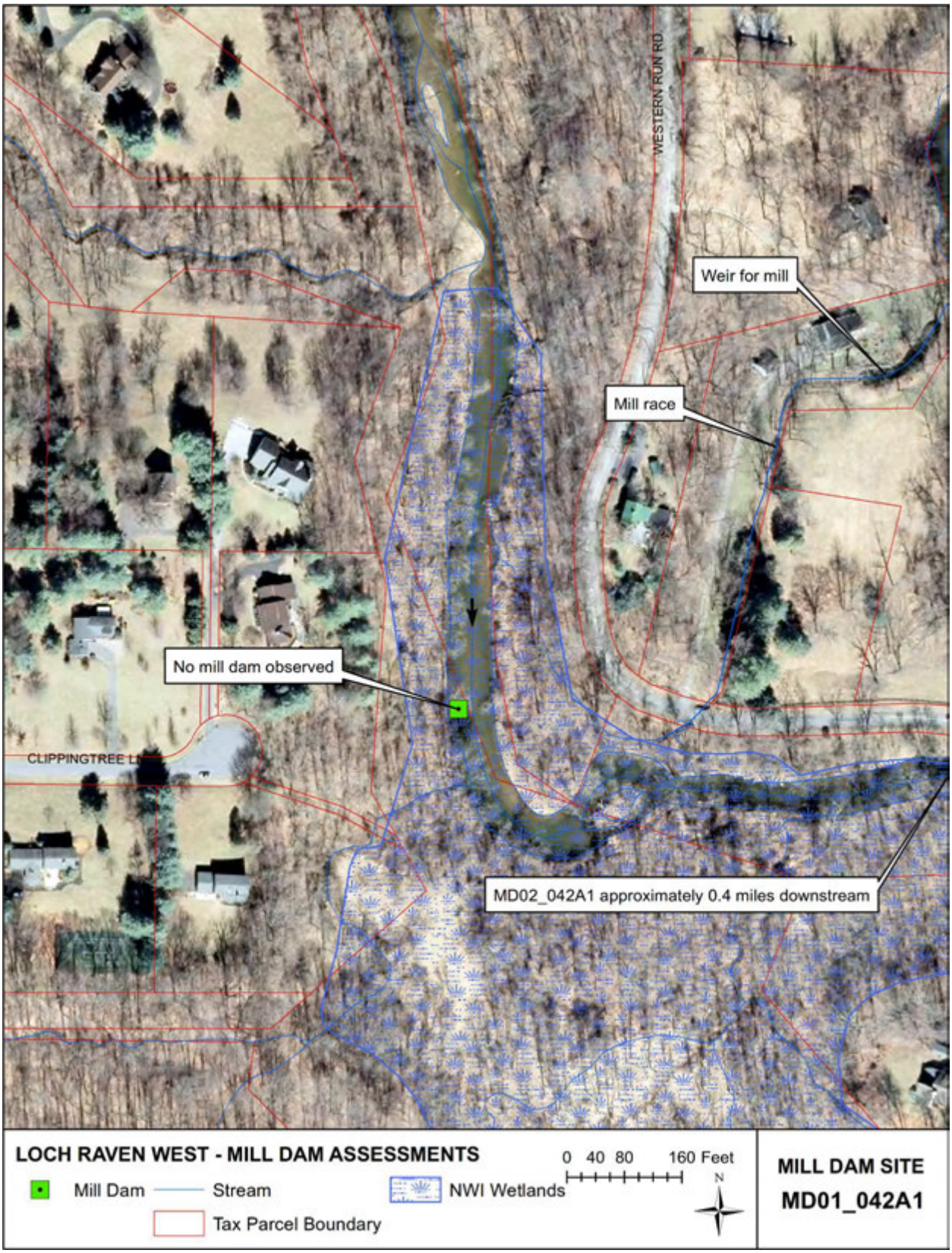

Figure 30: Plan view of mill dam location MD01_042A1

Table 13: Assessment Summary for Mill Dam Site MD01_025C1

Mill Dam ID	MD01_025C1
Subwatershed:	Little Piney Run
Nearest Cross Roads:	Dark Hollow Rd and Regina Ln
Land Ownership:	Private
Dam Intact:	Partial
Access Concerns/Notes:	The site is accessible through private property on Dark Hollow Rd.

Restoration Recommendations:	Legacy Sediment Removal	-
	Stream Restoration	-
	Wetland Creation	-
	Floodplain Reconnection	-
	Fish Passage	-
	Buffer Creation	-
Construction Constraints Rating:	-	
Restoration Potential Rating:	-	
Priority Ranking:	-	

General Notes:
The site of mill dam MD01_025C1 is located on private property off of Dark Hollow Road approximately 850 feet upstream from MD01_025C2. No mill building or race was found at the site, but the remains of a stone dam were observed. The dam was completely breached and is not impeding flow or fish passage (Figure 31). Upstream of the dam, there is legacy sediment, and the stream banks are between 8-10 feet. It appears the stream has returned to its historic levels and has created a floodplain bench within the confinements of the legacy sediment banks reaching a semi-state of equilibrium (Figure 32). The site is also well forested with a 200-500 foot buffer on both banks. Spring seeps and wetland plants were observed within the streams floodplain.

Based on the stream's relative stability and substantial buffer, no restoration actions are recommended at this site.

Figure 31: The remains of the breached stone dam (left) and upstream legacy sediment (right)

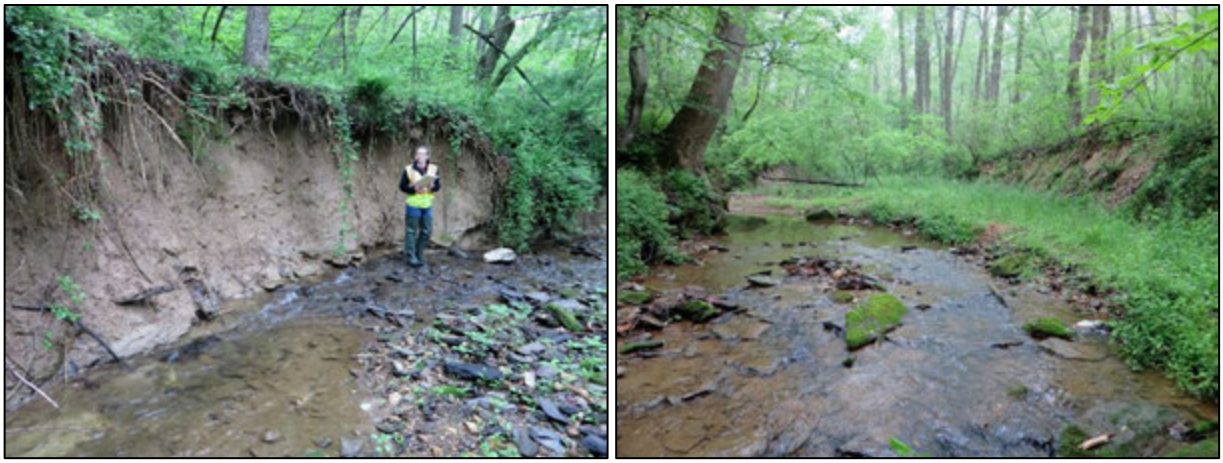

Figure 32: legacy sediment banks resulting from mill dam breaching (left) and typical stream segment upstream of dam breach (right)

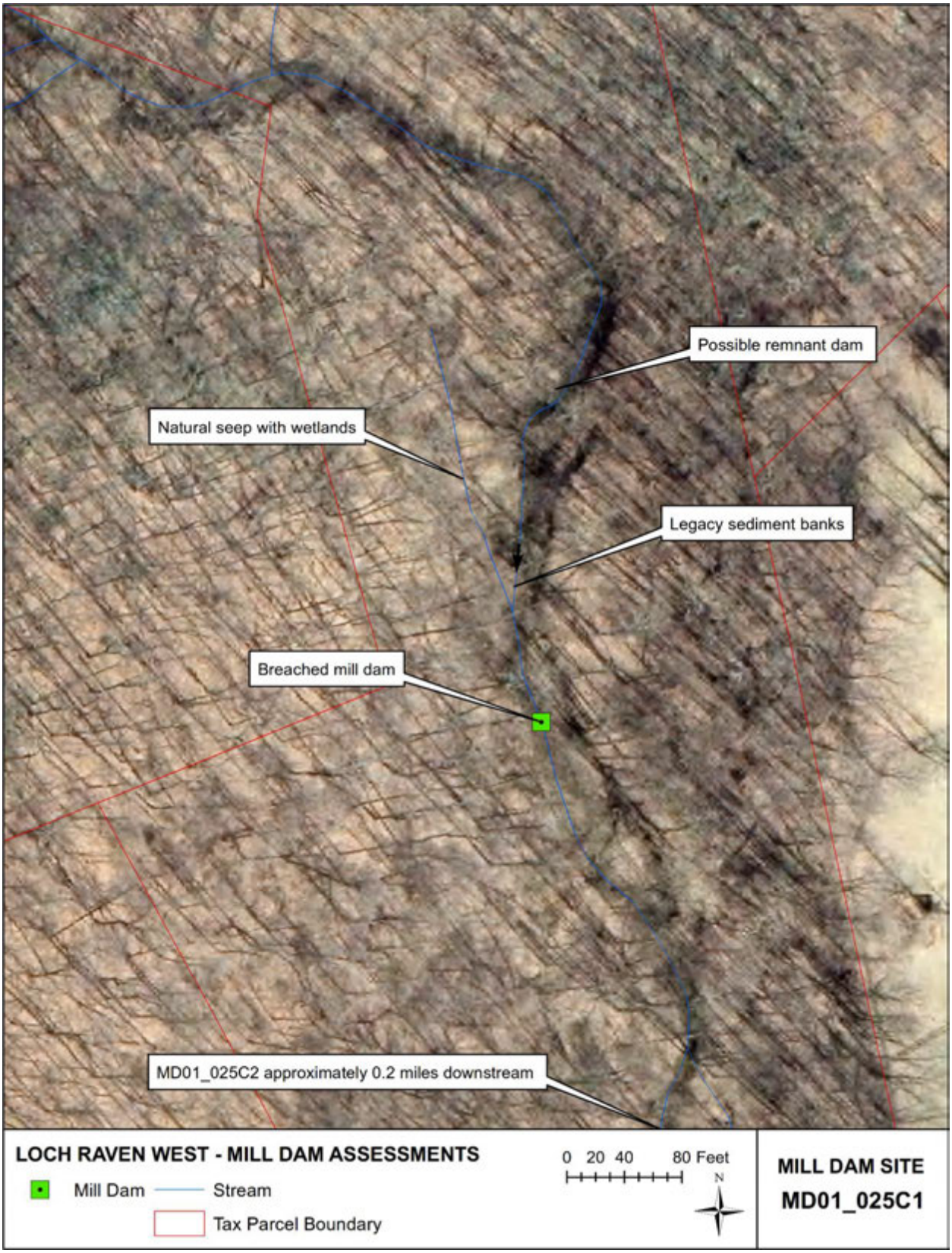

Figure 33: Plan view of mill dam site MD01_025C1

Table 14: Assessment Summary for Mill Dam Site MD01_025C2

Mill Dam ID	MD01_025C2
Subwatershed:	Little Piney Run
Nearest Cross Roads:	Dark Hollow Rd and Regina Ln
Land Ownership:	Private
Dam Intact:	Partial
Access Concerns/Notes:	The site is accessible through private property on Dark Hollow Rd.

Restoration Recommendations:	Legacy Sediment Removal	-
	Stream Restoration	-
	Wetland Creation	-
	Floodplain Reconnection	-
	Fish Passage	-
	Buffer Creation	-
Construction Constraints Rating:	-	
Restoration Potential Rating:	-	
Priority Ranking:	-	

General Notes:
The site of mill dam MD01_025C2 is located on private property off of Dark Hollow Road approximately 850 feet downstream from MD01_025C1. No mill dam was observed at this site, but the homeowner showed the field team the mill race and explained that the existing residence was constructed on the foundation of the original mill building (Figure 34). The stream has spots of bank erosion on one outside bend, but overall the stream is stable, with floodplain access, wetlands, and a good forest buffer (Figure 35). A drainage swale from the road showed signs of minor erosion but is not a concern at the moment.

There are no recommendations for restoration actions at this site.

Figure 34: The remains of the mill race runs next to the existing residence (left) and spot erosion on an outside bend (right)

Figure 35: Typical stream segment (left), and observed wetlands in the floodplain (right)

Figure 36: Plan view of mill dam site MD01_025C2

Table 15: Assessment Summary for Mill Dam Site MD02_042A1

Mill Dam ID	MD02_042A1	
Subwatershed:	Western Run	
Nearest Cross Roads:	Western Run Rd and Ford Rd	
Land Ownership:	Private	
Dam Intact:	No	
Access Concerns/Notes:	The site is accessible through private property on Western Run Rd.	
Restoration Recommendations:	Legacy Sediment Removal	-
	Stream Restoration	-
	Wetland Creation	-
	Floodplain Reconnection	-
	Fish Passage	-
	Buffer Creation	-
Construction Constraints Rating:	-	
Restoration Potential Rating:	-	
Priority Ranking:	-	

General Notes:
Mill dam site MD02_042A1 is located in the Western Run subwatershed off of private property from Western Run Road and is approximately 2,300 feet downstream from mill dam MD02_042A1. No mill dam was observed at this location. However, the mill race, which appears to originate from MD01_042A1 runs parallel to the private driveway and through the ruins of the mill wheel housing before discharging into Western Run (Figure 37 and Figure 38). It is possible, but not confirmed, that the residence is at the location of the original mill dam site, based on the location of the wheel housing ruins. This section of Western Run appears in stable condition with some sediment aggradation. The banks are well buffered and there was no observed erosion or fish passage barrier (Figure 38, right). A duplicate point was noted at this location in the historic mill dam GIS database.

No actions are recommended at this site.

Figure 37: The race for MD02_042A1 runs under Western Run Road (left) and parallel's the private driveway (right)

Figure 38: The race passes through the mill wheel housing ruins (left) and terminates at Western Run (right)

Figure 39: Plan view of mill dam site MD02_042A1

Table 16: Assessment Summary for Mill Dam Site MD01_027A2

Mill Dam ID	MD01_027A2
Subwatershed:	Blackrock Run
Nearest Cross Roads:	Falls Rd and Black Rock Rd
Land Ownership:	No
Dam Intact:	Partial
Access Concerns/Notes:	The site is accessible via a private drive off of Falls Rd.

Restoration Recommendations:	Legacy Sediment Removal	-
	Stream Restoration	-
	Wetland Creation	-
	Floodplain Reconnection	-
	Fish Passage	-
	Buffer Creation	-
Construction Constraints Rating:	-	
Restoration Potential Rating:	-	
Priority Ranking:	-	

General Notes:
Mill dam site MD01_027A2 is located off of a private road along Blackrock Run subwatershed approximately 2,500 feet upstream of MD01_027A3. The mill race and mill dam were not observed; however, a building which could be the historic mill was observed (Figure 40, left). Near the building a stand of bamboo along the stream bank was also observed (Figure 40, right). Overall the stream is stable and well shaded with an average forest buffer width of 1,500 feet on both banks. The exception of the buffer is near the mill site, where the trees have been cleared around the building. No fish barriers were observed, and a native brook trout was seen along this section of Blackrock Run. Upstream of the mill dam site, the stream has abandoned its historic oxbow as shown on the map and cut a direct flowpath past the bend.

No restoration actions are recommended at this site; however, it is recommended that the County reach out to the landowner about performing invasive species removal to address the bamboo along the banks of the stream.

Figure 40: Possible historic mill building (left) and invasive bamboo (right)

Figure 41: Blackrock Run at the mill site where trees have been cleared around the building (left) and further downstream (right)

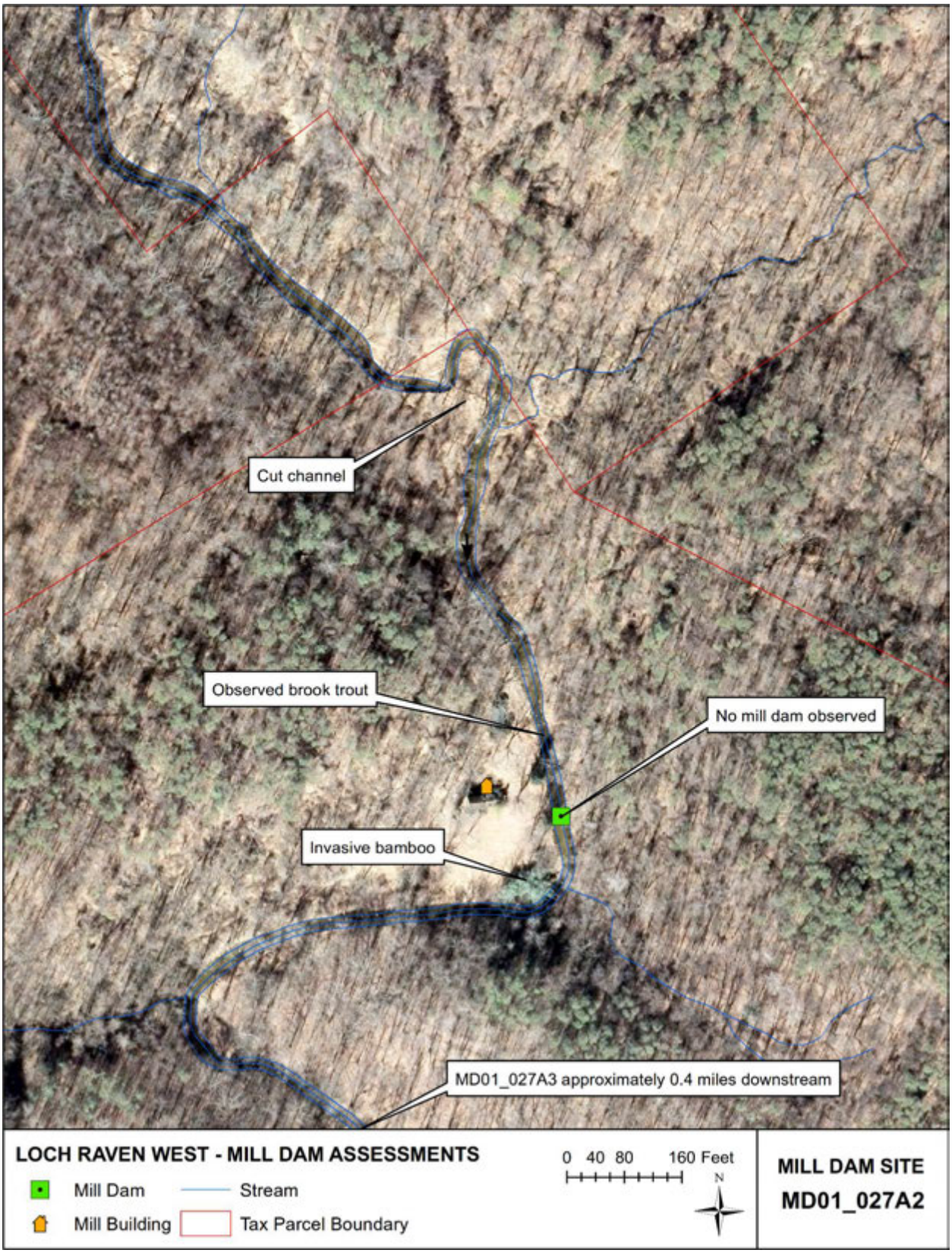

Figure 42: Plan view of mill dam site MD01_027A2

Table 17: Assessment Summary for Mill Dam Site MD01_027A3

Mill Dam ID	MD01_027A3
Subwatershed:	Blackrock Run
Nearest Cross Roads:	Falls Rd and Black Rock Rd
Land Ownership:	Private
Dam Intact:	No
Access Concerns/Notes:	The site is accessible through private property off of Falls Rd.

Restoration Recommendations:	Legacy Sediment Removal	-
	Stream Restoration	-
	Wetland Creation	-
	Floodplain Reconnection	-
	Fish Passage	-
	Buffer Creation	-
Construction Constraints Rating:	-	
Restoration Potential Rating:	-	
Priority Ranking:	-	

General Notes:
Located in the Blackrock Run subwatershed, mill dam MD01_027A3 is located on private property off of Falls Road, 2,500 feet downstream from MD01_027A2. No mill dam, building, or race was observed at this site. The stream appears to be in pristine condition (Figure 43). There was very limited observed bank erosion with an extensive forest buffer on both banks. An ATV trail was observed near the stream that does not appear to be causing any damage or erosion to the stream banks.

No restoration actions are recommended at this site.

Figure 43: No remnants of a historic mill dam were found along this portion of Blackrock Run

Figure 44: Plan view of mill dam site MD01_027A3

6. Mill Dam Site Investigation Guidelines

Introduction

This document provides guidelines for conducting mill dam assessments in Baltimore County and for evaluation of potential restoration approaches. These assessments are intended as preliminary assessments to effectively evaluate the current condition and potential restoration opportunities at a historic mill dam site. The Mill Dam Assessment Field Form is located at the end of the document. The protocol for completing each section of the field form is described below.

Header Data

Fill out the identifying information at the top of the field form. The Unique Site ID should be listed as MDxx_Baltimore County map grid number. For instance if there are two mill dams located on county map 006C3, then the first mill dam assessed should be labeled MD01_006C3 and the second mill dam assessed should be labeled MD02-006C3. Each map with a mill dam should start over with MD01_map grid number.

The camera image, , indicates that a photograph is required of the specific feature. Any feature that requires a picture should also be included in the sketch.

A. Site Information (Desktop Analysis)

This information should be filled out prior to the field investigation. Left Bank and Right Bank are determined as you are facing downstream.

A1. Predominant Land Use

The predominant land use should be the dominate land type in the drainage area around the immediate vicinity of the reach being investigated. The predominant land use should be determined using the Baltimore County Land Use GIS layer and aerials. The land use should be field verified. Land use should be determined for both the left and right banks. Only one dominant land use should be chosen for each bank.

A2. Land Ownership

Land ownership should be determined for the area within 200 feet of each bank, 200 feet downstream of the dam, and 1,000 feet upstream of the dam. Land ownership should be determined using the Baltimore County Parcel GIS layer and government owned lands GIS layer. Land ownership should be determined for both the left and right banks. Multiple land ownership categories may be marked if appropriate.

A3. Special Area Designation

Special area designation that exists within 200 feet of each bank, 200 feet downstream of the dam, and 1,000 feet upstream of the dam should be determined. Special area designations can be found on *DNR's MERLIN website* http://mdmerlin.net/mapper.html . The following table lists the appropriate MERLIN layers that should be used for the special area designations:

Table 18: MERLIN Layers to be Used for Special Area Designations

Special Area Designation	MERLIN Layer(s)
Sensitive Species Area	Living Resources → Sensitive Species Project Review Areas
Wetlands	Wetlands-DNR; Wetlands-NWI
Wetlands of SSC	Wetlands of Special State Concern
Permanent Preserve Ag Land	Permanently Preserved Agricultural Lands
Protected Land	Protected Lands – DNR Programs → ALL

All appropriate special area designations should be marked.

In addition to State protected land, special area designations by the County should also be noted. The County tax parcel information should be checked for parcel status as preserved agricultural land/easement and protected land.

A4. Floodplain Extent
The floodplain reach from the stream edge at the mill dam should be measured and noted. The floodplain reach should be measured in feet perpendicular to the mill dam and noted for both the left and right banks. Floodplain data can be found on the *Baltimore County Floodplain GIS layer* and *at http://mdfloodmaps.com/flood_risk* .

A5. Floodplain Constraints
Possible constraints located within the 100-yr floodplain should be determined. This should be determined using the *Baltimore County Land Use and Floodplain GIS layers and aerials*. Constraints should be verified in the field, specifically for Agricultural land. Constraints should be noted for both the left and right banks. All constraints identified should be noted.

B. Site Information (Field Investigation)
The following site information should be determined during the field visit.

B1. Accessibility
Accessibility should be considered based on the ease of construction equipment access. The following are descriptions of each classification. The site does not need to meet all specifications noted for each description but should be rated in the category that best describes the overall site.

Good: The site is in an open area and can be accessed from existing roads or trails.

Fair to good: The site has easy access but some limitations. Examples of limitations include: 1) the presence of mature trees that need to be maneuvered around but that will not need to be removed; and 2) the site is more than 200 feet from existing roads or trails.

Fair: The site is adjacent to a forested area, which may require the removal of trees for access.

Difficult to fair: The site is adjacent to a dense forest, which will require the removal of trees for access. The site is located more than 1000 feet from existing roads or trails.

Difficult: Access to the site is constrained by permanent structures, such as historic buildings, homes, or fences. The site is located more than 2000 feet from existing roads or trails.

Note that this section is rating accessibility not constructability. Infrastructure constraints, such as utilities, are considered in the next section.

Also note if the access will likely be through public or private land. The County tax parcel information should be used to determine parcel ownership.

B2. Infrastructure Constraints

The site and its floodplain should be evaluated for infrastructure constraints that may affect the constructability of the project. The presence of exposed pipes, visible manholes, and overhead utilities should be noted on the field form. The type of utility: water, sewer, gas, storm drain, electric, etc., should be noted on the form. It should also be noted whether the utility is primarily located: adjacent to the channel (in the floodplain) or in the channel itself. **All utilities found on site should be included in the sketch.**

B3. Crossings

Any crossings located within 200 feet of the mill dam, including any utilities noted in section B2, bridges, and culverts/outfalls, should be noted. Other crossings could include fords for roads/trails. Although outfalls present at the site are not likely crossing the stream, the presence of any outfalls should be noted here. **All crossings found on site should be included in the sketch.**

C. Mill Dam Structure

This section covers all information pertaining to the historic mill and its components. Because these are historic sites, it is possible that no structure will be found at the mapped mill dam location. If this is the case, the best estimate of the location of the dam should be determined based on the provided GPS coordinates and the presence of the mill pond and sediment deposition. In the event the mill dam is no longer present, mark N/A at each section, as appropriate.

C1. Site

In this section, the presence of various components of the original mill dam operation is noted. There are three components to a mill dam: the mill building; the dam used to back up water for storage; and the race, a shallow ditch that directed the stored water from the dam to the mill and then back to the stream.

Figure 45: Image of a mill dam with race and mill building (Foer, 2013)

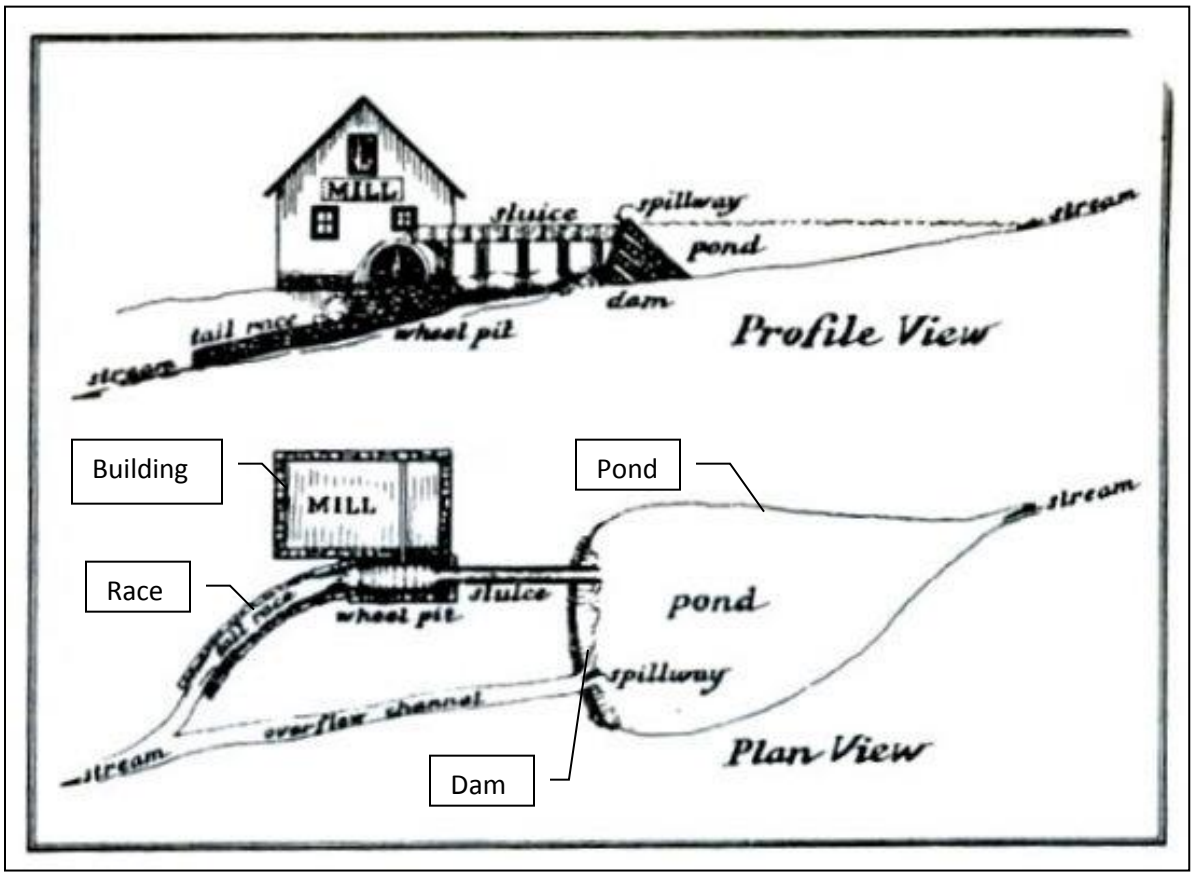

Figure 46: Sketch of typical mill (McGowan, 1986)

The mill itself may be found as an intact building or as only a partial foundation. The dam may be intact or completely gone. The race will be a secondary channel running next to the mill as shown in the sketch above. Check on the field form the presence of any of these components on the site. **All existing components found on site should be included in the sketch.**

Examples of historic mill buildings:

Figure 47: Clopper Mill, a saw- and gristmill, was erected in the early 18th century (left) and Black Rock Mill along Seneca Creek, as seen today (right) Source: (William, 2009)

Examples of mill dams:

Figure 48: Rockhouse Run Mill in Virginia is gone, but dam remnants remain (left) and an intact dam with millstones in the fore ground (right) Source: (Lucas, 2007); http://maineanencyclopedia.com/smyrna/

C2. Condition

The condition of the mill dam should be documented on the field form. Note whether the dam is intact, partially intact, or in pieces. If no dam was found, N/A should be selected.

C3. Material

If the dam still exists, the material it is made of should be documented. The dam may be made from multiple materials; check all that apply. If no dam was found, N/A should be selected.

C4. Dam Height

If the dam still exists, the dam height should be measured. The measurement should be estimated from the thalweg of the downstream channel to the top of the spillway. Depending on the size of the stream, it may not be safe to actually measure the dam height. If this is the case, the height should be visually

approximated from a safe location. The height of the dam should be estimated to one of the ranges listed on the field form. If no dam was found, N/A should be selected.

C5. Current Operation
It is possible the historic dam has been preserved or upgraded and is still in operation today. Document whether or not the mill is still in use.

C6. Historic Use
The historic use of the mill dam should be noted. This information can be found on the *Baltimore County Mill Dam GIS layer.*

D. Fish Passage
Dams have historically blocked fish passage. In this section, the field team should note if a fish blockage from the dam still remains.

D1. Fish Blockage Present
The field team should note whether the dam is still present and preventing the migration of fish up the stream.

D2. Fish Blockage Extent
If the dam is still acting as a fish blockage, it should be noted whether it is total blockage or a partial blockage. If the dam is still intact, it is a total blockage. If the dam is partially intact or a bypass channel is present that allows some fish passage, partial blockage should be selected. If the dam is no long present and is no longer acting as a fish blockage, N/A should be selected.

D3. Water Drop
The water drop is the distance from the spillway of the dam to the downstream water surface. Depending on the size of the stream, it may not be safe to actually measure the water drop. If this is the case, the height should be visually approximated from a safe location. The height of the water drop should be estimated to one of the ranges listed on the field form. If no fish blockage was found, N/A should be selected.

E. Bog Turtle Impact
The field team should note whether the dam is located near existing or potential bog turtle habitat.

E1. Existing Bog Turtle Habitat
The presence of known bog turtle habitat will need to be verified with Maryland DNR and will not be confirmed in the field.

E2. Potential Bog Turtle Habitat
The field team should field verify the site's potential as bog turtle habitat. This should be completed for sites both known to have bog turtles and sites not known to have bog turtles. Check any of the indicators that are present.

E3. Proximity of Habitat to Mill Dam
If potential or known bog turtle habitat is present on site, the approximate distance of the habitat to the mill dam should be noted. Distances should be noted for both the left and right banks. If no potential or existing bog turtle habitat is observed, check N/A. **All potential or known habitat found on site should be included in the sketch.**

F. Headcut

F1. Headcut present
Note whether there is an observed headcut its length upstream of the dam and the streambed erosion depth at the headcut. **All observed headcuts should be included in the sketch.**

G. Restoration Potential
Check the diamond for any restoration options recommended for each of the following possible restoration opportunities.

G1. Potential for legacy sediment removal
Note any reasons, other than those already specified, why legacy sediment removal is not an option.

G2. Potential for streambed stabilization/restoration
Note any reasons, other than those already specified, why stream stabilization or restoration is not an option.

G3. Potential for wetland creation
The following site characteristics would make wetland creation possible:

- Room for grading the banks with limited constraints
- No landownership constraints
- Presence of existing wetlands that could be added or enhanced

G4. Potential for floodplain reconnection
The following site characteristics would make floodplain reconnection possible:

- Area for grading the banks to connect the stream to the floodplain terrace with limited constraints
- No landownership constraints
- Limited constraints within the existing floodplain

G5. Potential for fish passage creation
The following site characteristics would make fish passage creation necessary and possible:

- Fish barrier present
- Sufficient space for bypass channel
- Low to moderate slope present

G6. Potential for buffer creation
The following site characteristics would make wetland creation possible:

- Unused open space

Photographs
Photos should be taken at the site of the general condition and any specific factors. Be sure to take photos of all floodplain constraints, infrastructure, crossings, mill dam structures, fish blockages, bog turtle habitat, the channel upstream, the channel downstream, both banks, and sediment deposition. Channel, bank, and sediment deposition photographs should include a tape measure or person for scale.

Sketch

The plan view of the site and a cross section of the channel should be sketched. Include in the sketch the stream channel, structures, utilities, crossings, potential bog turtle habitat, and dimensions. A cross section of the stream channel should also be sketched with dimensions. See example sketch below:

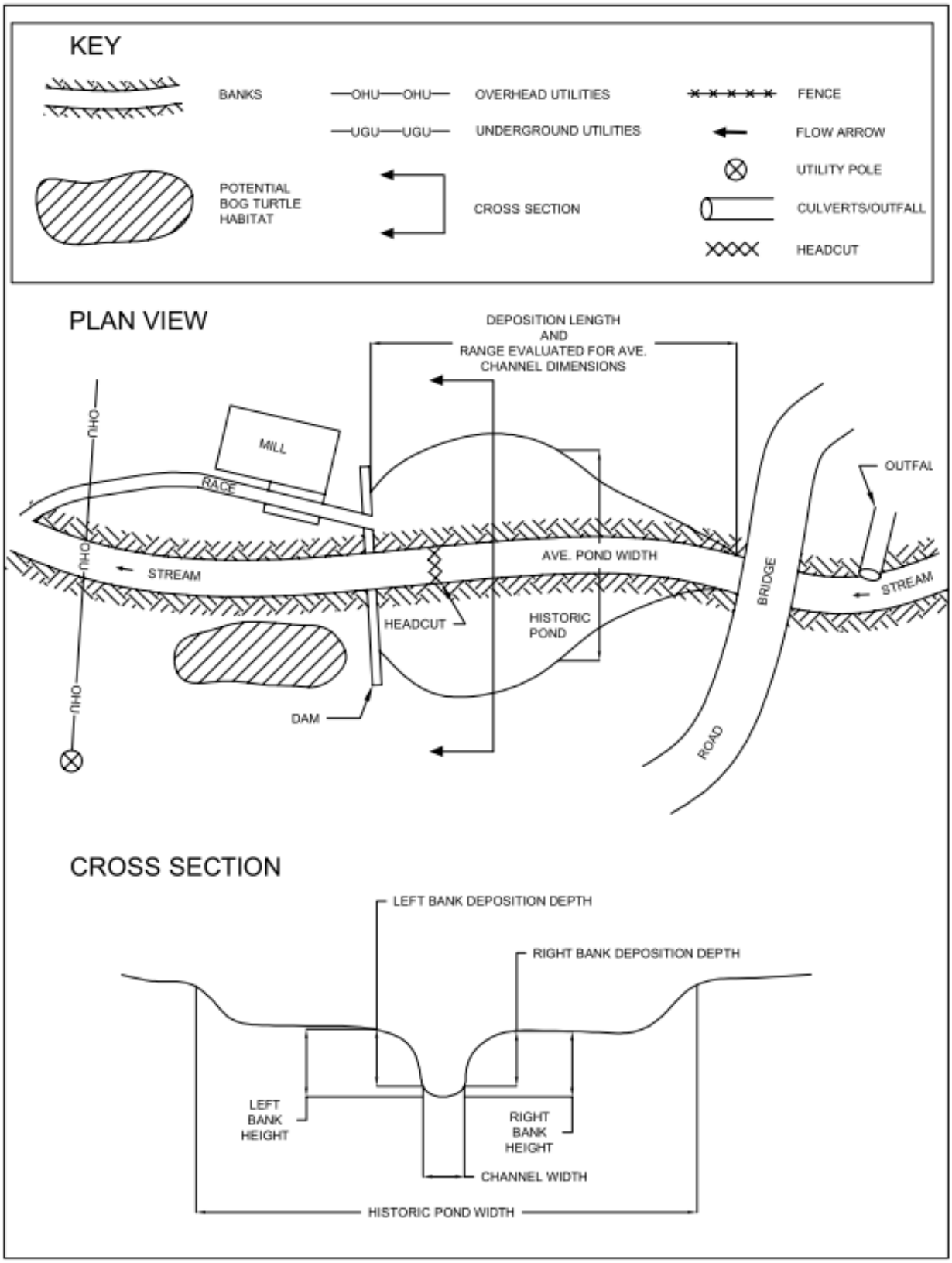

Figure 49: Example sketch of plan view and cross section views of the channel

Mill Dam Assessment

WATERSHED:	SUBWATERSHED:	UNIQUE SITE ID:
DATE: ___/___/_____	STREAM:	ASSESSED BY:

A. SITE INFORMATION (DESKTOP ANALYSIS)	INDEX*
A1. Predominant Land Use: (choose only one per bank) *Right Bank:* ☐ Woods; ☐ Open Space; ☐ Agricultural (livestock); ☐ Agricultural (cultivated); ☐ Residential; ☐ Commercial; ☐ Roadway *Left Bank:* ☐ Woods; ☐ Open Space; ☐ Agricultural (livestock); ☐ Agricultural (cultivated); ☐ Residential; ☐ Commercial; ☐ Roadway	
A2. Land Ownership: (check all that apply) *Right Bank:* ☐ County; ☐ Other Public; ☐ Private (Ag or Residential); ☐ Private (Commercial/Industrial); ☐ Other, If Other:_____ (check the circle if Private ownership)	○
Left Bank: ☐ County; ☐ Other Public; ☐ Private (Ag or Residential); ☐ Private (Commercial/Industrial); ☐ Other, If Other:_____ (check the circle if Private ownership)	○
A3. Special Area Designation: (check all that apply) (check the circle if any special area designation exists) ☐ Sensitive Species Area; ☐ Wetlands; ☐ Wetlands of SSC; ☐ Permanent Preserv Ag Land; ☐ Protected Land; ☐ County Preserved or Protected Land/Easement; ☐ Historic Property	○
A4. Floodplain Extent: What is the 100-yr floodplain extent from the stream edge at the mill dam (ft)? *Right Bank:* _____; *Left Bank:* _____	
A5. Floodplain Constraints: Are any of the following present in the 100-yr floodplain? (check all that apply) *Right Bank:* ☐ Woods; ☐ Open Space; ☐ Agricult (livestock); ☐ Agricult (cultivated); ☐ Improved Property	○ ◇
Left Bank: ☐ Woods; ☐ Open Space; ☐ Agricult (livestock); ☐ Agricult (cultivated); ☐ Improved Property (check the circles if woods or improved property constraints are present; check the diamonds if open space or agricultural land are present)	○ ◇
B. SITE INFORMATION (FIELD INVESTIGATION)	
B1. Accessibility: ☐ Good; ☐ Fair-Good; ☐ Fair; ☐ Difficult-Fair; ☐ Difficult (check the circle if difficult-fair or difficult) ☐ Private; ☐ Public (check the circle if private)	○ ○
B2. Infrastructure Constraints: ☐ Exposed Pipes; ☐ Manholes Present; ☐ Overhead Utilities; ☐ N/A **If Present, what type:** _____; **Located in:** ☐ Channel; ☐ Floodplain (check the circle if utilities are present)	○
B3. Crossings: ☐ Utilities; ☐ Culverts/Outfalls; ☐ Bridges; ☐ N/A; ☐ Other:_____ (check the circle if crossings are present)	○
C. MILL DAM STRUCTURE	
C1. Site: Historic mill building? ☐ Y ☐ N; **Mill dam present?** ☐ Y ☐ N; **Mill race present?** ☐ Y ☐N	
C2. Condition of dam: ☐ Intact; ☐ Partially intact; ☐ Pieces; ☐ N/A	
C3. Material of dam: (check all that apply) ☐ Stone; ☐ Timber; ☐ Concrete; ☐ Soil; ☐ N/A; ☐ Other:	
C4. Approximate dam height: ☐ 0-2 ft; ☐ 2-4 ft; ☐ 4-5 ft; ☐ 5-10 ft; ☐ >10 ft; ☐ N/A Ht:_____	
C5. Is mill dam currently in operation? ☐ Y ☐ N (check the circle if yes) Explain:_____	○
C6. Historic Use: ☐ Grist; ☐ Saw; ☐ Paper; ☐ Woolen; ☐ Bark; ☐ Unknown; ☐ Other:	
D. FISH PASSAGE	
D1. Fish Blockage Present: ☐ Y ☐ N (check the diamond if yes)	◇
D2. Fish Blockage Extent: ☐ Total; ☐ Partial; ☐ N/A	
D3. Water drop: ☐ 0-2 ft; ☐ 2-4 ft; ☐ 4-5 ft; ☐ 5-10 ft; ☐ >10 ft; ☐ N/A Ht:_____	

* INDEX: ○ denotes construction constraint; ◇ denotes restoration potential

mill dam assessment_final_12may14.doc

Figure 50: Mill Dam Assessment Field Form

E. BOG TURTLE IMPACT	
E1. Is the mill dam located in known bog turtle habitat? ☐ Y ☐ N (check the circles if yes)	○○
E2. Are there indicators of potential bog turtle habitat? ☐ Y ☐ N **If yes, in what indicators?** ☐ Local Spring; ☐ Wet/Dry Areas; ☐ Deep/Soft Mud; ☐ Open Canopy; ☐ Suitable vegetation (rushes, sedges, cattails, jewelweed, sphagnum); ☐ Other:_____ (check the circle if more than three indicators present)	○
E3. What is the proximity of potential habitat to the mill dam? *Right Bank:* ☐ 0-100 ft; ☐ 100-500 ft; ☐ 500-1,000 ft; ☐ 1,000-2,000 ft; ☐ > 2,000 ft; ☐ N/A *Left Bank:* ☐ 0-100 ft; ☐ 100-500 ft; ☐ 500-1,000 ft; ☐ 1,000-2,000 ft; ☐ > 2,000 ft; ☐ N/A	
F. HEADCUT	
F1. Headcut present? ☐ Y ☐N; **if yes, distance of headcut from dam (ft): Depth of bed erosion (ft):**	
G. RESTORATION POTENTIAL	
G1. Based on site conditions, is there potential for legacy sediment removal? ☐ Y ☐N If No, why:	
G2. Based on site conditions, is there potential for stream stabilization/restoration? ☐ Y ☐N If No, why:	
G3. Based on site conditions, is there potential for wetland creation? ☐ Y ☐N	◇
G4. Based on site conditions, is there potential for floodplain reconnection? ☐ Y ☐N	◇
G5. Based on site conditions, is there potential for creation of a fish passage? ☐ Y ☐N; If yes, is there potential for the creation of a bypass channel? ☐ Y ☐N	◇
G6. Based on site conditions, is there potential for buffer creation? ☐ Y ☐N	◇

Additional comments/observations:

Sketch: (Sketch plan and cross-section views. Include: floodplain constraints; infrastructure/utility constraints and crossings; mill building, dam and pond; fish blockage; bog turtle habitat; headcuts; and locations of potential restoration opportunities (buffers, fish passage, etc).)

* INDEX: ○ denotes construction constraint; ◇ denotes restoration potential

Figure 51: Mill Dam Assessment Field Form (continued)

7. Works Cited

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8. Mill Dam Assessment Data

LOCH RAVEN WEST MILL DAM DATA AND RECOMMENDED ACTIONS																		
Sub-watershed	Mill Dam ID	Land Use - Left Bank	Land Use - Right Bank	Land Owner-ship Left Bank	Land Owner-ship Right Bank	Special Area Designation	Mill Dam Building	Mill Dam	Mill Dam Race	Fish Barrier	Bog Turtle Habitat	Legacy Sediment Removal	Stream Restoration	Wetland Creation	Floodplain Reconnection	Fish Passage	Buffer Creation	Comments
Little Piney Run	MD01_025C1	Woods	Woods	Private (ag. or residential)	Private (ag. or residential)	Protected land	N	Y	Y	N	N	N	N	N	N	N	N	Dam breached, stream has downcut to original level. High banks (8-10'), legacy sediment banks upstream of dam. Established flood plain bench within confines of legacy sediment banks.
Little Piney Run	MD01_025C2	Open Space	Residential	Private (ag. or residential)	Private (ag. or residential)	Multiple	Y	N	Y	N	N	N	N	N	N	N	N	Spoke to owner. He showed us race and said home was on top of foundation of original mill. This point is likely tied to 25C1. No recommended action.
Piney Run	MD01_026A3	Open Space	Ag. (cultivated)	Private (ag. or residential)	Private (ag. or residential)	Multiple	N	N	N	N	N	N	N	N	N	N	Y	Recommended forest or no mowing buffer around stream.
Blackrock Run	MD01_026C1	Ag. (cultivated)	Woods	Private (ag. or residential)	Private (ag. or residential)	Multiple	N	N	Y	N	Y	Y	Y	N	Y	N	Y	Stream could benefit from terracing and plantings.
Blackrock Run	MD01_027A2	Woods	Woods	Private (ag. or residential)	Private (ag. or residential)	Multiple	Y	N	N	N	N	N	N	N	N	N	N	Observed brook trout.

LOCH RAVEN WEST MILL DAM DATA AND RECOMMENDED ACTIONS																		
Sub-watershed	Mill Dam ID	Land Use - Left Bank	Land Use - Right Bank	Land Owner-ship Left Bank	Land Owner-ship Right Bank	Special Area Designation	Mill Dam Building	Mill Dam	Mill Dam Race	Fish Barrier	Bog Turtle Habitat	Legacy Sediment Removal	Stream Restoration	Wetland Creation	Floodplain Reconnection	Fish Passage	Buffer Creation	Comments
Blackrock Run	MD01_027A3	Woods	Woods	Private (ag. or residential)	Private (ag. or residential)	Multiple	N	N	N	N	N	N	N	N	N	N	N	Beautiful stream. No recommended actions.
McGill Run	MD01_032B3	Woods	Ag. (cultivated)	Private (ag. or residential)	Private (ag. or residential)	Multiple	N	N	N	N	N	Y	Y	Y	Y	N	Y	Take banks back, wetland enhancement, reconnect floodplain, improve buffer.
Piney Run	MD01_032C3	Ag. (cultivated)	Ag. (cultivated)	Private (ag. or residential)	Private (ag. or residential)	Multiple	N	N	N	N	N	N	N	N	N	N	Y	Vegetated along banks but limited tree cover. Could benefit from tree planting to increase shade. Grass currently waist high, if not mowed to bank, fair buffer.
Blackrock Run	MD01_033A1	Woods	Woods	Private (ag. or residential)	Private (ag. or residential)	Multiple	Y	Y	N	N	N	N	N	N	N	N	N	Only recommended action is to educate residents about proper pet waste management. Multiple dog poops found on sandbar.
Western Run	MD01_033B2	Ag. (cultivated)	Ag. (cultivated)	Private (ag. or residential)	Private (ag. or residential)	Multiple	N	N	N	N	N	N	N	N	N	N	Y	Homeowner says bridge use to cross stream. Possible dam location? Could benefit from less mowing near banks and buffer creation.
Western Run	MD01_040C1	Residential	Residential	Other	Private (ag. or residential)	Protected land	N	N	Y	N	Y	Y	Y	Y	Y	N	Y	Found race & wheel weir. Dam likely upstream of permission. Main stem tall, vertical banks, limited buffer.

LOCH RAVEN WEST MILL DAM DATA AND RECOMMENDED ACTIONS																		
Sub-watershed	Mill Dam ID	Land Use - Left Bank	Land Use - Right Bank	Land Owner-ship Left Bank	Land Owner-ship Right Bank	Special Area Designation	Mill Dam Building	Mill Dam	Mill Dam Race	Fish Barrier	Bog Turtle Habitat	Legacy Sediment Removal	Stream Restoration	Wetland Creation	Floodplain Reconnection	Fish Passage	Buffer Creation	Comments
Western Run	MD01_042A1	Residential	Residential	County	Private (ag. or residential)	Wetlands	N	N	Y	N	N	N	N	N	N	N	N	Looks like a nice place to fish, no recommended actions. This is possibly connected to MD02_042A1 by race. This could be dam location and MD02 is mill location.
Piney Run	MD02_032B3	Ag. (cultivated)	Ag. (cultivated)	Private (ag. or residential)	Private (ag. or residential)	Multiple	N	N	N	N	N	N	N	N	N	N	Y	Nothing found. Improved buffer on southside of road. Upstream of bridge is a wetland protection area.
Western Run	MD02_033B2	Ag. (cultivated)	Ag. (cultivated)	Private (ag. or residential)	Private (ag. or residential)	Multiple	N	N	N	N	N	N	N	N	N	N	Y	New trees planted in buffer. Mow to banks. Could benefit from less mowing, more trees. Stream has vertical banks, spot erosion, but lots of vegetation, mostly stable. No recommended action.
Western Run	MD02_040C1	Ag. (cultivated)	Ag. (cultivated)	Private (ag. or residential)	Private (ag. or residential)	Multiple	N	N	Y	N	N	N	N	N	N	N	Y	Improved buffer on L bank, currently horse pasture, some trees. This site is likely connected to MD01_040C1 as the same race connects them. Possible this is dam site, and MD01 is mill site.

LOCH RAVEN WEST MILL DAM DATA AND RECOMMENDED ACTIONS																		
Sub-watershed	Mill Dam ID	Land Use - Left Bank	Land Use - Right Bank	Land Owner-ship Left Bank	Land Owner-ship Right Bank	Special Area Designation	Mill Dam Building	Mill Dam	Mill Dam Race	Fish Barrier	Bog Turtle Habitat	Legacy Sediment Removal	Stream Restoration	Wetland Creation	Floodplain Reconnection	Fish Passage	Buffer Creation	Comments
Western Run	MD02_042A1	Residential	Residential	Private (ag. or residential)	Private (ag. or residential)	Wetlands	Y	N	Y	N	N	N	N	N	N	N	N	Race runs along private drive. Wheel location maybe located. Home likely built on mill foundation. Race discharges to river is stable condition. No recommended action.
Blackrock Run	MD01_033A2																	Not Assessed - Permission NO
Slade Run	MD01_039C2																	Not Assessed - Permission NO
Slade Run	MD01_040A2																	Not Assessed - Permission NO

APPENDIX B:

UPLANDS SURVEY DATA

NEIGHBORHOOD INFORMATION AND RECOMMENDED ACTIONS																										
Sub-watershed	NSA ID	Neighborhood Name	Ac	PSI	ROI	Down-spout Redirect	Rain Barrel	Rain Garden	Stencil	# Inlets	Bay-scape	Lot Canopy Improve-ment	Fertilizer Reduction	% Lawns High	Pet Waste	Trash Manage-ment	Buffer Impact	Street Trees	Open Space Shade Trees	Park Creation	Parking Lot Retrofit	Alley Retrofiting	Other Action	Lot Size Acres	Impervious Acres
Piney Run	NSA_W_0101	Trenton Road	31	Moderate	Moderate	Y	Y	N	Y	11	Y	Y	N	0	N	Y	N	0	0	N	N	N		1-3	3.4
Piney Run	NSA_W_0102	Dover Road	20	Moderate	Moderate	Y	Y	Y	N	0	Y	N	Y	35	N	N	N	0	0	N	N	N		1	2.1
Blackrock Run	NSA_W_0201	Ridge Road	25	Moderate	Low	Y	Y	N	N	0	Y	N	Y	15	N	Y	N	0	0	N	N	N		1-3	1.5
Blackrock Run	NSA_W_0202	Hunter Green	84	Moderate	Moderate	N	N	Y	N	3	Y	Y	N	0	N	N	Y	0	0	N	N	N		3-5	4.3
Blackrock Run	NSA_W_0203	Gorsuch Mill Road	15	Moderate	Low	Y	Y	N	N	0	Y	N	N	0	N	N	N	0	0	N	N	N		1-3	0.9
Blackrock Run	NSA_W_0204	Dubbs Road	55	Low	Low	N	N	N	N	0	Y	N	N	0	N	N	N	0	0	N	N	N		1-3	4.6
Blackrock Run	NSA_W_0205	Mount Carmel Farms	15	Moderate	Moderate	N	N	N	Y	2	Y	Y	N	0	N	N	Y	0	0	N	N	N	Based on aerial map, stream buffer is less than 100 ft.	1-3	1.5
Blackrock Run	NSA_W_0206	Butler Road	16	Moderate	Moderate	Y	Y	Y	N	0	Y	Y	N	0	N	N	Y	0	0	N	N	N		1	2.1
Blackrock Run	NSA_W_0207	Benson Mill Estates	90	Moderate	Moderate	N	N	N	N	0	Y	N	N	0	N	N	Y	0	0	N	N	N		3-5	4.7
McGill Run	NSA_W_0501	Arcadia Manor	11	High	Moderate	N	N	Y	N	0	Y	Y	N	0	N	N	Y	0	0	N	N	N		1/2	0.9
McGill Run	NSA_W_0502	Pleasant Run	40	High	High	Y	Y	Y	Y	2	Y	Y	N	0	N	Y	N	0	0	N	N	N	Gutter and curb cleaning is recommended.	1-3	3.0
McGill Run	NSA_W_0503	Old Hanover Road	6	Moderate	Moderate	Y	Y	N	N	0	Y	N	N	0	N	Y	N	0	0	N	N	N		1/2	0.4
Western Run	NSA_W_0601	Western Run	107	Moderate	Moderate	N	N	N	N	0	Y	N	N	0	N	N	Y	0	0	N	N	N		5-10	4.8
Western Run	NSA_W_0602	Lambourne Downs	130	High	High	N/A	N/A	N/A	Y	4	Y	Y	N	0	N	N	Y	0	0	N	N	N		3-5	7.9
Western Run	NSA_W_0603	Greencroft	251	Low	Moderate	N	N	N	N	6	Y	N	N	0	N	N	Y	0	0	N	N	N		1-3	15.8
Western Run	NSA_W_0604	Hayfields Manor	50	High	High	Y	Y	Y	Y	6	Y	Y	Y	100	N	N	Y	0	0	N	N	N		1-3	7.5
Slade Run	NSA_W_0701	Glyndon Meadow	35	High	Moderate	Y	Y	Y	Y	18	Y	Y	Y	50	N	N	N	0	0	N	N	N		1-3	2.9
Slade Run	NSA_W_0702	Waugh Avenue	4	Moderate	Low	Y	Y	N	N	0	Y	N	N	0	N	N	N	0	0	N	N	N		1/2	0.4
Slade Run	NSA_W_0703	Neel Avenue	9	Low	Low	N	N	N	Y	3	N	N	N	5	N	N	N	0	0	N	N	N		1/2	1.5
Slade Run	NSA_W_0704	Longnecker Road	67	Moderate	Moderate	Y	Y	N	N	0	Y	N	N	0	N	N	Y	0	0	N	N	N	Most houses were not visible from the road since there were long driveways and heavily wooded areas.	3-5	3.8
Delaware Run	NSA_W_0801	Worthington Hill	13	Low	Moderate	Y	Y	N	Y	2	Y	N	N	3	N	N	N	0	0	N	N	N	One inlet was damaged. Most downspouts were most likely connected to the storm drain.	1	1.5
Delaware Run	NSA_W_0802	Sagamore Forest	218	Low	Moderate	N	Y	Y	Y	14	Y	N	N	5	N	N	Y	0	0	N	N	N		1-3	15.9
Delaware Run	NSA_W_0803	Glyndon Mews	15	Moderate	Moderate	Y	Y	N	Y	8	Y	N	Y	20	N	N	N	0	0	N	N	N	All inlets drain to BMP	1	2.1
Councilman's Run	NSA_W_0901	Worthington Hillside II	284	High	High	Y	Y	Y	Y	22	Y	N	Y	20	N	N	N	0	0	N	N	N		1-3	24.5

NEIGHBORHOOD INFORMATION AND RECOMMENDED ACTIONS																									
Sub-watershed	NSA ID	Neighborhood Name	Ac	PSI	ROI	Down-spout Redirect	Rain Barrel	Rain Garden	Stencil	# Inlets	Bay-scape	Lot Canopy Improve-ment	Fertilizer Reduction	% Lawns High	Pet Waste	Trash Manage-ment	Buffer Impact	Street Trees	Open Space Shade Trees	Park Creation	Parking Lot Retrofit	Alley Retrofiting	Other Action	Lot Size Acres	Impervious Acres
Councilman's Run	NSA_W_0902	Worthington Park	70	Moderate	Low	N	N	N	Y	7	Y	N	Y	50	N	N	N	0	0	N	N	N	Could not locate the two facilities on map. Found a culvert at cul-de-sac. Could not see anything at the other one.	1-3	7.8
Councilman's Run	NSA_W_0903	Valley Hills	46	Low	Low	N	N	N	N	5	Y	N	N	0	N	N	N	0	0	N	N	N		1-3	4.2
Waterspout Run	NSA_W_1001	Waterspout	112	Low	Low	N	N	N	Y	7	Y	N	N	0	N	N	N	0	0	N	N	N	Could not check the SWM facility.	1-3	8.8
Waterspout Run	NSA_W_1002	Chestnut Woods	79	Low	Moderate	Y	Y	N	Y	17	Y	N	N	0	N	N	N	0	0	N	N	N	Could not verify the three facilities on map.	1-3	7.1
Deadman's Run	NSA_W_1101	Tufton Farms	173	Low	Low	N	N	N	Y	10	Y	N	N	0	N	N	N	0	0	N	N	N	Could not see the facility marked on map.	5-10	9.0

INSTITUTION INFORMATION AND RECOMMENDED ACTIONS																
Site ID	Subwatershed	Name	Type	Public/ Private	Nutrient Manage-ment	# Trees for Planting	Storm-water Retrofit	Downspout Disconnect	Impervious Cover Removal	Trash Manage-ment	Storm Drain Marking	Buffer Improve-ment	Follow-up Inspection	Invasive Removal	Pollution Prevention Plan	Notes
ISI_W_0101	Piney Run	Christ Evangelical Lutheran Chuch	Faith-based	Public	N	0	N	Y	N	N	N	N	N	N	N	None
ISI_W_0201	Blackrock Run	5th District Elementary School	Elementary School	Public	Y	55	N	N	N	N	N	N	N	N	N	Existing rain garden treats part of the school roof and parking lot.
ISI_W_0301	Little Piney Run	Piney Branch Golf and Country Club	Golf Course	Private	Y	381	N	Y	N	Y	N	Y	N	N	N	None
ISI_W_0501	McGill Run	Pleasant Grove United Methodist Church	Faith-based	Public	Y	128	Y	N	N	N	N	Y	N	N	N	Potential for a new BMP bioretention area on-site.
ISI_W_0601	Western Run	Hayfield Inc.	Golf Course	Private	N	1946	N	N	N	N	Y	Y	N	N	N	None
ISI_W_0602	Western Run	Hunt Valley Baptist Church	Faith-based	Private	N	0	Y	N	N	Y	N	N	N	N	N	Potential SWM facility at the back of the parking lot.
ISI_W_0701	Slade Run	Emery Grove Camp Meeting Association	Faith-based	Private	N	0	N	N	N	N	N	N	N	N	N	
ISI_W_0801	Delaware Run	The Forbush School at Glyndon	Private School	Private	N	0	N	N	N	N	Y	N	N	N	N	None

HOTSPOT INFORMATION AND RECOMMENDED ACTION																			
Site ID	Subwatershed	Hot Spot Status	Refer for Enforce-ment	Follow Up Inspection	Test for IDDE	Education	Check NPDES Permit	On-Site Retrofit	PAA	Review SW PAA	Business Type	Category	Vehicle Operations	Outdoor Materials	Waste Manage-ment	Physical Plant	Turf/Land-scaping	Storm-water	Comments
HSI_W_0201	Blackrock Run	Potential Hotspot	N	Y	N	N	N	N	N	N	Construction Maintenance Yard	Industrial	Y	Y	Y	Y	N	N	Long term storage/trash on site; broken down vehicles; were not able to access to upper portion of the site which appears to have bare soil and additional vehicles.
HSI_W_0202																			Were unable to access the site, no trespassing sign; visible storage area drains towards a storm drain at the entrance to the property.
HSI_W_0203	Blackrock Run	Confirmed Hotspot	N	Y	Y	N	N	N	N	N	Quarry	Industrial	Y	Y	Y	Y	Y	N	Could not visit upper side of the site which is a quarry; field verify fuel tank; lack of Erosion and Sediment Control and water quality treatment.
HSI_W_0204	Blackrock Run	Potential Hotspot	N	N	N	N	N	N	Y	N	Fire Station	Municipal	Y	N	Y	Y	N	N	Recommend tree plantings to increase the stream buffer.
HSI_W_0205	Blackrock Run	Potential Hotspot	N	Y	N	N	N	N	N	N	Store	Commercial	N	Y	Y	Y	N	N	Dumpster at the back of the lot is close to stream. A portion of the parking lot drains to the stream.
HSI_W_0301	Little Piney Run	Potential Hotspot	N	N	N	Y	N	N	N	N	Meeting Place	Municipal	Y	N	Y	Y	Y	Y	Improved landscaping and tree planting is recommended; Improve trash management; the fire station is outside of the watershed boundary; this site only includes the fire hall and surrounding land.
HSI_W_0701																			Were unable to access the site.
HSI_W_0702	Slade Run	Potential Hotspot	N	N	N	Y	N	N	N	N	Shopping Center	Commercial	Y	Y	Y	Y	N	Y	Future education effort.
HSI_W_0703	Slade Run	Confirmed Hotspot	Y	Y	N	N	N	N	N	N	Fire Station	Municipal	Y	N	Y	Y	N	N	Remove oil drums by dumpster.

APPENDIX C:

SUPPORTING CALCULATIONS FOR NSA ANALYSIS

Supporting Calculations for NSA Analysis

Downspout Disconnection

Table 4-3 in the Loch Raven West Watershed Characterization Report summarizes rooftop acres and % of subwatershed rooftop area addressed by downspout redirection for the recommended neighborhoods. The method in which these two columns were calculated is described below.

Rooftop Acres Addressed

Only NSAs recommended for downspout redirection contribute to this analysis. Rooftop acres addressed by redirecting downspouts in a recommended neighborhood were calculated as follows:

Acres of Buildings x % Connected Downspouts

For example, NSA_W_0604 was recommended for downspout redirect and has a total of 3.15 acres of buildings (i.e., rooftop) based on Baltimore County's GIS buildings layer. During the uplands survey, it was estimated that 30% of the downspouts in NSA_W_0604 were directed onto impervious surfaces or were directly connected to storm drains. Therefore, the total rooftop acres addressed by redirecting downspouts in this neighborhood could be 3.15 acres x 0.30 = 0.945 acres.

In some cases, NSAs encompass more than one subwatershed. The rooftop acres addressed for a given subwatershed is calculated as the total rooftop acres in the NSA multiplied by the proportion of the NSA area within that subwatershed. NSA_W_0901, for example, overlaps Delaware Run and Councilman's Run where 23.1% of its area is within Delaware Run and 76.9% is within Councilman's Run. During the uplands survey, it was estimated that 30% of the downspouts in NSA_W_0901 were directed onto impervious surfaces. Given that the neighborhood has 10.05 acres of buildings, the rooftop acres addressed by redirecting downspouts in NSA_W_0901 in Delaware Run were calculated as 10.05 acres x 0.231 x 0.30 = 0.70 acres. The rooftop acres addressed through redirecting downspouts in Councilman's Run were 10.05 acres x 0.769 x 0.30 = 2.32 acres.

% of Subwatershed Rooftop Area Addressed

For a given subwatershed, the % of subwatershed rooftop area addressed by downspout redirection was calculated as:

(∑ Individual NSA Rooftop Acres Addressed / Total Subwatershed Rooftop Acres) x 100%

The total acres of rooftop within a subwatershed were determined using Baltimore County's GIS buildings layer.

Bayscaping

Table 4-4 in the Loch Raven West Watershed Characterization Report summarizes the acres of land and % of subwatershed area addressed by bayscaping for the recommended neighborhoods. The method in which these two columns were calculated is described below.

Acres of Land Addressed

Only NSAs recommended for bayscaping contributed to this analysis. Acres of land addressed by bayscaping in a recommended neighborhood were calculated as follows:

(NSA Total Acres – NSA Impervious Acres) x % Lot Available for Bayscaping

The first expression in parenthesis in the equation above represents the total acres of individual lots in an NSA. According to the Center for Watershed Protection (CWP), the minimum recommended proportion of bayscaping is 10% of an individual lot. Therefore, neighborhoods with less than 10% existing landscaping were recommended for bayscaping. The % Lot Available for Bayscaping was calculated as the % Grass Cover of a typical lot in a recommended NSA as this area could be converted into bayscaping. For example, NSA_W_0602 was recommended for bayscaping and has a total area of 129.6 acres. Based on Baltimore County's GIS layers, there are approximately 5.1 acres of roads and 2.8 acres of buildings in this NSA. This means NSA_W_0602 consists of approximately 129.6 – 5.1 – 2.8 = 121.7 acres of total pervious lots. During the uplands survey, it was estimated that the average lot in NSA_W_0602 consisted of 84% grass cover and 1% landscaping. This means that at a maximum, 121.7 acres x 0.84 = 102.2 acres of land could be addressed by bayscaping in this NSA.

As mentioned previously, some NSAs encompass more than one subwatershed. The acres of land addressed for a given subwatershed is calculated as the total acres of land recommended for bayscaping in the NSA multiplied by the proportion of the NSA area within that subwatershed. NSA_W_0201, for example, overlaps Piney Run and Blackrock Run where 9.9% of its area is within Piney Run and 90.1% is within Blackrock Run. Given that the neighborhood has 11.7 acres available for bayscaping, the acres of land addressed by bayscaping in NSA_W_0201 in Piney Run were calculated as 11.7 acres x 0.099 = 1.2 acres. The acres of land addressed through bayscaping in Blackrock Run were 11.7 acres x 0.901 = 10.5 acres.

% of Subwatershed Area Addressed

For a given subwatershed, the % of the total subwatershed area addressed by bayscaping was calculated as:

(∑ Individual NSA Land Acres Addressed / Total Subwatershed Acres) x 100%

Fertilizer Reduction and Education

Table 4-5 in the Loch Raven Watershed Characterization Report summarizes the acres of land and % of subwatershed area addressed by fertilizer reduction for the recommended neighborhoods. The method in which these two columns were calculated is described below.

Acres of Land Addressed

Only NSAs recommended for fertilizer reduction were included in the analysis (i.e., have more than 20% high maintenance lawns). Acres of land addressed by fertilizer reduction/education in a recommended neighborhood were calculated as follows:

(NSA Total Acres – NSA Impervious Acres) x % Lot Grass Cover x % High Maintenance Lawns

The first expression in the parenthesis above represents the total acres of pervious lots in an NSA. During the uplands assessment, the % of grass cover for a typical lot was estimated along with the % of highly maintained lawn. Multiplying these two percentages with the total pervious area in the NSA yields the acres of lawn that would be addressed via fertilizer reduction. For example, NSA_W_0803 was recommended for fertilizer reduction and has a total area of 14.7 acres. Based on Baltimore County's GIS layers, there are approximately 0.9 acres of road and 1.2 acres of buildings. This means NSA_W_0803 consists of approximately 14.7 – 0.9 – 1.2 = 12.6 acres of pervious lots. During the uplands survey, it was estimated that the average lot in NSA_W_0803 consists of 40% grass cover which equates to 12.6 acres x 0.40 = 5.0 total acres of lawn. It was also noted during the assessment that approximately 20% of the lawns were employing high maintenance lawn practices. So there are roughly 5.0 acres x 0.20 = 1.01 acres of high maintenance lawn that could be addressed by fertilizer reduction in NSA_W_0803.

As mentioned above, some NSAs encompass more than one subwatershed. The acres of land addressed for a given subwatershed is calculated as the total acres of land recommended for fertilizer reduction in the NSA multiplied by the proportion of the NSA area within that subwatershed. NSA_W_0102, for example, overlaps Piney Run and McGill Run where 98.6% of its area is within Piney Run and 1.4% is within McGill Run. Given that the neighborhood has 2.86 acres of high maintenance lawn, the acres of land addressed by fertilizer reduction/education in NSA_W_0102 in Piney Run were calculated as 2.86 acres x 0.986 = 2.82 acres. The acres of land addressed through fertilizer reduction/education in McGill Run were 2.86 acres x 0.014 = 0.04 acres.

As mentioned above, some NSAs encompass more than one subwatershed. The acres of land addressed for a given subwatershed is calculated as the total acres of land recommended for fertilizer reduction in the NSA multiplied by the proportion of the NSA area within that subwatershed. NSA_W_0102, for example, overlaps Piney Run and McGill Run where 98.6% of its area is within Piney Run and 1.4% is within McGill Run. Given that the neighborhood has 2.9 acres of high maintenance lawn, the acres of land addressed by fertilizer reduction/education in NSA_W_0102 in Piney Run were calculated as 2.9 acres x 0.986 = 2.9 acres. The acres of land addressed through fertilizer reduction/education in McGill Run were 2.9 acres x 0.14 = 0 acres.

% of Subwatershed Area Addressed

For a given subwatershed, the % of the total subwatershed area addressed by fertilizer reduction was calculated as:

(∑ Individual NSA Land Acres Addressed / Total Subwatershed Acres) x 100%

Storm Drain Marking

Table 4-6 in the Loch Raven West Watershed Characterization Report summarizes the number of inlets and % of subwatershed inlets addressed by storm drain marking for the recommended neighborhoods. The method in which these two columns were calculated is described below.

Number of Inlets Addressed

In past SWAPs, this section has utilized the Baltimore County OIT GIS layers containing major and minor outfalls within specific subwatersheds to determine an approximate inlet density. However, it was determined based on the upland assessments and visual inspection, that the County GIS data for Loch Raven West was incomplete. More inlets were observed in the NSAs than were accounted for in the GIS database. Therefore, the number of inlets in each NSA were counted and recorded during the uplands assessments to determine the total number of inlets addressed.

Some NSAs encompass more than one subwatershed. The number of inlets addressed for a given subwatershed is calculated as the total inlets recommended for stenciling in the NSA multiplied by the proportion of the NSA area within that subwatershed and rounded to the whole number. For example, NSA_W_0901 overlaps Delaware Run and Councilman's Run where 23.1% is located in Delaware Run and the remaining 76.9% is located in Councilman's Run. The inlets addressed were calculated in Delaware Run as 22 inlets in the NSA x 0.231 = 5 inlets while the inlets addressed for Councilman's Run were calculated as 22 inlets in the NSA x 0.769 = 17 inlets.

Lot Canopy Improvement

Table 4-7 in the Loch Raven West Watershed Characterization Report summarizes the acres of land and % of subwatershed area addressed by lot canopy improvement for recommended neighborhoods. The method in which these two columns were calculated is described below.

Acres of Land Addressed

Only NSAs recommended for lot canopy improvement contributed to this analysis. Acres of land addressed by lot canopy improvement in a recommended neighborhood were calculated as follows:

(NSA Total Acres – NSA Impervious Acres) x % Lot Available for Lot Canopy Improvement

The first expression in the parenthesis in the equation above represents the total acres of individual, pervious lots in an NSA. According to CWP, the recommended proportion of forest canopy is 40% of an individual lot. Therefore, the % Lot available for Lot Canopy Improvement was calculated as 40% minus the fraction of existing forest canopy of a typical lot in a recommended NSA. Multiplying these two factors yields the total acres of land in an NSA recommended/available for lot canopy improvement. For example, NSA_W_0502 was recommended for lot canopy improvement and has a total area of 40.2 acres. Based on Baltimore County's GIS layers, there are approximately 1.9 acres of roads and 1.1 acres of buildings in this NSA. This means that NSA_W_0502 consists of approximately 40.2 – 1.9 – 1.1 = 37.2 acres of total lots. During the uplands survey, it was estimated that the average lot has 35% forest

canopy. This means 40% - 35% = 5% would be recommended for additional lot canopy improvement. This equates to 37.2 acres x 0.05 = 1.9 acres of land that could be addressed by lot canopy improvement in this NSA. This acreage was compared to the total acreage of grass cover in the NSA, to ensure that there was adequate space available for tree planting. Since all NSAs fall within a single subwatershed, this methodology was followed for all NSAs recommended for lot canopy improvement.

<u>% of Subwatershed Area Addressed</u>

For a given subwatershed, the % of the total subwatershed area addressed by lot canopy improvement was calculated as:

(∑ Individual NSA Land Acres Addressed / Total Subwatershed Acres) x 100%

Trash Management

Table 4-8 in the Loch Raven West Watershed Characterization Report summarizes the acres of land and % of subwatershed area addressed by trash management for the recommended neighborhoods. The method in which these two columns were calculated is described below.

<u>Acres of Land Addressed</u>

Neighborhoods were recommended for trash management during the uplands survey if 10% or more of homes in the neighborhood contained trash or other indications of trash. Acres of land addressed by trash management in a recommended neighborhood were simply taken as the total area of the NSA. Only NSAs recommended for trash management contributed to the total acres of land addressed by this action in each subwatershed.

As mentioned above, some NSAs encompass more than one subwatershed. The acres of land addressed for a given subwatershed is calculated as the total acres of land recommended for trash management improvement in the NSA multiplied by the proportion of the NSA area within that subwatershed. NSA_W_0201, for example, overlaps Piney Run and Blackrock Run where 9.9% of its area is within Piney Run and 90.1% of its area is within Blackrock Run. Given that the neighborhood has 24.8 acres of land recommended for trash management, the acres of land addressed by trash management in NSA_W_0201 in Piney Run were calculated as 24.8 acres x 0.099 = 2.5 acres. The acres of land addressed through lot canopy improvement in Blackrock Run were 24.8 acres x 0.901 = 22.3 acres.

<u>% of Subwatershed Area Addressed</u>

For a given subwatershed, the % of the total subwatershed area addressed by trash management was calculated as:

(∑ Individual NSA Acres Addressed / Total Subwatershed Acres) x 100%

APPENDIX F:

Chesapeake Bay TMDL Executive Summary

CHESAPEAKE BAY TMDL EXECUTIVE SUMMARY

INTRODUCTION

The U.S. Environmental Protection Agency (EPA) has established the Chesapeake Bay Total Maximum Daily Load (TMDL), a historic and comprehensive "pollution diet" with rigorous accountability measures to initiate sweeping actions to restore clean water in the Chesapeake Bay and the region's streams, creeks and rivers.

Despite extensive restoration efforts during the past 25 years, the TMDL was prompted by insufficient progress and continued poor water quality in the Chesapeake Bay and its tidal tributaries. The TMDL is required under the federal Clean Water Act and responds to consent decrees in Virginia and the District of Columbia from the late 1990s. It is also a keystone commitment of a federal strategy to meet President Barack Obama's Executive Order to restore and protect the Bay.

The TMDL – the largest ever developed by EPA – identifies the necessary pollution reductions of nitrogen, phosphorus and sediment across Delaware, Maryland, New York, Pennsylvania, Virginia, West Virginia and the District of Columbia and sets pollution limits necessary to meet applicable water quality standards in the Bay and its tidal rivers and embayments. Specifically, the TMDL sets Bay watershed limits of 185.9 million pounds of nitrogen, 12.5 million pounds of phosphorus and 6.45 billion pounds of sediment per year – a 25 percent reduction in nitrogen, 24 percent reduction in phosphorus and 20 percent reduction in sediment. These pollution limits are further divided by jurisdiction and major river basin based on state-of-the-art modeling tools, extensive monitoring data, peer-reviewed science and close interaction with jurisdiction partners.

The TMDL is designed to ensure that all pollution control measures needed to fully restore the Bay and its tidal rivers are in place by 2025, with at least 60 percent of the actions completed by 2017. The TMDL is supported by rigorous accountability measures to ensure cleanup commitments are met, including short-and long-term benchmarks, a tracking and accountability system for jurisdiction activities, and federal contingency actions that can be employed if necessary to spur progress.

Watershed Implementation Plans (WIPs), which detail how and when the six Bay states and the District of Columbia will meet pollution allocations, played a central role in shaping the TMDL. Most of the draft WIPs submitted by the jurisdictions in September 2010 did not sufficiently identify programs needed to reduce pollution or provide assurance the programs could be implemented. As a result, the draft TMDL issued September 24, 2010 contained moderate- to high-level backstop measures to tighten controls on federally permitted point sources of pollution.

A 45-day public comment period on the draft TMDL was held from September 24 to November 8, 2010. During that time, EPA held 18 public meetings in all seven Bay watershed jurisdictions, which were attended by about 2,500 citizens. EPA received more than 14,000 public comments and, where appropriate, incorporated responses to those comments in developing the final TMDL.

After states submitted the draft WIPs, EPA worked closely with each jurisdiction to revise and strengthen its plan. Because of this cooperative work and state leadership, the final WIPs were significantly improved. Examples of specific improvements include:

- Regulated point sources and non-regulated nonpoint sources of nitrogen, phosphorus, and sediment are fully considered and evaluated separately in terms of their relative contributions to water quality impairment of the Chesapeake Bay's tidal waters.
- Committing to more stringent nitrogen and phosphorus limits at wastewater treatment plants, including on the James River in Virginia. (Virginia, New York, Delaware)
- Pursuing state legislation to fund wastewater treatment plant upgrades, urban stormwater management and agricultural programs. (Maryland, Virginia, West Virginia)
- Implementing a progressive stormwater permit to reduce pollution. (District of Columbia)
- Dramatically increasing enforcement and compliance of state requirements for agriculture. (Pennsylvania)
- Committing state funding to develop and implement state-of-the-art-technologies for converting animal manure to energy for farms. (Pennsylvania)
- Considering implementation of mandatory programs for agriculture by 2013 if pollution reductions fall behind schedule. (Delaware, Maryland, Virginia)

These improvements enabled EPA to reduce and remove most federal backstops, leaving a few targeted backstops and a plan for enhanced oversight and contingency actions to ensure progress. As a result, the final TMDL is shaped in large part by the jurisdictions' plans to reduce pollution, which was a long-standing priority for EPA and why the agency always provided the jurisdictions with flexibility to determine how to reduce pollution in the most efficient, cost-effective and acceptable manner.

Now the focus shifts to the jurisdictions' implementation of the WIP policies and programs that will reduce pollution on-the-ground and in-the-water. EPA will conduct oversight of WIP implementation and jurisdictions' progress toward meeting two-year milestones. If progress is insufficient, EPA is committed to take appropriate contingency actions including targeted compliance and enforcement activities, expansion of requirements to obtain NPDES permit coverage for currently unregulated sources, revision of the TMDL allocations and additional controls on federally permitted sources of pollution, such as wastewater treatment plants, large animal agriculture operations and municipal stormwater systems.

In 2011, while the jurisdictions continue to implement their WIPs, they will begin development of Phase II WIPs, designed to engage local governments, watershed organizations, conservation districts, citizens and other key stakeholders in reducing water pollution.

TMDL BACKGROUND

The Clean Water Act (CWA) sets an overarching environmental goal that all waters of the United States be "fishable" and "swimmable." More specifically it requires states and the District of Columbia to establish appropriate uses for their waters and adopt water quality standards that are protective of those uses. The CWA also requires that every two years jurisdictions develop – with EPA approval – a list of waterways that are impaired by pollutants and do not meet water

quality standards. For those waterways identified on the impaired list, a TMDL must be developed. A TMDL is essentially a "pollution diet" that identifies the maximum amount of a pollutant the waterway can receive and still meet water quality standards.

Most of the Chesapeake Bay and its tidal waters are listed as impaired because of excess nitrogen, phosphorus and sediment. These pollutants cause algae blooms that consume oxygen and create "dead zones" where fish and shellfish cannot survive, block sunlight that is needed for underwater Bay grasses, and smother aquatic life on the bottom. The high levels of nitrogen, phosphorus and sediment enter the water from agricultural operations, urban and suburban stormwater runoff, wastewater facilities, air pollution and other sources, including onsite septic systems. Despite some reductions in pollution during the past 25 years of restoration due to efforts by federal, state and local governments; non-governmental organizations; and stakeholders in the agriculture, urban/suburban stormwater, and wastewater sectors, there has been insufficient progress toward meeting the water quality goals for the Chesapeake Bay and its tidal waters.

More than 40,000 TMDLs have been completed across the United States, but the Chesapeake Bay TMDL will be the largest and most complex thus far – it is designed to achieve significant reductions in nitrogen, phosphorus and sediment pollution throughout a 64,000-square-mile watershed that includes the District of Columbia and large sections of six states. The TMDL is actually a combination of 92 smaller TMDLs for individual Chesapeake Bay tidal segments and includes pollution limits that are sufficient to meet state water quality standards for dissolved oxygen, water clarity, underwater Bay grasses and chlorophyll-*a*, an indicator of algae levels (Figure ES-1). It is important to note that the pollution controls employed to meet the TMDL will also have significant benefits for water quality in tens of thousands of streams, creeks, lakes and rivers throughout the region.

Since 2000, the seven jurisdictions in the Chesapeake Bay watershed (Delaware, District of Columbia, Maryland, New York, Pennsylvania, Virginia, and West Virginia), EPA and the Chesapeake Bay Commission, which are partners in the Chesapeake Bay Program, have been planning for a Chesapeake Bay TMDL.

Since September 2005, the seven jurisdictions have been actively involved in decision-making to develop the TMDL. During the October 2007 meeting of the Chesapeake Bay Program's Principals' Staff Committee, the Bay watershed jurisdictions and EPA agreed that EPA would establish the multi-state TMDL. Since 2008, EPA has sent official letters to the jurisdictions detailing all facets of the TMDL, including: nitrogen, phosphorus and sediment allocations; schedules for developing the TMDL and pollution reduction plans; EPA's expectations and evaluation criteria for jurisdiction plans to meet the TMDL pollution limits; reasonable assurance for controlling nonpoint source pollution; and backstop actions that EPA could take to ensure progress.

The TMDL also resolves commitments made in a number of consent decrees, Memos of Understanding, the Chesapeake Bay Foundation settlement agreement of 2010, and settlement agreements dating back to the late 1990s that address certain tidal waters identified as impaired in the District of Columbia, Delaware, Maryland and Virginia.

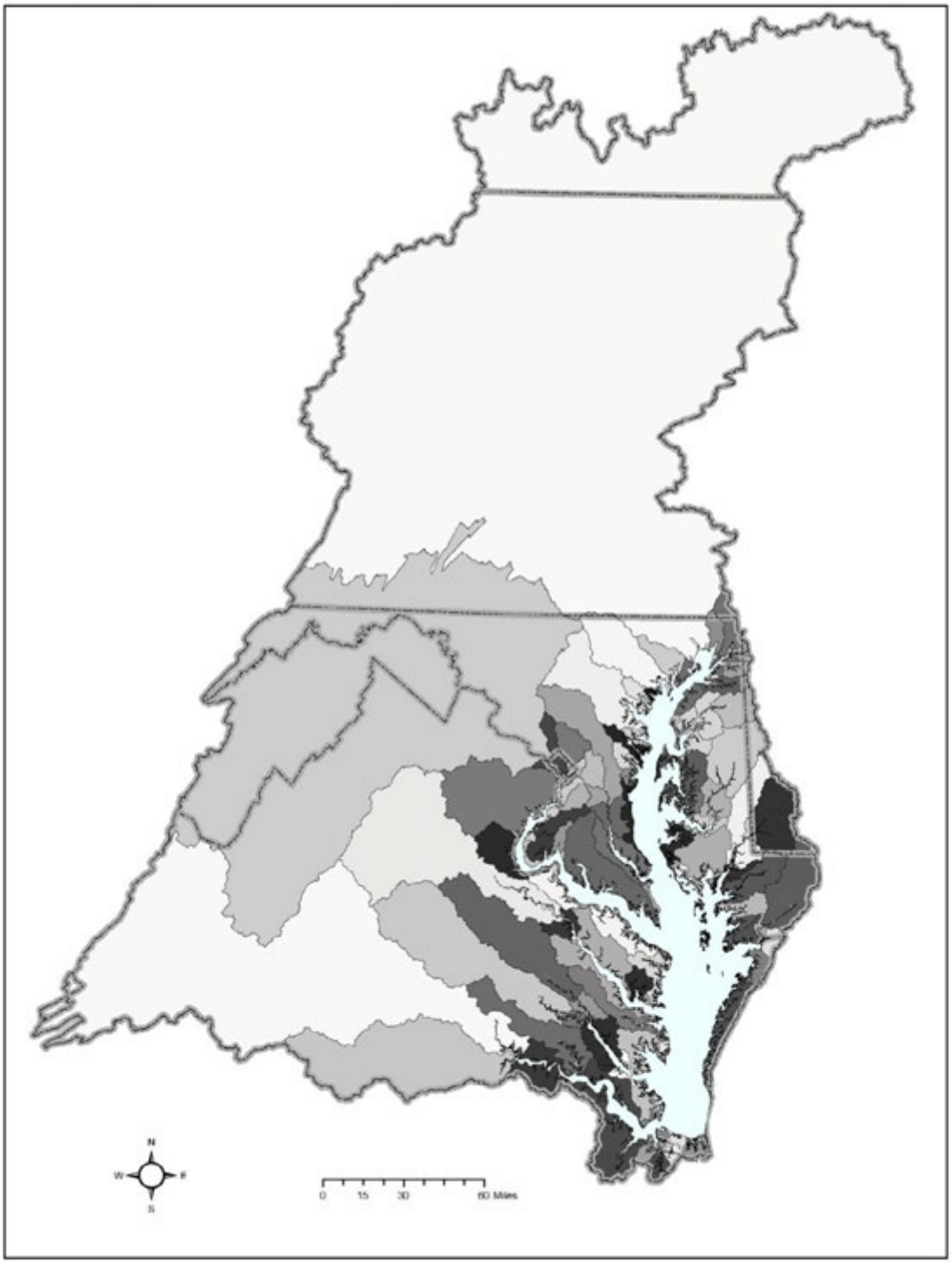

Figure ES-1. A nitrogen, phosphorus and sediment TMDL has been developed for each of the 92 Chesapeake Bay segment watersheds.

Additionally, President Obama issued Executive Order 13508 on May 12, 2009, which directed the federal government to lead a renewed effort to restore and protect the Chesapeake Bay and its watershed. The Chesapeake Bay TMDL is a keystone commitment in the strategy developed by 11 federal agencies to meet the President's Executive Order.

DEVELOPING THE CHESAPEAKE BAY TMDL

Development of the Chesapeake Bay TMDL required extensive knowledge of the stream flow characteristics of the watershed, sources of pollution, distribution and acreage of the various land uses, appropriate best management practices, the transport and fate of pollutants, precipitation data and many other factors. The TMDL is informed by a series of models, calibrated to decades of water quality and other data, and refined based on input from dozens of Chesapeake Bay scientists. Modeling is an approach that uses observed and simulated data to replicate what is occurring in the environment to make future predictions, and was a critical and valuable tool to develop the Chesapeake Bay TMDL.

The development of the TMDL consisted of several steps:

1. EPA provided the jurisdictions with loading allocations for nitrogen, phosphorus and sediment for the major river basins by jurisdiction.
2. Jurisdictions developed draft Phase I WIPs to achieve those basin-jurisdiction allocations. In those draft WIPs, jurisdictions made decisions on how to further sub-allocate the basin-jurisdiction loadings to various individual point sources and a number of point and nonpoint source pollution sectors.
3. EPA evaluated the draft WIPs and, where deficiencies existed, EPA provided backstop allocations in the draft TMDL that consisted of a hybrid of the jurisdiction WIP allocations modified by EPA allocations for some source sectors to fill gaps in the WIPs.
4. The draft TMDL was published for a 45-day public comment period and EPA held 18 public meetings in all six states and the District of Columbia. Public comments were received, reviewed and considered for the final TMDL.
5. Jurisdictions, working closely with EPA, revised and strengthened Phase I WIPs and submitted final versions to EPA.
6. EPA evaluated the final WIPs and used them along with public comments to develop the final TMDL.

Since nitrogen and phosphorus loadings from all parts of the Bay watershed have an impact on the impaired tidal segments of the Bay and its rivers, it was necessary for EPA to allocate the nitrogen and phosphorus loadings in an equitable manner to the states and basins. EPA used three basic guides to divide these loads.

- Allocated loads should protect living resources of the Bay and its tidal tributaries and should result in all segments of the Bay mainstem, tidal tributaries and embayments meeting water quality standards for dissolved oxygen, chlorophyll *a*, water clarity and underwater Bay grasses.
- Tributary basins that contribute the most to the Bay water quality problems must do the most to resolve those problems (on a pound-per-pound basis) (Figure ES-2).
- All tracked and reported reductions in nitrogen, phosphorus and sediment loads are credited toward achieving final assigned loads.

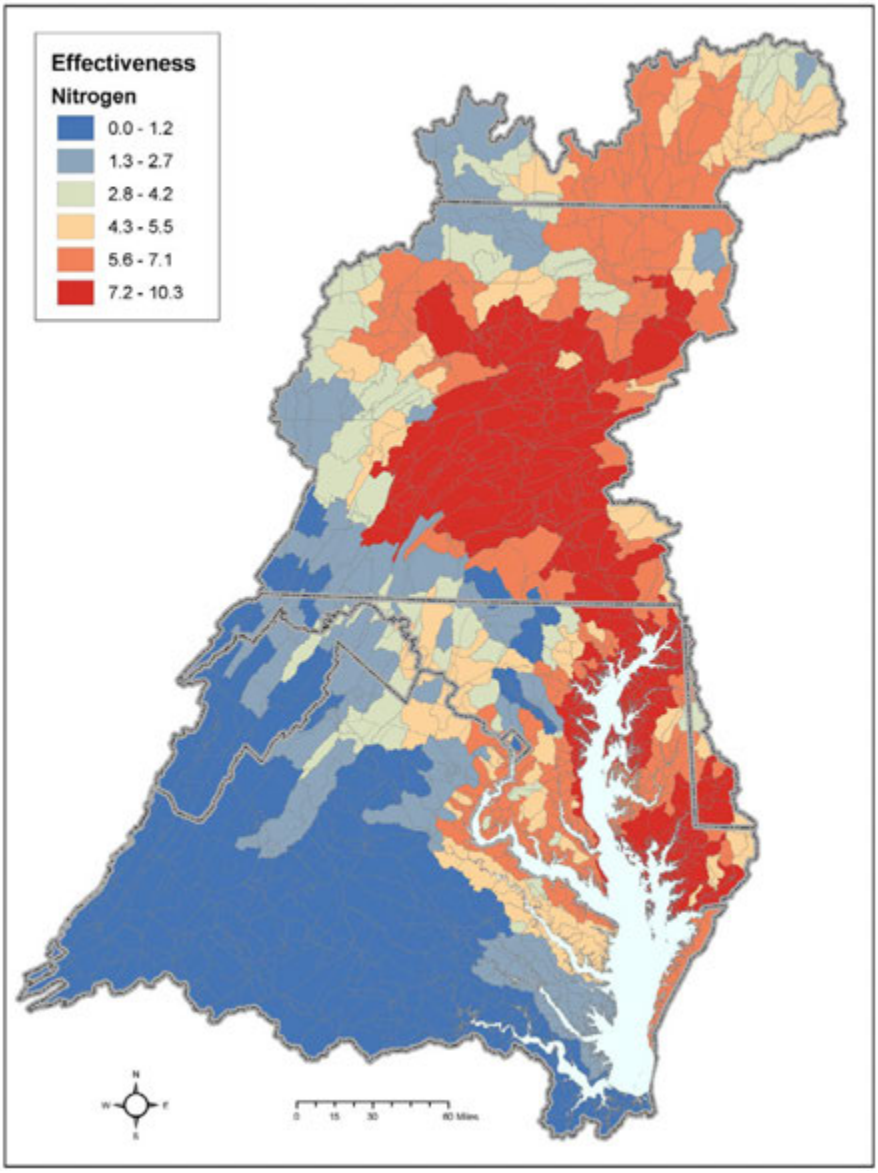

Figure ES-2. Sub-basins across the Chesapeake Bay watershed with the highest (red) to lowest (blue) pound for pound nitrogen pollutant loading effect on Chesapeake Bay water quality.

In addition, EPA has committed to reducing air deposition of nitrogen to the tidal waters of the Chesapeake Bay from 17.9 to 15.7 million pounds per year. The reductions will be achieved through implementation of federal air regulations during the coming years.

To ensure that these pollutant loadings will attain and maintain applicable water quality standards, the TMDL calculations were developed to account for critical environmental conditions a waterway would face and seasonal variation. An implicit margin of safety for nitrogen and phosphorus, and an explicit margin of safety for sediment, also are included in the TMDL.

Ultimately, the TMDL is designed to ensure that by 2025 all practices necessary to fully restore the Bay and its tidal waters are in place, with at least 60 percent of the actions taken by 2017.

The TMDL loadings to the basin-jurisdictions are provided in Table ES-1. These loadings were determined using the best peer-reviewed science and through extensive collaboration with the jurisdictions and are informed by the jurisdictions' Phase I WIPs.

Table ES-1. Chesapeake Bay TMDL watershed nitrogen, phosphorus and sediment final allocations by jurisdiction and by major river basin.

Jurisdiction	Basin	Nitrogen allocations (million lbs/year)	Phosphorus allocations (million lbs/year)	Sediment allocations (million lbs/year)
Pennsylvania	Susquehanna	68.90	2.49	1,741.17
	Potomac	4.72	0.42	221.11
	Eastern Shore	0.28	0.01	21.14
	Western Shore	0.02	0.00	0.37
	PA Total	**73.93**	**2.93**	**1,983.78**
Maryland	Susquehanna	1.09	0.05	62.84
	Eastern Shore	9.71	1.02	168.85
	Western Shore	9.04	0.51	199.82
	Patuxent	2.86	0.24	106.30
	Potomac	16.38	0.90	680.29
	MD Total	**39.09**	**2.72**	**1,218.10**
Virginia	Eastern Shore	1.31	0.14	11.31
	Potomac	17.77	1.41	829.53
	Rappahannock	5.84	0.90	700.04
	York	5.41	0.54	117.80
	James	23.09	2.37	920.23
	VA Total	**53.42**	**5.36**	**2,578.90**
District of Columbia	Potomac	2.32	0.12	11.16
	DC Total	**2.32**	**0.12**	**11.16**
New York	Susquehanna	8.77	0.57	292.96
	NY Total	**8.77**	**0.57**	**292.96**
Delaware	Eastern Shore	2.95	0.26	57.82
	DE Total	**2.95**	**0.26**	**57.82**
West Virginia	Potomac	5.43	0.58	294.24
	James	0.02	0.01	16.65
	WV Total	**5.45**	**0.59**	**310.88**
Total Basin/Jurisdiction Draft Allocation		**185.93**	**12.54**	**6,453.61**
Atmospheric Deposition Draft Allocationa		**15.7**	**N/A**	**N/A**
Total Basinwide Draft Allocation		**201.63**	**12.54**	**6,453.61**

[a] Cap on atmospheric deposition loads direct to Chesapeake Bay and tidal tributary surface waters to be achieved by federal air regulations through 2020.

ACCOUNTABILITY AND GOALS

The Chesapeake Bay TMDL is unique because of the extensive measures EPA and the jurisdictions have adopted to ensure accountability for reducing pollution and meeting deadlines for progress. The TMDL will be implemented using an accountability framework that includes WIPs, two-year milestones, EPA's tracking and assessment of restoration progress and, as necessary, specific federal contingency actions if the jurisdictions do not meet their commitments. This accountability framework is being established in part to provide demonstration of the reasonable assurance provisions of the Chesapeake Bay TMDL pursuant to both the Clean Water Act (CWA) and the Chesapeake Bay Executive Order, but is not part of the TMDL itself.

When EPA establishes or approves a TMDL that allocates pollutant loads to both point and nonpoint sources, it determines whether there is a "reasonable assurance" that the point and nonpoint source loadings will be achieved and applicable water quality standards will be attained. Reasonable assurance for the Chesapeake Bay TMDL is provided by the numerous federal, state and local regulatory and non-regulatory programs identified in the accountability framework that EPA believes will result in the necessary point and nonpoint source controls and pollutant reduction programs. The most prominent program is the CWA's National Pollutant Discharge Elimination System (NPDES) permit program that regulates point sources throughout the nation. Many nonpoint sources are not covered by a similar federal permit program; as a result, financial incentives, other voluntary programs and state-specific regulatory programs are used to achieve nonpoint source reductions. These federal tools are supplemented by a variety of state and local regulatory and voluntary programs and other commitments of the federal government set forth in the Executive Order strategy and identified in the accountability framework.

Beginning in 2012, jurisdictions (including the federal government) are expected to follow two-year milestones to track progress toward reaching the TMDL's goals. In addition, the milestones will demonstrate the effectiveness of the jurisdictions' WIPs by identifying specific near-term pollutant reduction controls and a schedule for implementation (see next section for further description of WIPs). EPA will review these two-year milestones and evaluate whether they are sufficient to achieve necessary pollution reductions and, through the use of a Bay TMDL Tracking and Accountability System, determine if milestones are met.

If a jurisdiction's plans are inadequate or its progress is insufficient, EPA is committed to take the appropriate contingency actions to ensure pollution reductions. These include expanding coverage of NPDES permits to sources that are currently unregulated, increasing oversight of state-issued NPDES permits, requiring additional pollution reductions from point sources such as wastewater treatment plants, increasing federal enforcement and compliance in the watershed, prohibiting new or expanded pollution discharges, redirecting EPA grants, and revising water quality standards to better protect local and downstream waters.

Watershed Implementation Plans

The cornerstone of the accountability framework is the jurisdictions' development of WIPs, which serve as roadmaps for how and when a jurisdiction plans to meet its pollutant allocations under the TMDL. In their Phase I WIPs, the jurisdictions were expected to subdivide the Bay TMDL allocations among pollutant sources; evaluate their current legal, regulatory,

programmatic and financial tools available to implement the allocations; identify and rectify potential shortfalls in attaining the allocations; describe mechanisms to track and report implementation activities; provide alternative approaches; and outline a schedule for implementation.

EPA provided the jurisdictions with detailed expectations for WIPs in November 2009 and evaluation criteria in April 2010. To assist with WIP preparation, EPA provided considerable technical and financial assistance. EPA worked with the jurisdictions to evaluate various "what if" scenarios – combinations of practices and programs that could achieve their pollution allocations.

The two most important criteria for a WIP is that it achieves the basin-jurisdiction pollution allocations and meets EPA's expectations for providing reasonable assurance that reductions will be achieved and maintained, particularly for non-permitted sources like runoff from agricultural lands and currently unregulated stormwater from urban and suburban lands.

After the draft Phase I WIP submittals in September 2010, a team of EPA sector experts conducted an intense evaluation process, comparing the submissions with EPA expectations. The EPA evaluation concluded that the pollution controls identified in two of the seven jurisdictions' draft WIPs could meet nitrogen and phosphorus allocations and five of the seven jurisdictions' draft WIPs could meet sediment allocations. The EPA evaluation also concluded that none of the seven draft Phase I WIPs provided sufficient reasonable assurance that pollution controls identified could actually be implemented to achieve the nitrogen, phosphorus and sediment reduction targets by 2017 or 2025.

In response to its findings, EPA developed a draft TMDL that established allocations based on using the adequate portions of the jurisdictions' draft WIP allocations along with varying degrees of federal backstop allocations in all seven jurisdictions. Backstop allocations focused on areas where EPA has the federal authority to control pollution allocations through NPDES permits, including wastewater treatment plants, stormwater permits, and animal feeding operations.

Public Participation

The draft Chesapeake Bay TMDL was developed through a highly transparent and engaging process during the past two years. The outreach effort included hundreds of meetings with interested groups; two rounds of public meetings, stakeholder sessions and media interviews in all six states and the District of Columbia in fall of 2009 and 2010; a dedicated EPA website; a series of monthly interactive webinars; notices published in the Federal Register; and a close working relationship with Chesapeake Bay Program committees representing citizens, local governments and the scientific community.

The release of the draft Chesapeake Bay TMDL on September 24, 2010 began a 45-day public comment period that concluded on November 8, 2010. During the comment period EPA conducted 18 public meetings in all six states and the District of Columbia. More than 2,500 people participated in the public meetings. Seven of these meetings were also broadcast live online. During the six weeks that EPA officials traveled around the watershed, they also held dozens of meetings with stakeholders, including local governments, agriculture groups, homebuilder and developer associations, wastewater industry representatives and environmental

organizations. EPA received more than 14,000 comments – most of which supported the TMDL – and the Agency's response to those comments is included as an appendix to the TMDL.

Final Watershed Implementation Plans and TMDL

Since submittal of the draft WIPs and release of the draft TMDL in September 2010, EPA worked closely with each jurisdiction to revise and strengthen its plan. Because of this cooperative work and state leadership, the final WIPs were significantly improved. Examples of specific improvements include:

- Committing to more stringent nitrogen and phosphorus limits at wastewater treatment plants, including on the James River in Virginia. (Virginia, New York, Delaware)
- Pursuing state legislation to fund wastewater treatment plant upgrades, urban stormwater management and agricultural programs. (Maryland, Virginia, West Virginia)
- Implementing a progressive stormwater permit to reduce pollution. (District of Columbia)
- Dramatically increasing enforcement and compliance of state requirements for agriculture. (Pennsylvania)
- Committing state funding to develop and implement state-of-the-art-technologies for converting animal manure to energy for farms. (Pennsylvania)
- Considering implementation of mandatory programs for agriculture by 2013 if pollution reductions fall behind schedule. (Delaware, Maryland, Virginia)

These improvements enabled EPA to reduce and remove most federal backstops, leaving a few targeted backstops and a plan for enhanced oversight and contingency actions to ensure progress.

Backstop Allocations, Adjustments, and Actions

Despite the significant improvement in the final WIPs, one of the jurisdictions did not meet all of its target allocations and two of the jurisdictions did not fully meet EPA's expectations for reasonable assurance for specific pollution sectors. To address these few remaining issues, EPA included in the final TMDL several targeted backstop allocations, adjustments and actions. As a result of the jurisdictions' significant improvements combined with EPA's backstops, EPA believes the jurisdictions are in a position to implement their WIPs and achieve the needed pollution reductions. This approach endorses jurisdictions' pollution reduction commitments, gives them the flexibility to do it their way first, and signals EPA's commitment to fully use its authorities as necessary to reduce pollution.

New York Wastewater – Backstop Allocation

- EPA closed the numeric gap between New York's WIP and its modified allocations by establishing a backstop that further reduces New York's wasteload allocation for wastewater. EPA is establishing an aggregate wasteload allocation for wastewater treatment plants.
- EPA calculated this backstop WLA using the nitrogen and phosphorus performance levels that New York committed to, but assumes that significant wastewater treatment plants (WWTPs) are at current flow rather than design flow.

- EPA understands that New York plans to renew and/or modify WWTP permits upon completion of its Phase II WIP, consistent with the applicable TMDL allocations at that time. New York is reviewing engineering reports from WWTPs and, in its Phase II WIP, will provide information to support individual WLAs for these plants.

Pennsylvania Urban Stormwater – Backstop Adjustment

- EPA transferred 50 percent of the stormwater load that is not currently subject to NPDES permits from the load allocation to the wasteload allocation. The TMDL allocation adjustment increases reasonable assurance that pollution allocations from urban stormwater discharges will be achieved and maintained by signaling that EPA is prepared to designate any of these discharges as requiring NPDES permits. Urban areas would only be subject to NPDES permit conditions protective of water quality as issued by Pennsylvania upon designation. EPA will consider this step if Pennsylvania does not demonstrate progress toward reductions in urban loads identified in the WIP. EPA may also pursue designation activities based on considerations other than TMDL and WIP implementation.
- EPA will maintain close oversight of general permits for the Pennsylvania stormwater sector (PAG-13 and PAG-2) and may object if permits are not protective of water quality standards and regulations. Upon review of Pennsylvania's Phase II WIP, EPA will revisit the wasteload allocations for wastewater treatment plants, including more stringent phosphorus limits, in the event that Pennsylvania does not reissue PAG-13 and PAG-2 general permits for Phase II MS4s and construction that are protective of water quality by achieving the load reductions called for in Pennsylvania's Phase I WIP.

West Virginia Agriculture – Backstop Adjustment

- EPA shifted 75 percent of West Virginia's animal feeding operation (AFO) load into the wasteload allocation and assumed full implementation of barnyard runoff control, waste management and mortality composting practices required under a CAFO permit on these AFOs. The shift signals that any of these operations could potentially be subject to state or federal permits as necessary to protect water quality. AFOs would only be subject to NPDES permit conditions as issued by West Virginia upon designation. EPA will consider this step if West Virginia does not achieve reductions in agricultural loads as identified in the WIP. EPA may also pursue designation activities based upon considerations other than TMDL and WIP implementation.
- Based upon West Virginia's ability to demonstrate near-term progress implementing the agricultural section of its WIP, including CAFO Program authorization and permit applications and issuance, EPA will assess in the Phase II WIP whether additional federal actions, such as establishing more stringent wasteload allocations for wastewater treatment plants, are necessary to ensure that TMDL allocations are achieved.

Enhanced Oversight and Contingencies

While final WIPs were significantly improved and the jurisdictions deserve credit for the efforts, EPA also has minor concerns with the assurance that pollution reductions can be achieved in certain pollution sectors in Pennsylvania, Virginia and West Virginia. EPA has informed these jurisdictions that it will consider future backstops if specific near-term progress is not demonstrated in the Phase II WIP.

Pennsylvania Agriculture

- Based on Pennsylvania's ability to demonstrate near-term progress implementing the agricultural section of its WIP, including EPA approval for its CAFO program and enhanced compliance assurance with state regulatory programs, EPA will assess in the Phase II WIP whether additional federal actions, such as shifting AFO loads from the load allocation to the wasteload allocation or establishing more stringent wasteload allocations for WWTPs, are necessary to ensure that TMDL allocations are achieved.

Pennsylvania Wastewater

- EPA established individual wasteload allocations for wastewater treatment plants in the TMDL to ensure that sufficient detail is provided to inform individual permits for sources within the wasteload allocation. Individual allocations do not commit wastewater plants to greater reductions than what the state has proposed in its WIP. Provisions of the TMDL allow, under certain circumstances, for modifications of allocations within a basin to support offsets and trading opportunities.
- EPA will assess Pennsylvania’s near-term urban stormwater and agriculture program progress and determine whether EPA should modify TMDL allocations to assume additional reductions from wastewater treatment plants.

Virginia Urban Stormwater

- If the statewide rule and/or the Phase II WIP do not provide additional assurance regarding how stormwater discharges outside of MS4 jurisdictions will achieve nitrogen, phosphorus, and sediment reductions proposed in the final Phase I WIP and assumed within the TMDL allocations, EPA may shift a greater portion of Virginia’s urban stormwater load from the load allocation to the wasteload allocation. This shift would signal that substantially more stormwater could potentially be subject to NPDES permits issued by the Commonwealth as necessary to protect water quality.

West Virginia Urban Stormwater

- If stormwater rules and/or the Phase II WIP do not provide additional assurance regarding how urban stormwater discharges outside of MS4 jurisdictions will achieve nitrogen, phosphorus, and sediment allocations proposed in the final Phase I WIP and assumed within the TMDL load allocations, EPA may shift a greater portion of West Virginia’s urban stormwater load from the load allocation to the wasteload allocation. The shift would signal that substantially more urban stormwater could potentially be subject to state permit coverage and/or federal Clean Water Act permit coverage as necessary to protect water quality.

West Virginia Wastewater

- EPA established individual wasteload allocations for significant wastewater treatment plants in the TMDL to ensure that sufficient detail is provided to inform individual permits for sources within the wastewater wasteload allocation. Individual allocations do not commit wastewater plants to greater reductions than what the state has proposed in its WIP. Provisions of this TMDL allow, under certain circumstances, for modifications of allocations within a basin to support offsets and trading opportunities.

- EPA will assess West Virginia's near-term agriculture program progress and determine whether additional federal actions consistent with EPA's December 29, 2009 letter, such as modifying TMDL allocations to assume additional reductions from wastewater treatment plants, are necessary to ensure that TMDL allocations are achieved.

Ongoing oversight of Chesapeake Bay jurisdictions

EPA will carefully review programs and permits in all jurisdictions. EPA's goal is for jurisdictions to successfully implement their WIPs, but EPA is prepared to take necessary actions in all jurisdictions for insufficient WIP implementation or pollution reductions. Federal actions can be taken at any time, although EPA will engage particularly during two-year milestones and refining the TMDL in 2012 and 2017. Actions include:

- Expanding coverage of NPDES permits to sources that are currently unregulated
- Increasing oversight of state-issued NPDES permits
- Requiring additional pollution reductions from federally regulated sources
- Increasing federal enforcement and compliance
- Prohibiting new or expanded pollution discharges
- Conditioning or redirecting EPA grants
- Revising water quality standards to better protect local and downstream waters
- Discounting nutrient and sediment reduction progress if jurisdiction cannot verify proper installation and management of controls

FINAL TMDL

As a result of the significantly improved WIPs and the removal and reduction of federal backstops, the final TMDL is shaped in large part by the jurisdictions' plans to reduce pollution. Jurisdiction-based solutions for reducing pollution was a long-standing priority for EPA and why the agency always provided the jurisdictions with flexibility to determine how to reduce pollution in the most efficient, cost-effective and acceptable manner.

Now, the focus shifts to jurisdictions' implementation of the WIP policies and programs designed to reduce pollution on-the-ground and in-the-water. EPA will conduct oversight of WIP implementation and jurisdictions' progress toward meeting two-year milestones. If progress is insufficient, EPA will utilize contingencies to place additional controls on federally permitted sources of pollution, such as wastewater treatment plants, large animal agriculture operations and municipal stormwater systems, as well as target compliance and enforcement activities.

Federal agencies will greatly contribute to restoration of the Chesapeake Bay watershed, particularly through implementation of the new federal strategy created under President Obama's Executive Order. Eleven federal agencies have committed to a comprehensive suite of actions and pursuit of critical environmental goals on the same 2025 timeline as the TMDL. Additionally, federal agencies will be establishing and meeting two-year milestones, with the specific charge of taking actions that directly support the jurisdictions in reducing pollution and restoring water quality.

The jurisdictions are expected to submit Phase II WIPs that provide local area pollution targets for implementation on a smaller scale; the timeframe for these Phase II WIPs will be determined in early 2011. Phase III WIPs in 2017 are expected to be designed to provide additional detail of restoration actions beyond 2017 and ensure that the 2025 goals are met.

APPENDIX G:

Total Maximum Daily Loads of Fecal Bacteria for the Loch Raven Reservoir Basin in Baltimore, Carroll, and Harford Counties, Maryland

Total Maximum Daily Loads of Fecal Bacteria for the Loch Raven Reservoir Basin in Baltimore, Carroll, and Harford Counties, Maryland

FINAL

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List of Abbreviations

ARCC	Average rates of correct classification
ARA	Antibiotic Resistance Analysis
BMP	Best Management Practice
BST	Bacteria Source Tracking
cfs	Cubic Feet per Second
CFR	Code of Federal Regulations
CFU	Colony Forming Units
COMAR	Code of Maryland Regulations
CSO	Combined Sewer Overflow
CSS	Combined Sewer System
CWA	Clean Water Act
DNR	Department of Natural Resources
EPA	Environmental Protection Agency
GIS	Geographic Information System
LA	Load Allocation
MACS	Maryland Agricultural Cost Share Program
MDE	Maryland Department of the Environment
MDP	Maryland Department of Planning
MGD	Millions of Gallons per Day
ml	Milliliter(s)
MOS	Margin of Safety
MPN	Most Probable Number
MPR	Maximum Practicable Reduction
MS4	Municipal Separate Storm Sewer System
MST	Microbial Source Tracking
NPDES	National Pollutant Discharge Elimination System
NRCS	National Resources Conservation Service
RCC	Rates of Correct Classification
RESAC	Mid-Atlantic Regional Earth Science Applications Center
SSO	Sanitary Sewer Overflows
SW	Stormwater
STATSGO	State Soil Geographic Database
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WQIA	Water Quality Improvement Act
WLA	Wasteload Allocation
WQLS	Water Quality Limited Segment
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes a Total Maximum Daily Load (TMDL) for fecal bacteria in the Loch Raven Reservoir watershed (Maryland 8-digit assessment unit MD-02130805). Section 303(d) of the federal Clean Water Act (CWA) and the 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, states are required to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards or demonstrate that water quality standards are being met.

The Maryland Department of the Environment (MDE) has identified the tributaries of Loch Raven Reservoir on the State's 303(d) List [Category 5 of the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report)] as impaired by fecal bacteria (listed in 2008) and impacts to biological communities (listed in 2002, 2004 and 2008). The reservoir itself is not listed as impaired by fecal bacteria. The Loch Raven Reservoir and all its tributaries have been designated as Use III-P (Nontidal Cold Water and Public Water Supply). See Code of Maryland Regulations (COMAR) 26.08.02.08J. This document proposes to establish a TMDL for fecal bacteria in the Loch Raven Reservoir watershed that will allow for attainment of the beneficial use designation of water contact recreation. The listings for impacts to biological communities will be addressed in a separate TMDL document. Listings for the impoundment have already been addressed by TMDLs for phosphorus, sediments and mercury, and a WQA for heavy metals. MDE monitored the Loch Raven Reservoir watershed from 2003-2004 for fecal bacteria. A data solicitation for fecal bacteria was conducted by MDE in 2003, and all readily available data from the past five years were considered. To account for portions of subwatersheds located in Pennsylvania (PA), an upstream load allocation (LA_{PA}), determined to be necessary in order to meet MD water quality standards in the MD portion of the watershed, is also included in this TMDL.

For this TMDL analysis, the Loch Raven Reservoir watershed has been divided into eight subwatersheds. For convenience, seven of these will be referenced by the downstream bacteria monitoring station's name and location: GUN0387 (Gunpowder Falls at Falls Road), LIT0002 (Little Falls), GUN0284 (Gunpowder Falls at Corbett Road), GUN0233 (Gunpowder Falls at Phoenix Road), WGP0050 (Western Run), BEV0005 (Beaverdam Run), and SBH0002 (Spring Branch). The eighth subwatershed encompasses all unmonitored areas downstream of the seven stations, excepting the impoundment, and will be referred to as the Downstream Subwatershed. The pollutant loads set forth in this document are for these eight subwatersheds. To establish baseline and allowable pollutant loads for this TMDL, a flow duration curve approach was employed, using bacteria data from MDE and flow strata estimated from United States Geological Survey (USGS) daily flow monitoring. The sources of fecal bacteria are estimated at seven representative stations in the Loch Raven Reservoir watershed where samples were collected for one year. Multiple antibiotic resistance analysis (ARA) source tracking was used to determine the relative proportion of domestic (pets and human associated animals), human (human waste), livestock (agriculture-related animals), and wildlife (mammals and waterfowl) source categories.

The baseline load is estimated from current monitoring data using a long-term geometric mean and weighting factors from the flow duration curve. The TMDL for fecal bacteria entering the Loch Raven Reservoir watershed is established after considering two different hydrological conditions: an average annual condition and an average seasonal dry weather condition (the period between May 1st and September 30th when water contact recreation is more prevalent). The allowable load quantified by the TMDL is reported in units of Most Probable Number (MPN)/day and represents a long-term load estimated over a variety of hydrological conditions.

Two scenarios were developed, with the first assessing if attainment of current water quality standards could be achieved by applying maximum practicable reductions (MPRs), and the second applying higher reductions than MPRs. Scenario solutions were based on an optimization method where the objective was to minimize the overall risk to human health, assuming that the risk varies across the four bacteria source categories. In six of the eight subwatersheds, it was estimated that water quality standards could not be attained with MPRs; thus, higher maximum reductions were applied.

The MD 8-digit Loch Raven Reservoir Total Baseline Load consists of upstream loads generated outside the MD 8-digit watershed assessment unit: a Pennsylvania Upstream Baseline Load (BL_{PA}), plus loads generated within the assessment unit: a MD 8-digit Loch Raven Reservoir Baseline Load (BL_{LR}) Contribution. The baseline loads are summarized in the following table:

MD 8-Digit Loch Raven Reservoir Fecal Bacteria Baseline Loads (Billion MPN *E. coli*/year)								
Total Baseline Load	**=**	**Upstream Baseline Load[1]**	**+**	**MD 8-digit Loch Raven Reservoir Baseline Load Contribution**				
		BL_{PA}		**Nonpoint Source BL_{LR}**	**+**	**NPDES Stormwater BL_{LR}**	**+**	**WWTP BL_{LR}**
2,194,308	=	7,106	+	2,033,052	+	152,583	+	1,567

[1]Although the upstream baseline load is reported here as a single value, it could include point and nonpoint sources.

The MD 8-digit Loch Raven Reservoir TMDL of fecal bacteria consists of an annual average allocation attributed to loads generated outside the assessment unit: a Pennsylvania Upstream Load Allocation (LA_{PA}), plus allocations attributed to loads generated within the assessment unit: a MD 8-digit Loch Raven Reservoir TMDL Contribution.

The MD 8-digit Loch Raven Reservoir TMDL Contribution, representing the sum of individual TMDLs for the eight subwatersheds or portions thereof within MD, is distributed between a load allocation (LA_{LR}) for nonpoint sources and waste load allocations (WLA_{LR}) for point sources. Point sources include any National Pollutant Discharge Elimination System (NPDES) wastewater treatment plants (WWTPs) and NPDES regulated stormwater (SW) discharges, including county and municipal separate storm sewer systems (MS4s). The margin of safety (MOS) has been incorporated using a conservative assumption by estimating the loading capacity of the stream based on a water quality endpoint concentration more stringent than the applicable MD water quality standard criterion. The *E. coli* water quality criterion concentration was reduced by 5%, from 126 MPN/100ml to 119.7 MPN/100ml.

The MD 8-digit Loch Raven Reservoir TMDL of fecal bacteria is presented in the following table:

MD 8-Digit Loch Raven Reservoir Fecal Bacteria TMDL (Billion MPN *E. coli*/year)										
TMDL	**=**	**LA**			**+**	**WLA**			**+**	**MOS**
		LA_{PA}[1]	**+**	**LA_{LR}**		**SW WLA_{LR}**	**+**	**WWTP WLA_{LR}**		
513,894	=	6,200	+	487,750	+	18,377	+	1,567	+	Incorpo-rated
		Upstream Load Allocation		MD 8-digit Loch Raven Reservoir TMDL Contribution (507,694)						

[1]Although the upstream load is reported here as a single value, it could include point and nonpoint sources.

The LA_{PA}, accounting for portions of subwatersheds located in Pennsylvania, is determined to be necessary in order to meet MD water quality standards in the MD 8-digit Loch Raven Reservoir watershed. The LA_{PA} represents a reduction of approximately 13% from the PA baseline load of 7,106 billion MPN *E. coli*/year. The MD 8-digit TMDL Contribution (507,694 billion MPN *E. coli*/year) represents a reduction of approximately 77% from the MD 8-digit Baseline Load Contribution of 2,187,202 billion MPN *E. coli*/year.

Pursuant to recent EPA guidance (US EPA 2006a), maximum daily load (MDL) expressions of the long-term annual average TMDLs are also provided, as shown in the following table:

MD 8-Digit Loch Raven Reservoir Fecal Bacteria MDL Summary (Billion MPN *E. coli*/day)										
MDL	**=**	**LA**			**+**	**WLA**			**+**	**MOS**
		LA_{PA}	**+**	**LA_{LR}**		**SW WLA_{LR}**	**+**	**WWTP WLA_{LR}**		
17,951	=	243	+	16,876	+	819	+	13	+	Incorpo-rated
		Upstream MDL		MD 8-digit Loch Raven Reservoir MDL Contribution (17,708)						

Once EPA has approved a TMDL, MDE intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impacts to water quality and creating the greatest risks to human health, with consideration given to ease and cost of implementation. In addition, follow-up monitoring plans will be established to track progress and to assess the implementation efforts. As previously stated, water quality standards cannot be attained in six of the eight subwatersheds using the MPR scenario. MPRs may not be sufficient in subwatersheds where wildlife is a significant component or where very high reductions of fecal bacteria loads are required to meet water quality standards. In these cases, it is expected that the MPR scenario will be the first stage of TMDL implementation. Progress will be made through the iterative implementation process described above, and the situation will be reevaluated in the future..

1.0 INTRODUCTION

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes a Total Maximum Daily Load (TMDL) for fecal bacteria in the Loch Raven Reservoir watershed (Maryland 8-digit assessment unit MD-02130805). Section 303(d)(1)(C) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) implementing regulations direct each state to develop a TMDL for each impaired water quality limited segment (WQLS) on the Section 303(d) List, taking into account seasonal variations and a protective margin of safety (MOS) to account for uncertainty. A TMDL reflects the total pollutant loading of the impairing substance a waterbody can receive and still meet water quality standards.

TMDLs are established to achieve and maintain water quality standards. A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include activities such as swimming, drinking water supply, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. Criteria may differ among waters with different designated uses.

The Maryland Department of the Environment (MDE) has identified the tributaries of Loch Raven Reservoir on the State's 303(d) List [Category 5 of the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report)] as impaired by fecal bacteria (listed in 2008) and impacts to biological communities (listed in 2002, 2004 and 2008). The reservoir itself is not listed as impaired by fecal bacteria. The Loch Raven Reservoir and all its tributaries have been designated as Use III-P (Nontidal Cold Water and Public Water Supply). See Code of Maryland Regulations (COMAR) 26.08.02.08J. This document proposes to establish a TMDL for fecal bacteria in the Loch Raven Reservoir watershed that will allow for attainment of the beneficial use designation of water contact recreation. The listings for impacts to biological communities will be addressed in a separate TMDL document. Listings for the impoundment have already been addressed by TMDLs for phosphorus, sediments and mercury, and a WQA for heavy metals. MDE monitored the Loch Raven Reservoir watershed from 2003-2004 for fecal bacteria. A data solicitation for fecal bacteria was conducted by MDE in 2003, and all readily available data from the past five years were considered. To account for portions of subwatersheds located in Pennsylvania (PA), an upstream load allocation (LA_{PA}), determined to be necessary in order to meet MD water quality standards in the MD portion of the watershed, is also included in this TMDL.

Fecal bacteria are microscopic single-celled organisms (primarily fecal coliform and fecal streptococci) found in the wastes of warm-blooded animals. Their presence in water is used to assess the sanitary quality of water for body-contact recreation, for consumption of molluscan bivalves (shellfish), and for drinking water. Excessive amounts of fecal bacteria in surface water used for recreation are known to indicate an increased risk of pathogen-induced illness to humans. Infections due to pathogen-contaminated recreation waters include gastrointestinal, respiratory, eye, ear, nose, throat, and skin diseases (US EPA 1986).

In 1986, EPA published "Ambient Water Quality Criteria for Bacteria," in which three indicator organisms were assessed to determine their correlation with swimming-associated illnesses. Fecal coliform, *E. coli* and enterococci were the indicators used in the analysis. Fecal coliform bacteria are a subgroup of total coliform bacteria and *E. coli* bacteria are a subgroup of fecal coliform bacteria. Most *E. coli* are harmless and are found in great quantities in the intestines of people and warm-blooded animals. However, certain pathogenic strains may cause illness. Enterococci are a subgroup of bacteria in the fecal streptococcus group. Fecal coliform, *E. coli* and enterococci can all be classified as fecal bacteria. The results of the EPA study demonstrated that fecal coliform showed less correlation to swimming-associated gastroenteritis than did either *E. coli* or enterococci.

Based on EPA's guidance (US EPA 1986), adopted by Maryland in 2004, the State has revised the bacteria water quality criteria and it is now based on water column limits for either *E. coli* or enterococci. Because multiple monitoring datasets are available within this watershed for various pathogen indicators, the general term "fecal bacteria" will be used to refer to the impairing substance throughout this document. The TMDL will be based on the pathogen indicator organisms specified in MD's current bacteria water quality criteria, either *E. coli* or enterococci. The indicator organism used in the Loch Raven Reservoir TMDL analysis was *E. coli*.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

Location

The Loch Raven Reservoir watershed is located in both Maryland (MD) and Pennsylvania (PA), with a drainage area of 224.4 square miles (143,617 acres). The majority of the watershed is in MD with a portion in York County, PA (see Figure 2.1.1). The MD portion is largely in Baltimore County, with small areas in Carroll and Harford counties.

The watershed includes the towns of Lutherville, Timonium, Cockeysville, Phoenix, Parkton, and Hampstead. The tributaries to the reservoir include Gunpowder Falls, Greene Branch, Beaverdam Run, Royston Branch, Overshot Run, Merryman Branch, Fitzhugh Run, Jenkins Run, Dulaney Branch, Kelly Branch, Spring Branch, Long Quarter Branch and Rush Brook. Gunpowder Falls begins at the outlet of the Prettyboy Reservoir. A major tributary to Gunpowder Falls is Little Falls, which begins near the PA border. See Figure 2.1.1.

Antidegradation Policy and Tier II Waters

Antidegradation is one of three key components required by the Clean Water Act. These three components are: designated uses, water quality criteria, and antidegradation policy. The Clean Water Act's (CWA) Tier II antidegradation policy is found in section 303(d) and its goals are to 1) ensure that no activity will lower water quality to support existing uses, and 2) maintain and protect high quality waters.

Waters of the Loch Raven Reservoir watershed designated as Tier II are listed in Table 2.1.1.

Table 2.1.1: High Quality (Tier II) Waters in the Loch Raven Reservoir Watershed

Tier II Segment	County	Segment Length (miles)	Subwatershed
Beetree Run 1	Baltimore	1.59	LIT0002
First Mine Branch 1	Baltimore, Harford	3.15	LIT0002
Little Falls 1	Baltimore	0.96	LIT0002
Blackrock Run 1	Baltimore	1.41	WGP0050
Delaware Run 1	Baltimore	0.73	WGP0050
Indian Run 1	Baltimore	0.85	WGP0050
Western Run 1	Baltimore	1.64	WGP0050

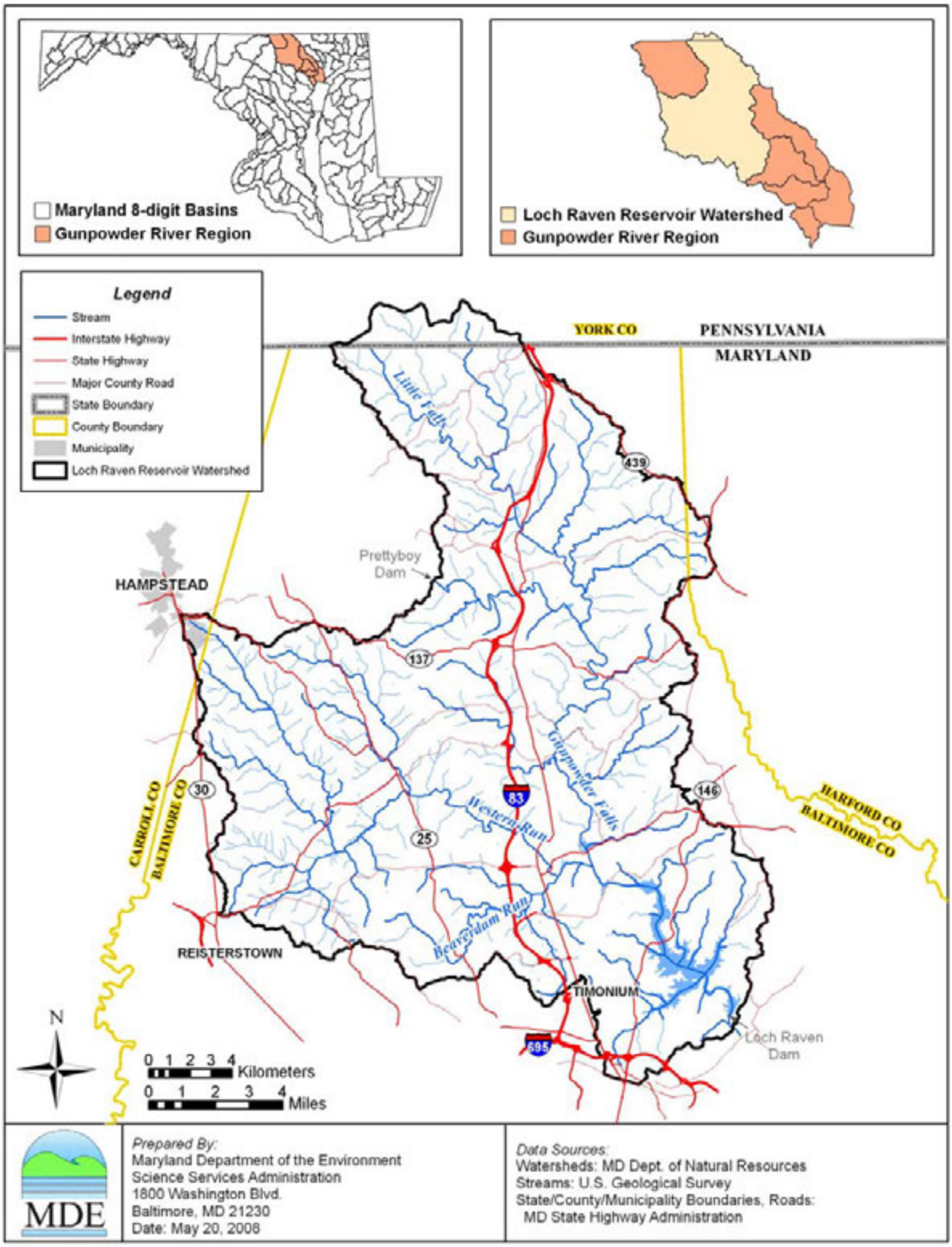

Figure 2.1.1: Location Map of the Loch Raven Reservoir Watershed

Land Use

The Loch Raven Reservoir watershed covers an area of 143,617 acres in MD and PA. Based on the 2002 Maryland Department of Planning (MDP) land use/land cover data, MD's portion of the watershed can be characterized as primarily forest and agricultural land, but with significant urban area as well. The forested areas are mainly along Gunpowder Falls and surrounding the reservoir. The urban areas are mostly in the southern part of the watershed. Regional Earth Science Application Center (RESAC) land use/land cover was used to estimate the land use for the PA portion of the watershed. RESAC shows that the PA portion is largely pasture and agricultural.

The land use acreage and percentage distribution is shown in Table 2.1.1, and spatial distributions for each land use are shown in Figure 2.1.2. Table 2.1.2 shows the land use percentage distribution for each of the eight subwatersheds considered in the analysis. Note that seven of the subwatersheds are identified by the MDE monitoring stations located in the mainstem of the river and its main tributaries, and are listed by flow from upstream to downstream. The eighth subwatershed encompasses all unmonitored areas downstream of the monitoring stations, excepting the impoundment, and is identified as the Downstream Subwatershed.

Table 2.1.2: Land Use Percentage Distribution for the Loch Raven Reservoir Watershed

Land Type	Maryland Area		Pennsylvania Area		*Total*	
	Acres	%	Acres	%	Acres	%
Forest	52,000	36.9	515	19.0	52,515	36.6
Agricultural	42,410	30.1	826	30.5	43,236	30.1
Urban	34,201	24.3	333	12.3	34,534	24.0
Pasture	10,201	7.2	1,037	38.3	11,238	7.8
Water	2,093	1.5	1	0.02	2,094	1.5
Total	**140,905**	**100**	**2,712**	**100**	**143,617**	**100**

Table 2.1.3: Land Use Percentage Distribution for the Loch Raven Reservoir Watershed

Station / Subwatershed	Land Use Area (%)				
	Agricultural	Forest	Pasture	Urban	Water
GUN0387 / Gunpowder Falls at Falls Rd.	5.1	78.5	3.0	13.3	0.04
LIT0002 / Little Falls	34.7	38.1	12.9	14.3	0.01
GUN0284 / Gunpowder Falls at Corbett Rd.	23.4	53.1	8.6	14.7	0.1
GUN0233 / Gunpowder Falls at Phoenix Rd.	36.0	35.2	10.8	18.0	0
WGP0050 / Western Run	48.8	32.7	6.7	11.8	0
BEV0005 / Beaverdam Run	12.1	23.7	1.2	62.9	0.1
SBH0002 / Spring Branch	0	2.7	0	97.3	0
Downstream Subwatershed	7.1	39.5	4.4	41.0	7.9

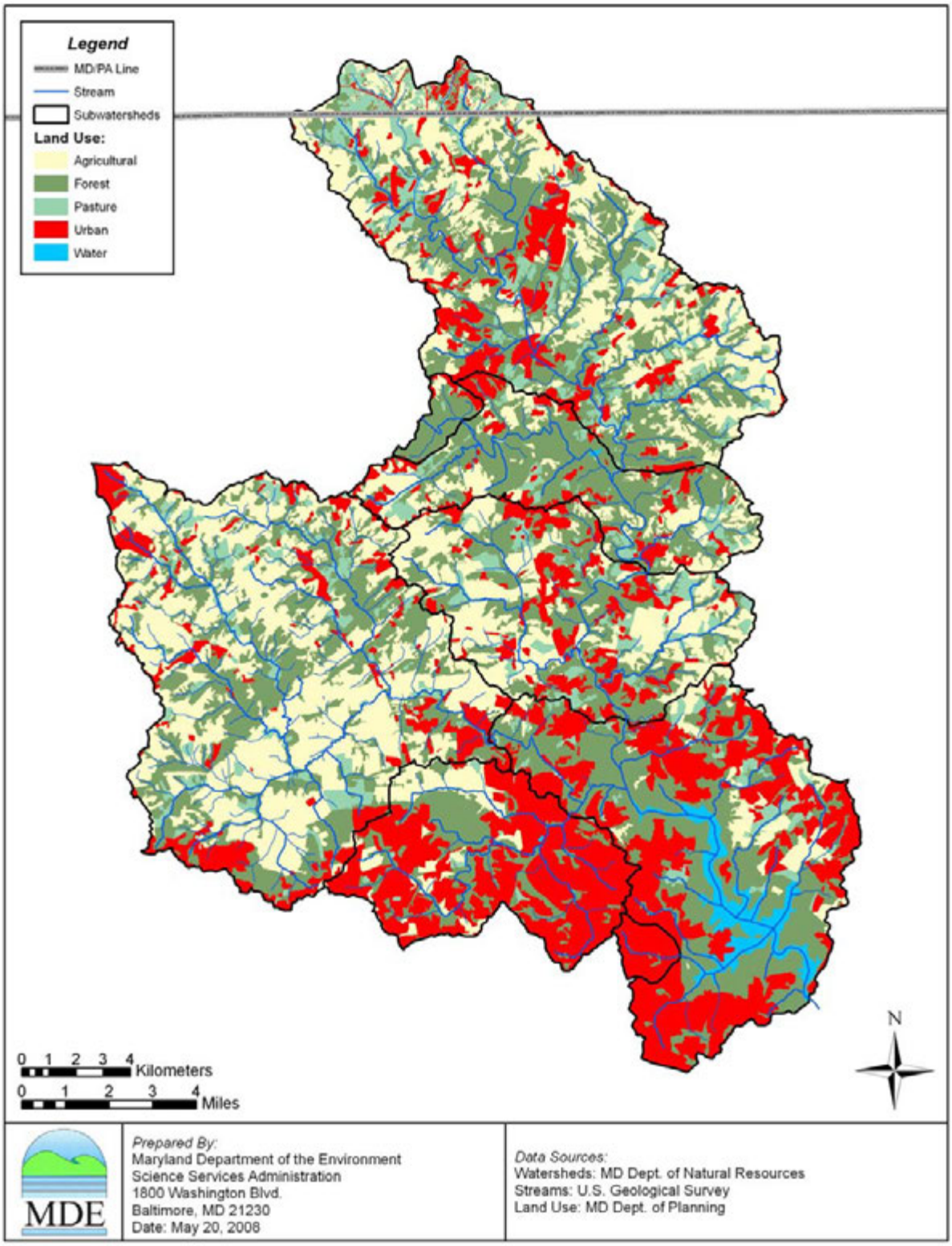

Figure 2.1.2: Land Use of the Loch Raven Reservoir Watershed

Population

The total population in the Loch Raven Reservoir watershed is estimated to be 90,345 people. Figure 2.1.3 illustrates the population density in the watershed. The human population in the Pennsylvania portion of the watershed was estimated based on a weighted average from the 2000 Census GIS Block Groups and the RESAC land cover mapping. Since the boundaries of the watershed differ from the boundaries of the block groups, residential land use data were used to extract the necessary areas of the Census block groups. The residential density designations used for this estimation are shown in Table 2.1.3. The population in the Maryland portion of the watershed was estimated based on a weighted average from the Census block groups and the 2007 MDP Property View. The population for each subwatershed was estimated and is presented in Table 2.1.4.

Table 2.1.4: Number of Dwellings Per Acre

Land Use Code	Dwellings Per Acre
Low Density Residential	1
Medium Density Residential	5
High Density Residential	8

Table 2.1.5: Total Population Per Subwatershed in the Loch Raven Reservoir Watershed

Station / Subwatershed	Population
GUN0387 / Gunpowder Falls at Falls Rd.	219
LIT0002 / Little Falls	8,346
GUN0284 / Gunpowder Falls at Corbett Rd.	2,938
GUN0233 / Gunpowder Falls at Phoenix Rd.	4,854
WGP0050 / Western Run	9,580
BEV0005 / Beaverdam Run	24,541
SBH0002 / Spring Branch	4,940
Downstream Subwatershed	34,927
Total	**90,345**

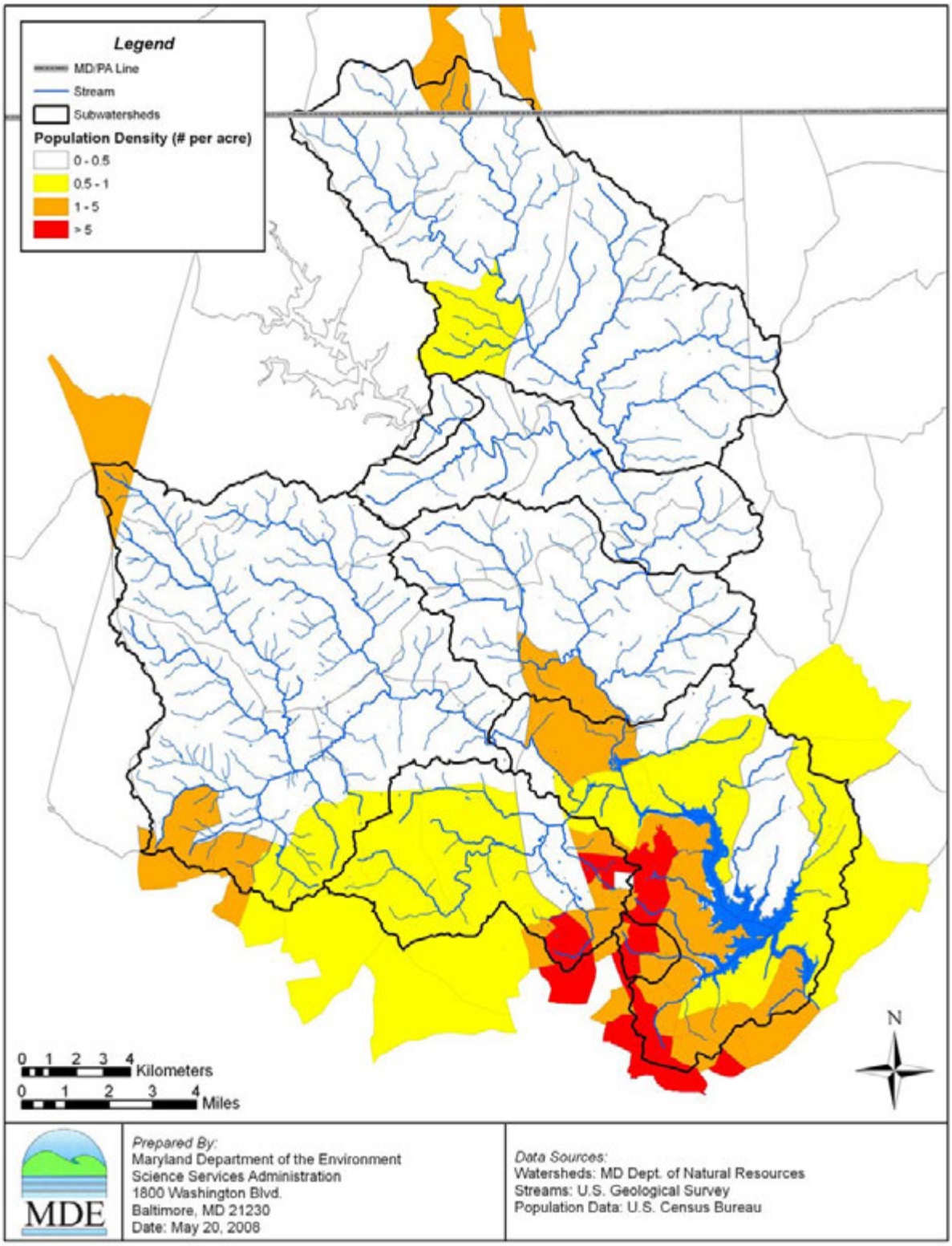

Figure 2.1.3: Population Density in the Loch Raven Reservoir Watershed

2.2 Water Quality Characterization

EPA's guidance document, "Ambient Water Quality Criteria for Bacteria" (1986), recommended that states use *E. coli* (for fresh water) or enterococci (for fresh or salt water) as pathogen indicators. Fecal bacteria, *E. coli*, and enterococci were assessed as indicator organisms for predicting human health impacts. A statistical analysis found that the highest correlation to gastrointestinal illness was linked to elevated levels of *E. coli* and enterococci in fresh water (enterococci in salt water).

As per EPA's guidance, Maryland has adopted the new indicator organisms, *E. coli* and enterococci, for the protection of public health in Use I, II, III and IV waters. These bacteria listings were originally assessed using fecal coliform bacteria. The analysis was based on a geometric mean of the monitoring data, where the result had to be less than or equal to 200 MPN/100ml. From EPA's analysis (US EPA 1986), this fecal coliform geometric mean target equates to an approximate risk of 8 illnesses per 1,000 swimmers at fresh water beaches and 19 illnesses per 1,000 swimmers at marine beaches (enterococci only), which is consistent with MDE's revised Use I bacteria criteria. Therefore, the original 303(d) List fecal coliform listings can be addressed using the refined bacteria indicator organisms to ensure that risk levels are acceptable.

Bacteria Monitoring

Table 2.2.1 lists the historical monitoring data for the Loch Raven Reservoir watershed. MDE conducted monitoring sampling at seven stations in the Loch Raven Reservoir watershed from November 2003 through October 2004. Four United States Geological Survey (USGS) gage stations were used in deriving the surface water flow. The locations of these stations are shown in Tables 2.2.2 to 2.2.4 and in Figure 2.2.1. Observations recorded from the seven MDE monitoring stations are provided in Appendix A.

Bacteria counts are highly variable, which is typical due to the nature of bacteria and their relationship to flow. The E. coli counts for the seven stations ranged between 1 and 14,140 MPN/100 ml.

Table 2.2.1: Historical Monitoring Data in the Loch Raven Reservoir Watershed

Organization	Date	Design	Summary
DNR	01/1986 through 12/2003	Fecal Coliform*	1 station 1 sample per month
MDE	11/2003 through 10/2004	*E. coli*	7 stations 2 samples per month
MDE	11/2003 through 10/2004	BST (*Enterococcus)*	7 stations 1 sample per month

*Only *E. coli* was used for this analysis.

Table 2.2.2: Location of DNR Core Station in the Loch Raven Reservoir Watershed

Station	Tributary	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)
GUN0258	Gunpowder Falls	39.550	-76.636

Table 2.2.3: Location of MDE Monitoring Stations in Loch Raven Reservoir Watershed

Tributary	Station	Observation Period	Total Observations	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)
Gunpowder Falls	GUN0387	2003 – 2004	24	39.619	-76.690
Little Falls	LIT0002	2003 – 2004	24	39.602	-76.622
Gunpowder Falls	GUN0284	2003 – 2004	24	39.568	-76.611
Gunpowder Falls	GUN0233	2003 – 2004	23	39.519	-76.620
Western Run	WGP0050	2003 – 2004	24	39.511	-76.677
Beaverdam Run	BEV0005	2003 – 2004	24	39.487	-76.645
Spring Branch	SBH0002	2003 – 2004	24	39.440	-76.597

Table 2.2.4: Location of USGS Gauging Stations in Loch Raven Reservoir Watershed

Site Number	Observation Period Used	Total Observations	Latitude	Longitude
01582000	1982-2007	9,131	39.604	-76.620
01582500	1982-2007	9,061	39.550	-76.636
01583500	1982-2007	9,131	39.511	-76.677
01583600	1982-2007	9,131	39.486	-76.646

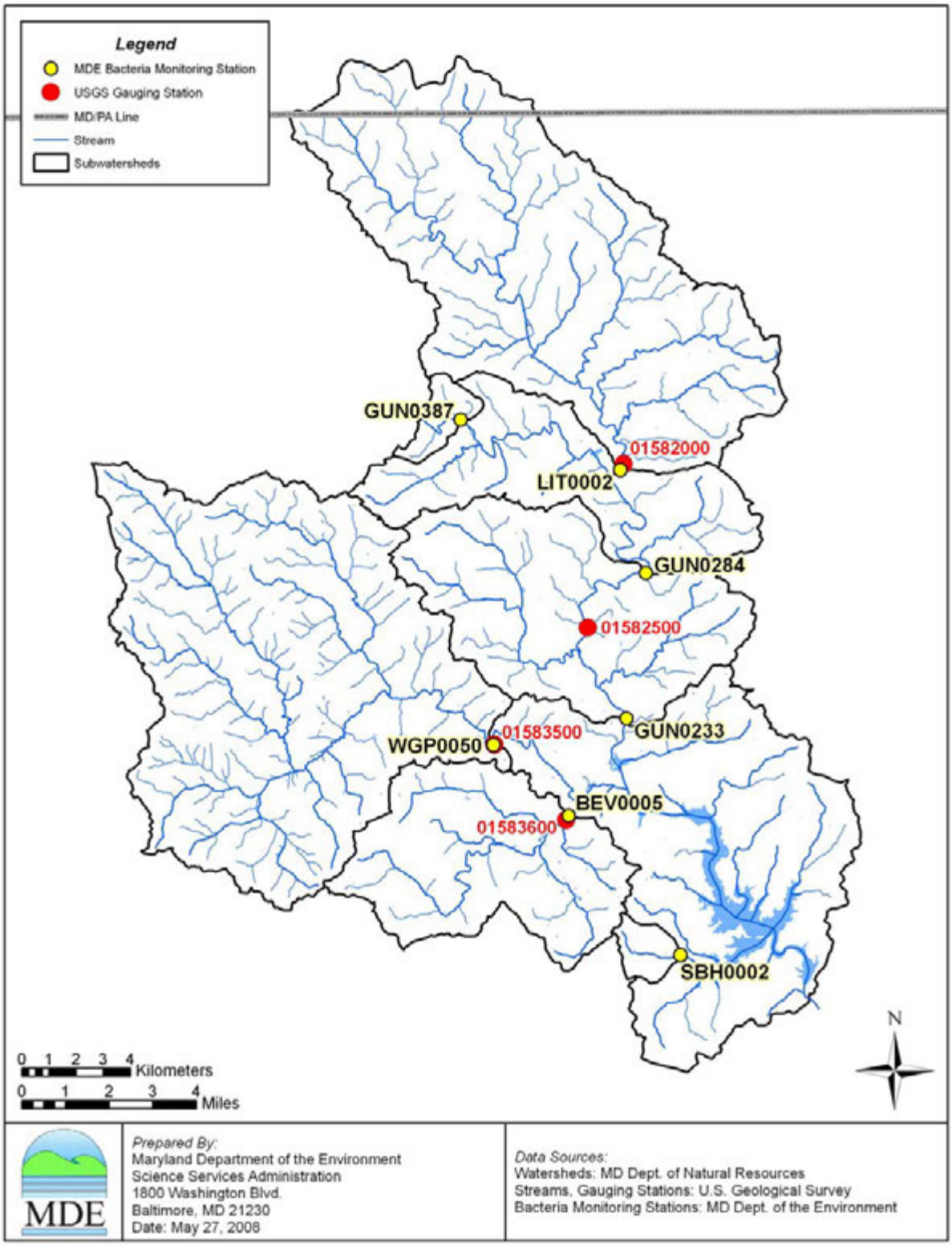

Figure 2.2.1: Monitoring Stations and Subwatersheds in the Loch Raven Reservoir Watershed

2.3 Water Quality Impairment

Designated Uses and Water Quality Standard

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the waters of the MD 8-digit Loch Raven Reservoir watershed is Use III-P (Nontidal Cold Water and Public Water Supply). (COMAR 26.08.02.08J) The waters of the MD 8-digit Loch Raven Reservoir watershed were listed on Maryland's 303(d) List [Category 5 of the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report)] as impaired by fecal bacteria in 2008.

Water Quality Criteria

The State water quality standard for bacteria applicable to freshwater and used in this study is as follows:

Table 2.3.1: Bacteria Criteria Values
(Source: COMAR 26.08.02.03-3 Water Quality Criteria Specific to Designated Uses; Table 1)

Indicator	Steady-State Geometric Mean Indicator Density
Freshwater	
E. coli	126 MPN/100ml

Water Quality Assessment

Interpretation of Bacteria Data for General Recreational Use

Pursuant to the 2008 Integrated Report, the requirements to confirm a Category 5 listing for fecal bacteria impairment in all Use Waters (Water Contact Recreation and Protection of Aquatic Life) are as follows:

A steady-state geometric mean will be calculated with available data from the previous two to five years. The data shall be from samples collected during steady-state, dry weather conditions and during the beach season (Memorial Day through Labor Day), to be representative of the critical condition (highest water contact recreation use). If the resulting steady-state geometric mean is greater than 35 cfu/100 ml enterococci in marine/estuarine waters, 33 cfu/100 ml enterococci in freshwater, or 126 cfu/100 ml *E. coli* in freshwater, the waterbody is confirmed as impaired and a TMDL should be established.

Bacteria water quality impairment in the MD 8-digit Loch Raven Reservoir watershed was assessed as explained above, by comparing the dry weather steady-state geometric means of *E.*

coli concentrations for each subwatershed of the Loch Raven Reservoir with the water quality criterion. The 1986 EPA criteria guidance document assumed steady-state conditions in determining the risk at various bacterial concentrations, and therefore the chosen criterion value of 126 cfu/100 ml *E. coli* also reflects steady-state conditions (EPA 1986).

The dry weather steady-state geometric means are calculated using samples taken during non-rainy days and from May 1st to September 30th, capturing the beach season. Results of these calculations are presented in Table 2.3.2. As shown in the table below, all but one of the seven monitored subwatersheds of the Loch Raven Reservoir had steady-state geometric mean concentrations of *E. coli* above the water quality criterion, supporting the 2008 listing for fecal bacteria and it is therefore concluded that a TMDL is required.

Table 2.3.2: Loch Raven Reservoir Watershed Dry Weather Period Steady-State Geometric Means

Station / Tributary	Number of Samples	Seasonal Steady-State Geometric Mean (MPN/100ml)	Water Quality Criterion (MPN/100ml)
GUN0387 Gunpowder Falls at Falls Rd.	10	18	126
LIT0002 Little Falls	10	139	126
GUN0284 Gunpowder Falls at Corbett Rd.	10	168	126
GUN0233 Gunpowder Falls at Phoenix Rd.	10	224	126
WGP0050 Western Run	10	491	126
BEV0005 Beaverdam Run	9	611	126
SBH0002 Spring Branch	10	1,080	126

2.4 Source Assessment

Nonpoint Source Assessment

Nonpoint sources of fecal bacteria do not have one discharge point but occur over the entire length of a stream or waterbody. During rain events, surface runoff transports water and fecal bacteria over the land surface and discharges to the stream system. This transport is dictated by rainfall, soil type, land use, and topography of the watershed. Many types of nonpoint sources introduce fecal bacteria to the land surface, including the manure spreading process, direct deposition from livestock during the grazing season, and excretions from pets and wildlife. The deposition of non-human fecal bacteria directly to the stream occurs when livestock, domestic animals, or wildlife have direct access to the waterbody. Nonpoint source contributions from human sources generally arise from failing septic systems and their associated drain fields or leaking infrastructure (i.e., sewer systems).

Sewer Systems

The MD Loch Raven Reservoir watershed is serviced by both sewer systems and septic systems. Sewer systems are present in the towns of Timonium, Cockeysville, and Hampstead. Wastewater collected by the Hampstead WWTP is treated and discharged into Piney Run, a tributary of Western Run.

Septic Systems

On-site disposal (septic) systems are located throughout the Loch Raven Reservoir watershed. Table 2.4.1 presents the number of septic systems per subwatershed in MD. Figure 2.4.1 displays the areas that are serviced by sewers and the locations of the septic systems in MD.

Table 2.4.1: Septic Systems Per Subwatershed in the Loch Raven Reservoir Watershed in MD

Station / Subwatershed	Septic Systems
GUN0387 / Gunpowder Falls at Falls Rd.	79
LIT0002 / Little Falls	2,407
GUN0284 / Gunpowder Falls at Corbett Rd.	997
GUN0233 / Gunpowder Falls at Phoenix Rd.	1,483
WGP0050 / Western Run	2,379
BEV0005 / Beaverdam Run	3,961
SBH0002 / Spring Branch	6
Downstream Subwatershed	4,331
Total	**15,643**

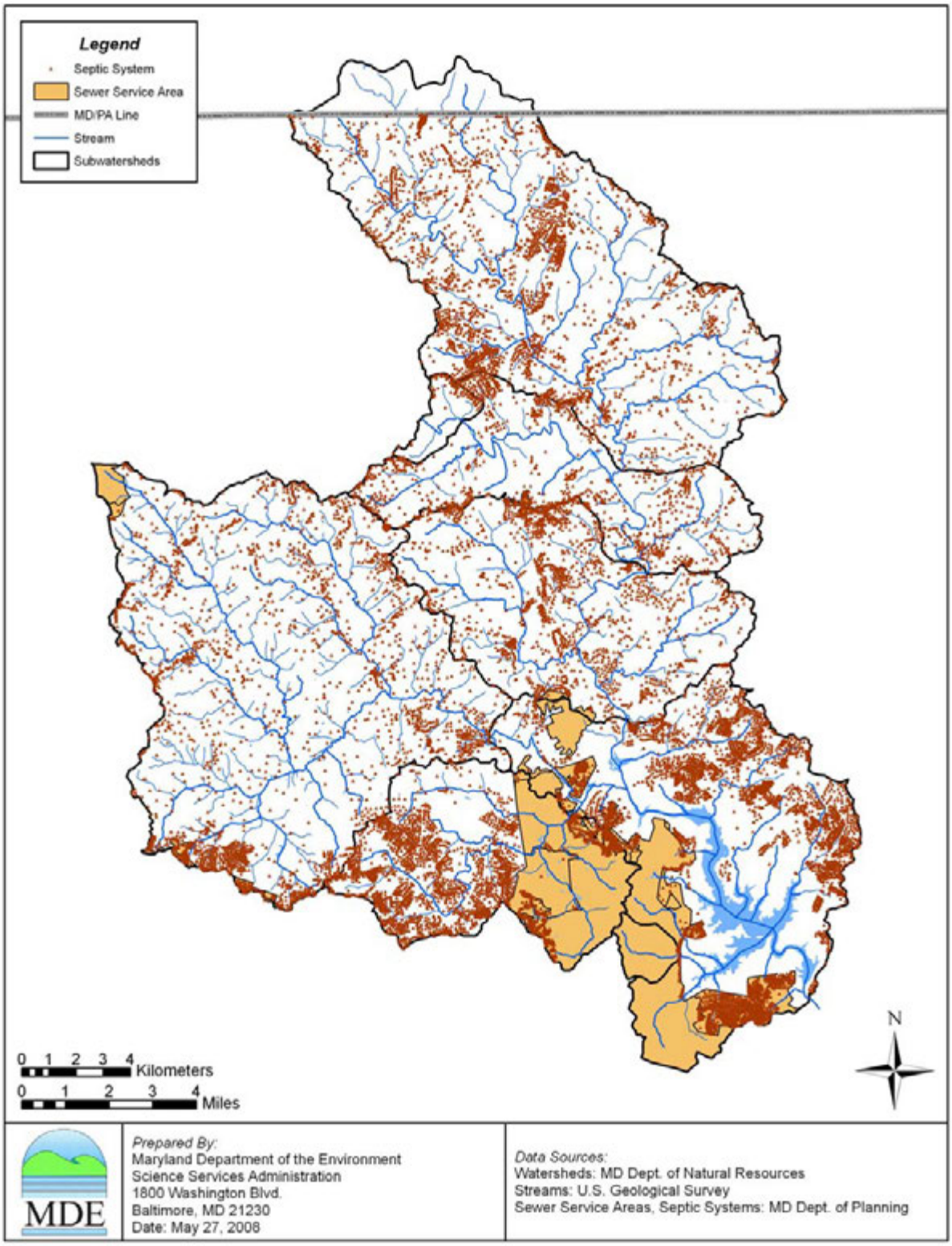

Figure 2.4.1: Sanitary Sewer Service Areas and Septic Locations in MD's Portion of the Loch Raven Reservoir Watershed

Point Source Assessment

There are two broad types of National Pollutant Discharge Elimination System (NPDES) permits considered in this analysis; individual and general. Both types of permits include industrial and municipal categories. Individual permits are issued for industrial and municipal WWTPs and Phase I municipal separate storm sewer systems (MS4s). MDE general permits have been established for surface water discharges from: Phase II and other MS4 entities; surface coal mines; mineral mines; quarries; borrow pits; ready-mix concrete; asphalt plants; seafood processors; hydrostatic testing of tanks and pipelines; marinas; concentrated animal feeding operations; and stormwater associated with industrial activities.

NPDES Regulated Stormwater

NPDES regulated stormwater discharges are considered point sources subject to assignment to the waste load allocation (WLA). Stormwater runoff is an important source of water pollution, including bacterial pollution. For example, domestic animal and wildlife waste may be transported through an MS4 conveyance or system of conveyances. MS4s may include roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, storm drains, best management practices (BMPs), and environmental site design (ESD), designed or used for collecting and conveying, or treating and reducing, stormwater before delivering it to a waterbody. MS4 stormwater management programs are designed to reduce the amount of pollution that enters a waterbody from storm sewer systems to the maximum extent practicable.

MD's portion of the Loch Raven Reservoir watershed is located in Baltimore, Carroll, and Harford Counties, which all have individual Phase I NPDES MS4 permits. The municipality of Hampstead is covered separately by a general Phase II NPDES MS4 permit. Nonpoint source bacteria loads attributable to these MS4s, and any other Phase I and Phase II NPDES-regulated stormwater entities in the watershed, including the MD State Highway Administration (SHA) Phase I MS4, Phase II State and federal MS4s, and industrial stormwater permittees, are combined in aggregate stormwater waste load allocations (SW-WLAs) in this TMDL.

Sanitary Sewer Overflows

Sanitary Sewer Overflows (SSOs) occur when the capacity of a separate sanitary sewer is exceeded. There are several factors that may contribute to SSOs from a sewerage system, including pipe capacity, operations and maintenance effectiveness, sewer design, age of system, pipe materials, geology and building codes. SSOs are prohibited by the facilities' permits, and must be reported to MDE's Water Management Administration in accordance with COMAR 26.08.10 to be addressed under the State's enforcement program.

There were a total of 8 SSOs reported to MDE between November 2003 and October 2004 in the Loch Raven Reservoir watershed. Approximately 14,000 gallons of SSOs were discharged through various waterways (surface water, groundwater, sanitary sewers, etc.). Figure 2.4.2 shows the locations where SSOs occurred in the MD portion of the watershed between November 2003 and October 2004.

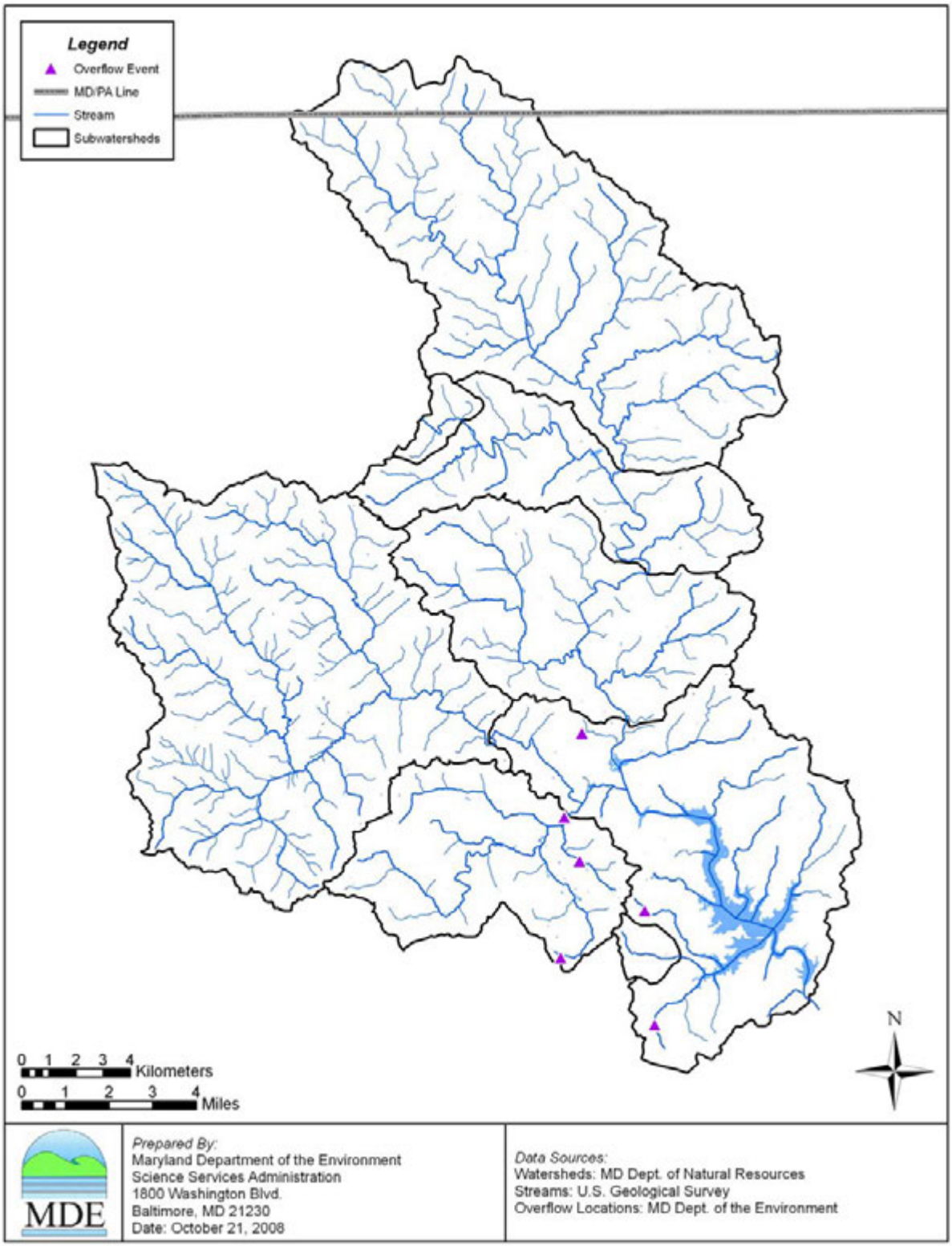

Figure 2.4.2: Sanitary Sewer Overflow Areas in the Loch Raven Reservoir Watershed

Municipal and Industrial Wastewater Treatment Plants (WWTPs)

WWTPs are designed to treat wastewater before it is discharged to a stream or river. The goals of wastewater treatment are to protect the public health, protect aquatic life, and to prevent harmful substances from entering the environment.

Based on MDE's point source permitting information, there is one active municipal NPDES permitted point source facility with a permit regulating the discharge of fecal bacteria in the Loch Raven Reservoir watershed. This facility, Hampstead WWTP, treats approximately 0.94 MGD (million gallons per day). There are no industrial facilities in the Loch Raven Reservoir watershed with NPDES permits regulating the discharge of fecal bacteria. Table 2.4.2 lists the Hampstead facility and Figure 2.4.3 shows its location in the watershed.

Table 2.4.2: NPDES Permit Holders Regulated for Fecal Bacteria Discharge in the Loch Raven Reservoir Watershed

Facility	NPDES Permit No.	County	Average Flow (MGD)	Fecal Coliform Concentration Annual AVG (MPN/100ml)	Fecal Coliform Load (Billion MPN/day)
Hampstead WWTP	MD0022446	Carroll	0.944	7.9	0.28

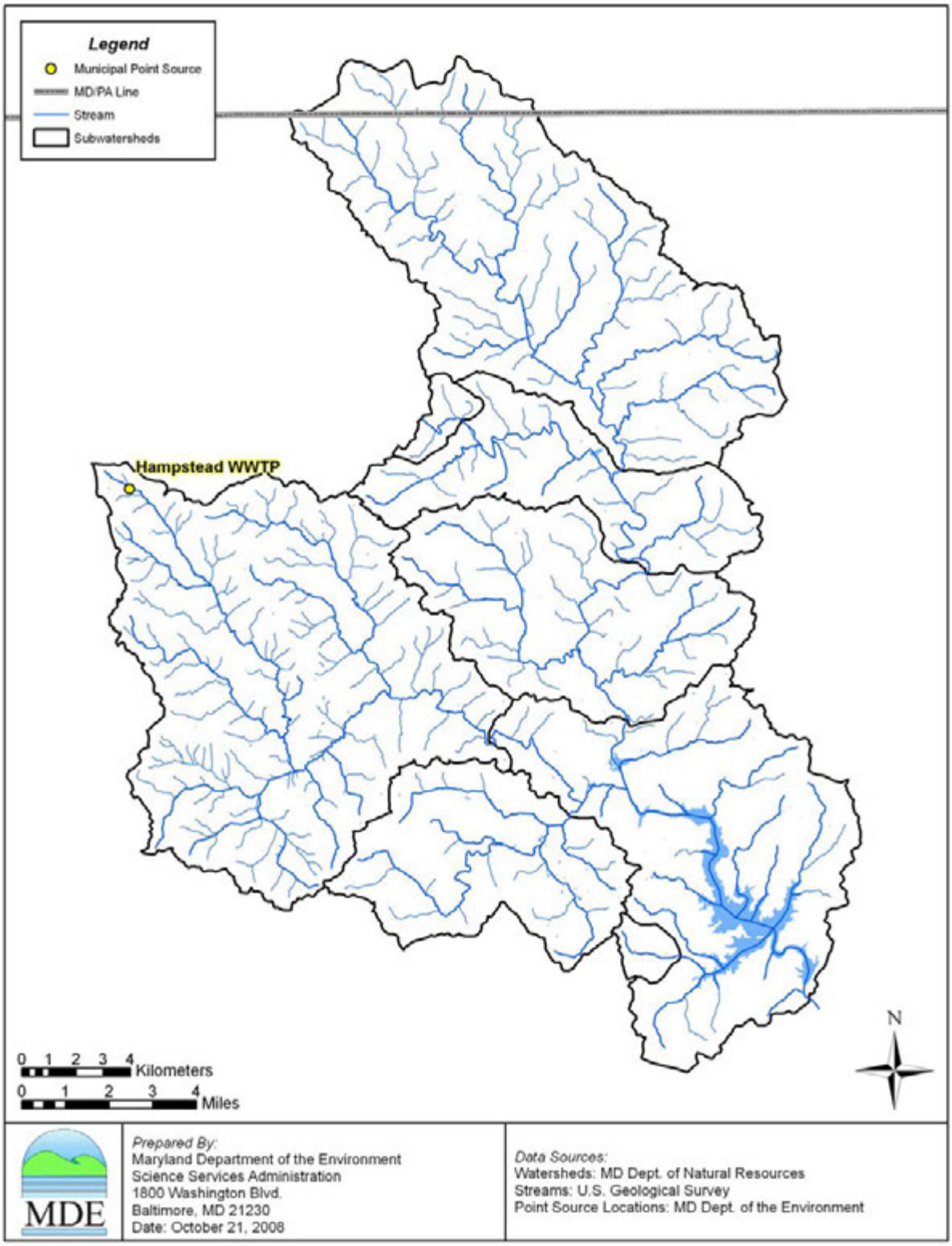

Figure 2.4.3: Permitted Point Sources Discharging Fecal Bacteria in the Loch Raven Reservoir Watershed

Bacteria Source Tracking

Bacteria source tracking (BST) was used to identify the relative contributions of different sources of bacteria to in-stream water samples. BST monitoring was conducted at five stations in the Loch Raven Reservoir watershed, where samples were collected once per month for a one-year duration. Sources are defined as domestic (pets and human associated animals), human (human waste), livestock (agricultural animals), and wildlife (mammals and waterfowl). Samples are collected within the watershed from known fecal sources, and a BST technique known as antibiotic resistance analysis (ARA) was used to identify the patterns of antibiotic resistance of these known sources. To identify probable sources, these antibiotic resistance patterns are then compared to isolates of unknown bacteria from ambient water samples. Figure 2.4.4 presents the relative contributions by probable sources of bacteria for the Loch Raven Reservoir Watershed. Details of the BST methodology and data can be found in Appendix C.

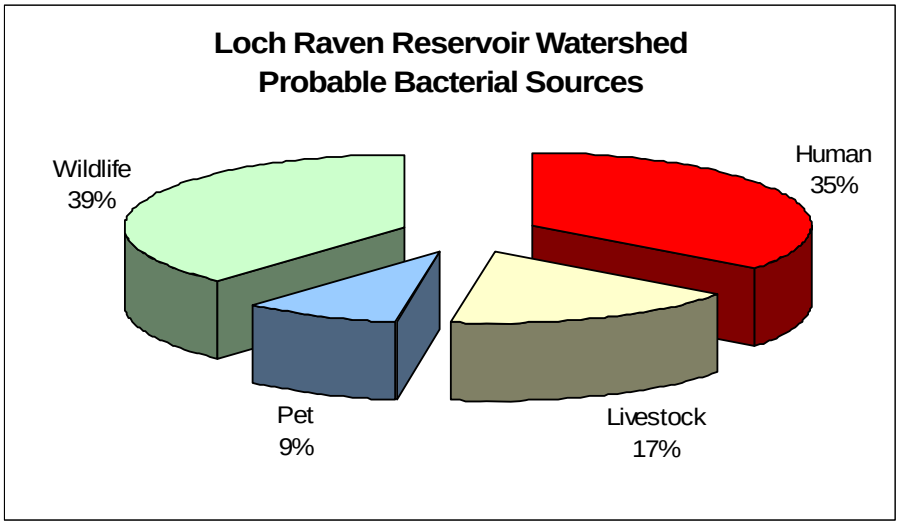

Figure 2.4.4: Loch Raven Reservoir Watershed Relative Contributions by Probable Sources of Fecal Bacteria Contamination

3.0 TARGETED WATER QUALITY GOAL

The overall objective of the fecal bacteria TMDL set forth in this document is to establish the loading caps needed to assure attainment of water quality standards in the Loch Raven Reservoir watershed. These standards are described fully in Section 2.3, "Water Quality Impairment."

4.0 TOTAL MAXIMUM DAILY LOADS AND SOURCE ALLOCATION

4.1 Overview

This section provides an overview of the non-tidal fecal bacteria TMDL development, with a discussion of the many complexities involved in estimating bacteria concentrations, loads, and sources. Section 4.2 presents the analysis framework and how the hydrological, water quality, and BST data are linked together in the TMDL process. Section 4.3 describes the analysis for estimating a representative geometric mean fecal bacteria concentration and baseline loads. This analysis methodology is based on available monitoring data and is specific to a free-flowing stream system. Section 4.4 shows how the BST analysis results are used to estimate the relative contributions of the different sources of bacteria for each subwatershed of the Loch Raven Reservoir watershed. Section 4.5 addresses the critical condition and seasonality. Section 4.6 presents the margin of safety. Section 4.7 discusses annual average TMDL loading caps and how maximum daily loads are estimated. Section 4.8 presents TMDL scenario descriptions. Section 4.9 presents the load allocations. Finally, in Section 4.10, the TMDL equation is summarized.

To be most effective, the TMDL provides a basis for allocating loads among the known pollutant sources in the watershed so that appropriate control measures can be implemented and water quality standards achieved. By definition, the TMDL is the sum of the individual waste load allocations (WLAs) for point sources and load allocations (LAs) for non point sources and natural background sources. A margin of safety (MOS) is also included and accounts for the uncertainty in the analytical procedures used for water quality modeling, as well as the limits in scientific and technical understanding of water quality in natural systems. Although this formulation suggests that the TMDL be expressed as a load, the Code of Federal Regulations (40 CFR 130.2(i)) states that the TMDL can be expressed in terms of “mass per time, toxicity or other appropriate measure.”

For many reasons, bacteria are difficult to simulate in water quality models. They reproduce and die off in a non-linear fashion as a function of many environmental factors, including temperature, pH, turbidity (UV light penetration) and settling. They occur in concentrations that vary widely (i.e., over orders of magnitude) and an accurate estimation of source inputs is difficult to develop. Finally, limited data are available to characterize the effectiveness of any program or practice at reducing bacteria loads (Schueler 1999).

Bacteria concentrations, determined through laboratory analysis of in-stream water samples for bacteria indicators (e.g., enterococci), are expressed in either colony forming units (CFU) or most probable number (MPN) of colonies. The first method (US EPA 1985) is a direct estimate of the bacteria colonies (Method 1600). The second method is a statistical estimate of the number of colonies (ONPG MUG Standard Method 9223B, AOAC 991.15). Sample results indicate the extreme variability in the total bacteria counts (see Appendix A). The distribution of the sample results tends to be lognormal, with a strong positive skew of the data. Estimating loads of constituents that vary by orders of magnitude can introduce much uncertainty and result in large confidence intervals around the final results.

Estimating bacteria sources can also be problematic due to the many assumptions required and limited available data. Lack of specific numeric and spatial location data for several source categories, from failing septic systems to domestic animals, livestock, and wildlife populations, can create many potential uncertainties in traditional water quality modeling. For this reason, MDE applies an analytical method combined with the bacteria source tracking described above for the calculation of this TMDL.

4.2 Analytical Framework

The TMDL analysis uses flow duration curves to identify flow intervals that are used as indicators of hydrological conditions (i.e., annual average and critical conditions). This analytical method, combined with water quality monitoring data and BST, provides reasonable results (Cleland 2003), a better description of water quality than traditional water quality modeling, and also meets TMDL requirements.

In brief, baseline loads are estimated first for each subwatershed by using bacteria monitoring data and long-term flow data. These baseline loads are divided into four bacteria source categories, using the results of BST analysis. Next, the percent reduction required to meet the water quality criterion in each subwatershed is estimated from the observed bacteria concentrations after accounting for critical condition and seasonality. Critical condition and seasonality are determined by assessing annual and dry weather seasonal hydrological conditions. Finally, TMDLs for each subwatershed are estimated by applying these percent reductions.

Figure 4.2.1 illustrates how the hydrological (flow duration curve), water quality, and BST data are linked together for the TMDL development.

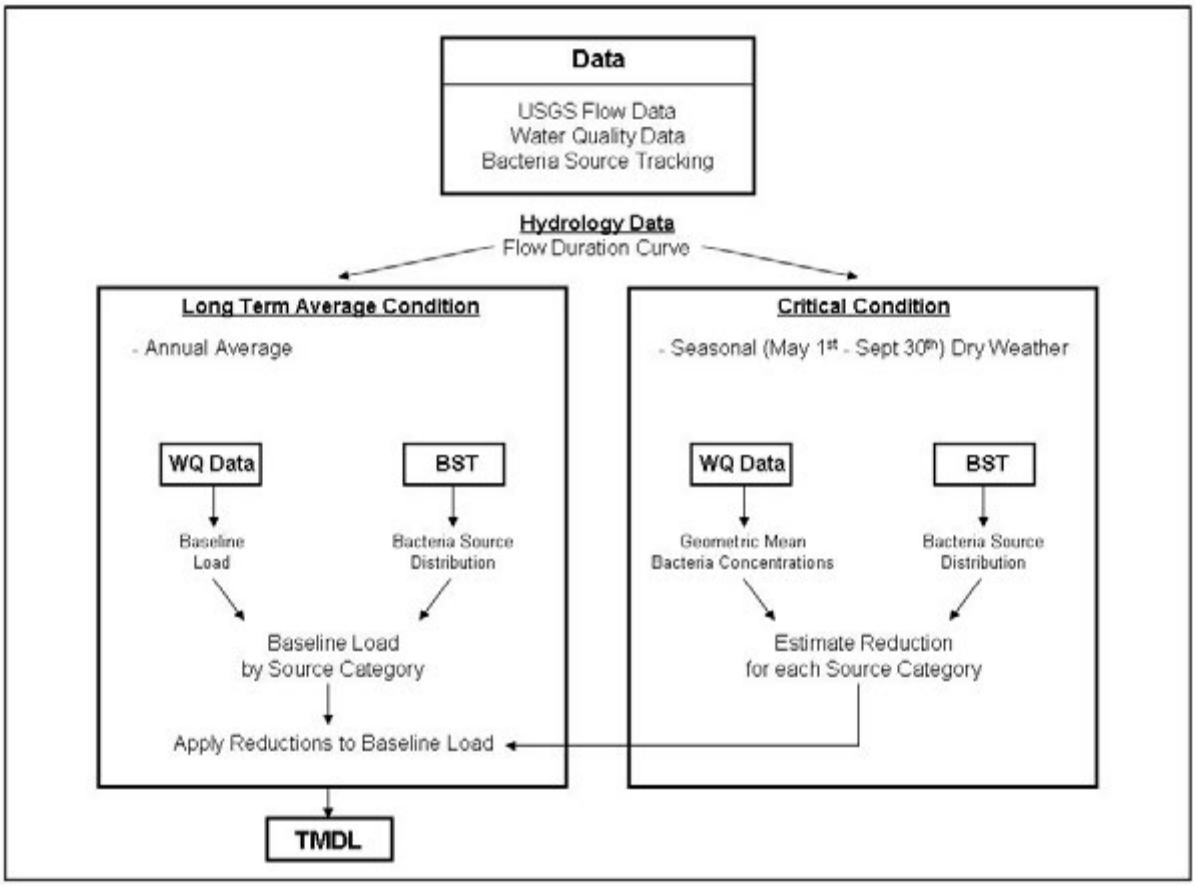

Figure 4.2.1: Diagram of the Non-tidal Bacteria TMDL Analysis Framework

4.3 Estimating Baseline Loads

Baseline loads are estimated for all subwatersheds of the Loch Raven Reservoir watershed. Baseline loads estimated in this TMDL analysis are reported as long-term average annual loads. These loads are estimated using geometric mean concentrations and bias correction factors (calculated from bacteria monitoring data) and daily average flows (estimated from long-term flow data).

Estimating Weighted Annual Average Geometric Mean Concentrations

The weighted annual average geometric mean used in the calculation of baseline loads can be estimated either by monitoring design or by statistical analysis as follows:

1. A stratified monitoring design is used where the number of samples collected is proportional to the duration of high flows, mid flows, and low flows within the watershed. This sample design allows a geometric mean to be calculated directly from the monitoring data without bias.

2. Routine monitoring typically results in samples from varying hydrologic conditions (i.e., high flows, mid flows, and low flows) where the numbers of samples are not proportional to the duration of those conditions. Averaging these data without consideration of the sampling conditions results in a biased estimate of geometric means. The potential bias of these geometric means can be reduced by weighting the sampling results collected during high flow, mid flow, and low flow regimes by the proportion of time each flow regime is expected to occur. This ensures that the high flow and low flow conditions are proportionally balanced.

3. If (1) the monitoring design was not stratified based on flow regime or (2) flow information is not available to weight the samples accordingly, then a geometric mean of sequential monitoring data can be used as an estimate of the geometric mean for the specified period.

A routine monitoring design was used to collect bacteria data in the Loch Raven Reservoir watershed. To estimate the weighted geometric mean, the monitoring data were first reviewed by plotting the sample results versus their corresponding daily flow duration percentile.

To calculate the weighted geometric mean with routine monitoring data, a conceptual model was developed by dividing the daily flow frequency for the stream segment into strata that are representative of hydrologic conditions. A conceptual continuum of flows is illustrated in Figure 4.3.1.

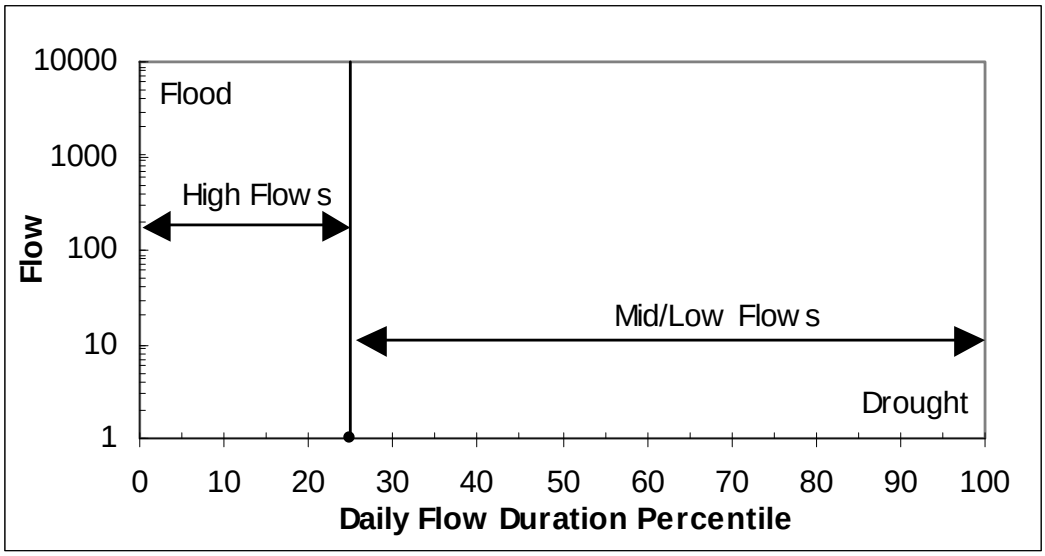

Figure 4.3.1: Conceptual Diagram of Flow Duration Zones

During high flows, a significant portion of the total stream flow is from surface flow contributions. Low flow conditions represent periods with minimal rainfall and surface runoff. There is typically a transitional mid flow period between the high and low flow durations, representative of varying contributions of surface flow inputs that result from differing rainfall volumes and antecedent soil moisture conditions. Because the bacteria samples were taken during a routine monitoring design and not a stratified monitoring design, the division of the entire flow regime into strata enables the estimation of a less flow-biased geometric mean.

Based on flow data of USGS gages 01582000, 01582500, 01583500 and 01583600 it was determined that the long-term average daily flow corresponds to a daily flow duration of 34.3%. Hence for this analysis it is defined that flows greater than the 34.3 percentile flow represent high flows, and flows lesser than the 34.3 percentile flow represent mid/low flows. A detailed method of how the flow strata were defined is presented in Appendix B.

Factors for estimating a weighted geometric mean are based on the frequency of each flow stratum. The weighting factor accounts for the proportion of time that each flow stratum represents. The weighting factors for an average hydrological year used in the Loch Raven Reservoir watershed TMDL analysis are presented in Table 4.3.1.

Table 4.3.1: Weighting Factors for Average Hydrology Year Used for Estimation of Geometric Means in the Loch Raven Reservoir Watershed

Flow Duration Zone	Duration Interval	Weighting Factor
High Flows	0 – 34.3%	0.343
Mid/Low Flows	34.3 – 100%	0.657

Bacteria enumeration results for samples within a specified stratum will receive their corresponding weighting factor. The geometric mean is calculated as follows:

$$M = \sum_{i=1}^{2} M_i * W_i \qquad (1)$$

where,

$$M_i = \frac{\sum_{j=1}^{n_i} \log_{10}(C_{i,j})}{n_i} \qquad (2)$$

M = log weighted mean
M_i = log mean concentration for stratum i
W_i = proportion of stratum i
$C_{i,j}$ = concentration for sample j in stratum i
n_i = number of samples in stratum

Finally, the weighted geometric mean concentration is estimated using the following equation:

$$C_{gm} = 10^{M} \qquad (3)$$

where,

C_{gm} = Steady-state geometric mean concentration

For both the annual and seasonal analysis only the overall geometric mean for the period was applied due to an insufficient number of samples in both hydrological conditions. Table 4.3.2 presents the annual maximum and minimum concentrations and the overall annual geometric means for each subwatershed of the Loch Raven Reservoir. Table 4.3.3 presents the seasonal dry weather steady-state (May 1st –September 30th) maximum and minimum concentrations and the overall geometric mean concentrations for each subwatershed. Graphs illustration these results can be found in Appendix B. For the downstream subwatershed the average geometric mean concentrations of the three upstream watersheds, GUN0233, WGP0050 and BEV0005, were applied to account for the unmonitored streams. The watershed of SBH0002 was not used in this calculation due to its unique land use (highly urbanized) conditions and extreme concentrations.

Table 4.3.2: Loch Raven Reservoir Watershed Annual Geometric Means

Station / Tributary	**Number of Samples**	***E. coli* Minimum Concentration** (MPN/100ml)	***E. coli* Maximum Concentration** (MPN/100ml)	**Annual* Average Geometric Mean** (MPN/100ml)
GUN0387 Gunpowder Falls at Falls Rd.	24	1	120	14
LIT0002 Little Falls	24	10	770	96
GUN0284 Gunpowder Falls at Corbett Rd.	24	10	770	75
GUN0233 Gunpowder Falls at Phoenix Rd.	23	10	14,140	142
WGP0050 Western Run	24	10	2,910	233
BEV0005 Beaverdam Run	24	20	2,500	213
SBH0002 Spring Branch	24	30	9,210	300
Downstream Subwatershed	N/A			196

*** Used for estimating average annual baseline loads**

Table 4.3.3: Loch Raven Reservoir Watershed Seasonal (May 1 - September 30) Dry Weather Steady-State Geometric Means

Station / Tributary	Number of Samples	*E. coli* Minimum Concentration (MPN/100ml)	*E. coli* Maximum Concentration (MPN/100ml)	Dry Weather* Steady-State Geometric Mean (MPN/100ml)
GUN0387 Gunpowder Falls at Falls Rd.	10	10	120	18
LIT0002 Little Falls	10	10	770	139
GUN0284 Gunpowder Falls at Corbett Rd.	10	50	770	168
GUN0233 Gunpowder Falls at Phoenix Rd.	10	60	3,800	224
WGP0050 Western Run	10	190	1,400	491
BEV0005 Beaverdam Run	9	140	2,500	611
SBH0002 Spring Branch	10	260	9,210	1,080
Downstream Subwatershed	N/A			442

***Used for estimating reductions needed to meet water quality standards**

As stated previously, for both the annual and seasonal analysis an overall geometric mean was calculated, rather than by flow stratum, due to an insufficient number of samples in the two flow conditions. The geometric mean concentration is calculated from the log transformation of the raw data. Statistical theory tells us that when back-transformed values are used to calculate average daily loads or total annual loads, the loads will be biased low (Richards 1998). To avoid this bias, a factor should be added to the log-concentration before it is back-transformed. There are several methods of determining this bias correction factor, ranging from parametric estimates resulting from the theory of the log-normal distribution to non-parametric estimates using a bias correction factor [Ferguson 1986; Cohn et al. 1989; Duan 1983]. There is much literature on the applicability and results from these various methods with a summary provided in Richards (1998). Each has advantages and conditions of applicability. A non-parametric estimate of the bias correction factor (Duan 1983) was used in this TMDL analysis.

With calculated geometric means and arithmetic means for each subwatershed, the bias correction factors are estimated as follows:

$$F_1 = A/C \qquad (6)$$

where,

F_1 = bias correction factor
A = long term annual arithmetic mean
C = long term annual geometric mean

Daily average flows are estimated for each subwatershed using the watershed area ratio approach, since nearby long-term monitoring data are available.

For each subwatershed, the baseline loads are then estimated as follows:

$$L = Q * C * F_1 * F_2 \qquad (7)$$

where,

L = daily average load (Billion MPN/day) at monitoring station
Q = daily average flow (cfs)
C = geometric mean (MPN/100ml)
F_1 = bias correction factor
F_2 = unit conversion factor (0.0245)

Estimating Subwatershed Loads

Subwatersheds with more than one monitoring station are subdivided into unique watershed segments, thus allowing individual load and reduction targets to be determined for each. In the Loch Raven Reservoir watershed two stations have upstream monitoring stations, as listed in Table 4.3.4. In these two cases the subwatershed is differentiated by adding the extension "sub" to the name of the downstream monitoring station. For example, GUN0233sub signifies only the area and load between stations GUN0233 and GUN0284 while GUN0233 refers to the cumulative area draining to that station. The portion of the watershed downstream of stations, GUN0233, WGP0050, BEV0005 and SBH0002, is referred to as the Downstream Subwatershed. This identification represents only the area and load downstream of those four stations. There are a total of eight subwatersheds considered in this analysis, corresponding to the seven monitoring stations and the unmonitored downstream portion.

Table 4.3.4: Subdivided Watersheds in the Loch Raven Reservoir Watershed

Subwatershed	Upstream Station(s)
GUN0284sub	GUN0387, LIT0002
GUN0233sub	GUN0284
Downstream Subwatershed	GUN0233, WGP0050, BEV0005, SBH0002

Bacteria loads from these subwatersheds are joined by loads from their upstream subwatersheds to result in the concentration measured at the downstream monitoring station. The total baseline loads from the upstream watersheds, estimated from the monitoring data, were multiplied by a transport factor derived from first order decay. The decay factor for *E. coli* used in the analysis was obtained from the study "Pathogen Decay in Urban Waters" by Easton et al. (2001), and was estimated by linear regression of counts of microorganisms versus time (die-off plots). The estimated transported loads were then subtracted from the downstream cumulative load to estimate the adjacent subwatershed load. The general equation for the flow mass balance is:

$$\sum Q_{us} + Q_{sub} = Q_{ds} \qquad (8)$$

where,

Q_{us} = upstream flow (cfs)
Q_{sub} = subwatershed flow (cfs)
Q_{ds} = downstream flow (cfs)

And the general equation for the bacteria loading mass balance is:

$$\sum (e^{-kt} Q_{us} C_{us}) + Q_{sub} C_{sub} = Q_{ds} C_{ds} \qquad (9)$$

where,

C_{us} = upstream bacteria concentration (MPN/100ml)
k = bacteria (*E. coli*) decay coefficient (1/day) = 0.762 day^{-1}
t = travel time from upstream watershed to outlet (days)
C_{sub} = subwatershed bacteria concentration (MPN/100ml)
C_{ds} = downstream bacteria concentration (MPN/100ml)

The subwatershed load, expressed as $Q_{sub}C_{sub}$ in equation (9), and the average flow are used to estimate the geometric mean concentration of the subwatershed.

As explained above, to estimate the load from subwatershed GUN0284sub, the transported load from stations GUN0387 and LIT0002 is subtracted from the load measured at station GUN0284. The difference is assigned to subwatershed GUN0284sub. To estimate the load from subwatershed GUN0233sub, the transported load from stations GUN0284 is subtracted from the load measured at station GUN0233. The difference is assigned to subwatershed GUN0233sub.

Source estimates from the BST analysis are completed for each station and are based on the contribution from the upstream watershed. Given the uncertainty of in-stream bacteria processes and the complexity involved in back-calculating an accurate source transport factor, the sources for GUN0284sub and GUN0233sub were assigned from the analysis for GUN0284 and GUN0233, respectively.

The bacteria concentration for the watershed referred to as the Downstream Subwatershed, is assigned as the average of the concentrations at the three upstream stations, GUN0233, WGP0050 and BEV0005, and is assumed to be representative of that subwatershed. The bacteria source distribution for the downstream subwatershed is also assigned as the average of the BST analysis results of the three specified upstream stations.

Results of the baseline load calculations, including subwatersheds partially located in PA, are presented in Table 4.3.5.

Table 4.3.5: Baseline Loads Calculations

Subwatershed	Area (mi^2)	Daily Average Flow (cfs)	*E. coli* Concentration (MPN/100ml)	Baseline *E. coli* Load (Billion MPN/year)
GUN0387	1.8	2.3	14	460
LIT0002[1]	53.8	70.3	96	97,368
GUN0284sub	18.6	24.3	343	142,466
GUN0233sub	26.9	35.2	572	1,177,287
WGP0050	60.1	69.7	233	307,744
BEV0005	20.9	30.3	213	115,900
SBH0002	1.5	2.2	300	21,893
Downstream Subwatershed	40.7	53.2	196	331,190

[1]Subwatershed partially located in Pennsylvania

Baseline loads for subwatersheds located in both MD and PA were estimated using the ratios of the areas of the MD and PA portions to the total area of the subwatershed. The total baseline

load for all subwatersheds or portions thereof located in MD is estimated as 2,187,202 billion MPN *E.coli*/year. The total baseline load for the portions of subwatersheds located in PA is 7,106 billion MPN E. coli/year. A summary of the baseline loads is given in Table 4.3.6.

Table 4.3.6: Baseline Loads Summary

MD 8-Digit Loch Raven Reservoir Fecal Bacteria Baseline Loads (Billion MPN *E. coli*/year)								
Total Baseline Load	**=**	**Upstream Baseline Load[1]**	**+**	**MD 8-digit Loch Raven Reservoir Baseline Load Contribution**				
		BL_{PA}		**Nonpoint Source BL_{LR}**	**+**	**NPDES Stormwater BL_{LR}**	**+**	**WWTP BL_{LR}**
2,194,308	=	7,106	+	2,033,052	+	152,583	+	1,567

[1]Although the upstream baseline load is reported here as a single value, it could include point and nonpoint sources.

4.4 Bacteria Source Tracking

As explained above in the Source Assessment Section, ARA was used to identify probable bacterial sources in the Loch Raven watershed. An accurate representation of the expected contribution of each source (human, pets, livestock and wildlife) at each station is estimated by using a weighted mean of the identified sample results. The weighting factors are based on the $\log_{10}$ of the bacteria concentration. The procedure for calculating the weighted mean of the sources per monitoring station is as follows:

1. Calculate the percentage of isolates per source per each sample date (S).
2. Calculate an initial weighted percentage (IMS) of each source. The weighting is based on the $\log_{10}$ bacteria concentration for the water sample.
3. Adjust the weighted percentage based on the classification of known sources.

The weighted mean for each source category is calculated using the following equations:

$$MS_l = \sum_{k=1}^{5} \frac{A_{l,k} * IMS_k}{P_k} \qquad (4)$$

where,

$$IMS_k = \frac{\sum_{j=1}^{n} \log_{10}(C_j) * S_{j,k}}{\sum_{j=1}^{n} \log_{10}(C_j)} \qquad (5)$$

and where,

MS_l = weighted mean proportion of isolates of source l
IMS_k = initial weighted mean proportion of isolates for source k

$A_{l,k}$ = number of known source l isolates initially predicted as source k
P_k = number of total known isolates initially predicted as source k
j = sample
k = source category (1=human, 2=domestic, 3=livestock, 4=wildlife, 5=unknown)
l = final source category (1=human, 2=domestic, 3=livestock, 4=wildlife)
C_j = concentration for sample j
$S_{j,k}$ = proportion of isolates for sample j, of source k
n = number of samples

The complete distributions of the annual and seasonal period source loads are listed in Tables 4.4.1 and 4.4.2. Details of the BST data and tables with the BST analysis results can be found in Appendix C. For the downstream subwatershed, averages of the three upstream (GUN0233, WGP0050 and BEV0005) source percentages were used.

Table 4.4.1: Distribution of Fecal Bacteria Source Loads in the Loch Raven Reservoir Watershed for the Average Annual Period

Station	% Domestic Animals	% Human	% Livestock	% Wildlife
GUN0387	7.9	41.4	4.7	46.0
LIT0002	5.0	53.8	10.6	30.7
GUN0284	15.1	26.0	13.4	45.5
GUN0233	6.4	26.2	13.7	53.7
WGP0050	5.4	28.1	14.3	52.2
BEV0005	7.6	37.4	12.4	42.6
SBH0002	5.4	33.1	13.9	47.6
Downstream Subwatershed	6.5	30.6	13.5	49.5

Table 4.4.2: Distribution of Fecal Bacteria Source Loads in the Loch Raven Reservoir Watershed for the Seasonal (May 1 – September 30) Dry Weather Period

Station	% Domestic Animals	% Human	% Livestock	% Wildlife
GUN0387	15.8	46.7	4.4	33.2
LIT0002	9.6	58.7	6.7	25.0
GUN0284	23.8	28.6	8.2	39.4
GUN0233	11.2	30.2	9.3	49.2
WGP0050	8.3	33.0	10.1	48.6
BEV0005	7.9	38.0	12.0	42.1
SBH0002	4.6	29.0	14.0	52.4
Downstream Subwatershed	9.2	33.7	10.5	46.6

4.5 Critical Condition and Seasonality

Federal regulations (40 CFR 130.7(c)(1)) require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when it is most vulnerable.

For this TMDL the critical condition is determined by assessing both the annual and dry weather seasonal conditions. Seasonality is assessed as the time period when water contact recreation is expected, specifically dry weather days during May 1st through September 30th. The critical condition requirement is met by determining the maximum reduction per bacteria source that satisfies both conditions and meets the water quality standard, thereby minimizing the risk to water contact recreation. It is assumed that the reduction applied to a bacteria source category will be constant through both conditions.

The reductions of fecal bacteria required to meet water quality standards in each subwatershed of the Loch Raven Reservoir watershed are shown in Table 4.4.1. For computational purposes, the calculations include those subwatersheds partially located in PA.

Table 4.5.1: Required Fecal Bacteria Reductions (by Condition) to Meet Water Quality Standards

Station	Condition	Domestic Animals %	Human %	Livestock %	Wildlife %
GUN0387	Annual	0.0	0.0	0.0	0.0
	Seasonal	0.0	0.0	0.0	0.0
	Maximum Source Reduction	**0.0**	**0.0**	**0.0**	**0.0**
LIT0002[1]	Annual	0.0	0.0	0.0	0.0
	Seasonal	0.0	23.7	0.0	0.0
	Maximum Source Reduction	**0.0**	**23.7**	**0.0**	**0.0**
GUN0284sub	Annual	98.0	98.0	98.0	25.7
	Seasonal	98.0	98.0	98.0	76.1
	Maximum Source Reduction	**98.0**	**98.0**	**98.0**	**76.1**
GUN0233sub	Annual	98.0	98.0	98.0	62.8
	Seasonal	98.0	98.0	98.0	68.3
	Maximum Source Reduction	**98.0**	**98.0**	**98.0**	**68.3**
WGP0050	Annual	98.0	98.0	98.0	3.4
	Seasonal	98.0	98.0	98.0	51.9
	Maximum Source Reduction	**98.0**	**98.0**	**98.0**	**51.9**
BEV0005	Annual	29.8	95.0	48.9	0.0
	Seasonal	98.0	98.0	98.0	56.2
	Maximum Source Reduction	**98.0**	**98.0**	**98.0**	**56.2**
SBH0002	Annual	98.0	98.0	98.0	18.3
	Seasonal	98.0	98.0	98.0	80.7
	Maximum Source Reduction	**98.0**	**98.0**	**98.0**	**80.7**
Downstream Subwatershed	Annual	28.8	95.0	59.9	0.0
	Seasonal	98.0	98.0	98.0	44.2
	Maximum Source Reduction	**98.0**	**98.0**	**98.0**	**44.2**

[1]Subwatersheds partially located in Pennsylvania

4.6 Margin of Safety

A margin of safety (MOS) is required as part of this TMDL in recognition of the many uncertainties in the understanding and simulation of bacteriological water quality in natural systems and in statistical estimates of indicators. As mentioned in Section 4.1, it is difficult to estimate stream loadings for fecal bacteria due to the variation in loadings across sample locations and time. Load estimation methods should be both precise and accurate to obtain the true estimate of the mean load.

Based on EPA guidance, the MOS can be achieved through two approaches (EPA 1991). One approach is to reserve a portion of the loading capacity as a separate term in the TMDL (i.e., TMDL = LA + WLA + MOS). The second approach is to incorporate the MOS as conservative assumptions used in the TMDL analysis. The second approach was used for this TMDL by estimating the loading capacity of the stream based on a reduced (more stringent) water quality criterion concentration. The *E. coli* water quality criterion concentration was reduced by 5%, from 126 *E. coli* MPN/100ml to 119.7 *E. coli* MPN/100ml.

4.7 Scenario Descriptions

Source Distribution

The final bacteria source distribution and corresponding baseline loads are derived from the source proportions listed in Table 4.4.1. The source distribution and baseline loads used in the TMDL scenarios are presented in Table 4.67.1. As stated in Section 4.3, the source distributions for subwatersheds GUN0284sub and GUN0233sub were based on the sources identified at stations GUN0284 and GUN0233 respectively.

Table 4.7.1: Bacteria Source Distributions and Corresponding Baseline Loads Used in the Annual Average TMDL Analysis

Subwatershed	Domestic		Human		Livestock		Wildlife		Total Load (Billion *E. coli* MPN/year)
	%	Load (Billion *E. coli* MPN/year)	%	Load (Billion *E. coli* MPN/year)	%	Load (Billion *E. coli* MPN/year)	%	Load (Billion *E. coli* MPN/year)	
GUN0387	7.9	36	41.4	190	4.7	22	46.0	212	460
LIT0002[1]	5.0	4,835	53.8	52,396	10.6	10,275	30.7	29,862	97,368
GUN0284sub	15.1	21,497	26.0	37,092	13.4	19,028	45.5	64,849	142,466
GUN0233sub	6.4	75,552	26.2	308,913	13.7	160,834	53.7	631,988	1,177,287
WGP0050	5.4	16,654	28.1	86,556	14.3	43,975	52.2	160,559	307,744
BEV0005	7.6	8,765	37.4	43,373	12.4	14,377	42.6	49,385	115,900
SBH0002	5.4	1,184	33.1	7,254	13.9	3,032	47.6	10,423	21,893
Downstream Subwatershed	6.5	21,408	30.6	101,331	13.5	44,551	49.5	163,900	331,190

[1]Subwatersheds partially located in Pennsylvania

First Scenario: Fecal Bacteria Practicable Reduction Targets

The maximum practicable reduction (MPR) for each of the four source categories is listed in Table 4.7.2. These values are based on review of the available literature and best professional judgment. It is assumed that human sources would potentially have the highest risk of causing gastrointestinal illness and therefore should have the highest reduction. If a domestic WWTP is located in the upstream watershed, this is considered in the MPR so as to not violate the permitted loads. The domestic animal category includes sources from pets (e.g., dogs) and the MPR is based on an estimated success of education and outreach programs.

Table 4.7.2: Maximum Practicable Reduction Targets

Max Practicable Reduction per Source	Human	Domestic	Livestock	Wildlife
	95%	75%	75%	0%
Rationale	(a) Direct source inputs. (b) Human pathogens more prevalent in humans than animals. (c) Enteric viral diseases spread from human to human.[1]	Target goal reflects uncertainty in effectiveness of urban BMPs[2] and is also based on best professional judgment	Target goal based on sediment reductions from BMPs[3] and best professional judgment	No programmatic approaches for wildlife reduction to meet water quality standards. Waters contaminated by wild animal wastes offer a public health risk that is orders of magnitude less than that associated with human waste.[4]

[1]Health Effects Criteria for Fresh Recreational Waters. EPA-600/1-84-004. U.S. Environmental Protection Agency, Washington, DC. EPA. 1984.
[2]Preliminary Data Summary of Urban Storm Water Best Management Practices. EPA-821-R-99-012. U.S. Environmental Protection Agency, Washington, DC. EPA. 1999.
[3]Agricultural BMP Descriptions as Defined for The Chesapeake Bay Program Watershed Model. Nutrient Subcommittee Agricultural Nutrient Reduction Workshop. EPA. 2004.
[4]Environmental Indicators and Shellfish Safety. 1994. Edited by Cameron, R., Mackeney and Merle D. Pierson, Chapman & Hall.

As previously stated, these maximum practicable reduction targets are based on the available literature and best professional judgment. There is much uncertainty with estimated reductions from best management practices (BMP). The BMP efficiency for bacteria reduction ranged from –6% to +99% based on a total of 10 observations (US EPA 1999). The MPR to agricultural lands was based on sediment reductions identified by EPA (US EPA 2004).

The practicable reduction scenario was developed based on an optimization analysis whereby a subjective estimate of risk was minimized and constraints were set on maximum reduction and allowable background conditions. Risk was defined on a scale of one to five, where it was assumed that human sources had the highest risk (5), domestic animals and livestock next (3), and wildlife the lowest (1) (See Table 4.7.2). The model was defined as follows:

$$\text{Risk Score} = \text{Min} \sum_{i=1}^{4} P_j * W_j \qquad (10)$$

where,

$$P_j = \frac{(1 - R_i) * Pb_j}{1 - TR} \qquad (11)$$

and,

$$TR = \frac{C - C_{cr}}{C} \qquad (12)$$

Therefore the risk score can be represented as:

$$Risk\ Score = Min\sum_{i=1}^{4}\left[\frac{(1-R_j)*Pb_j}{(1-\frac{C-Ccr}{C})}*W_j\right] \qquad (13)$$

where,

i	= hydrological condition
j	= bacteria source category =human, domestic animal, livestock and wildlife
P_j	= % of each source category (human, domestic animals, livestock and wildlife) in final allocation
W_j	= weight of risk per source category = 5, 3 or 1
R_j	= percent reduction applied by source category (human, domestic animals, livestock and wildlife) for the specified hydrological condition (variable)
Pb_j	= original (baseline) percent distribution by source category (variable)
TR	= total reduction (constant within each hydrological condition) = Target reduction
C	= in-stream concentration
Ccr	= water quality criterion

The model is subject to the following constraints:

$$C = Ccr$$
$$0 \leq R_{human} \leq 95\%$$
$$0 \leq R_{pets} \leq 75\%$$
$$0 \leq R_{livestock} \leq 75\%$$
$$R_{wildlife} = 0$$
$$P_j \geq 1\%$$

In six of the eight subwatersheds, the constraints of this scenario could not be satisfied, indicating there was not a practicable solution. A summary of the first scenario analysis results is presented in Table 4.7.3.

Table 4.7.3: Practicable Reduction Scenario Results

Subwatershed	Applied Reductions				Total Reduction %	Target Reduction %
	Domestic %	Human %	Livestock %	Wildlife %		
GUN0387	0.0	0.0	0.0	0.0	0.0	0.0
LIT0002[1]	0.0	23.7	0.0	0.0	12.7	12.7
GUN0284sub	75.0	95.0	75.0	0.0	46.1	88.0
GUN0233sub	75.0	95.0	75.0	0.0	40.0	82.1
WGP0050	75.0	95.0	75.0	0.0	41.5	73.9
BEV0005	75.0	95.0	75.0	0.0	50.5	80.2
SBH0002	75.0	95.0	75.0	0.0	45.9	89.8
Downstream Subwatershed	75.0	95.0	75.0	0.0	44.0	71.4

[1]Subwatersheds partially located in Pennsylvania

Second Scenario: Fecal Bacteria Reductions Higher than MPRs

The TMDL must specify load allocations that will meet the water quality standards. In the practicable reduction targets scenario, six of the eight subwatersheds could not meet water quality standards based on MPRs.

To further develop the TMDL, a second scenario was analyzed in which the constraints on the MPRs were relaxed. In these subwatersheds, the maximum allowable reduction was increased to 98% for all sources, including wildlife. A similar optimization procedure as before was used to minimize risk. Again, the objective is to minimize the sum of the risk for all conditions while meeting the scenario reduction constraints. The model was defined in the same manner as considered in the practicable reduction scenario but subject to the following constraints:

$$C = Ccr$$
$$0 \leq R_{human} \leq 98\%$$
$$0 \leq R_{pets} \leq 98\%$$
$$0 \leq R_{livestock} \leq 98\%$$
$$0 \leq R_{wildlife} \leq 98\%$$
$$P_j \geq 1\%$$

A summary of the results of this second scenario analysis is presented in Table 4.7.4.

Table 4.7.4: Reduction Results Based on Optimization Model Allowing Up to 98% Reduction

Subwatershed	Applied Reductions				Total Reduction %	Target Reduction %
	Domestic %	Human %	Livestock %	Wildlife %		
GUN0387	0.0	0.0	0.0	0.0	0.0	0.0
LIT0002[1]	0.0	23.7	0.0	0.0	12.7	12.7
GUN0284sub	98.0	98.0	98.0	76.1	88.0	88.0
GUN0233sub	98.0	98.0	98.0	68.3	82.1	82.1
WGP0050	98.0	98.0	98.0	51.9	73.9	73.9
BEV0005	98.0	98.0	98.0	56.2	80.2	80.2
SBH0002	98.0	98.0	98.0	80.7	89.8	89.8
Downstream Subwatershed	98.0	98.0	98.0	44.2	71.4	71.4

[1]Subwatersheds partially located in Pennsylvania

4.8 TMDL Loading Caps

The TMDL loading cap is an estimate of the assimilative capacity of the monitored watershed. The TMDL loading caps are provided in billion MPN *E. coli*/day. These loading caps are for the seven subwatersheds located upstream of their respective monitoring stations as well as the one downstream watershed. Loading caps for subwatersheds of Loch Raven Reservoir partially located in PA were included in the TMDL scenario. A TMDL summary for the entire Loch Raven Reservoir watershed will include an upstream load allocation for the portion of the watershed located in PA to indicate estimated loads necessary to meet MD water quality standards in the MD 8-digit assessment unit for the Loch Raven Reservoir watershed.

Annual Average TMDL

As explained in the sections above, the annual average TMDL loading caps are estimated by first determining the baseline or current condition loads for each subwatershed and the associated geometric mean from the available monitoring data. This annual average baseline load is estimated using the geometric mean concentration and the long-term annual average daily flow.

Next, the percent reduction required to meet the water quality criterion is estimated from the observed bacteria concentrations accounting for the critical conditions (See Section 4.5). A reduction in concentration is proportional to a reduction in load; thus the TMDL is equal to the current baseline load multiplied by one minus the required reduction. This reduction, estimated as explained in Section 4.5, represents the maximum reduction per source that satisfies the two

hydrological conditions in each subwatershed, and that is required to meet water quality standards.

$$\text{TMDL Loading Cap} = L_b * (1 - R) \qquad (14)$$

where,

L_b = current or baseline load estimated from monitoring data
R = reduction required from baseline to meet water quality criterion.

The annual average bacteria TMDL loading caps for the subwatersheds, including those partially located in PA, are shown in Tables 4.8.1 and 4.8.2.

Table 4.8.1: Annual Average TMDL Loading Caps

Subwatershed	*E. coli* Baseline Load (Billion MPN/year)	Long-Term Average *E. coli* TMDL Load (Billion MPN/year)	% Target Reduction
GUN0387	460	460	0.0
LIT0002[1]	97,368	84,958	12.7
GUN0284sub	142,466	17,029	88.0
GUN0233sub	1,177,287	211,228	82.1
WGP0050	307,744	80,168	73.9
BEV0005	115,900	22,967	80.2
SBH0002	21,893	2,244	89.8
Downstream Subwatershed	331,190	94,840	71.4
Total	**2,194,308**	**513,894**	**76.6**

[1]Subwatersheds partially located in Pennsylvania

Table 4.8.2: Annual Average TMDL Loading Caps by Source Category

Subwatershed	Domestic		Human		Livestock		Wildlife		Total Load (Billion *E. coli* MPN/year)
	%	Load (Billion *E. coli* MPN/year)	%	Load (Billion *E. coli* MPN/year)	%	Load (Billion *E. coli* MPN/year)	%	Load (Billion *E. coli* MPN/year)	
GUN0387	7.9	36	41.4	190	4.7	22	46.0	212	460
LIT0002[1]	5.7	4,835	47.1	39,986	12.1	10,275	35.1	29,862	84,958
GUN0284sub	2.5	430	4.4	742	2.2	381	90.9	15,476	17,029
GUN0233sub	0.7	1,511	2.9	6,178	1.5	3,217	94.8	200,322	211,228
WGP0050	0.4	333	2.2	1,731	1.1	879	96.3	77,225	80,168
BEV0005	0.8	175	3.8	868	1.3	288	94.2	21,636	22,967
SBH0002	1.1	24	6.5	145	2.7	61	89.8	2,014	2,244
Downstream Subwatershed	0.5	428	2.1	2,027	0.9	891	96.5	91,494	94,840

[1]Subwatersheds partially located in Pennsylvania

Maximum Daily Loads

Recent EPA guidance (US EPA 2006a) recommends that maximum daily load (MDL) expressions of long-term annual average TMDLs should also be provided as part of the TMDL analysis and report. Selection of an appropriate method for translating a TMDL based on a longer time period into one using a daily time period requires decisions regarding 1) the level of resolution, and 2) the level of protection. The level of resolution pertains to the amount of detail used in specifying the maximum daily load. The level of protection represents how often the maximum daily load (MDL) is expected to be exceeded. Draft EPA/TetraTech guidance on daily loads (Limno-Tech 2007) provides three categories of options for both level of resolution and level of protection, and discusses these categories in detail.

For the Loch Raven Reservoir watershed MDLs, a "representative daily load" option was selected as the level of resolution, and a value "that will be exceeded with a pre-defined probability" was selected as the level of protection. In these options, the MDLs have an upper bound percentile that accounts for the variability of daily loads. The upper bound percentile and the MDLs were estimated following EPA's "*Technical Support Document for Water Quality-Based Toxics Control*" (1991 TSD) (EPA 1991); and "*Approaches For Developing a Daily Load Expression for TMDLs Computed for Longer Term Averages*" (EPA 2006).

There are three steps to the overall process of estimating these MDLs. First, all the data available from each monitoring station are examined and the percentile rank of the highest observed concentration (at each station) is computed. The highest computed percentile rank is the upper bound percentile to be used in estimating the MDLs.

Secondly, the long-term annual average TMDL (see Table 4.8.1) concentrations are estimated. This is conducted for each station using a statistical methodology (the "Statistical Theory of Rollback," or "STR," described more fully in Appendix D).

Third, based on the estimated long-term average (LTA) TMDL concentrations, the MDL at each station is estimated using the upper boundary percentile computed in the first step above. Finally, MDLs are computed from these MDL concentrations and their corresponding flows.

Results of the fecal bacteria MDL analysis for the Loch Raven Reservoir subwatersheds, including for computational purposes those partially located in PA, are shown in Table 4.8.3. The downstream subwatershed is assigned the average MDL of the upstream subwatersheds (GUN0233, WGP0050 and BEV0005).

Table 4.8.3: Loch Raven Reservoir Watershed Maximum Daily Loads Summary

Subwatershed	Maximum Daily Load (Billion *E. coli* MPN/day)
GUN0387	11
LIT0002[1]	3,327
GUN0284sub	157
GUN0233sub	2,186
WGP0050	5,251
BEV0005	1,194
SBH0002	212
Downstream Subwatershed	5,613

[1]Subwatersheds partially located in Pennsylvania

See Appendix D for a more detailed explanation of the procedure for obtaining these daily loads.

4.9 TMDL Allocations

The Loch Raven Reservoir watershed fecal bacteria TMDL is composed of the following components:

$$TMDL = LA_{LR} + WLA_{LR} + LA_{PA} + MOS \qquad (15)$$

where,

LA_{LR} = MD Loch Raven Reservoir Watershed Load Allocation
WLA_{LR} = MD Loch Raven Reservoir Watershed Waste Load Allocation
LA_{PA} = Pennsylvania Load Allocation
MOS = Margin of Safety

The TMDL allocation for the Loch Raven Reservoir MD 8-digit basin includes load allocations (LA_{LR}) for nonpoint sources and waste load allocations (WLA_{LR}) for point sources including WWTPs and NPDES-regulated stormwater discharges. The Stormwater (SW) WLA_{LR} includes any nonpoint source loads determined to be transported and discharged by regulated stormwater systems. An explanation of the distribution of nonpoint source loads and point source loads to the LA_{LR} and to the SW-WLA_{LR} and WWTP-WLA_{LR} is provided in the subsections that follow.

In addition to these allocation categories for the MD 8-digit watershed, the Loch Raven Reservoir watershed TMDL includes an upstream load allocation for the portion of the watershed located in PA (LA_{PA}). The LA_{PA} was calculated using the ratios of the areas of the watershed in MD and in PA to the total area of the watershed, and is presented as a "lump-sum" upstream load comprising all bacteria source categories. The LA_{PA}, determined to be necessary in order to meet MD water quality standards in the Loch Raven Reservoir MD 8-digit basin, will not be distributed between nonpoint sources (LA) and point sources (WLA).

The margin of safety (MOS) is explicit and is incorporated in the analysis using a conservative assumption; it is not specified as a separate term. The assumption is that a 5% reduction of the criterion concentration established by MD to meet the applicable water quality standard will result in more conservative allowable loads of fecal bacteria, and thus provide the MOS. The final loads are based on average hydrological conditions, with reductions estimated based on critical hydrological conditions. The load reduction scenario results in load allocations that will achieve water quality standards. The State reserves the right to revise these allocations provided such revisions are consistent with the achievement of water quality standards.

<u>Bacteria Source Categories and Allocation Distributions</u>

The bacteria sources are grouped into four categories that are also consistent with divisions for various management strategies. The categories are human, domestic animal, livestock and wildlife. TMDL allocation rules are presented in Table 4.8.1. This table identifies how the TMDL will be allocated among the LA_{LR} (those nonpoint sources or portions thereof not transported and discharged by stormwater systems) and the WLA_{LR} (point sources including WWTPs, and NPDES regulated stormwater discharges). Only the final LA_{LR} or WLA_{LR} is

reported in this TMDL. Note that the assignment of an allowable human load to the LA_{LR} is in consideration of the possible presence of such loads in the watershed beyond the reach of the sanitary sewer systems. The term "allowable load" means the load that the waterbody can assimilate and still meet water quality standards.

Table 4.9.1: Potential Source Contributions for TMDL Allocation Categories in the Loch Raven Reservoir Watershed in MD

Source Category	TMDL Allocation Categories		
	LA_{LR}	WLA_{LR}	
		WWTP	Stormwater
Human	X	X	
Domestic	X		X
Livestock	X		
Wildlife	X		X

* These allocations apply only to the portion of the watershed in MD. The TMDL allocation scenario load attributed to PA includes all four bacteria source categories in one single load.

LA_{LR}

All four bacteria source categories could potentially contribute to nonpoint source loads. For human sources, the nonpoint source contribution is estimated by subtracting any WWTP loads from the TMDL human load, and is then assigned to the LA_{LR}. Livestock loads are also assigned to the LA_{LR}. Since the entire Loch Raven Reservoir watershed is covered by NPDES MS4 permits, bacteria loads from domestic animal and wildlife sources are distributed between the SW-WLA_{LR} and LA_{LR}.

WLA_{LR}

NPDES Regulated Stormwater

EPA's guidance document, "Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs" (November 2002), advises that all individual and general NPDES Phase I and Phase II stormwater permits are point sources subject to WLA assignment in the TMDL. The document acknowledges that quantification of rainfall-driven nonpoint source loads is uncertain, stating that available data and information usually are not detailed enough to determine WLAs for NPDES-regulated stormwater discharges on an outfall-specific basis; therefore, the EPA guidance allows the stormwater WLA to be expressed as an aggregate allotment.

Bacteria loads from domestic animal sources are distributed between the SW-WLA_{LR} and the LA_{LR} based on a ratio of the population in urban land use areas to the population in non-urban areas. The bacteria load from wildlife sources is distributed between the SW-WLA_{LR} and LA_{LR} based on a ratio of the per capita acreage in urban areas to the per capita acreage in non-urban areas. This weighting allows for a greater domestic animal source allocation in urban areas, and a greater wildlife source allocation to non-urban areas. In watersheds with no existing NPDES-regulated stormwater permits, these loads will be included entirely in the LA.

Within the MD portion of the Loch Raven Reservoir watershed, the jurisdictions of Baltimore County, Carroll County, and Harford County have individual Phase I MS4 permits. The municipality of Hampstead is also covered by a general Phase II MS4 permit. Based on EPA's guidance, the SW-WLA is presented as one combined load for the entire land area of each jurisdiction in each subwatershed. In addition to the county and municipal MS4s, the SW-WLA category includes any other Phase I and Phase II NPDES regulated stormwater entities in the watershed, including the MD SHA Phase I MS4, Phase II State and federal MS4s, and industrial stormwater permittees. In the future, when more detailed data and information become available, it is anticipated that the SW-WLA may be disaggregated into more specific allocations by permit type.

The NPDES regulated stormwater baseline loads of fecal bacteria for the MD portion of the Loch Raven Reservoir watershed are presented by jurisdiction and subwatershed in Table 4.9.2. The corresponding SW-WLA_{LR} distribution is presented in Table 4.9.3. It is important to note that these apportioned loads are still aggregate SW-WLAs within each jurisdiction. The average annual allocations represent overall reductions in fecal bacteria loads from regulated stormwater sources of 88% from Baltimore County, 95% from Carroll County, 98% from the municipality of Hampstead, and 0% from Harford County. Upon approval of the TMDL, "NPDES-regulated municipal stormwater and small construction storm water discharges effluent limits should be expressed as BMPs or other similar requirements, rather than as numeric effluent limits" (US EPA 2002a).

Table 4.9.2: Stormwater Baseline Loads in MD

Subwatershed	Baltimore County $SW\text{-}BL_{LR}$	Carroll County $SW\text{-}BL_{LR}$	Hampstead $SW\text{-}BL_{LR}$	Harford County $SW\text{-}BL_{LR}$
	(Billion MPN *E. coli*/year)			
GUN0387	33	N/A	N/A	N/A
LIT0002[1]	3,234	N/A	N/A	35
GUN0284sub	15,284	N/A	N/A	N/A
GUN0233sub	66,357	N/A	N/A	N/A
WGP0050	10,332	426	4,714	N/A
BEV0005	17,961	N/A	N/A	N/A
SBH0002	10,750	N/A	N/A	N/A
Downstream Subwatershed	23,457	N/A	N/A	N/A

[1]MD portion of the subwatershed only.

Table 4.9.3: Annual Average Stormwater Allocations in MD

Subwatershed	Baltimore County $SW\text{-}WLA_{LR}$	Carroll County $SW\text{-}WLA_{LR}$	Hampstead $SW\text{-}WLA_{LR}$	Harford County $SW\text{-}WLA_{LR}$
	(Billion MPN *E. coli*/year)			
GUN0387	33	N/A	N/A	N/A
LIT0002[1]	3,234	N/A	N/A	35
GUN0284sub	512	N/A	N/A	N/A
GUN0233sub	4,538	N/A	N/A	N/A
WGP0050	1,556	21	104	N/A
BEV0005	4,498	N/A	N/A	N/A
SBH0002	1,874	N/A	N/A	N/A
Downstream Subwatershed	1,972	N/A	N/A	N/A

[1]MD portion of the subwatershed only.

Municipal and Industrial WWTPs

As explained in the source assessment section above, there is one NPDES permitted point source facility with a permit regulating the discharge of fecal bacteria in the Loch Raven Reservoir watershed. This facility discharges into the subwatershed of WGP0050 (Western Run). The WLA for the WWTP is estimated using the design flow of the plant stated in the facility's

NPDES permit and the *E. coli* criterion concentration of 126 MPN/100ml. Bacteria loads assigned to the WWTP are allocated as the WWTP-WLA_{LR}.

4.10 Summary

The long-term annual average TMDL and TMDL allocations are presented in Table 4.10.1. Table 4.10.2 presents the maximum daily loads for the subwatersheds or portions thereof within the Loch Raven Reservoir MD 8-digit basin.

Table 4.10.1: Loch Reservoir Watershed Annual Average TMDL

Subwatershed	Total Allocation	LA_{LR}	SW-WLA_{LR}	WWTP-WLA_{LR}
	(Billion MPN *E. coli* /year)			
GUN0387	460	427	33	0
LIT0002[1]	78,758	75,490	3,268	0
GUN0284sub	17,029	16,517	512	0
GUN0233sub	211,228	206,690	4,538	0
WGP0050	80,168	76,920	1,681	1,567
BEV0005	22,967	18,469	4,498	0
SBH0002	2,244	369	1,875	0
Downstream Subwatershed	94,840	92,868	1,972	0
MD Total	507,694	487,750	18,377	1,567
PA Upstream Load	6,200			
***TMDL*[2]**	**513,894**			

[1]MD portion of the subwatershed only.
[2]The MOS is incorporated.

Table 4.10.2: Loch Raven Reservoir Watershed Maximum Daily Loads

Subwatershed	Total Allocation	LA_{LR}	$SW\text{-}WLA_{LR}$	$WWTP\text{-}WLA_{LR}$
	(Billion MPN *E. coli* /day)			
GUN0387	11	10	1	0
LIT0002[1]	3,084	2,956	128	0
GUN0284sub	157	152	5	0
GUN0233sub	2,186	2,139	47	0
WGP0050	5,251	5,128	110	13
BEV0005	1,194	960	234	0
SBH0002	212	35	177	0
Downstream Subwatershed	5,613	5,496	117	0
MD Total	17,708	16,876	819	13
PA Upstream Load	243			
***TMDL*[2]**	**17,951**			

[1]MD portion of the subwatershed only.
[2]The MOS is incorporated.

The long-term annual average fecal bacteria TMDL summary for the entire Loch Raven Reservoir watershed is presented in Table 4.10.3.

Table 4.10.3: MD 8-Digit Loch Raven Reservoir Watershed Annual Average TMDL Summary

(Billion MPN *E. coli*/year)										
TMDL	=	**LA**			+	**WLA**			+	**MOS**
		LA_{PA}[1]	+	**LA_{LR}**		**SW WLA_{LR}**	+	**WWTP WLA_{LR}**		
513,894	=	6,200	+	487,750	+	18,377	+	1,567	+	Incorpo-rated
		Upstream Load Allocation		MD 8-digit Loch Raven Reservoir TMDL Contribution (507,694)						

[1]This upstream PA load allocation is determined to be necessary in order to meet MD water quality standards in the MD portion of the Loch Raven Reservoir watershed. Although the upstream load is reported here as a single value, it could include point and nonpoint sources.

The maximum daily loads of fecal bacteria for the MD 8-digit Loch Raven Reservoir watershed, including the PA upstream load, are summarized in Table 4.10.4.

Table 4.10.4: MD 8-Digit Loch Raven Reservoir Watershed MDL Summary

(Billion MPN *E. coli*/day)										
MDL	=	**LA**			+	**WLA**			+	**MOS**
		LA_{PA}	+	**LA_{LR}**		**SW WLA_{LR}**	+	**WWTP WLA_{LR}**		
17,951	=	243	+	16,876	+	819	+	13	+	Incorpo-rated
		Upstream MDL		MD 8-digit Loch Raven Reservoir MDL Contribution (17,708)						

In certain watersheds, the goal of meeting water quality standards may require very high reductions that are not achievable with current technologies and management practices. In this situation, where there is no feasible TMDL scenario, MPRs are increased to provide estimates of the reductions required to meet water quality standards. In six of the eight Loch Raven Reservoir subwatersheds, water quality standards cannot be achieved with the maximum practicable reduction rates specified in Table 4.7.3. For these six subwatersheds the TMDLs shown in Tables 4.10.1 and 4.10.2 represent reductions from current bacteria loadings that are beyond practical reductions. In cases where such high reductions are required to meet standards, it is expected that the first stage of implementation will be to carry out the MPR scenario.

5.0 ASSURANCE OF IMPLEMENTATION

Section 303(d) of the Clean Water Act and current EPA regulations require reasonable assurance that the TMDL load and wasteload allocations can and will be implemented. In the Loch Raven Reservoir watershed, the TMDL analysis indicates that, for six of the eight subwatersheds, the reductions of fecal bacteria loads are beyond the MPR targets. These MPR targets were defined based on a literature review of BMPs effectiveness and assuming a zero reduction for wildlife sources. The tributaries of Loch Raven Reservoir may not be able to attain water quality standards. The fecal bacteria load reductions required to meet water quality criteria in six of the eight Loch Raven Reservoir subwatersheds are not feasible by implementing effluent limitations and cost-effective, reasonable BMPs to nonpoint sources. Therefore, MDE proposes a staged approach to implementation beginning with the MPR scenario, with regularly scheduled follow-up monitoring to assess the effectiveness of the implementation plan.

Additional reductions will be achieved through the implementation of BMPs; however, the literature reports considerable uncertainty concerning the effectiveness of BMPs in treating bacteria. As an example, pet waste education programs have varying results based on stakeholder involvement. Additionally, the extent of wildlife reduction associated with various BMPs methods (e.g., structural, non-structural, etc.) is uncertain. Therefore, MDE intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality and human health risk, with consideration given to ease of implementation and cost. The iterative implementation of BMPs in the watershed has several benefits: tracking of water quality improvements following BMP implementation through follow-up stream monitoring; providing a mechanism for developing public support through periodic updates on BMP implementation; and helping to ensure that the most cost-effective practices are implemented first.

Low interest loans are available to property owners with failing septic systems through MDE's Linked Deposit Program, for assistance in correction of such systems through replacement or connection to public sewer systems. In addition, Maryland’s Bay Restoration Fund provides funding to upgrade onsite sewage disposal systems. These upgrades, which enhance nitrogen removal, will also help reduce human source fecal bacteria loads from failing septic systems in the watershed.

Potential funding sources for implementation include the Maryland’s Agricultural Cost Share Program (MACS), which provides grants to farmers to help protect natural resources, and the Environmental Quality and Incentives Program, which focuses on implementing conservation practices and BMPs on land involved with livestock and production. Though not directly linked, it is assumed that the nutrient management plans from the Water Quality Improvement Act of 1998 (WQIA) will have some reduction of bacteria from manure application practices.

The Loch Raven Reservoir watershed is managed under NPDES MS4 permits for Baltimore, Carroll, and Harford Counties, and for the municipality of Hampstead, as well as all other Phase I MS4s in the watershed, including the MD State Highway Administration, Phase II State and federal MS4s, and industrial stormwater permittees. This provides regulatory assurances that

urban stormwater sources will be managed to the maximum extent practicable. The State's NPDES stormwater permits use a watershed approach for improving the water quality of stormwater runoff because it is comprehensive and efficient. By examining all stormwater pollutants including physical and biological impairments at the same time, cost effective control strategies can be developed. This approach is based upon detailed stormwater assessments regarding: water quality conditions, identifying and ranking water quality problems, identifying all structural and nonstructural BMP opportunities, conducting visual watershed inspections, specifying how restoration efforts are monitored, and providing estimated costs and detailed implementation schedules for restoration work. Stormwater BMPs and programs implemented as required by MS4 permits shall be consistent with available WLAs developed under the TMDL. Where fecal bacteria are transported through an MS4 conveyance system, stormwater BMPs implemented to control urban runoff should help in reducing fecal bacteria loads in the Loch Raven Reservoir watershed.

Baltimore County is under a Consent Decree regarding its sanitary sewer overflows. Implementation of the conditions of the Consent Decree should assist in addressing the bacteria sources, particularly the human sources, in the sewered portion of the watershed.

Implementation and Wildlife Sources

It is expected that in some waters for which TMDLs will be developed, the bacteria source analysis indicates that after controls are in place for all anthropogenic sources, the waterbody will not meet water quality standards. Managing the overpopulation of wildlife remains an option for state and local stakeholders.

After developing and implementing, to the maximum extent possible, a reduction goal based on the anthropogenic sources identified in the TMDL, Maryland anticipates that implementation to reduce the controllable nonpoint sources may also reduce some wildlife inputs to the waters.

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Appendix A – Bacteria Data

Table A-1: Measured Bacteria Concentration with Daily Flow Frequency

Station	Date	Daily flow frequency	*E. coli* Concentration (MPN/100ml)
BEV0005	11/05/2003	14.1371	200
	11/19/2003	0.8979	140
	12/03/2003	41.8528	50
	12/17/2003	0.8760	960
	01/05/2004	10.2825	150
	01/20/2004	31.9755	60
	02/02/2004	36.1805	20
	02/17/2004	26.5112	50
	03/01/2004	36.1805	480
	03/15/2004	36.1805	30
	04/05/2004	13.5567	40
	04/19/2004	23.4341	110
	05/10/2004	44.8861	140
	05/24/2004	51.5659	380
	06/07/2004	29.9058	790
	06/21/2004	71.3973	370
	07/06/2004	78.9860	2500
	07/19/2004	48.3574	910
	08/09/2004	85.9396	830
	08/23/2004	90.9220	420
	09/07/2004	91.9076	120
	09/20/2004	71.3973	960
	10/04/2004	71.3973	380
	10/18/2004	82.8625	190

Station	Date	Daily flow frequency	*E. coli* Concentration (MPN/100ml)
GUN0233	11/05/2003	15.7360	130
	11/19/2003	3.8733	100
	12/03/2003	13.0545	70
	12/17/2003	1.2249	14140
	01/05/2004	7.2832	50
	01/20/2004	15.7360	30
	02/17/2004	15.7360	40
	03/01/2004	19.8742	30
	03/15/2004	21.7833	10
	04/05/2004	7.5811	470
	04/19/2004	14.7650	60
	05/10/2004	25.7559	60
	05/24/2004	28.4816	270
	06/07/2004	4.9327	350
	06/21/2004	17.4465	270
	07/06/2004	38.0049	3800
	07/19/2004	31.7921	260
	08/09/2004	29.4968	70
	08/23/2004	38.0049	60
	09/07/2004	47.2633	70
	09/20/2004	20.9777	710
	10/04/2004	24.7848	260
	10/18/2004	37.1993	60

Station	Date	Daily flow frequency	*E. coli* Concentration (MPN/100ml)
GUN0284	11/05/2003	15.7360	50
	11/19/2003	3.8733	40
	12/03/2003	13.0545	30
	12/17/2003	1.2249	250
	01/05/2004	7.2832	40
	01/20/2004	15.7360	30
	02/02/2004	19.6866	30
	02/17/2004	15.7360	30
	03/01/2004	19.8742	10
	03/15/2004	21.7833	10
	04/05/2004	7.5811	320
	04/19/2004	14.7650	30
	05/10/2004	25.7559	50
	05/24/2004	28.4816	210
	06/07/2004	4.9327	300
	06/21/2004	17.4465	230
	07/06/2004	38.0049	770
	07/19/2004	31.7921	70
	08/09/2004	29.4968	90
	08/23/2004	38.0049	170
	09/07/2004	47.2633	70
	09/20/2004	20.9777	420
	10/04/2004	24.7848	160
	10/18/2004	37.1993	20

Station	Date	Daily flow frequency	*E. coli* Concentration (MPN/100ml)
GUN0387	11/05/2003	12.5602	30
	11/19/2003	1.4455	10
	12/03/2003	12.1770	30
	12/17/2003	1.3250	40
	01/05/2004	7.5011	10
	01/20/2004	15.5278	10
	02/02/2004	17.9698	10
	02/17/2004	15.8563	10
	03/01/2004	19.0101	10
	03/15/2004	21.8791	20
	04/05/2004	12.1770	1
	04/19/2004	19.3714	10
	05/10/2004	25.2957	10
	05/24/2004	32.2711	10
	06/07/2004	14.8270	10
	06/21/2004	16.8309	10
	07/06/2004	36.5747	120
	07/19/2004	22.9851	10
	08/09/2004	24.7919	20
	08/23/2004	34.7678	20
	09/07/2004	50.2081	10
	09/20/2004	27.5186	90
	10/04/2004	25.2957	20
	10/18/2004	40.3198	10

Station	Date	Daily flow frequency	*E. coli* Concentration (MPN/100ml)
LIT0002	11/05/2003	12.5602	160
	11/19/2003	1.4455	40
	12/03/2003	12.1770	120
	12/17/2003	1.3250	220
	01/05/2004	7.5011	70
	01/20/2004	15.5278	40
	02/02/2004	17.9698	20
	02/17/2004	15.8563	10
	03/01/2004	19.0101	100
	03/15/2004	21.8791	20
	04/05/2004	12.1770	260
	04/19/2004	19.3714	90
	05/10/2004	25.2957	80
	05/24/2004	32.2711	260
	06/07/2004	14.8270	10
	06/21/2004	16.8309	320
	07/06/2004	36.5747	130
	07/19/2004	22.9851	250
	08/09/2004	24.7919	150
	08/23/2004	34.7678	120
	09/07/2004	50.2081	90
	09/20/2004	27.5186	770
	10/04/2004	25.2957	280
	10/18/2004	40.3198	110

Station	Date	Daily flow frequency	*E. coli* Concentration (MPN/100ml)
SBH0002	11/05/2003	14.1371	100
	11/19/2003	0.8979	1310
	12/03/2003	41.8528	70
	12/17/2003	0.8760	3650
	01/05/2004	10.2825	120
	01/20/2004	31.9755	40
	02/02/2004	36.1805	180
	02/17/2004	26.5112	50
	03/01/2004	36.1805	30
	03/15/2004	36.1805	30
	04/05/2004	13.5567	30
	04/19/2004	23.4341	50
	05/10/2004	44.8861	990
	05/24/2004	51.5659	1440
	06/07/2004	29.9058	720
	06/21/2004	71.3973	770
	07/06/2004	78.9860	4600
	07/19/2004	48.3574	9210
	08/09/2004	85.9396	610
	08/23/2004	90.9220	380
	09/07/2004	91.9076	260
	09/20/2004	71.3973	1070
	10/04/2004	71.3973	170
	10/18/2004	82.8625	380

Station	Date	Daily flow frequency	*E. coli* Concentration (MPN/100ml)
WGP0050	11/05/2003	22.7332	130
	11/19/2003	2.7705	110
	12/03/2003	21.4849	140
	12/17/2003	1.4126	2910
	01/05/2004	10.1621	90
	01/20/2004	21.4849	120
	02/02/2004	17.9260	10
	02/17/2004	20.4008	50
	03/01/2004	25.2738	40
	03/15/2004	23.4012	20
	04/05/2004	7.9720	930
	04/19/2004	15.1226	220
	05/10/2004	21.4849	280
	05/24/2004	32.1507	700
	06/07/2004	17.0061	1100
	06/21/2004	44.8204	430
	07/06/2004	50.1533	200
	07/19/2004	47.3390	910
	08/09/2004	57.9829	400
	08/23/2004	65.8892	190
	09/07/2004	74.4306	450
	09/20/2004	59.3408	1400
	10/04/2004	56.6908	840
	10/18/2004	65.8892	190

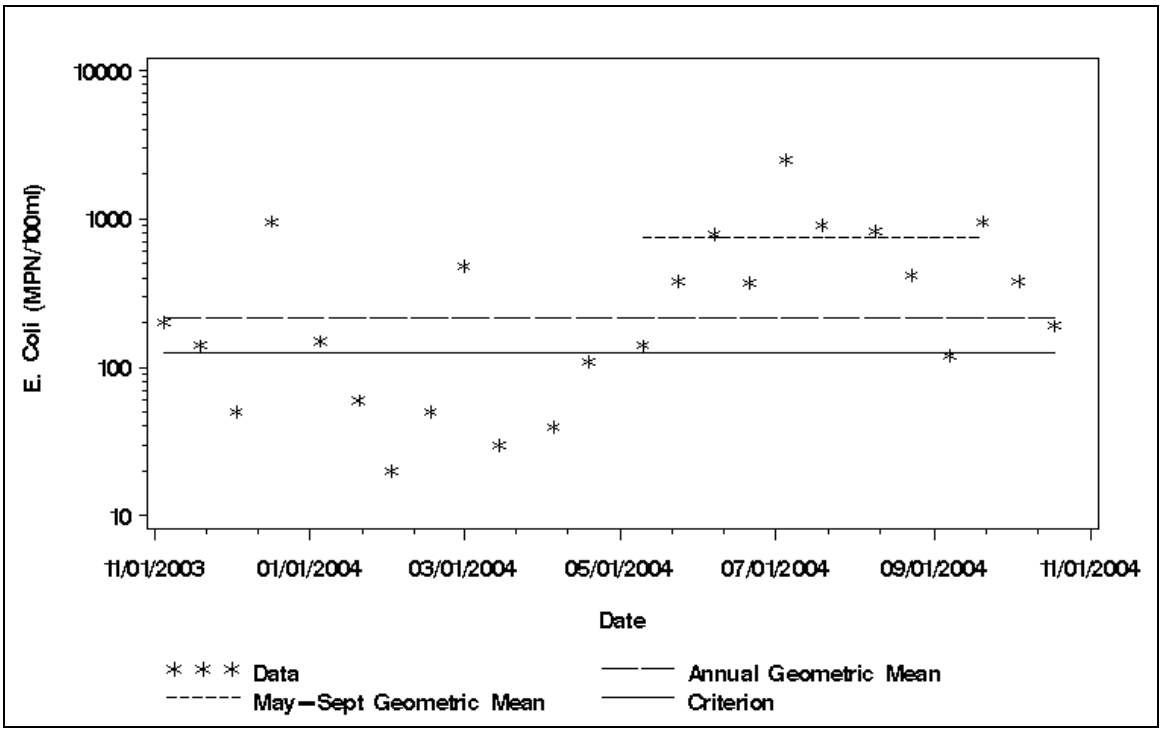

Figure A-1: *E. coli* Concentration vs. Time for MDE Monitoring Station BEV0005

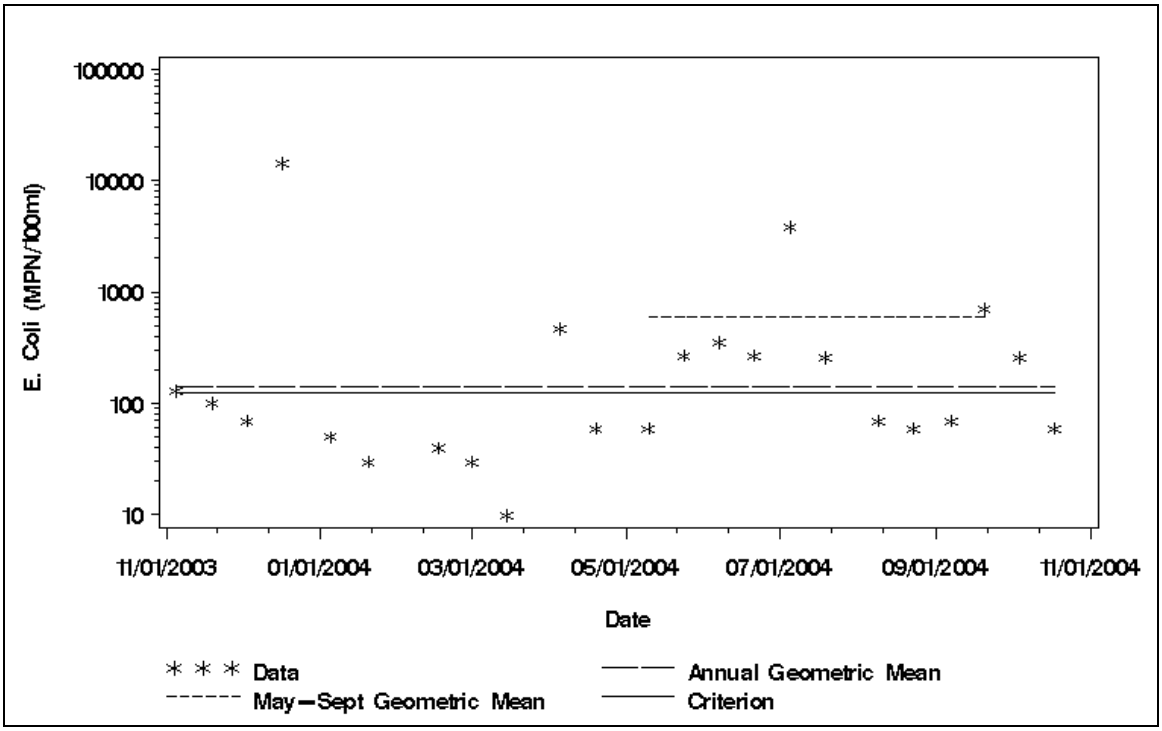

Figure A-2: *E. coli* Concentration vs. Time for MDE Monitoring Station GUN0233

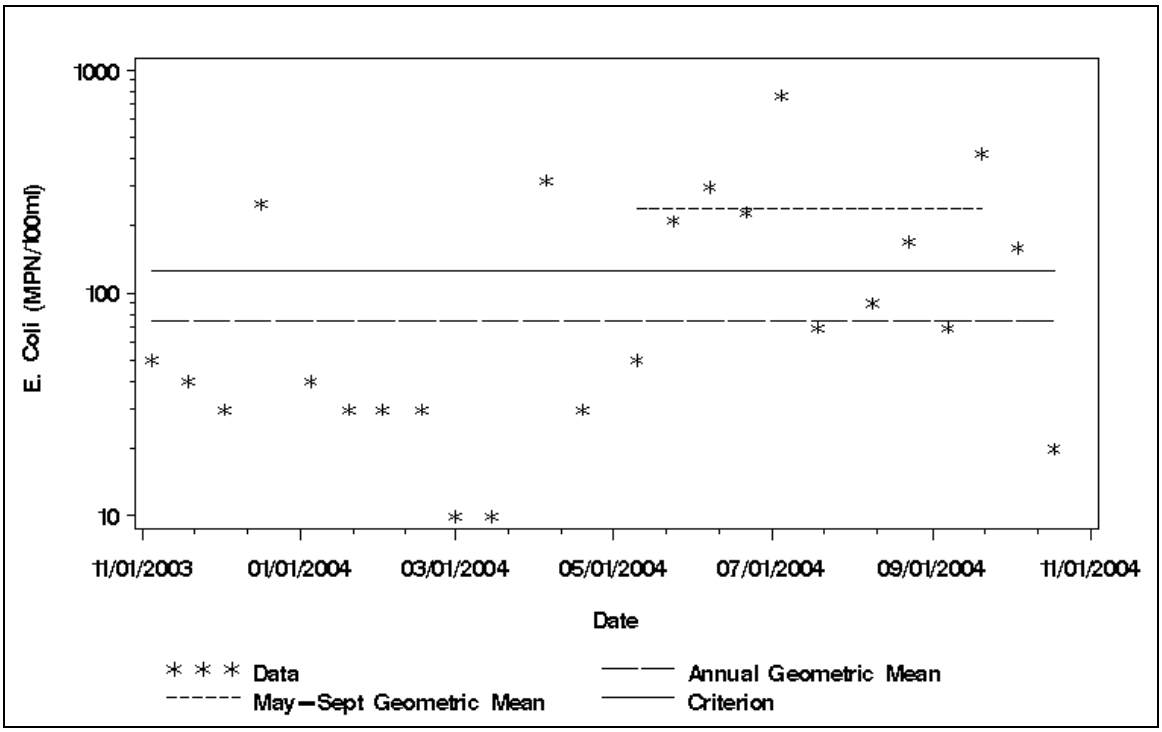

Figure A-3: *E. coli* Concentration vs. Time for MDE Monitoring Station GUN0284

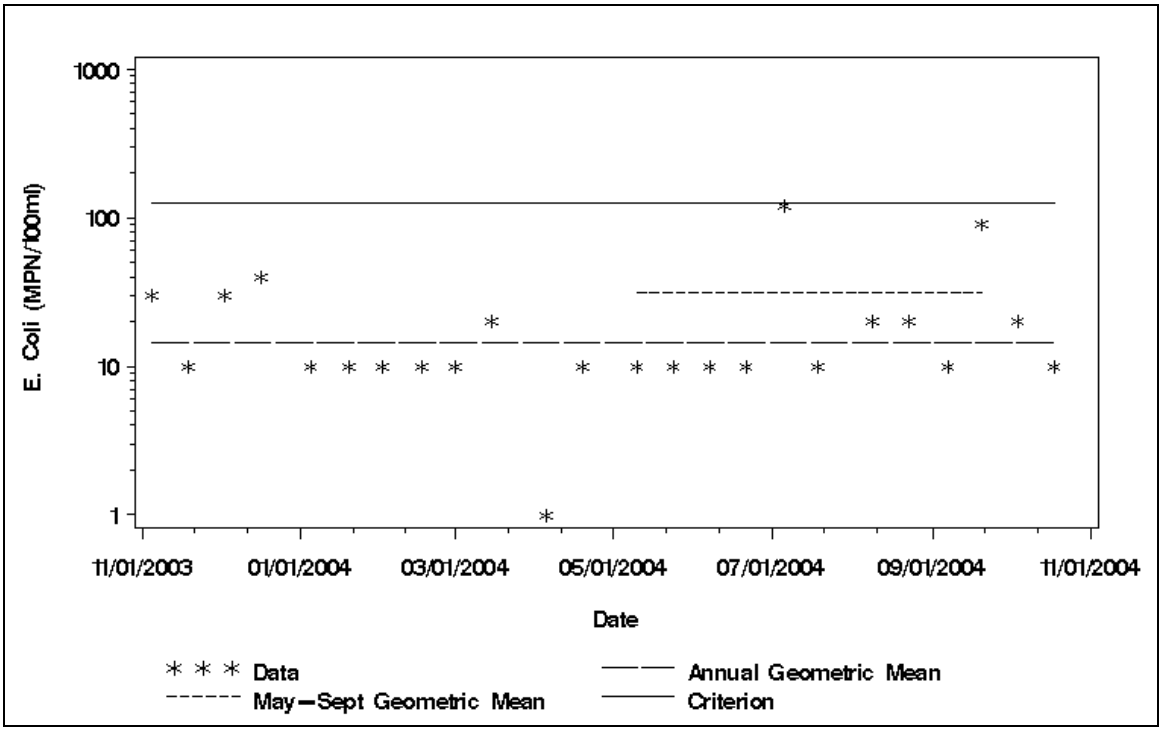

Figure A-4: *E. coli* Concentration vs. Time for MDE Monitoring Station GUN0387

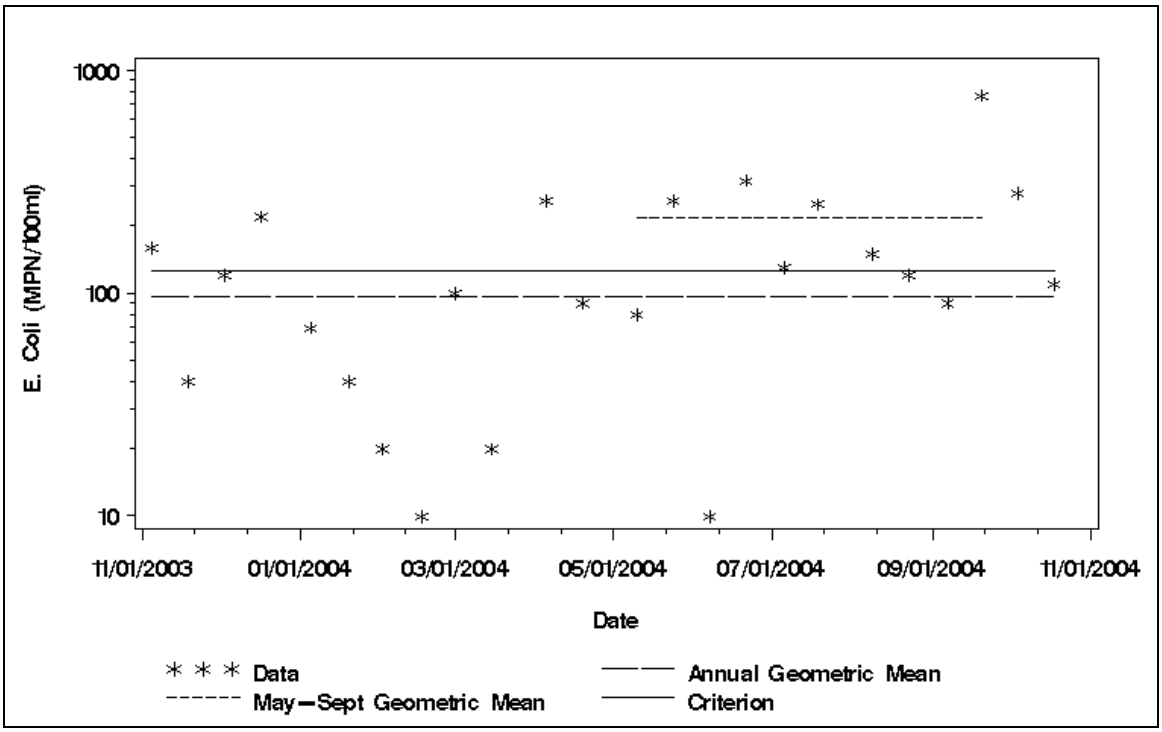

Figure A-5: *E. coli* Concentration vs. Time for MDE Monitoring Station LIT0002

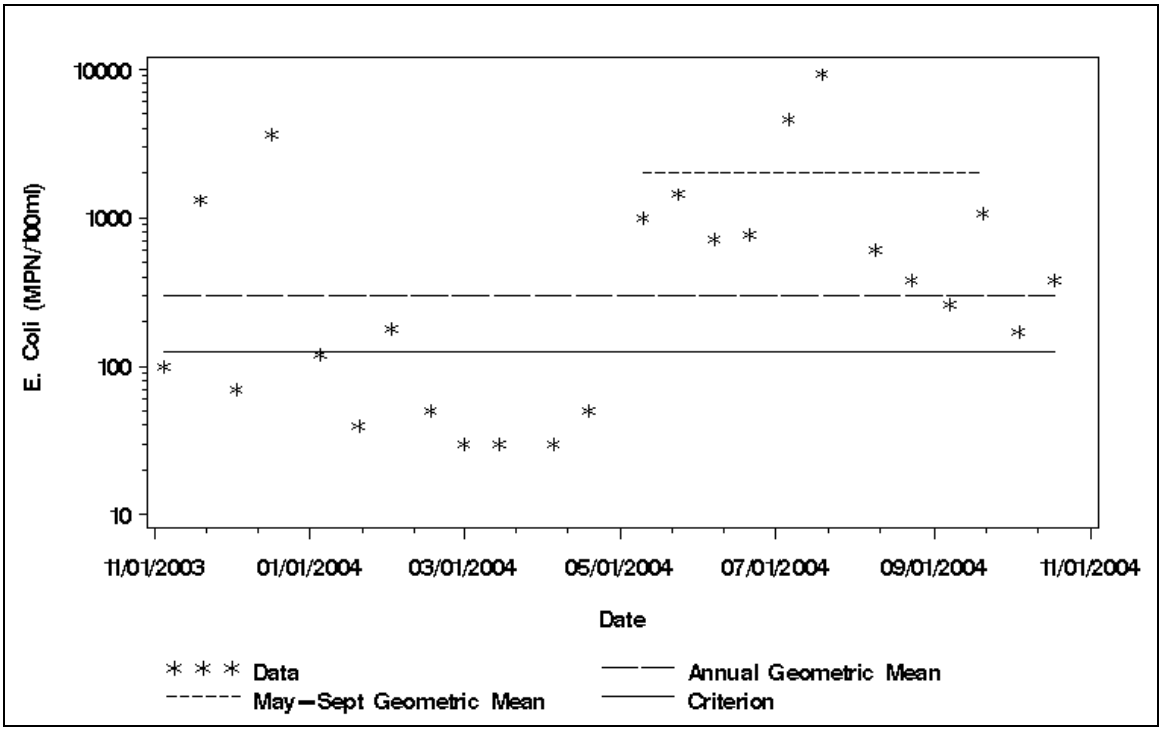

Figure A-6: *E. coli* Concentration vs. Time for MDE Monitoring Station SBH0002

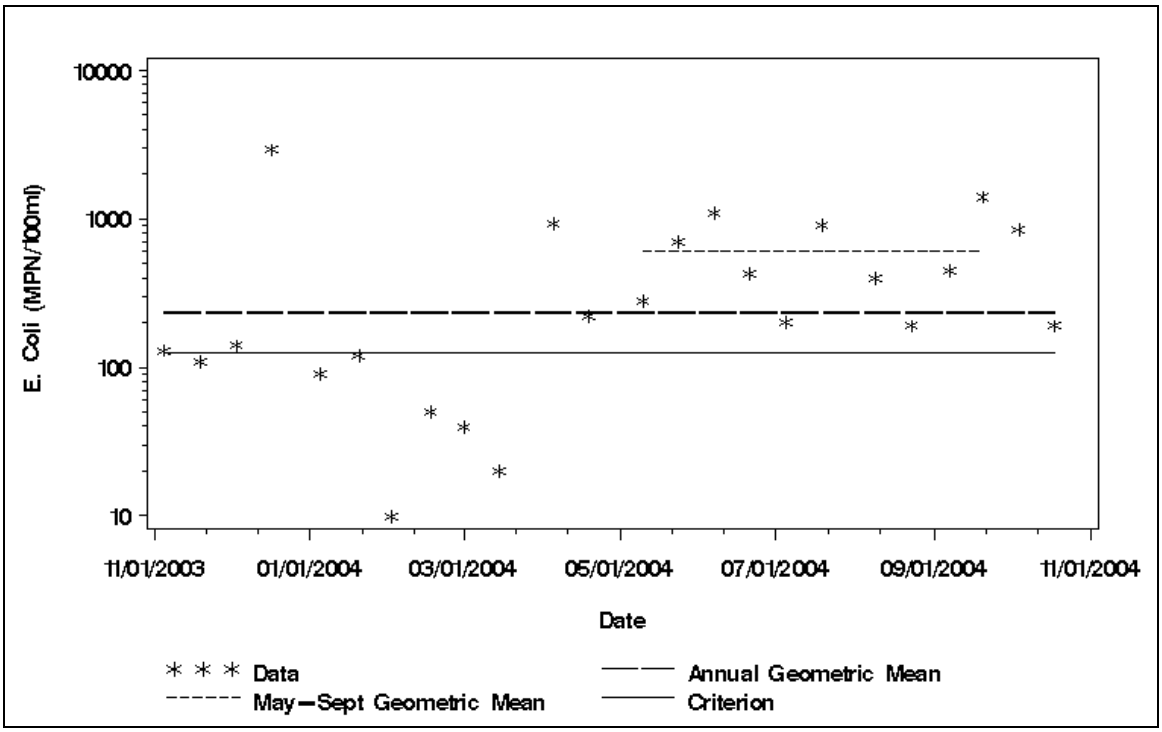

Figure A-7: *E. coli* Concentration vs. Time for MDE Monitoring Station WGP0050

Appendix B - Flow Duration Curve Analysis to Define Strata

The Loch Raven Reservoir watershed was assessed to determine hydrologically significant strata. The purpose of these strata is to apply weights to monitoring data and thus reduce bias associated with the monitoring design. The strata group hydrologically similar water quality samples and provide a better estimate of the mean concentration at the monitoring station.

The flow duration curve for a watershed is a plot of all possible daily flows, ranked from highest to lowest, versus their probability of exceedance. In general, the higher flows will tend to be dominated by excess runoff from rain events and the lower flows will result from drought type conditions. The mid-range flows are a combination of high base flow with limited runoff and lower base flow with excess runoff. The range of these mid-level flows will vary with antecedent soil moisture conditions. The purpose of the following analysis is to identify hydrologically significant groups, based on the previously described flow regimes, within the flow duration curve.

Flow Analysis

There are four USGS gage stations in the Loch Raven Reservoir watershed used for the analysis. These sites are listed in Table B-1. Flow duration curves for these sites are presented in Figure B-1.

Table B-1: USGS Sites in the Loch Raven Reservoir Watershed

USGS Site #	Dates Used	Location
01582000	10/01/1982 – 9/30/2007	Little Falls at Blue Mount, MD
01582500	12/10/1982 – 9/30/2007	Gunpowder Falls at Glencoe, MD
01583500	10/01/1982 – 9/30/2007	Western Run at Western Run, MD
01583600	10/01/1982 – 9/30/2007	Beaverdam Run at Cockeysville, MD

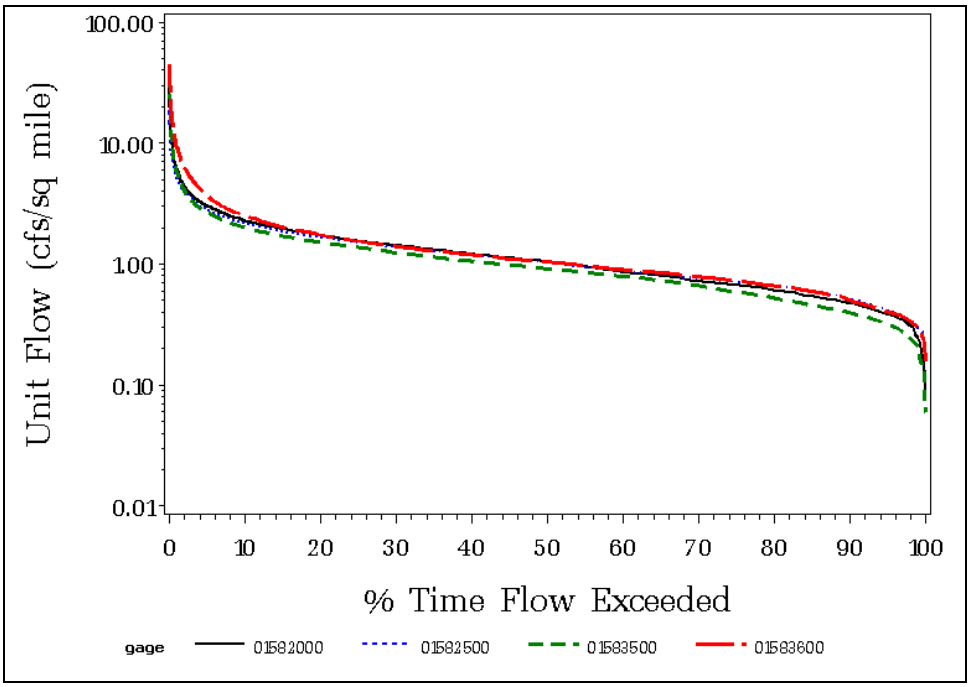

Figure B-1: Flow Duration Curve for Loch Raven Reservoir Watershed USGS Sites

The long-term average daily unit flows at the four stations correspond to a weighted average flow frequency of 34.3%. Using the definition of a high flow condition as occurring when flows are higher than the long-term average flow and a low flow condition as occurring when flows are lower than the long-term average flow, the 34.3 percentile threshold was selected to define the limits between high flows and low flows in this watershed. Therefore, a high flow condition will be defined as occurring when the daily flow duration percentile is less than 34.3% and a low flow condition will be defined as occurring when the daily flow duration percentile is greater than 34.3%. Definitions of high and low range flows are presented in Table B-2.

Table B-2: Definition of Flow Regimes

High Flow	Represents conditions where stream flow tends to be dominated by surface runoff.
Low Flow	Represents conditions where stream flow tends to be more dominated by groundwater flow.

The final analysis to define the daily flow duration intervals (flow regions, strata) includes the bacteria monitoring data. Bacteria (*E. coli*) monitoring data are "placed" within the regions (strata) based on the daily flow duration percentile of the date of sampling.

Maryland's water quality standards for bacteria state that, when available, the geometric mean indicator should be based on at least five samples taken representatively over 30 days. Therefore,

in situations in which fewer than five samples “fall” within a particular flow regime interval, the interval and the adjacent interval will be joined. In the Loch Raven Reservoir watershed there are not sufficient samples in both flow regimes to estimate the geometric means by stratum. Therefore an overall geometric mean will be calculated for both the annual and seasonal conditions.

Appendix C – BST Report

Final Report

Maryland Department of the Environment

MOU U00P7200322

Identifying Sources of Fecal Pollution in Shellfish and Nontidal Waters in Maryland Watersheds

November 2006 – June 2008

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June 30, 2008

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INTRODUCTION

Microbial Source Tracking. Microbial Source Tracking (MST) is a relatively recent scientific and technological innovation designed to distinguish the origins of enteric microorganisms found in environmental waters. Several different methods and a variety of different indicator organisms (both bacteria and viruses) have successfully been used for MST, as described in recent reviews (Scott *et al.*, 2002; Simpson *et al.*, 2002). When the indicator organism is bacteria, the term Bacterial Source Tracking (BST) is often used. Some common bacterial indicators for BST analysis include: *E. coli*, *Enterococcus* spp., *Bacteroides-Prevotella*, and *Bifidobacterium* spp.

Techniques for MST can be grouped into one of the following three categories: molecular (genotypic) methods, biochemical (phenotypic) methods, or chemical methods. Ribotyping, Pulsed-Field Gel Electrophoresis (PFGE), and Randomly-Amplified Polymorphic DNA (RAPD) are examples of molecular techniques. Biochemical methods include Antibiotic Resistance Analysis (ARA), F-specific coliphage typing, and Carbon Source Utilization (CSU) analysis. Chemical techniques detect chemical compounds associated with human activities, but do not provide any information regarding nonhuman sources. Examples of this type of technology include detection of optical brighteners from laundry detergents or caffeine (Simpson *et al*., 2002).

Many of the molecular and biochemical methods of MST are "library-based," requiring the collection of a database of fingerprints or patterns obtained from indicator organisms isolated from known sources. Statistical analysis determines fingerprints/patterns of known sources species or categories of species (*i.e.*, human, livestock, pets, wildlife). Indicator isolates collected from water samples are analyzed using the same MST method to obtain their fingerprints or patterns, which are then statistically compared to those in the library. Based upon this comparison, the final results are expressed in terms of the "statistical probability" that the water isolates came from a given source (Simpson *et al*. 2002).

In this BST project, we studied the following Maryland nontidal watersheds: Liberty Reservoir, Loch Raven Reservoir, and the Upper Patuxent River Also included in the study were the following tidal shellfish harvesting areas: Honga River, Hunting Creek and Leeds Creek, Little Choptank River, Little Creek, Miles River, Shipping Creek, and Wells Cove watersheds . The methodology used was the ARA with *Enterococcus* spp. as the indicator organism. Previous BST publications have demonstrated the predictive value of using this particular technique and indicator organism (Price *et al*., 2006; Hagedorn, 1999; Wiggins, 1999). A pilot study using PFGE, a genotypic BST method, was used on a subset of deer scat isolates collected from watersheds across Maryland.

Antibiotic Resistance Analysis. A variety of different host species can potentially contribute to the fecal contamination found in natural waters. Many years ago, scientists speculated on the possibility of using resistance to antibiotics as a way of determining the sources of this fecal contamination (Bell *et al.*, 1983; Krumperman, 1983). In ARA, the premise is that bacteria

isolated from different hosts can be discriminated based upon differences in the selective pressure of microbial populations found in the gastrointestinal tract of those hosts (humans, livestock, pets, wildlife) (Wiggins, 1996). Microorganisms isolated from the fecal material of wildlife would be expected to have a much lower level of resistance to antibiotics than isolates collected from the fecal material of humans, livestock and pets. In addition, depending upon the specific antibiotics used in the analysis, isolates from humans, livestock and pets could be differentiated from each other.

In ARA, isolates from known sources are tested for resistance or sensitivity against a panel of antibiotics and antibiotic concentrations. This information is then used to construct a library of antibiotic resistance patterns from known-source bacterial isolates. Microbial isolates collected from water samples are then tested and their resistance results are recorded. Based upon a comparison of resistance patterns of water and library isolates, a statistical analysis can predict the likely host source of the water isolates (Hagedorn 1999; Price *et al*., 2006; Wiggins 1999).

LABORATORY METHODS

Isolation of *Enterococcus* from Known-Source Samples. Fecal samples, identified to source, were delivered to the Salisbury University (SU) BST lab by Maryland Department of the Environment (MDE) personnel. Fecal material suspended in phosphate buffered saline was plated onto selective m-Enterococcus agar. After incubation at 37° C, up to eight (8) *Enterococcus* isolates were randomly selected from each fecal sample for ARA testing.

Isolation of Enterococcus from Water Samples. Water samples were collected by MDE staff and shipped overnight to MapTech Inc, Blacksburg, Va. Bacterial isolates were collected by membrane filtration. Up to 24 randomly selected *Enterococcus* isolates were collected from each water sample and all isolates were then shipped to the SU BST lab.

Antibiotic Resistance Analysis. Each bacterial isolate from both water and scat were grown in Enterococcosel® broth (Becton Dickinson, Sparks, MD) prior to ARA testing. *Enterococci* are capable of hydrolyzing esculin, turning this broth black. Only esculin-positive isolates were tested for antibiotic resistance.

Bacterial isolates were plated onto tryptic soy agar plates, each containing a different concentration of a given antibiotic. Plates were incubated overnight at 37° C and isolates then scored for growth (resistance) or no growth (sensitivity). Data consisting of a “1” for resistance or “0” for sensitivity for each isolate at each concentration of each antibiotic was then entered into a spread-sheet for statistical analysis.

The following table includes the antibiotics and concentrations used for isolates in analyses for all the study watersheds.

Table C-1. Antibiotics and concentrations used for ARA.

Antibiotic	Concentration (µg/ml)
Amoxicillin	0.625
Cephalothin	10, 15, 30, 50
Chloramphenicol	10
Chlortetracycline	60, 80, 100
Erythromycin	10
Gentamycin	5, 10, 15
Neomycin	40, 60, 80
Oxytetracycline	20, 40, 60, 80, 100
Salinomycin	10
Streptomycin	40, 60, 80, 100
Tetracycline	10, 30, 50, 100
Vancomycin	2.5

KNOWN-SOURCE LIBRARY

Construction and Use. Fecal samples (scat) from known sources in each watershed were collected during the study period by MDE personnel and delivered to the BST Laboratory at SU. *Enterococcus* isolates were obtained from known sources (e.g., human, cow, goat, horse, dog, bear, beaver, deer, duck, fox, goose, heron, opossum, rabbit, raccoon, and squirrel). For each watershed, a library of patterns of *Enterococcus* isolate responses to the panel of antibiotics was analyzed using the statistical software CART® (Salford Systems, San Diego, CA). *Enterococcus* isolate response patterns were also obtained from bacteria in water samples collected at the monitoring stations in each basin. Using statistical techniques, these patterns were then compared to those in the appropriate library to identify the probable source of each water isolate. For both the nontidal and tidal watersheds, no combined known-source libraries were used for any shellfish harvesting area; a known-source isolate library collected from each area was used for the particular watershed.

STATISTICAL ANALYSIS

We applied a tree classification method, [1]CART®, to build a model that classifies isolates into source categories based on ARA data. CART® builds a classification tree by recursively splitting the library of isolates into two nodes. Each split is determined by the antibiotic variables (antibiotic resistance measured for a collection of antibiotics at varying concentrations). The first step in the tree-building process splits the library into two nodes by considering every binary split associated with every variable. The split is chosen that maximizes a specified index of homogeneity for isolate sources within each of the nodes. In subsequent steps, the same process is applied to each resulting node until a *stopping* criterion is satisfied. Nodes where an additional split would lead to only an insignificant increase in the *homogeneity index* relative to the *stopping* criterion are referred to as *terminal* nodes.[2] The collection of *terminal* nodes defines the classification model. Each *terminal* node is associated with one source, the source isolate with an unknown source), based that is most populous among the library isolates in the node. Each water sample isolate (*i.e*., an on its antibiotic resistance pattern, is identified with one specific *terminal* node and is assigned the source of the majority of library isolates in that *terminal* node.[3]

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1 The Elements of Statistical Learning: Data Mining, Inference, and Prediction. Hastie T, Tibshirani R, and Friedman J. Springer 2001.

2 An ideal split, i.e., a split that achieves the theoretical maximum for homogeneity, would produce two nodes each containing library isolates from only one source.

3 The CART® tree-classification method we employed includes various features to ensure the development of an optimal classification model. For brevity in exposition, we have chosen not to present details of those features, but suggest the following sources: Breiman L, et al. *Classification and Regression Trees*. Pacific Grove: Wadsworth, 1984; and Steinberg D and Colla P. *CART—Classification and Regression Trees.* San Diego, CA: Salford Systems, 1997.

Loch Raven Reservoir Watershed ARA Results

Known-Source Library. A 620 known-source isolate library was constructed from sources in the Loch Raven Reservoir Watershed. The number of unique antibiotic resistance patterns was calculated, and the known sources in the combined library were grouped into four categories: human, livestock (cow, horse), pet (dog), and wildlife (deer, duck, goose, fox, rabbit, raccoon) (Table C-2). The library was analyzed for its ability to take a subset of the library isolates and correctly predict the identity of their host sources when they were treated as unknowns. Average rates of correct classification (ARCC) for the library were found by repeating this analysis using several probability cutoff points, as described above in the "Statistical Analysis" section of this document. The number-not-classified for each probability was determined. From these results, the percent unknown and percent correct classification (RCCs) was calculated (Table C-3).

Table C-2: Category, total number, and number of unique patterns in the Loch Raven Reservoir known-source library.

Category	Potential Sources	Total Isolates	Unique Patterns
Human	human	187	101
Livestock	cow, horse	96	24
Pet	dog	56	22
Wildlife	deer, duck, goose, fox, rabbit, raccoon	281	65
Total		620	212

For Loch Raven Reservoir Watershed, a cutoff probability of 0.50 (50%) was shown to yield an overall rate of correct classification of 76% (Figure C-1; Table C-3). The resulting rates of correction classification (RCCs) for the four categories of sources in the Loch Raven Reservoir library are shown in Table C-4.

Table C-3: Number of isolates not classified, percent unknown, and percent correct for seven (7) cutoff probabilities for Loch Raven Reservoir known-source isolates using the Loch Raven Reservoir known-source library.

Threshold	0	0.375	**0.5**	0.6	0.7	0.8	0.9
% correct	67.1%	71.6%	**76.3%**	76.9%	81.7%	86.9%	92.2%
% unknown	0.0%	9.2%	**27.7%**	35.8%	49.8%	61.8%	73.2%
# not classified	0	57	**172**	222	309	383	454

Figure C-1: Loch Raven Reservoir Classification Model: Percent Correct versus Percent Unknown using the Loch Raven Reservoir library.

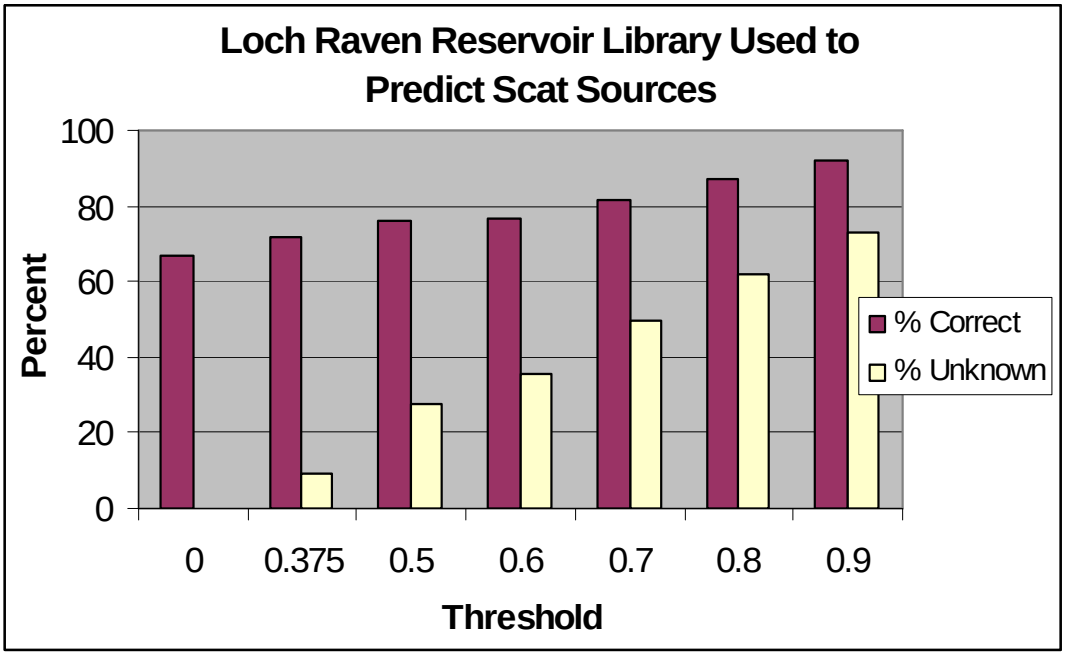


Table C-4: Actual species categories versus predicted categories, at 50% probability cutoff, with rates of correct classification (RCC) for each category.

	Predicted						
Actual	Human	Livestock	Pet	Wildlife	Unknown	Total	RCC*
Human	122	1	8	16	40	187	83.0%
Livestock	1	41	5	12	37	96	69.5%
Pet	1	1	40	1	13	56	93.0%
Wildlife	20	35	5	139	82	281	69.8%
Total	144	78	58	168	172	620	76.3%

*RCC = Actual number of predicted species category / Total number predicted. Example: 163 pet correctly predicted / 175 total number predicted for pet = 163/175 = 93%.

Loch Raven Reservoir Water Samples. Monthly monitoring from seven (7) monitoring stations on Loch Raven Reservoir was the source of water samples. The maximum number of *Enterococcus* isolates obtained per water sample was 24, although the number of isolates that actually grew was sometimes less than 24. A total of 1,447 *Enterococcus* isolates were analyzed by statistical analysis. The BST results by species category, shown in Table C-5, indicate that 97% of the water isolates were able to be classified to a probable host source when using a 0.50 (50%) probability threshold.

Table C-5: Probable host sources of water isolates by species category, number of isolates, and percent isolates classified at a cutoff probability of 50%.

Source	Count	Percent	Percent Without Unknowns
Human	498	34.4%	35.4%
Livestock	238	16.4%	16.9%
Pet	132	9.1%	9.4%
Wildlife	538	37.2%	38.3%
Unknown	41	2.8%	
Total	1447	100.0%	100.0%
% classified	**97.2%**		

*Percentages may not add up to 100% due to rounding.

The seasonal distribution of water isolates from samples collected at each sampling station is shown below in Table C-6.

Table C-6: *Enterococcu*s isolates obtained from water collected during the spring, summer, fall, and winter seasons for Loch Raven Reservoir's seven (7) monitoring stations.

	Season				
Station	Spring	Summer	Fall	Winter	Total
BEV0005	68	71	60	58	257
GUN0233	61	67	60	17	205
GUN0284	58	58	62	32	210
GUN0387	13	8	35	9	65
LIT0002	56	68	49	29	202
SBH0002	60	72	68	51	251
WGP0050	66	68	69	54	257

Tables C-7 and C-8 on the following pages show the number and percent of the probable sources for each monitoring station by month.

Table C-7: BST Analysis: Number of Isolates per Station per Date.

		Predicted Source					
Station	Date	Human	Livestock	Pet	Wildlife	Unknown	Total
BEV0005	11/19/03	5	13	0	4	0	22
BEV0005	12/03/03	2	2	2	7	7	20
BEV0005	01/05/04	15	2	1	5	1	24
BEV0005	02/17/04	6	5	2	9	2	24
BEV0005	03/01/04	2	2	3	3	0	10
BEV0005	04/05/04	18	0	0	0	2	20
BEV0005	05/10/04	3	9	0	12	0	24
BEV0005	06/07/04	9	1	5	9	0	24
BEV0005	07/06/04	6	1	4	12	0	23
BEV0005	08/09/04	18	6	0	0	0	24
BEV0005	09/07/04	11	0	0	12	1	24
BEV0005	10/04/04	5	0	2	11	0	18
GUN0233	11/19/03	7	4	0	11	2	24
GUN0233	12/03/03	4	9	0	3	0	16
GUN0233	01/05/04	0	0	0	4	2	6
GUN0233	02/17/04	5	3	0	1	0	9
GUN0233	03/01/04	0	0	0	2	0	2
GUN0233	04/05/04	5	6	0	12	0	23
GUN0233	05/10/04	3	4	3	5	0	15
GUN0233	06/07/04	11	3	4	5	0	23
GUN0233	07/06/04	7	1	2	14	0	24
GUN0233	08/09/04	5	0	9	10	0	24
GUN0233	09/07/04	2	0	0	17	0	19
GUN0233	10/04/04	1	5	2	12	0	20
GUN0284	11/19/03	0	2	3	13	0	18
GUN0284	12/03/03	5	14	0	5	0	24
GUN0284	01/05/04	3	13	0	8	0	24
GUN0284	02/17/04	0	3	0	3	0	6
GUN0284	03/01/04	0	0	1	1	0	2
GUN0284	04/05/04	13	4	0	7	0	24
GUN0284	05/10/04	7	0	1	1	1	10
GUN0284	06/07/04	3	1	17	3	0	24
GUN0284	07/06/04	2	0	7	13	0	22
GUN0284	08/09/04	7	0	6	7	0	20
GUN0284	09/07/04	1	3	2	10	0	16

Table C-7 (continued): BST Analysis: Number of Isolates per Station per Date.

		Predicted Source					
Station	Date	Human	Livestock	Pet	Wildlife	Unknown	Total
GUN0284	10/04/04	6	1	3	10	0	20
GUN0387	11/19/03	0	0	0	1	0	1
GUN0387	12/03/03	6	0	0	14	1	21
GUN0387	01/05/04	4	0	0	0	0	4
GUN0387	02/17/04	0	0	0	5	0	5
GUN0387	06/07/04	12	0	1	0	0	13
GUN0387	07/06/04	4	0	3	0	0	7
GUN0387	08/09/04	0	0	0	1	0	1
GUN0387	10/04/04	7	0	1	5	0	13
LIT0002	11/19/03	2	2	0	0	0	4
LIT0002	12/03/03	15	1	1	3	1	21
LIT0002	01/05/04	0	16	0	8	0	24
LIT0002	02/17/04	2	0	0	0	0	2
LIT0002	03/01/04	2	0	0	0	1	3
LIT0002	04/05/04	5	1	0	7	0	13
LIT0002	05/10/04	8	0	5	6	0	19
LIT0002	06/07/04	21	1	2	0	0	24
LIT0002	07/06/04	19	0	3	2	0	24
LIT0002	08/09/04	15	2	3	0	0	20
LIT0002	09/07/04	12	5	0	5	2	24
LIT0002	10/04/04	18	2	0	2	2	24
SBH0002	11/19/03	9	11	2	2	0	24
SBH0002	12/03/03	7	0	3	10	1	21
SBH0002	01/05/04	13	3	0	7	0	23
SBH0002	02/17/04	10	7	2	3	0	22
SBH0002	03/01/04	1	0	0	4	1	6
SBH0002	04/05/04	6	1	0	4	1	12
SBH0002	05/10/04	7	5	1	11	0	24
SBH0002	06/07/04	7	9	2	6	0	24
SBH0002	07/06/04	9	1	1	13	0	24
SBH0002	08/09/04	4	5	0	15	0	24
SBH0002	09/07/04	5	3	3	12	1	24
SBH0002	10/04/04	6	2	4	10	1	23
WGP0050	11/19/03	5	0	1	14	3	23
WGP0050	12/03/03	1	9	0	11	1	22
WGP0050	01/05/04	1	3	0	12	1	17
WGP0050	02/17/04	6	2	1	12	0	21

Table C-7 (continued): BST Analysis: Number of Isolates per Station per Date.

		Predicted Source					
Station	Date	Human	Livestock	Pet	Wildlife	Unknown	Total
WGP0050	03/01/04	2	3	1	6	4	16
WGP0050	04/05/04	7	11	0	6	0	24
WGP0050	05/10/04	5	4	0	8	1	18
WGP0050	06/07/04	9	3	7	5	0	24
WGP0050	07/06/04	9	0	0	15	0	24
WGP0050	08/09/04	8	1	5	10	0	24
WGP0050	09/07/04	4	2	0	13	1	20
WGP0050	10/04/04	8	6	1	9	0	24
Total		498	238	132	538	41	1447

Table C-8: BST Analysis: Percent of Isolates per Station per Date.

		Predicted Source					
Station	Date	Human	Livestock	Pet	Wildlife	Unknown	Total
BEV0005	11/19/03	23%	59%	0%	18%	0%	100%
BEV0005	12/03/03	10%	10%	10%	35%	35%	100%
BEV0005	01/05/04	63%	8%	4%	21%	4%	100%
BEV0005	02/17/04	25%	21%	8%	38%	8%	100%
BEV0005	03/01/04	20%	20%	30%	30%	0%	100%
BEV0005	04/05/04	90%	0%	0%	0%	10%	100%
BEV0005	05/10/04	13%	38%	0%	50%	0%	100%
BEV0005	06/07/04	38%	4%	21%	38%	0%	100%
BEV0005	07/06/04	26%	4%	17%	52%	0%	100%
BEV0005	08/09/04	75%	25%	0%	0%	0%	100%
BEV0005	09/07/04	46%	0%	0%	50%	4%	100%
BEV0005	10/04/04	28%	0%	11%	61%	0%	100%
GUN0233	11/19/03	29%	17%	0%	46%	8%	100%
GUN0233	12/03/03	25%	56%	0%	19%	0%	100%
GUN0233	01/05/04	0%	0%	0%	67%	33%	100%
GUN0233	02/17/04	56%	33%	0%	11%	0%	100%
GUN0233	03/01/04	0%	0%	0%	100%	0%	100%
GUN0233	04/05/04	22%	26%	0%	52%	0%	100%
GUN0233	05/10/04	20%	27%	20%	33%	0%	100%
GUN0233	06/07/04	48%	13%	17%	22%	0%	100%
GUN0233	07/06/04	29%	4%	8%	58%	0%	100%
GUN0233	08/09/04	21%	0%	38%	42%	0%	100%
GUN0233	09/07/04	11%	0%	0%	89%	0%	100%
GUN0233	10/04/04	5%	25%	10%	60%	0%	100%
GUN0284	11/19/03	0%	11%	17%	72%	0%	100%
GUN0284	12/03/03	21%	58%	0%	21%	0%	100%
GUN0284	01/05/04	13%	54%	0%	33%	0%	100%

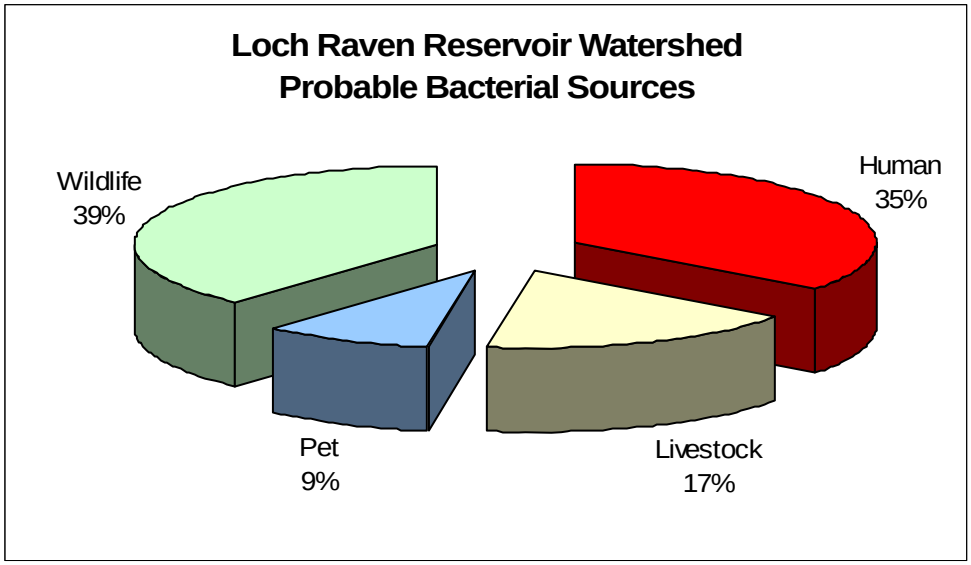
Table C-8 (continued): BST Analysis: Percent of Isolates per Station per Date.

		Predicted Source					
Station	Date	Human	Livestock	Pet	Wildlife	Unknown	Total
GUN0284	02/17/04	0%	50%	0%	50%	0%	100%
GUN0284	03/01/04	0%	0%	50%	50%	0%	100%
GUN0284	04/05/04	54%	17%	0%	29%	0%	100%
GUN0284	05/10/04	70%	0%	10%	10%	10%	100%
GUN0284	06/07/04	13%	4%	71%	13%	0%	100%
GUN0284	07/06/04	9%	0%	32%	59%	0%	100%
GUN0284	08/09/04	35%	0%	30%	35%	0%	100%
GUN0284	09/07/04	6%	19%	13%	63%	0%	100%
GUN0284	10/04/04	30%	5%	15%	50%	0%	100%
GUN0387	11/19/03	0%	0%	0%	100%	0%	100%
GUN0387	12/03/03	29%	0%	0%	67%	5%	100%
GUN0387	01/05/04	100%	0%	0%	0%	0%	100%
GUN0387	02/17/04	0%	0%	0%	100%	0%	100%
GUN0387	06/07/04	92%	0%	8%	0%	0%	100%
GUN0387	07/06/04	57%	0%	43%	0%	0%	100%
GUN0387	08/09/04	0%	0%	0%	100%	0%	100%
GUN0387	10/04/04	54%	0%	8%	38%	0%	100%
LIT0002	11/19/03	50%	50%	0%	0%	0%	100%
LIT0002	12/03/03	71%	5%	5%	14%	5%	100%
LIT0002	01/05/04	0%	67%	0%	33%	0%	100%
LIT0002	02/17/04	100%	0%	0%	0%	0%	100%
LIT0002	03/01/04	67%	0%	0%	0%	33%	100%
LIT0002	04/05/04	38%	8%	0%	54%	0%	100%
LIT0002	05/10/04	42%	0%	26%	32%	0%	100%
LIT0002	06/07/04	88%	4%	8%	0%	0%	100%
LIT0002	07/06/04	79%	0%	13%	8%	0%	100%
LIT0002	08/09/04	75%	10%	15%	0%	0%	100%
LIT0002	09/07/04	50%	21%	0%	21%	8%	100%
LIT0002	10/04/04	75%	8%	0%	8%	8%	100%
SBH0002	11/19/03	38%	46%	8%	8%	0%	100%
SBH0002	12/03/03	33%	0%	14%	48%	5%	100%
SBH0002	01/05/04	57%	13%	0%	30%	0%	100%
SBH0002	02/17/04	45%	32%	9%	14%	0%	100%
SBH0002	03/01/04	17%	0%	0%	67%	17%	100%
SBH0002	04/05/04	50%	8%	0%	33%	8%	100%
SBH0002	05/10/04	29%	21%	4%	46%	0%	100%
SBH0002	06/07/04	29%	38%	8%	25%	0%	100%
SBH0002	07/06/04	38%	4%	4%	54%	0%	100%

Table C-8 (continued): BST Analysis: Percent of Isolates per Station per Date.

		Predicted Source					
Station	Date	Human	Livestock	Pet	Wildlife	Unknown	Total
SBH0002	08/09/04	17%	21%	0%	63%	0%	100%
SBH0002	09/07/04	21%	13%	13%	50%	4%	100%
SBH0002	10/04/04	26%	9%	17%	43%	4%	100%
WGP0050	11/19/03	22%	0%	4%	61%	13%	100%
WGP0050	12/03/03	5%	41%	0%	50%	5%	100%
WGP0050	01/05/04	6%	18%	0%	71%	6%	100%
WGP0050	02/17/04	29%	10%	5%	57%	0%	100%
WGP0050	03/01/04	13%	19%	6%	38%	25%	100%
WGP0050	04/05/04	29%	46%	0%	25%	0%	100%
WGP0050	05/10/04	28%	22%	0%	44%	6%	100%
WGP0050	06/07/04	38%	13%	29%	21%	0%	100%
WGP0050	07/06/04	38%	0%	0%	63%	0%	100%
WGP0050	08/09/04	33%	4%	21%	42%	0%	100%
WGP0050	09/07/04	20%	10%	0%	65%	5%	100%
WGP0050	10/04/04	33%	25%	4%	38%	0%	100%
Total		34%	16%	9%	37%	3%	100%

Figure C-2: Loch Raven Reservoir Watershed relative contributions by probable sources of *Enterococcus* contamination.



Loch Raven Reservoir Summary

The use of ARA was successful for identification of probable bacterial sources in the Loch Raven Reservoir Watershed. When water isolates were compared to the library and potential sources predicted, 97% of the isolates were classified as to category by statistical analysis. The highest RCC for the library was 93% (for pet), with 70% for livestock and wildlife. Human sources had a RCC of 83%.

The largest category of potential sources in the watershed as a whole was wildlife (39% of classified water isolates), followed by human and livestock (35% and 17%, respectively). The lowest potential source contribution was for pet (9%) (Fig. C-2).

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Adjustment of BST Results

As explained in the BST Summary for the Loch Raven Reservoir, the percent of correct classification (RCC) for bacteria sources can introduce a potential misclassification of the more probable sources in the watershed. This is seen in Table C-4, which shows results of the analysis of samples from known sources. For example, out of 620, 96 isolates were known to be of livestock source but only 41 were classified by the analysis as being of livestock source. Of those 96, 1 was classified as human, 5 as pet, 12 as wildlife and 37 as unknown. Similarly, of the other three categories, 1 isolates known to be human, 1 isolates known to be pet, and 35 known wildlife isolates were classified as livestock, resulting in a total of 78 of all 620 isolates classified as livestock of which only 41 were known to be of livestock source.

The results provided by the BST methodology can be adjusted based on the known source percent of correct classification results provided in Table C-4.

Example:

The current BST methodology provides the following source percentages for station GUN0284 during annual conditions:

Source Category	Original Percentage
Pets	20.93 %
Human	22.38 %
Livestock	15.94 %
Wildlife	40.00 %
Unknown	0.75 %

To get the correct human source percentage we redistributed the above percentages based on the % of correct classification as follows.

From Table C-4:

Source Category	Isolates known to be from Human Source	Total Isolates Predicted for Each category	Percentage
Pets	8	58	13.8 %
Human	122	144	84.7 %
Livestock	1	78	1.3 %
Wildlife	16	168	9.5 %
Unknown	40	172	23.3 %

Applying those percentages to the original estimated source distribution presented above will result in the adjusted percentage for human sources:

= (13.8 x 20.93) + (84.7 x 22.38) + (1.3 x 15.94) + (9.5 x 40.00) + (23.3 x 0.75) = 26.04 %

Thus the correct human source percentage, the value used in the TMDL analysis, is 26.04% and not 22.38%. Corrected percentages are also calculated as above for domestic animal (pet), livestock and wildlife sources. The classification of unknown is eliminated in the process as all known isolates are of known source. For station GUN0284 the annual corrected source percentages are as follows:

Source Category	**Adjusted Percentage**
Pets	15.1 %
Human	26.0 %
Livestock	13.4 %
Wildlife	45.5 %

Appendix D – Estimating Maximum Daily Loads

This appendix documents the technical approach used to define maximum daily loads of fecal bacteria consistent with the annual average TMDL which, when met, are protective of water quality standards in the Loch Raven Reservoir watershed. The approach builds upon the TMDL analysis that was conducted to ensure that compliance with the annual average target will result in compliance with the applicable water quality standards. The annual average loading target was converted into allowable *daily* values by using the loadings developed from the TMDL analysis. The approach is consistent with available EPA guidance on generating daily loads for TMDLs.

The available guidance for developing daily loads does not specify a single allowable approach; it contains a range of options. Selection of a specific method for translating a time-series of allowable loads into expression of a TMDL requires decisions regarding both the level of resolution (e.g., single daily load for all conditions vs. loads that vary with environmental conditions) and level of probability associated with the TMDL.

Level of Resolution

The level of resolution pertains to the amount of detail used in specifying the maximum daily load. The draft EPA guidance on daily loads provides three categories of options for level of resolution.

1. **Representative daily load:** In this option, a single daily load (or multiple representative daily loads) is specified that covers all time periods and environmental conditions.
2. **Flow-variable daily load:** This option allows the maximum daily load to vary based upon the observed flow condition.
3. **Temporally-variable daily load:** This option allows the maximum daily load to vary based upon seasons or times of varying source or water body behavior.

Probability Level

Essentially all TMDLs have some probability of being exceeded, with the specific probability being either explicitly specified or implicitly assumed. This level of probability reflects, directly or indirectly, two separate phenomena:

1. Water quality criteria consist of components describing acceptable magnitude, duration, and frequency. The frequency component addresses how often conditions can allowably surpass the combined magnitude and duration components.
2. Pollutant loads, especially from wet weather sources, typically exhibit a large degree of variability over time. It is rarely practical to specify a “never to be exceeded value” for a daily load, as essentially any loading value has some finite probability of being exceeded.

The draft daily load guidance states that the probability component of the maximum daily load should be “based on a representative statistical measure” that is dependent upon the specific TMDL and best professional judgment of the developers. This statistical measure represents

how often the maximum daily load is expected/allowed to be exceeded. The primary options for selecting this level of protection would be:

1. **The maximum daily load reflects some central tendency:** In this option, the maximum daily load is based upon the mean or median value of the range of loads expected to occur. The variability in the actual loads is not addressed.
2. **The maximum daily load reflects a level of protection implicitly provided by the selection of some "critical" period**: In this option, the maximum daily load is based upon the allowable load that is predicted to occur during some critical period examined during the analysis. The developer does not explicitly specify the probability of occurrence.
3. **The maximum daily load is a value that will be exceeded with a pre-defined probability:** In this option, a "reasonable" upper bound percentile is selected for the maximum daily load based upon a characterization of the variability of daily loads. For example, selection of the 95th percentile value would result in a maximum daily load that would be exceeded 5% of the time.

Selected Approach for Defining Maximum Daily Loads for Nonpoint Sources and MS4

To calculate the Loch Raven Reservoir watershed MDL for non-point sources and MS4s, a "representative daily load" option was selected as the level of resolution, and a value "that will be exceeded with a pre-defined probability" was selected as the level of protection. In these options, the maximum daily load is one single daily load that covers the two flow strata, with an upper bound percentile that accounts for the variability of daily loads. The upper bound percentile and the maximum daily loads were estimated following EPA's "Technical Support Document for Water Quality-Based Toxics Control" (1991 TSD) (EPA 1991); and "Approaches For Developing a Daily Load Expression for TMDLs Computed for Longer Term Averages" (EPA 2006).

The 1991 TSD illustrates a way to identify a target maximum daily concentration from a long-term average concentration (LTA) based on a coefficient of variation (CV) and the assumption of a log-normal distribution of the data. The equations for determining both the upper boundary percentile and corresponding maximum daily load described in the TSD are as follows:

$$MDLC = LTA * e^{[Z\sigma - 0.5\sigma^2]} \qquad \text{(D1)}$$

and,

$$MDL = MDLC*Q*F \qquad \text{(D2)}$$

where,

MDLC = maximum daily load concentration (MPN/100ml)
LTAC = long-term average TMDL concentration (MPN/100ml)
MDL = Maximum Daily Load (MPN/day)
Z = z-score associated with upper bound percentile (unitless)

σ^2 = $\ln(CV^2 + 1)$
CV = coefficient of variation
Q = flow (cfs)
F = conversion factor

The first step is to use the bacteria monitoring data to estimate the upper bound percentile as the percentile of the highest observed bacteria concentration in each of the seven monitoring stations of the Loch Raven Reservoir watershed. Using the maximum value of *E. coli* observed in each monitoring station, and solving for the z-score using the above formula, the value of "z" and its corresponding percentile is found as shown below. The percentile associated with the particular value of z can be found in tables in statistics books or using the function NORMSINV(%) in EXCEL©.

$$Z = [\log_{10}(MOC) - \log(AM) + 0.5\sigma^2]/\sigma \qquad \text{(D3)}$$

where,

Z = z-score associated with upper bound percentile
MOC = maximum observed bacteria concentration (MPN/100ml)
AM = arithmetic mean observed bacteria concentrations (MPN/100ml)
σ^2 = $\ln(CV^2 + 1)$
CV = coefficient of variation (arithmetic)

Note that these equations use arithmetic parameters, not geometric parameters as used in the calculations of the long-term annual average TMDL. Therefore, bias correction factors are not necessary to estimate the loads as will be explained below.

The highest percentile of all the stations will define the upper bound percentile to be used in estimating the maximum daily limits. In the case of the Loch Raven Reservoir watershed, a value measured at the GUN0233 station resulted in the highest percentile of the seven stations. This value translates to the 99.8th percentile, which is the upper boundary percentile to be used in the computation of the maximum daily limits (MDLs) throughout this analysis. Results of the analysis to estimate the recurrence or upper boundary percentile are shown in Table D-1.

Table D-1: Percentiles of Maximum Observed Bacteria Concentrations

Subwatershed	Maximum Observed *E. coli* Concentration (MPN/100ml)	Percentile (%)
GUN0387	120	99.0
LIT0002[1]	770	97.0
GUN0284	770	97.5
GUN0233	14,140	99.8
WGP0050	2,910	96.6
BEV0005	2,500	97.3
SBH0002	9,210	97.8

[1]Subwatersheds partially located in Pennsylvania

The 99.8th percentile value results in a maximum daily load that would not be exceeded 99.8% of the time, as, in a similar manner, a TMDL that represents the long term average condition would be expected to be exceeded half the time even after all required controls were implemented.

The MDLCs are estimated based on a statistical methodology referred to as "Statistical Theory of Rollback (STR)". This method predicts concentrations of a pollutant after its sources have been controlled (post-control concentrations), in this case after annual average TMDL implementation. Using STR, the daily TMDLs are calculated as presented below.

First, the long-term average TMDL concentrations (C_{LTA}) are estimated by applying the required percent reduction to the baseline (monitoring data) concentrations (C_b):

From Section 4.3, equations (7):

$$L_b = Q*C_b*F_1$$

And from equation (14):

$$Annual\ Average\ TMDL = L_b * (1 - R)$$

Therefore,

$$L_b*(1-R) = Q*C*F_1*(1-R) \qquad \text{(D4)}$$

As explained before, a reduction in concentration is proportional to a reduction in load, thus the bacteria concentrations expected after reductions are applied are equal to the baseline concentrations multiplied by one minus the required reduction:

$$C_{LTA} = C_b * (1-R) \qquad \text{(D5)}$$

The TMDL concentrations estimated as explained above are shown in Table D-2.

Table D-2: Long-term Annual Average (LTA) TMDL Bacteria Concentrations

Subwatershed	LTA Geometric Mean *E. coli* Concentration (MPN/100ml)	LTA Arithmetic Mean* *E. coli* Concentration (MPN/100ml)
GUN0387	14	22
LIT0002[1]	84	154
GUN0284	55	112
GUN0233	83	307
WGP0050	61	157
BEV0005	42	96
SBH0002	31	130

*Only arithmetic parameters are used in the daily loads analysis.
[1]Subwatersheds partially located in Pennsylvania

The next step is to calculate the 99.8th percentile (the MDL concentrations) of these expected concentrations (LTA concentrations) using the coefficient of variation of the baseline concentrations. Based on a general rule for coefficient of variations, the coefficient of variation of the distribution of pollutant concentrations does not change after these concentrations have been reduced or controlled by a fixed proportion (Ott 1995). Therefore, the coefficient of variation estimated using the monitoring data concentrations does not change, and it can be used to estimate the 99.8th percentile of the long-term average TMDL concentrations (LTAC) using equation (D1). These values are shown in Table D-3.

Table D-3: Maximum Daily Load (MDL) Concentrations

Subwatershed	Coefficient of Variation	MDL *E. coli* Concentration (MPN/100ml)
GUN0387	1.15	196
LIT0002[1]	1.54	1,933
GUN0284	1.77	1,640
GUN0233	3.56	8,255
WGP0050	2.39	3,077
BEV0005	2.04	1,611
SBH0002	4.13	3,875

[1]Subwatersheds partially located in Pennsylvania

With the 99.8th percentiles of LTA TMDL bacteria concentrations estimated as explained above, the maximum daily load for MS4 and non-point sources for each subwatershed can be now estimated as:

$$\textit{Daily TMDL (MPN/day)} = Q*(99.8^{th}C_{LTA})*F_1 \qquad \text{(D6)}$$

Selected Approach for Defining Maximum Daily Loads for Other Point Sources

The TMDL also considers contributions from other point sources (i.e., municipal and industrial WWTP) in watersheds that have NPDES permits with fecal bacteria limits. The TMDL analysis that defined the average annual TMDL held each of these sources constant at their existing NPDES permit limit (daily or monthly) for the entire year. The approach used to determine maximum daily loads was dependent upon whether a maximum daily load was specified within the permit. If a maximum daily load was specified within the permit, then the maximum design flow is multiplied by the maximum daily limit to obtain a maximum daily load. If a maximum daily limit was not specified in the permit, then the maximum daily loads are calculated from guidance in the TSD for Water Quality-based Toxics Control (EPA 1991). The long-term average annual TMDL was converted to maximum daily limits using Table 5-2 of the TSD assuming a coefficient of variation of 0.6 and a 99th percentile probability. This results in a dimensionless multiplication factor of 3.11. The average annual bacteria loads for WWTPs are reported in billion MPN/year. In the Loch Raven Reservoir watershed, to estimate the maximum daily loads for WWTPs, the annual average loads are multiplied by the multiplication factor as follows:

$$\textit{WWTP-WLA MDL (billion MPN/day)} = [\textit{WWTP-WLA (billion MPN/year)}]*(3.11/365) \qquad \text{(D7)}$$

The Maximum Daily Loads for the Loch Raven Reservoir subwatersheds, including those partially located in PA, are presented in Table D-4 below. For the unmonitored downstream

subwatershed an average load of the upstream stations, GUN0233, WGP0050 and BEV0005, is used.

Table D-4: Maximum Daily Loads Summary

Subwatershed	**Maximum Daily Load** (Billion *E.* coli MPN/day)
GUN0387	11
LIT0002[1]	3,327
GUN0284sub	157
GUN0233	2,186
WGP0050	5,251
BEV0005	1,194
SBH0002	212
Downstream Subwatershed	5,613

[1]Subwatersheds partially located in Pennsylvania

Maximum Daily Loads Allocations

Using the MDLs estimated as explained above, loads are allocated following the same methodology as the annual average TMDL (See section 4.8). The maximum daily load allocations for the Loch Raven Reservoir watershed are presented in Table D-5.

Table D-5: Loch Raven Reservoir Watershed Maximum Daily Loads in MD

Subwatershed	Total Allocation	LA_{LR}	$SW\text{-}WLA_{LR}$	$WWTP\text{-}WLA_{LR}$
	(Billion MPN *E. coli* /day)			
GUN0387	11	10	1	0
LIT0002[1]	3,084	2,956	128	0
GUN0284sub	157	152	5	0
GUN0233	2,186	2,139	47	0
WGP0050	5,251	5,128	110	13
BEV0005	1,194	960	234	0
SBH0002	212	35	177	0
Downstream Subwatershed	5,613	5,496	117	0
Total	**17,708**	**16,876**	**819**	**13**

[1]MD portion of the subwatershed only.

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APPENDIX H:

Total Maximum Daily Loads of Phosphorus and Sediments for Loch Raven Reservoir and Total Maximum Daily Loads of Phosphorus for Prettyboy Reservoir, Baltimore, Carroll, and Harford Counties, Maryland

Total Maximum Daily Loads of Phosphorus and Sediments for Loch Raven Reservoir And Total Maximum Daily Loads of Phosphorus for Prettyboy Reservoir, Baltimore, Carroll and Harford Counties, Maryland

FINAL

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List of Abbreviations

BMP	Best Management Practice
BOD	Biological Oxygen Demand
CBOD	Carbonaceous Biochemical Oxygen Demand
CE-QUAL-W2	U.S. Army Corps of Engineers Water Quality and Hydrodynamic Model, Version 3
Chla	Active Chlorophyll *a*
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
CWAP	Clean Water Action Plan
DO	Dissolved Oxygen
DPW	Baltimore City Department of Public Works
EPA	Environmental Protection Agency
FSA	Farm Service Administration
HSPF	Hydrological Simulation Program Fortran
ICPRB	Interstate Commission on the Potomac River Basin
LA	Load Allocation
lbs/yr	Pounds per Year
MD	Maryland
MDA	Maryland Department of Agriculture
MDE	Maryland Department of the Environment
MDP	Maryland Department of Planning
MGS	Maryland Geological Survey
mg/l	Milligrams per Liter
MGD	Million Gallons per Day
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer System
NBOD	Nitrogenous Biochemical Oxygen Demand
NMP	Nutrient Management Plan
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System

NPS	Nonpoint Source
POM	Particulate Organic Matter
PO4	Phosphate
RTG	Reservoir Technical Group
SCWQP	Soil Conservation and Water Quality Plan
SOD	Sediment Oxygen Demand
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSI	Trophic State Index
TSS	Total Suspended Solids
W2	CE-QUAL-W2
WLA	Wasteload Allocation
WQIA	Water Quality Improvement Act
WQLS	Water Quality Limited Segment
WRAS	Watershed Restoration Action Strategy
WWTP	Waste Water Treatment Plant
µg/l	Micrograms per Liter

EXECUTIVE SUMMARY

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes Total Maximum Daily Loads (TMDLs) for phosphorus and sediments in Loch Raven Reservoir (basin code 02-13-08-05) and for phosphorus in Prettyboy Reservoir (basin code 02-13-08-06).

Prettyboy Reservoir and Loch Raven Reservoir (referred to also as the Gunpowder Reservoirs), Use III-P waterbodies (COMAR 26.08.02.08J(4)), were identified on the 303(d) List submitted to EPA by the Maryland Department of the Environment (MDE) as impaired by nutrients (1996), sediments (1996 – Loch Raven), metals (1996), bacteria (2002 – Prettyboy), mercury in fish tissue (2002), and impacts to biological communities (2002 & 2004). This document upon approval from EPA, establishes TMDLs for the nutrient and sediment impairments. TMDLs were completed in 2002 for both reservoirs for the mercury listings. Water Quality Analyses were completed for both reservoirs for the metals listings in 2003. Other impairments within these watersheds will be addressed separately at a future date.

The water quality goal of the nutrient TMDLs is to reduce high chlorophyll *a* (Chla) concentrations that reflect excessive algal blooms, and to maintain dissolved oxygen (DO) at a level supportive of the designated uses for Prettyboy and Loch Raven Reservoirs. The water quality goal of the sediment TMDL for Loch Raven Reservoir is to increase the useful life of the reservoir for water supply by preserving storage capacity.

The TMDLs for the nutrient total phosphorus (TP) were determined using a time-variable, two-dimensional water quality eutrophication model, CE-QUAL-W2 ("W2"), to simulate water quality in each reservoir. The TMDLs are based on average annual total phosphorus loads for the simulation period 1992-1997, which includes both wet and dry years, and thus takes into account a variety of hydrological conditions. Chla concentrations indicative of eutrophic conditions can occur at any time of year and are the cumulative result of phosphorus loadings that span seasons. Thus, average annual phosphorus total loads are the most appropriate measure for expressing the nutrient TMDLs for Prettyboy and Loch Raven Reservoirs. Similarly, the sediment TMDL for Loch Raven Reservoir, which is based on the water quality modeling performed for the nutrient TMDLs, is expressed as an average annual load in keeping with the long-term water quality goal of preserving the storage capacity of the reservoir.

The TMDLs include (1) a wasteload allocation (WLA) to municipal wastewater treatment plants and municipal storm sewer systems, (2) a load allocation (LA) to nonpoint sources, and (3) a 5% margin of safety (MOS) for the nutrient TMDLs and an implicit MOS for the sediment TMDL. The table below summarizes the nutrient and sediment TMDLs.

Summary of Nutrient and Sediment TMDLs for Prettyboy and Loch Raven Reservoirs

Waterbody	Constituent	TMDL	WLA	LA	MOS
Prettyboy Reservoir	TP (lbs/yr)	23,192	2,940	19,072	1,160
Loch Raven Reservoir	TP (lbs/yr)	54,941	22,010	30,184	2,747
Loch Raven Reservoir	Sediment (tons/yr)	28,925	1,210	27,715	Implicit

Numerous factors provide assurance that these TMDLs will be implemented. First, National Pollutant Discharge Elimination System (NPDES) permits for both wastewater treatment plants and urban stormwater systems will play important roles in assuring implementation. Second, Maryland has several well-established programs that may be drawn upon, including Maryland's Tributary Strategies for Nutrient Reductions developed in accordance with the Chesapeake Bay Agreement. Third, Maryland's Water Quality Improvement Act of 1998 requires that nutrient management plans be implemented for all agricultural lands throughout Maryland. Fourth, local jurisdictions, along with MDE and other stakeholders, have implemented a formal agreement, the Reservoir Watershed Management Agreement, to protect water quality in the reservoirs. Fifth, a Watershed Restoration Action Strategy (WRAS) is currently in development for the Prettyboy Reservoir. Sixth, Maryland has adopted a watershed cycling strategy, which will assure that routine future monitoring and TMDL evaluations are conducted. Additionally, the federal Safe Drinking Water Act requires states to develop and implement source water assessment programs to study the safety and evaluate the vulnerability of drinking water sources to contamination. The source water assessment for Loch Raven Reservoir Watershed (including Prettyboy Reservoir) is described fully in MDE, 2004.

1.0 INTRODUCTION

Section 303(d)(1)(C) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) implementing regulations direct each state to develop a Total Maximum Daily Load (TMDL) for each water quality limited segment (WQLS) on the Section 303(d) List, taking into account seasonal variations and a protective margin of safety (MOS) to account for uncertainty. A TMDL reflects the total pollutant loading of the impairing substance a waterbody can receive and still meet water quality standards.

TMDLs are established to achieve and maintain water quality standards. A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include activities such as swimming, drinking water supply, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. Criteria may differ among waters with different designated uses.

Prettyboy Reservoir and Loch Raven Reservoir (also referred to as the Gunpowder Reservoirs), Use III-P waterbodies (COMAR 26.08.02.08J(4)), were identified on the 303(d) List submitted to EPA by the Maryland Department of the Environment (MDE) as impaired by nutrients (1996) – due to signs of eutrophication, expressed as high chlorophyll *a* (Chla) levels, sediments (1996 – Loch Raven), metals (1996), bacteria (2002 – Prettyboy), mercury in fish tissue (2002), and impacts to biological communities (2002 and 2004). Eutrophication is the over-enrichment of aquatic systems by excessive inputs of nutrients, especially nitrogen and/or phosphorus. The nutrients act as a fertilizer leading to the excessive growth of aquatic plants, which eventually die and decompose, leading to bacterial consumption of dissolved oxygen (DO). Prettyboy Reservoir is also listed as impaired because of seasonal DO concentrations less than 5.0 mg/l in the hypolimnion. This document upon approval from EPA, establishes TMDLs for the nutrient and sediment impairments. TMDLs were completed in 2002 for both reservoirs for the mercury listings. Water Quality Analyses were completed for both reservoirs for the metals listings in 2003. Other impairments within these watersheds will be addressed separately at a future date.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting and Source Assessment

Both Prettyboy and Loch Raven Reservoirs lie in the Gunpowder Falls watershed (Figure 1). Gunpowder Falls drains into Chesapeake Bay north of the City of Baltimore. The portion of the watershed draining to the reservoirs lies primarily in Baltimore and Carroll Counties, but also includes small portions of Harford County and York County, PA. Both reservoirs are part of the water supply system for Baltimore City and surrounding jurisdictions. Water supply intakes in Loch Raven Reservoir feed Baltimore City's

Montebello Water Treatment Plant. Prettyboy Reservoir, which is upstream of Loch Raven Reservoir, is used as a secondary reservoir to maintain capacity in Loch Raven Reservoir.

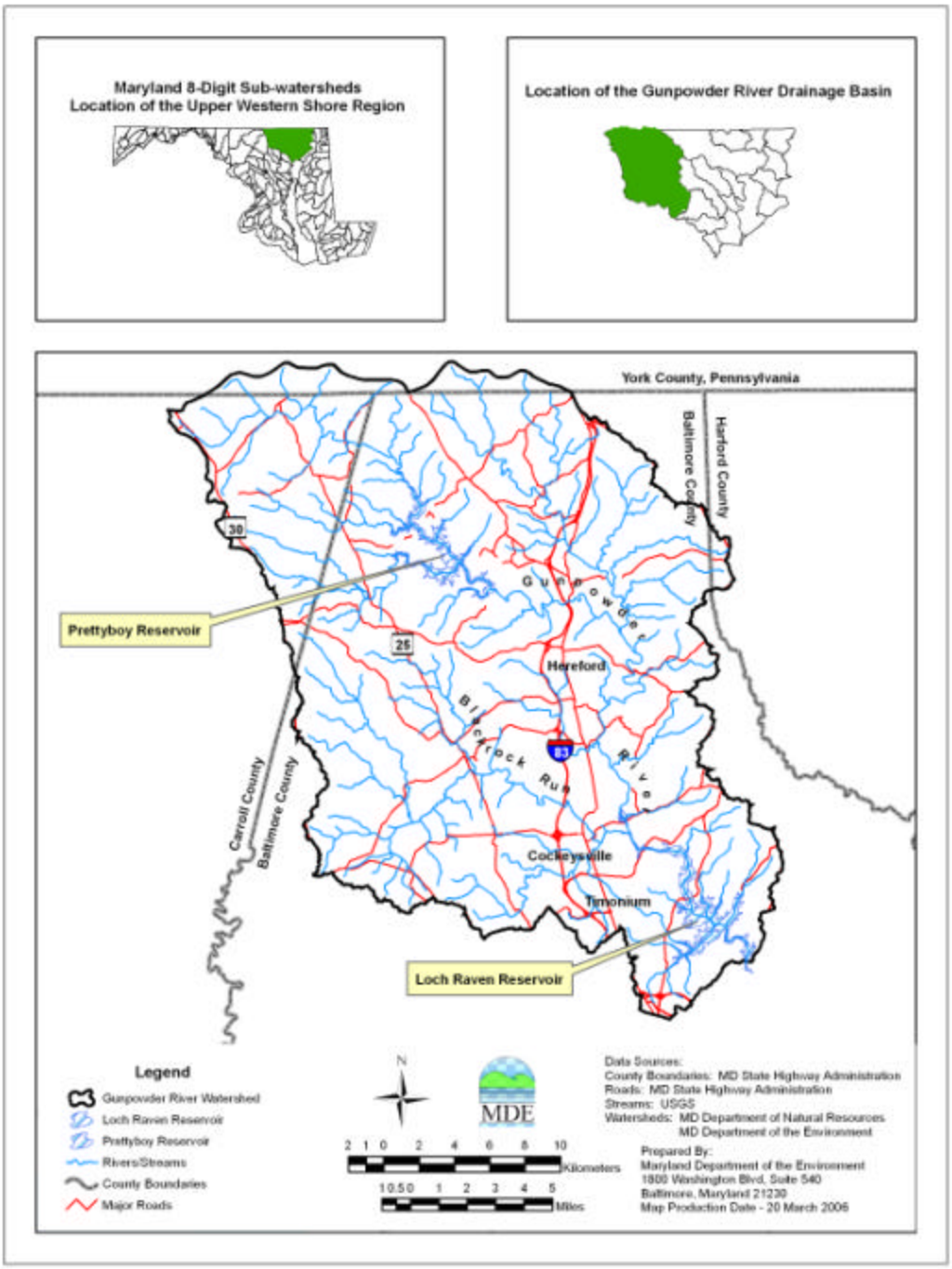

Figure 1: Location of Prettyboy and Loch Raven Reservoirs

Several relevant statistics for Prettyboy and Loch Raven Reservoirs are provided below in Table 1.

Table 1: Current Physical Characteristics of Prettyboy and Loch Raven Reservoirs

Characteristic	Prettyboy	Loch Raven
Location:	Baltimore County, MD Lat. 39° 37' 12" N Long. 76° 42' 36" W	Baltimore County, MD Lat. 39° 25' 48" N Long. 76° 32' 24" W
Surface Area:	1500 acres (65,340,000 ft^2)	2400 acres (104,544,000 ft^2)
Normal Reservoir Depth[1]:	98.5 feet	76.0 feet
Purpose:	Water Supply Recreation	Water Supply Recreation
Basin Code:	02-13-08-06	02-13-08-05
Volume:	60,100 acre-feet	72,700 acre-feet
Drainage Area to Reservoir:	80.0 mi^2 (51,200 acres)	303 mi^2 (193,920 acres)

Source: Inventory of Maryland Dams and Hydropower Resources (Weisberg *et al*., 1985). [1]Measured from base of dam to spillway.

2.1.1 Land Use

Figure 2 shows the land use in the Prettyboy and Loch Raven watersheds. The land use is based on 1997 Maryland Department of Planning Land Use/Land Cover data. The Prettyboy Reservoir watershed (excluding the reservoir surface area) covers approximately 49,000 acres or 77 square miles. About half of the watershed is in crops or pasture, 39% in forest, and 12% in residential, commercial, or industrial land uses (Figure 3). The Loch Raven Reservoir watershed, excluding the drainage to Prettyboy Reservoir and the reservoir surface areas, covers approximately 140,000 acres or about 218 square miles. Approximately 21% of the watershed is developed and 38% is forest, with the remainder in crops, pasture or "mixed open" land uses (Figure 4). Mixed open land uses represent a mixture of several categories of anthropogenically modified open land, including low-density urban cover, horse pasture, fallow cropland or transitional agricultural land.

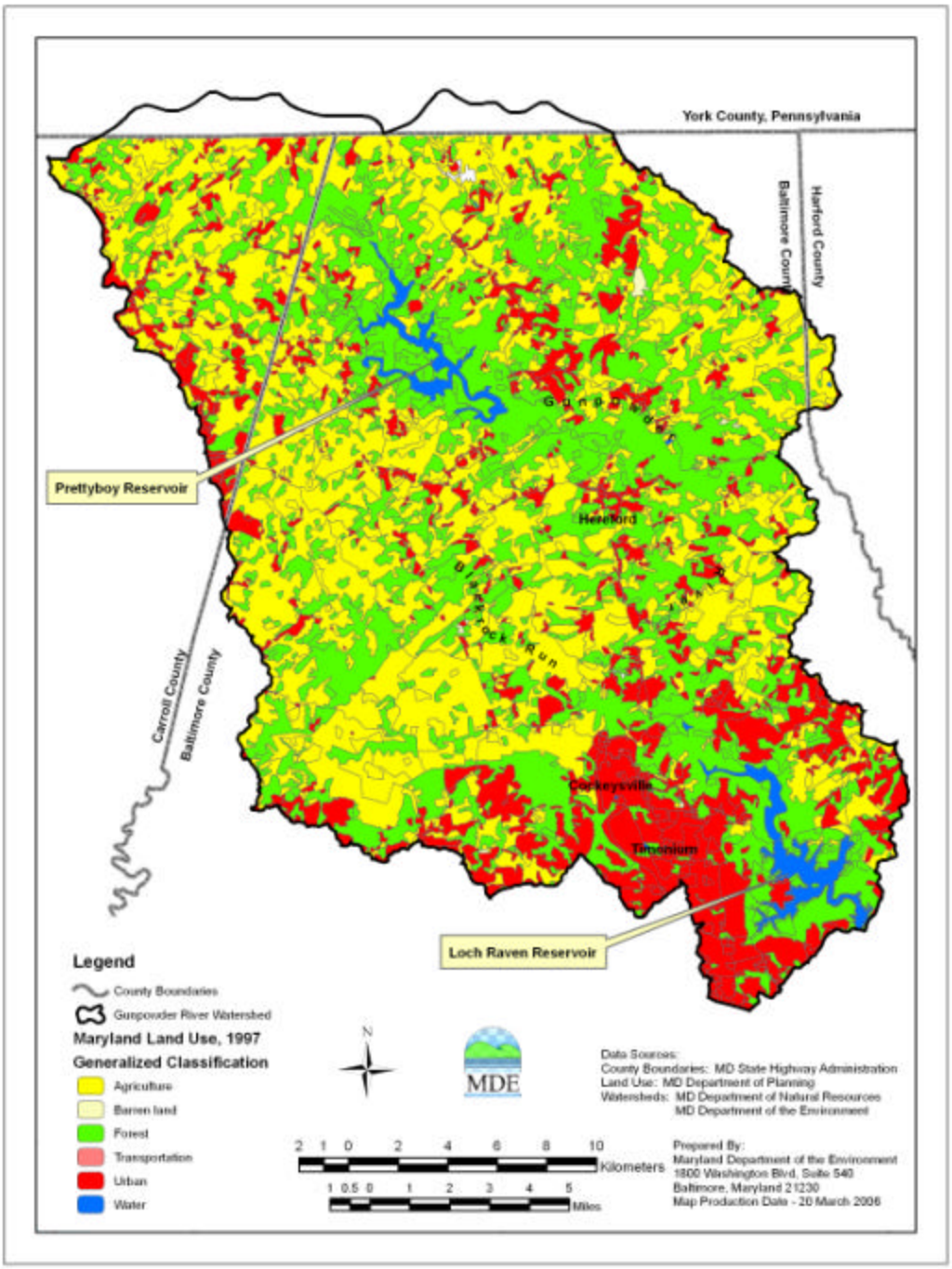

Figure 2: Land Use in Gunpowder Falls Watershed

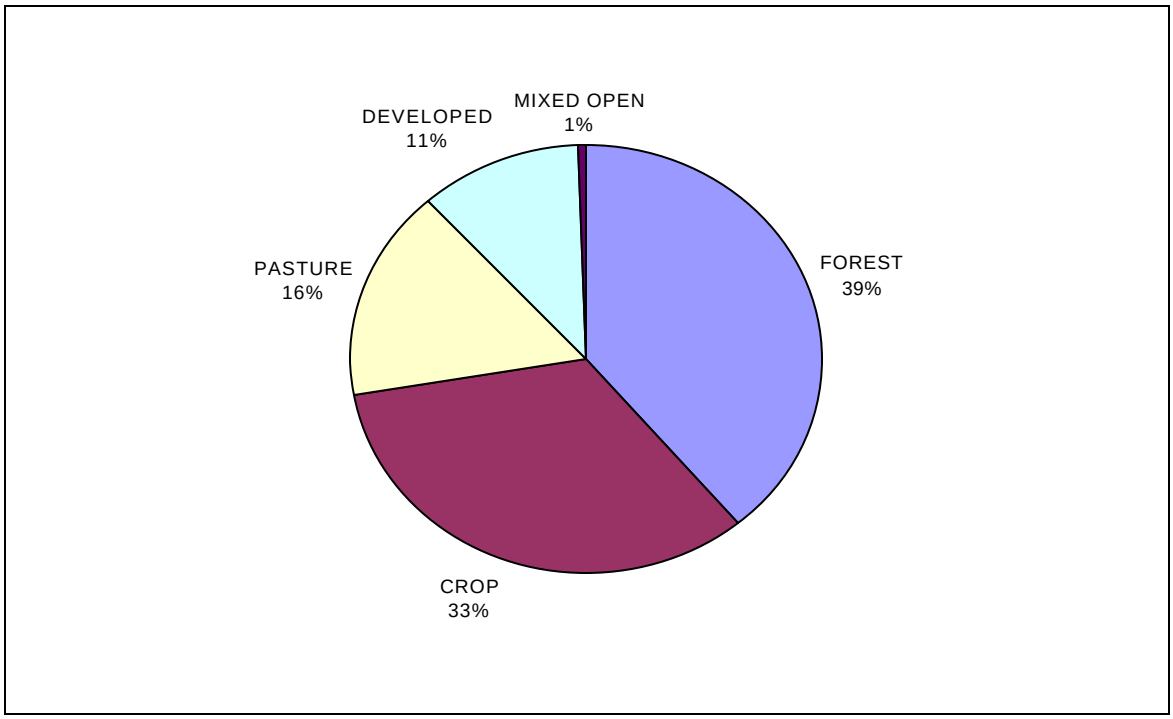

Figure 3: Proportion of Land Use in the Prettyboy Reservoir Watershed

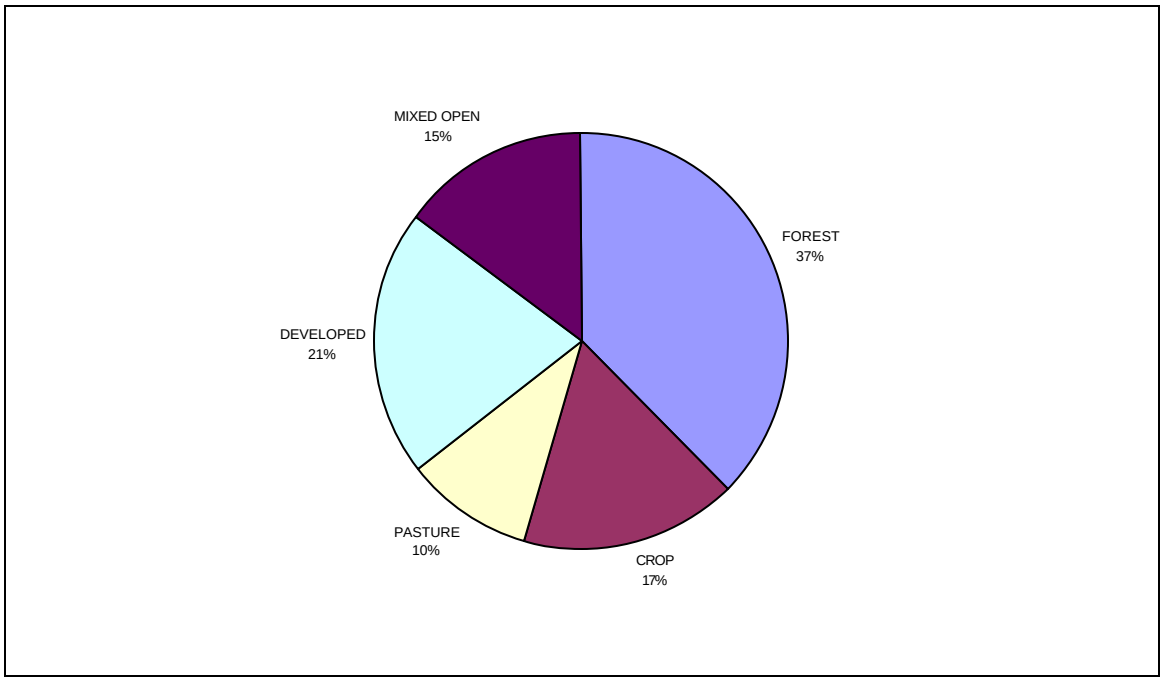

Figure 4: Proportion of Land Use in the Loch Raven Reservoir Watershed

2.1.2 Geology and Soils

The watersheds of Prettyboy and Loch Raven Reservoirs lie in the Piedmont physiographic province. The surficial geology is characterized by metamorphic rock of Precambrian and Cambrian age. Prettyboy schist is the underlying bedrock of the Prettyboy Reservoir watershed (MDE, 2004). The underlying metamorphic rock complex of the Loch Raven watershed downstream of Prettyboy consists mainly of crystalline schists and gneiss with smaller areas of marble. The underlying marble formations, Cockeysville Marble and the Patuxent Formation, are less resistant to weathering than the schists and gneiss and consequently occur mainly in valleys.

The primary soil associations in the watershed are the Manor-Glenelg, Chester-Glenelg, Baltimore-Conestoga-Hagerstown, Beltsville-Chillum-Sassafras, Glenelg-Chester-Manor, and Mt. Airy-Linganore associations. These soils are mainly deep and well-drained to moderately well-drained (Reybold and Matthews, 1976; Matthews, 1969). Within the stream floodplains, alluvial, Codorus and Hatboro soil series predominate. Nearly 85% of the soils in the watershed below Prettyboy Reservoir are classified as Hydrologic Group B, which means that they have low to moderate surface runoff potential, moderate infiltration rates, and moderately fine to moderately coarse soil texture (Tetra Tech, 1997).

2.1.3 Point Sources and Wastewater Treatment Plant Loads

The development of nutrient TMDLs for Prettyboy and Loch Raven Reservoirs was based on computer simulation modeling of water quality conditions from 1992 to 1997. During that time, the Manchester municipal wastewater treatment plant (WWTP) discharged within the Prettyboy Reservoir watershed, and the Hampstead municipal WWTP, along with ten small industrial sources, discharged within the Loch Raven Reservoir watershed. Table 2 shows the annual phosphorus and sediment loads from the municipal WWTPs during the simulation period, 1992-1997.

Table 2: Annual Municipal Wastewater Treatment Plant Loads 1992-1997

	Manchester (MD0022446)			Hampstead (MD0022578)		
Year	PO_4 (lbs/yr)	Organic P (lbs/yr)	TSS (tons/yr)	PO_4 (lbs/yr)	Organic P (lbs/yr)	TSS (tons/yr)
1992	192.33	177.84	2.77	276.41	173.39	0.27
1993	300.08	275.61	4.15	489.03	291.04	0.35
1994	382.14	370.30	7.06	254.56	195.37	0.39
1995	195.65	37.44	0.89	139.16	146.87	0.40
1996	90.65	80.92	0.83	168.81	107.44	0.85
1997	126.78	114.59	3.30	207.61	88.88	0.39
Average	214.60	176.11	3.16	255.93	167.16	0.44

Currently, the Manchester WWTP discharges through spray irrigation from April 1 through November 30, and in March if weather permits. Its current design flow is 0.5 million gallons per day (MGD). The Hampstead WWTP's current design flow is 0.9 MGD.

There are no industrial sources permitted for discharging phosphorus. Three facilities are permitted to discharge total suspended solids. Only one of them, a limestone quarry and concrete production facility owned by co-permittees Lafarge Mid-Atlantic and Imerys, has the potential to discharge solids in significant quantities.

2.1.4 Nonpoint Source Loads and Urban Stormwater Loads

Nonpoint source loads and urban stormwater loads entering the Prettyboy and Loch Raven Reservoirs were estimated using the Hydrologic Simulation Program-Fortran (HSPF) model. The HSPF model is used to estimate flows, suspended solids and nutrient loads from the watershed's sub-basins, which are linked to two-dimensional CE-QUAL-W2 models of each reservoir. These are used to determine the maximum loads of total phosphorus (TP) that can enter each reservoir while maintaining the water quality criteria associated with their designated uses. The water quality modeling framework is addressed in more detail in Section 4.2.

The simulation of the Loch Raven and Prettyboy Reservoir watersheds used the following assumptions: (1) variability in patterns of precipitation were estimated from existing National Oceanic and Atmospheric Administration (NOAA) meteorological stations; (2) hydrologic response of land areas were estimated for a simplified set of land uses in the basin; and (3) agricultural information was estimated from the Maryland Department of Planning (MDP) land use data, the 1997 Agricultural Census Data (U. S. Department of Commerce, 1997), and the Farm Service Agency (FSA). The HSPF simulates nonpoint source and urban stormwater loads and integrates all natural and human induced sources, including direct atmospheric deposition, and loads from septic tanks, which are associated with river base flow during low flow conditions. Details of the HSPF watershed model developed to estimate these urban and non-urban loads can be found in *Modeling Framework for Simulating Hydrodynamics and Water Quality in Prettyboy and Loch Raven Reservoirs* (ICPRB and MDE, 2006).

Figures 5 and 6 show the relative size of the contribution of point and nonpoint sources of total phosphorus to Prettyboy and Loch Raven Reservoirs, respectively, 1992-1997. Figure 7 shows the relative size of the contribution of sediment sources to Loch Raven Reservoir over the same period.

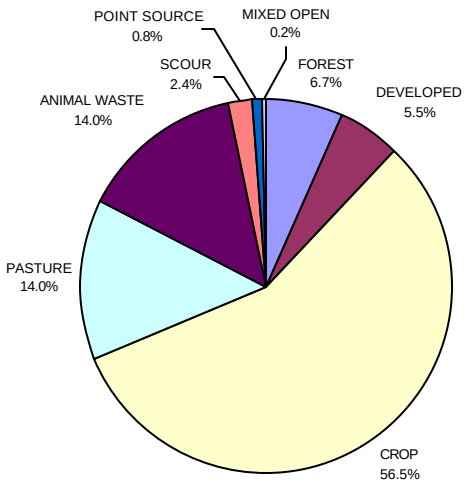

Figure 5: Percent Contribution of Sources to Total Phosphorus Loads to Prettyboy Reservoir

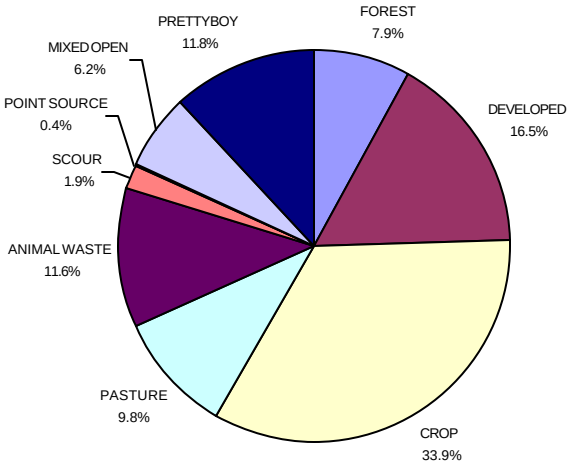

Figure 6: Percent Contribution of Sources to Total Phosphorus Loads to Loch Raven Reservoir

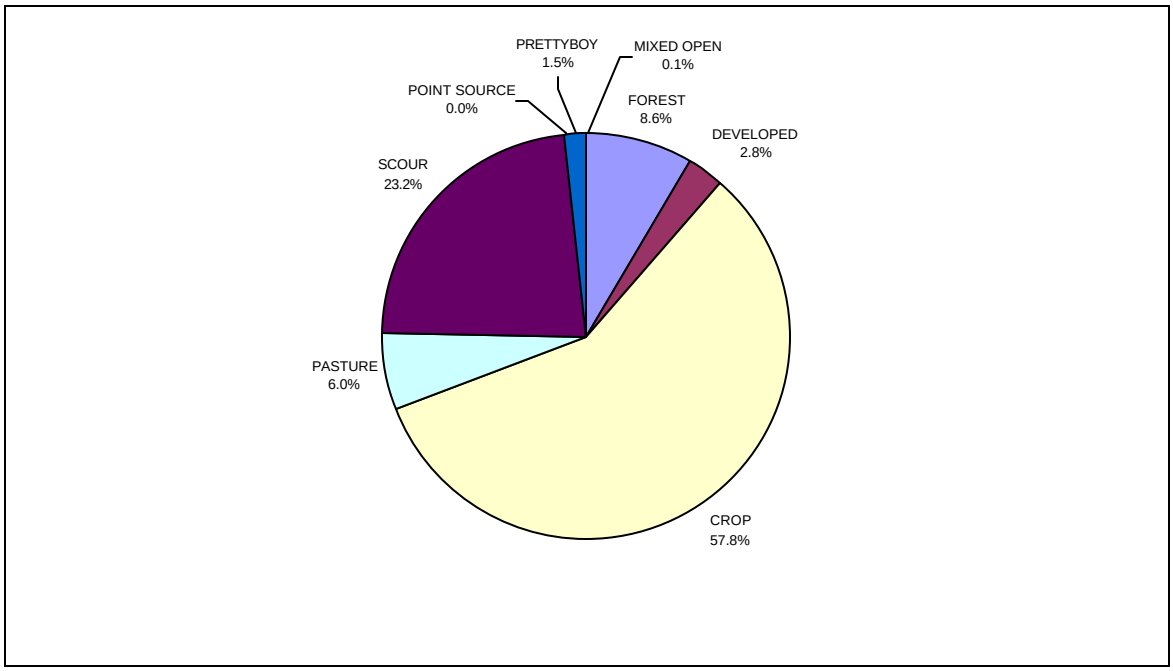

Figure 7: Percent Contribution of Sources to Sediment Loads to Loch Raven Reservoir

2.2 Water Quality Characterization

2.2.1 Baltimore City Department of Public Works Monitoring Program

Baltimore City Department of Public Works (DPW) is the only agency that monitors water quality in the reservoirs. DPW samples at three locations in Prettyboy Reservoir, and at five locations in Loch Raven Reservoir. Figures 8 and 9 show the sites of these sampling locations. Not all locations are sampled at the same time. Sampling is performed by boat at locations GUN0401, GUN0171, and GUN0190 weather permitting; otherwise, in the winter months, sampling is at fixed locations GUN0399, GUN0156, and GUN0174. Sampling at GUN0142 and GUN0437 can occur either by boat or from a fixed platform.

Samples are analyzed for water temperature, dissolved oxygen, total phosphorus, ammonia, nitrate, turbidity, and Secchi depth, among other constituents. Samples are not analyzed for phosphorus species, organic or total nitrogen, or suspended sediment. Starting at the surface, samples are taken every five feet up to sixty feet; samples are taken at ten-foot intervals thereafter.

Not every sample is analyzed for the entire suite of constituents. Generally, only field measurements like temperature and dissolved oxygen are measured at every depth sampled. Lab analysis is performed for Chla for each sample collected at the surface and at ten-foot depths down to 50 feet. In Loch Raven, chemical analysis is performed on samples collected at the surface and every ten feet down to sixty feet. In Prettyboy, chemical analysis is performed on samples taken at the surface and at 10, 20, and 40 feet below the surface, with an additional sample taken at either 60 feet below the surface, in the case of GUN0437, or 80 feet below in the case of the other two stations.

For the purpose of data analysis and the presentation of results, the locations in Loch Raven sampled by boat and the locations with fixed sampling positions have been paired to yield an annual representation of the middle and upper portion of the reservoir. Stations GUN0399 and GUN401 in Prettyboy have been paired to represent the lower portion of the reservoir. GUN0437 by itself represents the middle portion of Prettyboy. There are no sampling locations in the upper portion of Prettyboy reservoir. Table 3 summarizes how the sampling locations are grouped together in this report.

Table 3: Characterization of Reservoir Monitoring Locations

Station	Reservoir	Location	Classification
GUN0142	Loch Raven	Gatehouse	Lower
GUN0156	Loch Raven	Loch Raven Drive bridge	Middle
GUN0171	Loch Raven	Between picnic area and golf course	Middle
GUN0174	Loch Raven	Dulaney Valley Road bridge	Upper
GUN0190	Loch Raven	At the power lines	Upper
GUN0399	Prettyboy	Gatehouse	Lower
GUN0401	Prettyboy	1000 ft. upstream of dam	Lower
GUN0437	Prettyboy	Beckleysville Road Bridge	Middle

Figure 8: Sampling Locations in Prettyboy Reservoir (from DPW)

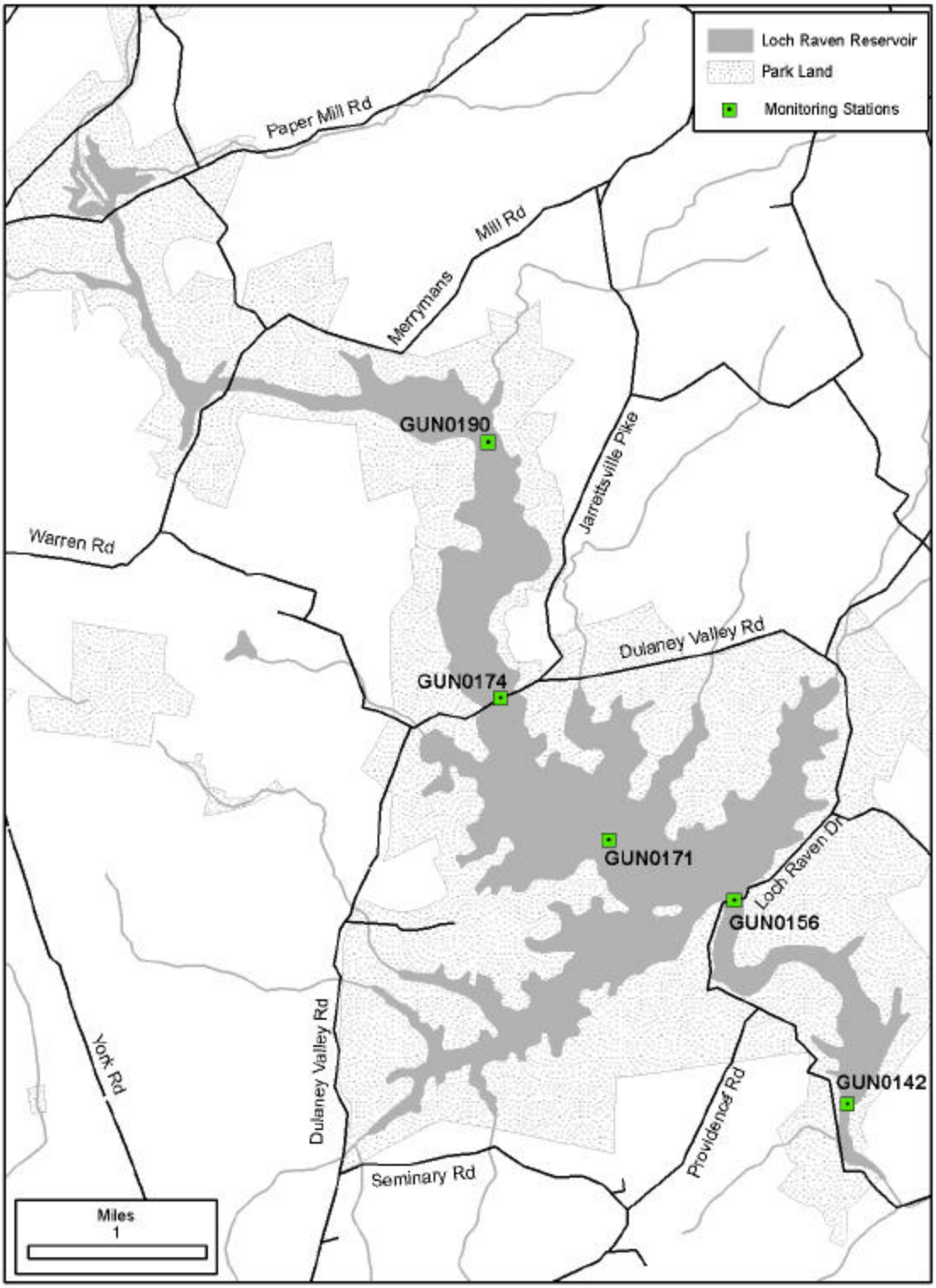

Figure 9: Sampling Locations in Loch Raven Reservoir (from DPW)

2.2.2 Temperature Stratification

Prettyboy and Loch Raven Reservoirs both regularly exhibit temperature stratification starting in April or May and lasting until November. Stratification sometimes occurs in winter but without significant consequences for water quality. Under stratified conditions during the summer and early fall, bottom waters in both reservoirs can become hypoxic, because stable density differences inhibit the turbulent mixing that transports oxygen from the surface. Under such conditions, the reservoirs can be divided vertically into a well-mixed surface layer, or epilimnion; a relatively homogeneous bottom layer or hypolimnion; and a transitional zone between them, the metalimnion, characterized by a sharp density gradient.

Contour plots of isotherms effectively illustrate seasonal position of the well-mixed surface layer or epilimnion. Figure 10 presents a contour plot of isothermals for GUN0142 in Loch Raven Reservoir for 1993, a representative year. Contours are shown only for the first 30 feet from the surface. In the winter, isothermal lines are vertical, showing that the reservoir has fairly uniform temperature over the first 30 feet of depth. In spring, isothermal lines begin to tilt away from the vertical, until by May, at depths greater than 15 to 20 feet, they are parallel to each other horizontally. At the surface, isothermal lines run vertically to a depth of 10 to 15 feet; this defines the epilimnion.

Figures A1 - A20 in Appendix A present contour plots for each monitoring location (lower, middle and upper) over the period 1992-2004. Generally, in both reservoirs, the epilimnion is limited to a depth of 10 to 15 feet in the summer. For the purposes of data analysis, the surface layer is considered to be 20 feet deep, with the understanding that in spring and fall the epilimnion can extend deeper than 20 feet, and in the summer it is likely to be shallower. For screening purposes, samples taken at depths of 40 feet or greater are considered in the bottom layer or hypolimnion.

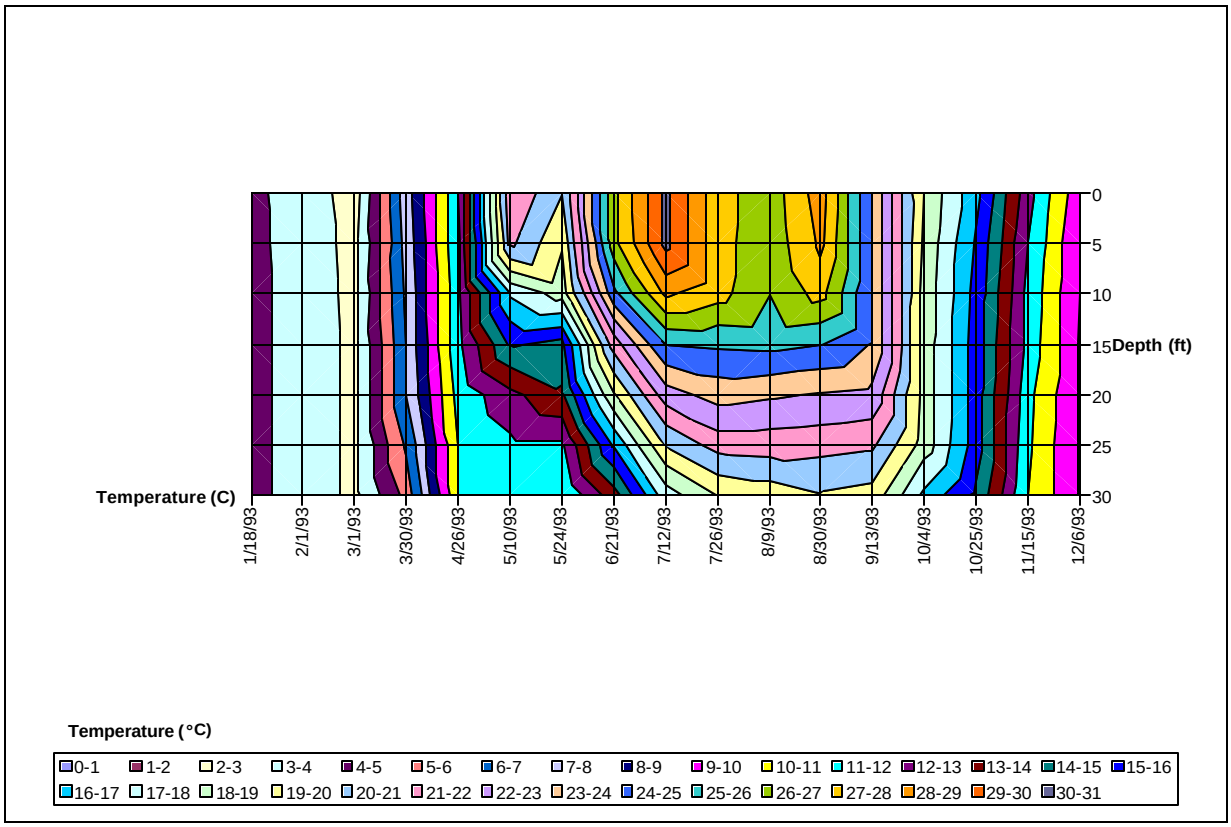

Figure 10: Isothermal Contours, Loch Raven Reservoir, Middle Stations, 1993

2.2.3 Dissolved Oxygen

Figures A21 - A25 in Appendix A show time series of average bottom DO concentrations at all monitoring locations in Prettyboy and Loch Raven Reservoirs. Quite clearly, hypoxia occurs in the hypolimnion of both Prettyboy and Loch Raven Reservoirs with regularity.

Figures A26-30 in Appendix A also show time series of DO at the surface and at five-foot intervals up to 20 feet, the screening-level definition of the epilimnion. For the most part, DO concentrations are above the 5.0 mg/l criterion, but there are periodic excursions below 5.0 mg/l at the 15- and 20-foot depths. In the majority of cases in which apparent hypoxia is observed in the epilimnion, the 20-foot screening depth has over-estimated the depth of the well-mixed layer, as shown by the temperature observations. As noted in the previous section, the depth of the epilimnion ranges between 10 and 15 feet in the summer months. See Tables B1 and B2 in Appendix B for a listing of all dates when DO concentrations were below 5.0 mg/l at either 15- or 20-foot sampling depth in Loch Raven and Prettyboy Reservoirs, respectively.

There are two related causes of these low DO concentrations. The first is temperature stratification, as explained above; the second is the entrainment of low DO waters into the epilimnion. Entrainment refers to the process by which turbulent layers spread into a non-turbulent region (Ford and Johnson, 1986). The onset of cool weather causes the epilimnion to increase in depth by entraining water from the metalimnion. This water can be low in oxygen and reduce the DO concentration in the well-mixed layer. This can occur any time under stratified conditions when the surface mixed-layer deepens, often well before the fall overturn typical of many lakes and reservoirs (including Prettyboy and Loch Raven), when the surface and bottom layers displace one another. All nineteen dates on which low DO occurred in Loch Raven without an approximately 2ºC difference in temperature between the 5- and 20-foot depths occurred in September, October or November, and all but five occurred in September alone.

This is illustrated by the low DO reading recorded on September 13, 1993, in GUN0171, the middle of Loch Raven Reservoir. Figure 11 shows the DO contour at this location. Figure 10 in the previous section, shows the temperature contour. A comparison of the figures indicates that at the end of August the reservoir at this location was highly stratified, with the well-mixed layer extending to about 15 feet. Throughout September, the surface waters cooled and the epilimnion deepened. The layers with low oxygen concentrations in the summer were drawn into the epilimnion. By October, the epilimnion once again had fairly uniform DO concentrations, although the reservoir had not completely overturned.

Entrainment and overturning account for the other low DO oxygen observations in Loch Raven and Prettyboy as well. In Prettyboy, another factor also can influence entrainment: drawdown. Withdrawals from a reservoir can induce currents that enhance mixing. Figure 12 shows the surface elevation of Prettyboy Reservoir from 1994 through 2004. In 1999 and 2002 (drought years), releases from Prettyboy to fill Loch Raven dropped the surface elevation by 30 feet or more. These drawdowns are probably a contributing factor in mixing low DO concentrations into the surface levels of the reservoir.

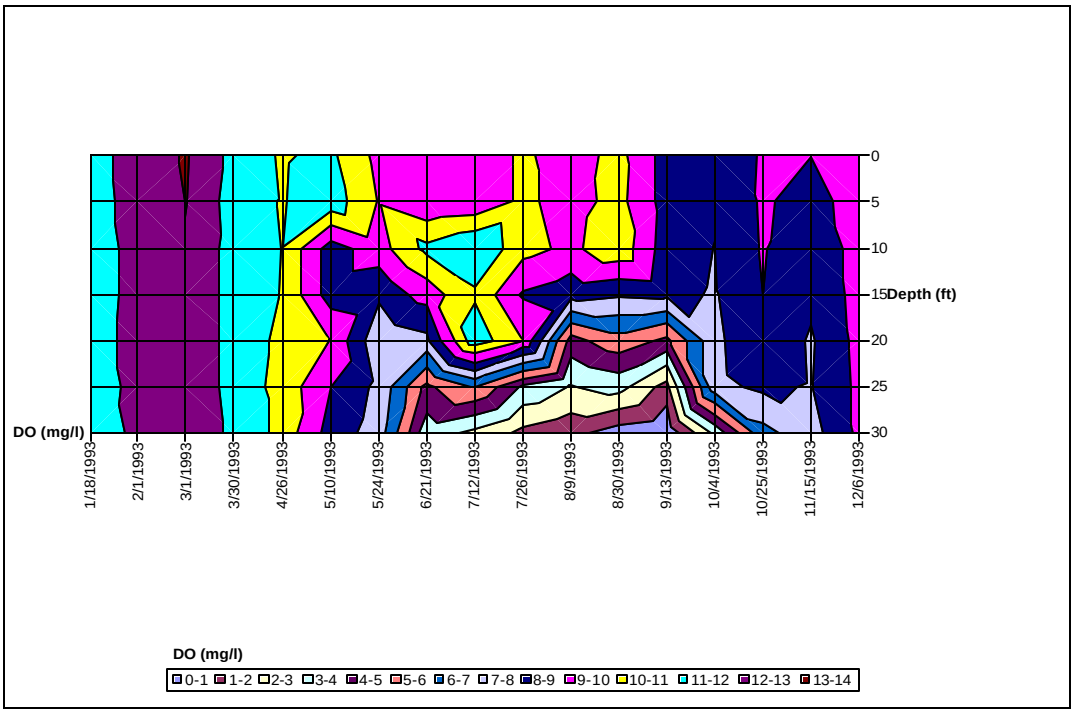

Figure 11: DO Contour, Loch Raven Reservoir, Middle Locations, 1993

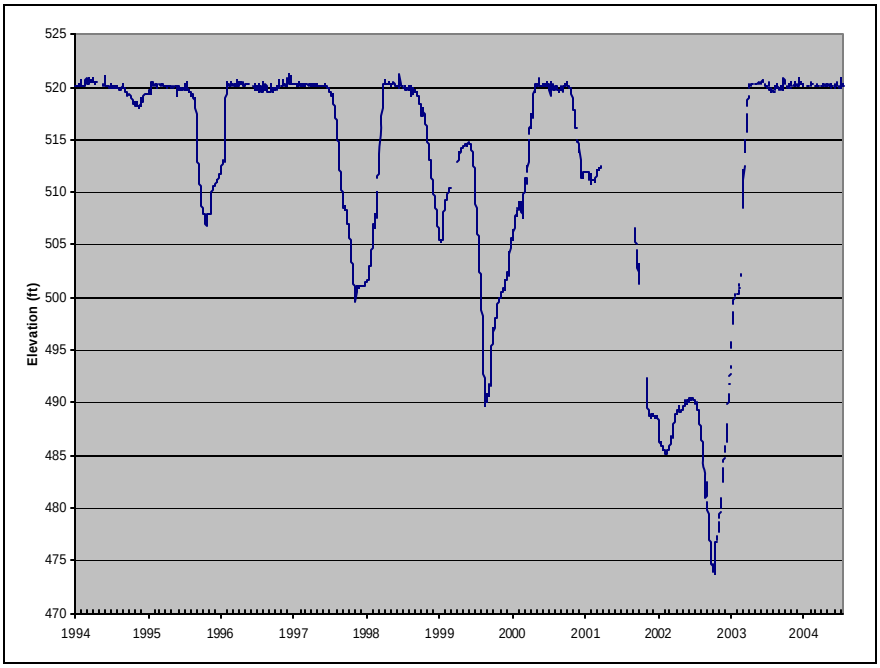

Figure 12: Surface Water Elevations in Prettyboy Reservoir, 1994-2004

2.2.4 Total Phosphorus

Figures A31 - A35 in Appendix A show average total phosphorus concentrations in the top and bottom sampling depths at each monitoring location in Prettyboy and Loch Raven Reservoirs. Surface layer concentrations are an average of the 10- and 20-foot depth samples. Bottom concentrations are averages of samples taken at 40-foot depths or greater. Tables 4 and 5 give summary statistics for TP concentrations (mg/l) in Prettyboy and Loch Raven Reservoirs, respectively. As the tables show, there is a longitudinal gradient to TP concentrations, with concentrations generally decreasing downstream. This is thought to reflect the fact that much of the phosphorus entering the reservoir is bound to sediment, and thus settles out before reaching the dams.

Table 4: Summary Statistics: TP Concentrations (mg/l) in Prettyboy Reservoir, 1992-2004

Statistic	Surface		Bottom	
	Middle	Lower	Middle	Lower
Mean	0.079	0.058	0.075	0.067
Standard deviation	0.112	0.082	0.106	0.110
Minimum	0.002	0.003	0.002	0.002
1st Quartile	0.021	0.019	0.025	0.018
Median	0.045	0.035	0.041	0.040
3rd Quartile	0.078	0.065	0.073	0.066
Maximum	0.675	0.552	0.825	0.970
Count	127	127	127	127

Table 5: Summary Statistics: TP Concentrations (mg/l) in Loch Raven Reservoir, 1992-2004

Statistic	Surface			Bottom		
	Upper	Middle	Lower	Upper	Middle	Lower
Mean	0.078	0.066	0.054	0.084	0.082	0.062
Standard Deviation	0.108	0.102	0.092	0.092	0.148	0.109
Minimum	0.005	0.003	0.002	0.005	0.003	0.003
1st Quartile	0.027	0.023	0.019	0.033	0.026	0.022
Median	0.053	0.042	0.036	0.058	0.045	0.033
3rd Quartile	0.085	0.071	0.060	0.100	0.081	0.078
Maximum	1.010	0.835	1.040	0.580	1.313	1.260
Count	136	139	205	90	138	205

The surface sample itself was excluded from the analysis because samples periodically have concentrations as high as 1.0 mg/l. Some of these high concentrations are confined to the surface layer and are suspected to be surface films. For this reason DPW also excludes surface layer concentrations (Baltimore City DPW, 1996).

2.2.5 Nutrient Limitation

Nitrogen and phosphorus are essential nutrients for algae growth. If one nutrient is available in great abundance relative to the other, then the nutrient that is less available limits the amount of plant matter that can be produced; this is known as the "limiting nutrient." The amount of the abundant nutrient does not matter because both nutrients are needed for algae growth. In general, a Nitrogen:Phosphorus (N:P) ratio in the range of 5:1 to 10:1 by mass is associated with plant growth being limited by neither phosphorus nor nitrogen. If the N:P ratio is greater than 10:1, phosphorus tends to be limiting; if the N:P ratio is less than 5:1, nitrogen tends to be limiting (Chiandani *et al*, 1974).

Since there are no data on organic nitrogen concentrations in the reservoir, nitrate is substituted for total nitrogen (TN) in the TN:TP ratio assessment, and the TN:TP ratio is underestimated. In both reservoirs, only about 7% of the samples taken at the 10- and 20-foot depths have nitrate:TP ratios less than 10:1, which can be taken as a cutoff for distinguishing nitrogen limitation from phosphorus limitation. The median nitrate:TP ratio in Loch Raven is 38:1 and the median in Prettyboy is 47:1. About half the samples from Loch Raven with nitrate:TP ratios less than 10:1 occur on five dates, all of which appear to be associated with storm events. Storm events are likely to have high concentrations of particulate nitrogen and phosphorus, but while particulate phosphorus is accounted for in nitrate:TP ratios, particulate organic nitrogen is not. Storm events therefore inflate TP concentrations and exacerbate the underestimation of TN, so the resultant ratios are considered anomalous. Based on the available monitoring data and prevalent high N:P ratios, the evidence is conclusive that both Prettyboy and Loch Raven Reservoirs are strongly phosphorus limited.

2.2.6 Ammonia and Nitrogen

Figures A36 - A45 in Appendix A show the average surface and bottom concentrations of ammonia and nitrate in Prettyboy and Loch Raven Reservoirs. Since the surface layers of the reservoirs are not nitrogen limited, bottom concentrations of ammonia and nitrate are more important from the water quality standpoint for two reasons.

First, the time series graphs of ammonia show that, particularly for Loch Raven, there are significant releases of ammonia from the sediments. This contributes to oxygen demand. Although observed ammonia concentrations range as high as 4.0 mg/l, Maryland's ammonia water quality criteria (COMAR 26.08.02.03-2H(1)) were not exceeded. Second, nitrate concentrations for the most part remain above 0.5 mg/l. Nitrate is preferred to ferric iron (III) as an electron acceptor in diagenesis. Phosphate in the sediments is bound through ferric iron. It is less likely that phosphate will be released from sediments until ferric iron is reduced in diagenesis. Thus it can be anticipated that the phosphorus release rate from the sediments will remain low.

2.2.7 Algae and Chlorophyll *a*

Figures A46 – A50 in Appendix A show the time series of maximum Chla concentrations in the surface layer at the sampling locations in Prettyboy and Loch Raven Reservoirs. The same information is presented in a different format in Tables B3 and B4 in Appendix B, showing maximum Chla concentrations by month and year, 1992-2004. As these tables indicate, Chla concentrations above 10 µg/l (the approximate threshold of eutrophy) occur frequently but not regularly. Concentrations above 30 µg/l are infrequent.

In Loch Raven Reservoir, the largest concentrations tend to occur in early spring or in October. Concentrations are most consistently above 10 µg/l in the summer months, and most consistently below 10 µg/l in the winter months. In Prettyboy Reservoir, in contrast, surface Chla concentrations are most consistently above 10 µg/l in late winter and early spring. Concentrations above 30 µg/l are most frequently found in March or secondarily in September and October. Surface Chla concentrations tend to be below 10 µg/l from May through July, as well as in November and December.

2.2.8 Sedimentation

The Maryland Geological Survey (MGS) performed a new bathymetry survey of Loch Raven Reservoir in 1998 (Ortt *et al.*, 2000). In conjunction with the survey, MGS also estimated sedimentation rates. Average annual sedimentation rates can be described in many ways: percent loss of capacity, inches of sediment accumulation per year, or tons/mi^2/yr. The latter measure was estimated by the Reservoir Technical Group (RTG) (2004), based on the new survey. Table 6 summarizes the average sediment accumulation rate for Loch Raven Reservoir.

The annual percent capacity loss (volumetric reduction) rate in Loch Raven Reservoir, 0.13%, compares favorably with the national averages. The mean average capacity loss rate for comparably sized reservoirs is 0.43%; the median is 0.27% *(*Ortt *et al., 2000)*. However, sediment accumulation varies spatially within the reservoir. MGS estimated that the Dulaney Branch of Loch Raven has lost 8% of its capacity, the Long Quarter Branch 13% of its capacity, and the upper reservoir 19% of its capacity. Sediment deposits in the former stream channel were greater than 10 feet thick and ran as high as 59 feet thick. The survey was not able to proceed above Warren and Merryman's Mill Road bridge because the reservoir became unnavigable.

Table 6: Sedimentation Rates in Loch Raven Reservoir

Sedimentation Rates	Loch Raven (built 1923)
Total Capacity Lost Since Construction	10.8%
Annual Average Capacity Lost	0.13%
Sediment Accumulation Rate (in/yr)	0.6
Sediment Deposition Rate (tons/mi^2/year)	0.49

2.3 Water Quality Impairments

The Maryland Water Quality Standards Stream Segment Designations for Prettyboy and Loch Raven Reservoirs are Use III-P: Nontidal Cold Water and Public Water Supply (COMAR 26.08.02.08J(4)). Designated Uses present in the Prettyboy and Loch Raven Reservoirs are: 1) growth and propagation of trout; and 2) public water supply.

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)). Excessive eutrophication, indicated by elevated levels of Chla, can produce nuisance levels of algae and interfere with designated uses such as fishing and swimming. The excess algal blooms eventually die off and decompose, consuming oxygen. Excessive eutrophication in Prettyboy and Loch Raven Reservoirs is ultimately caused by nutrient overenrichment. An analysis of the available water quality data presented in Section 2.2 has demonstrated that phosphorus is the limiting nutrient. In conjunction with excessive nutrients, Loch Raven Reservoir has experienced excessive sediment loads, resulting in a shortened projected lifespan of the reservoir.

Use III waters are subject to DO criteria of not less than 6.0 mg/l daily average and 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 (there are no natural lakes in Maryland) 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. This interpretation recognizes that, given the morphology of the reservoir or impoundment, the resulting degree of stratification, and the naturally occurring sources of organic material in the watershed, hypoxia in the hypolimnion is a natural consequence. The interim interpretation of the non-tidal DO standard, as applied to reservoirs, is as follows:

- A minimum DO concentration of 5.0 mg/l (and 6.0 mg/ daily average for Use III) will be maintained throughout the water column during periods of complete and stable mixing;
- A minimum DO concentration of 5.0 mg/l (and 6.0 mg/ daily average for Use III) will be maintained in the mixed surface layer at all times, including during stratified conditions, except during periods of overturn or other naturally-occurring disruptions of stratification; and
- Hypolimnetic hypoxia will be addressed on a case-by-case basis, taking into account morphology, degree of stratification, sources of diagenic organic material in reservoir sediments, and other such factors.

The analysis of water quality data in Section 2.2 has shown that all observed DO concentrations below 5.0 mg/l in the surface layers of Prettyboy and Loch Raven Reservoirs are associated with stratification or the mixing of stratified waters into the surface layers during periods of reservoir overturn or drawdown. On the other hand, seasonal hypoxia occurs regularly in both reservoirs in the hypolimnion.

3.0 TARGETED WATER QUALITY GOALS

The overall objective of the TMDLs proposed in this document is to reduce phosphorus and sediment loads to levels that are expected to result in the attainment of the water quality criteria that support the Use III-P designation for Loch Raven and Prettyboy Reservoirs. The Chla endpoints selected for the reservoirs are (1) a maximum permissible instantaneous chlorophyll concentration of 30 µg/l in the surface layers and (2) a 30-day moving average concentration not to exceed 10 µg/l in the surface layers. A concentration of 10 µg/l corresponds to a score of approximately 53 on the Carlson Trophic State Index (TSI). This is the approximate boundary between mesotrophic and eutrophic conditions, which is an appropriate trophic state at which to manage these reservoirs. Mean Chla concentrations exceeding 10 ug/l are associated with peaks exceeding 30 ug/l, which in turn are associated with a shift to blue-green assemblages,

which present taste, odor and treatment problems (Walker 1984). These Chla endpoints should thus avoid nuisance algal blooms. Reduction of the phosphorus loads is predicted to reduce excessive algal growth and therefore prevent violations of narrative criteria associated with nuisances, such as taste and odor problems.

In summary, the TMDLs for phosphorus and sediment are intended to:

1. Resolve violations of narrative criteria resulting in excessive algal growth in Prettyboy and Loch Raven Reservoirs;
2. Resolve violations of narrative criteria associated with excess sedimentation of Loch Raven Reservoir; and
3. Assure both Prettyboy and Loch Raven Reservoirs provide dissolved oxygen levels sufficient to support aquatic life.

4.0 TOTAL MAXIMUM DAILY LOADS (TMDLs) AND ALLOCATIONS

4.1 Overview

Section 4.2 describes the modeling framework for simulating hydrodynamics, nutrient and sediment loads, and water quality responses in Prettyboy and Loch Raven Reservoirs. Section 4.3 describes the baseline scenario developed on the basis of modeling results. Section 4.4 explains how the nutrient TMDLs and load allocations for point sources and nonpoint sources were developed for the reservoirs, based on computer modeling of the water quality response to reduced nutrient and sediment loads. Section 4.5 presents the modeling results in the proper format for TMDLs and allocates the TMDLs between point sources and nonpoint sources. Section 4.6 explains the rationale for the margin of safety. Finally, the elements of the equations are combined in a summary of TMDLs for total phosphorus for both Prettyboy and Loch Raven Reservoirs, as well as a TMDL for sediments for Loch Raven Reservoir.

4.2 Computer Modeling Framework

To develop a TMDL, a linkage must be defined between the selected targets or goals and the identified sources. This linkage establishes the cause-and-effect relationship between the pollutant of concern and the pollutant sources. The relationship can vary seasonally, particularly for nonpoint sources, with factors such as precipitation. Once defined, the linkage yields the estimate of total loading capacity or TMDL (U.S. EPA, 1999).

CE-QUAL-W2 is a laterally averaged two-dimensional computer simulation model, capable in its most recent formulations of representing the hydrodynamics and water quality of rivers, lakes, and estuaries. It is particularly well-suited for representing temperature stratification that occurs in reservoirs like Prettyboy and Loch Raven. The W2 reservoir models were used to simulate not only hydrodynamics and temperature but dissolved oxygen and eutrophication dynamics as well. The reservoir models use version

3.2 of CE-QUAL-W2. Cole and Wells (2003) give a general description of the CE-QUAL-W2 model.

Prettyboy Reservoir was represented by eighteen active longitudinal segments in two branches. Each segment contains from four to thirty one-meter thick layers. Loch Raven Reservoir is represented by a single branch of sixteen segments, each with four to sixteen one-meter thick layers. The simulation period was set to 1992-1997 to coincide with the Gunpowder HSPF Model. These six years provide a range of hydrological conditions, including wet years (1993, 1996), dry years (1992, 1997), and average years (1994, 1995), thus fulfilling the requirement that TMDLs take into account a variety of hydrological conditions. Each year was simulated separately, and observed data, where available, were used to set the initial conditions for the simulation.

State variables in the CE-QUAL-W2 model include dissolved oxygen, ammonia, nitrate, dissolved inorganic phosphorus, and both dissolved and particulate organic matter (POM) in labile and refractory forms. In addition, any number of inorganic solids, carbonaceous biochemical oxygen demand (CBOD) variables or algal species can be represented in the model. Organic nitrogen and phosphorus, however, are only implicitly represented through CBOD, organic matter, and algal biomass state variables. In order to preserve a mass balance of all species of phosphorus, the state variables in the W2 models were configured as follows:

1. Inorganic phosphorus attached to silt and clay was modeled as distinct inorganic solids. Sorption between sediment and the water column was not simulated in the model.
2. Three biochemical oxygen demand (BOD) variables were used to represent allochthonous organic matter inputs to the reservoirs: (1) labile dissolved BOD, labile particulate CBOD, and refractory particulate CBOD. The concentration of these CBOD inputs were calculated based on the concentration of organic phosphorus determined by the HSPF model, using the stoichiometric ratio between phosphorus and oxygen demand in the reservoir models.
3. The organic matter state variables were reserved to represent the recycling of nutrients within the reservoir between algal biomass and reservoir nutrient pools. No organic matter, as represented by these variables, was input into the reservoirs. They were used to track nutrients released from algal decomposition.

To use the W2 model in this configuration, several minor changes had to be made to the W2 code. Inorganic solids contribute to light extinction, but inorganic solids representing solid-phase phosphorus do not contribute to light extinction over and above the sediment to which they are attached. The W2 code was altered so solid-phase phosphorus would not contribute to light extinction. Second, in the W2 model, sediment oxygen demand (SOD) can be represented as a first-order reaction based on the quantity of labile organic matter that has settled to the bottom of a segment. In the original code the CBOD variables do not settle and do not contribute to the pool of organic material in the sediments. The code was altered so that (1) CBOD species could be assigned a settling

velocity and (2) labile particulate CBOD contributed to sediment organic matter. Each year's simulation was initialized with the final concentrations of sediment organic matter from the previous year's simulation, because no observations of sediment organic matter were available.

4.3 Scenario Descriptions and Results

4.3.1 Scenario Descriptions

TMDL development for the Gunpowder reservoirs involved the following four scenarios:

1. **Calibration Scenario**: The Calibration Scenario represents actual loads over the simulation period 1992-1997. As the name suggests, the loads in this scenario were used to calibrate the CE-QUAL-W2 models of Prettyboy and Loch Raven Reservoirs. Loads from wastewater treatment plants and other point source dischargers are based on reported flows and concentrations for the period. Loads from developed land falling under the National Pollutant Discharge Elimination System (NPDES) permit for stormwater discharge, as well as nonpoint source loads from forests and agricultural land, were determined through the calibration of the Gunpowder Falls HSPF Model.

2. **Baseline Scenario**: The Baseline Scenario differs from the Calibration Scenario only in that design flows and concentrations at the permitted limits are used to determine loads from wastewater treatment plants and other point source dischargers. Loads from developed land under Municipal Separate Storm Sewer System (MS4) permits and nonpoint source loads are the same as in the Calibration Scenario.

3. **TMDL Scenario**: The TMDL Scenario represents the maximum allowable loads from developed land falling under NPDES stormwater permits and the maximum allowable loads from nonpoint sources such that computer simulation predicts water quality standards will be met in Prettyboy and Loch Raven Reservoirs. Loads from permitted dischargers are calculated based on the design flow of the permit and the maximum permitted concentration.

4. **All-Forest Scenario**: The All-Forest Scenario simulates the response of the reservoirs to the phosphorus, sediment, nitrogen, and BOD loading rates that would occur if all of the land in the reservoirs' watersheds were forested. The All-Forest Scenario is used to determine to what extent hypoxic conditions in the hypolimnion are a function of external loading rates or reservoir morphology. The All-Forest Scenario constitutes an estimate of hypolimnetic DO concentrations under natural conditions. Flows and temperature were taken from the Calibration Scenario, while constituent loads were taken from the HSPF model simulation whereby all land in the watershed was forested.

4.3.2 Calibration Scenario Results

The primary function of the CE-QUAL-W2 models of Prettyboy and Loch Raven Reservoirs is to link algae biomass concentrations, as represented by Chla concentrations, to total phosphorus loads. The models were calibrated conservatively, to ensure that simulated Chla concentrations were at least as high as observed concentrations, even if maximum seasonal concentrations were shifted upstream or downstream in simulation, or occurred a month earlier or later than the corresponding observed concentrations.

Figures B1 and B2 in Appendix B compare simulated and observed maximum Chla concentrations in the surface layers of Prettyboy and Loch Raven Reservoirs, respectively, by sampling date. The models capture the observed peak seasonal average Chla concentrations, though sometimes shifted spatially or temporally. Similarly, Figures B3 and B4 show the cumulative distribution of simulated and observed maximum Chla concentrations. In both reservoirs, simulated concentrations are higher than observed concentrations above the 10 µg/l level, demonstrating further the conservative character of the calibration.

Figures B5 and B6 in Appendix B compare simulated and observed average surface DO concentrations at the lower sampling locations in Prettyboy and Loch Raven Reservoir, respectively. The models follow the seasonal trend in DO but tend to over-simulate DO in winter and under-simulate DO in summer. Figures B7 and B8 show the simulated and observed average bottom DO concentrations. The models capture the seasonal trend in bottom DO. The coefficients of determination between observed and simulated values are 0.80 and 0.81 for Prettyboy and Loch Raven Reservoirs, respectively.

Appendix C contains time series plots comparing simulated and observed concentrations at other locations. It also shows time series plots for total phosphorus, nitrate, and ammonia.

4.3.3 Baseline Scenario Results

Wastewater treatment plants and other permitted point sources (excluding MS4 discharges) contribute less than 1% of the total phosphorus load to Prettyboy and Loch Raven Reservoirs, and an insignificant amount to the sediment load to Loch Raven Reservoir. The results of the Baseline Scenario are indistinguishable from the Calibration Scenario. Baseline loads are broken out by land use and jurisdiction in Appendix D.

4.3.4 TMDL Scenario Results

The CE-QUAL-W2 models of Prettyboy and Loch Raven Reservoirs were used to determine the maximum total phosphorus loads compatible with water quality standards. Simulated loads were reduced until two conditions were met: (1) no simulated Chla concentration in any cell was above 30 µg/l, and (2) the 30-day moving average Chla

concentration of each modeling cell within 15 meters of the surface was not greater than 10 µg/l. Figures B9 and B10 in Appendix B compare maximum Chla concentrations by date under the Calibration and TMDL Scenarios to observed concentrations in the surface layer of Prettyboy and Loch Raven Reservoirs, respectively.

The TMDL Scenario was also analyzed to determine whether the reservoirs would meet the DO criteria for Use III-P waters under TMDL loading rates. Figures B11 and B12 show the average surface DO concentrations at the lower sampling locations in Prettyboy and Loch Raven Reservoirs, based on a screening depth of 20 feet. To more accurately screen for potential violations, the position of the well-mixed surface layer was more precisely determined on a daily basis. Instantaneous DO concentrations were output from all cells in the surface layer at 0.1-day intervals; the daily average DO concentration was also calculated for each cell in the surface layer. Under the TMDL scenario, there is no cell in the surface layer of either reservoir with an instantaneous DO concentration less than 5.0 mg/l, or a daily average DO concentration of less than 6.0 mg/l, except during periods such as the fall overturn when the surface layer deepens and entrains water with low DO concentrations from the metalimnion.

Seasonal hypoxia persists in the hypolimnion in both reservoirs even under the TMDL Scenario. Figures B13 and B14 in Appendix B show the average bottom DO concentrations at the lower sampling locations in Prettyboy and Loch Raven Reservoirs. As the figures indicate, although the average DO in the bottom layers improves under the TMDL Scenario, neither reservoir maintains a DO concentration of 5.0 mg/l in the hypolimnion throughout the simulation period.

4.3.5 All-Forest Scenario Results

As explained earlier, the purpose of the All-Forest Scenario is to help determine whether hypoxia in the bottom layers of Prettyboy and Loch Raven Reservoirs is primarily due to the stratification induced by reservoir morphology, or to input loads. If hypoxia occurs even under all-forested loading rates, then reservoir stratification is the primary cause of hypoxia and it can be concluded that the reservoir meets the water quality standards for DO as described in Section 2.3.

Average annual TP loads in the All-Forest Scenario are 20% of the load in the Calibration Scenario in Prettyboy Reservoir, and 28% of the load in the Calibration Scenario in Loch Raven Reservoir. The reduction in average annual loads of POM, the precursor to sediment oxygen demand, is not as large. Average annual POM loads in the All-Forest Scenario are 29% of the load in Calibration Scenario in Prettyboy and 41% of the load in Calibration Scenario in Loch Raven. The load decrease is less in the Loch Raven watershed because of the high percentage of forested and developed land.

Figures 13 and 14 below show the average bottom DO concentrations at lower sampling locations in the reservoirs under the All-Forest Scenario. Minimum concentrations at the sampling locations are also shown.

Average DO in the bottom layers of both reservoirs improves considerably under the All-Forest Scenario. The minimum DO concentration, however, frequently drops below 5.0 mg/l. Even under the All-Forest Scenario, the hypolimnion remains hypoxic in many (but not all) years of the simulation. The hypoxia tends to be worse in the lower stations of the reservoirs where the depths are greatest.

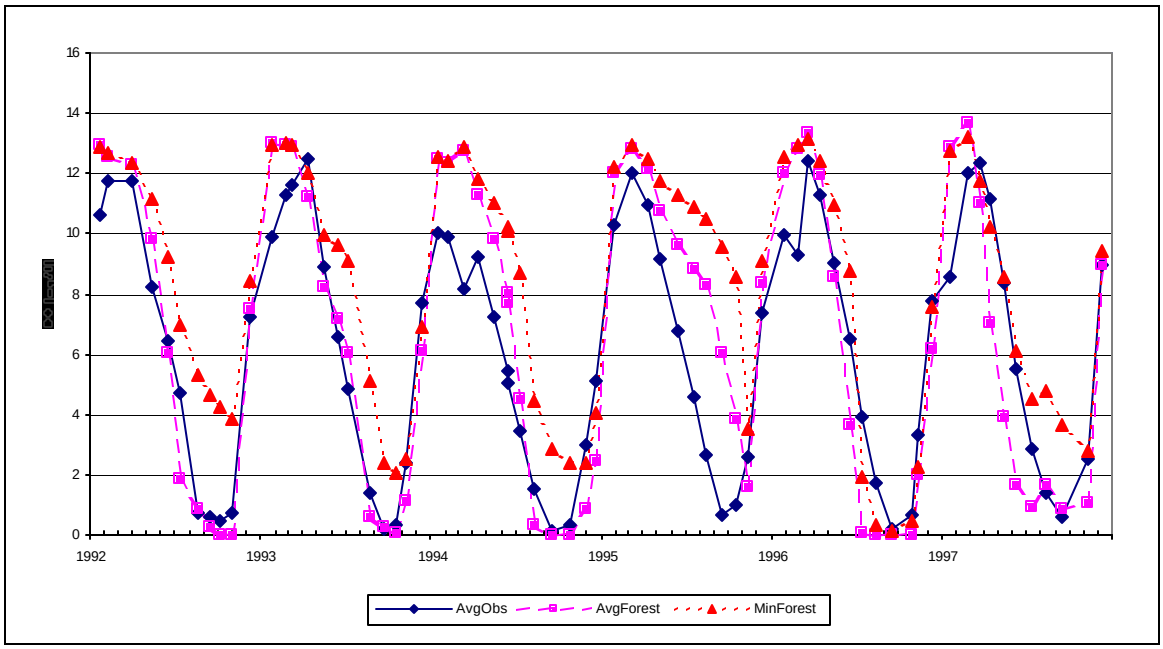

Figure 13: Observed and Simulated Average Bottom DO Concentrations, Lower Stations, All-Forest Scenario, Prettyboy Reservoir

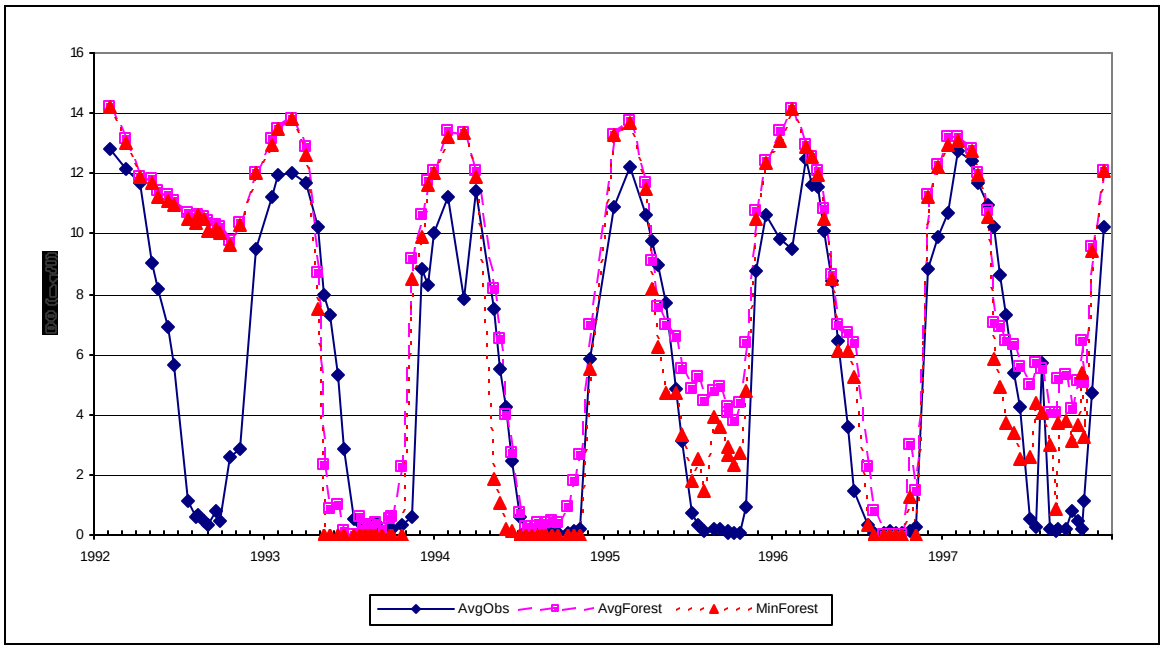

Figure 14: Observed and Simulated Average Bottom DO Concentrations, Lower Stations, All-Forest Scenario, Loch Raven Reservoir

A sensitivity analysis was performed to better determine how phosphorus and organic matter loading rates impact hypoxia in the hypolimnion. POM and TP loading rates were reduced to 50%, 20% and 10% of the loads of the All-Forest Scenario, and the percent of sampling dates where DO < 2.0 mg/l at the sampling locations was calculated. Figure 15 shows the results. Significant hypoxia persists even when loads are reduced to only 10% of the All-Forest Scenario, particularly in Prettyboy Reservoir, which is deeper than Loch Raven even though it has less volume. The sensitivity analysis shows that low DO in the bottom layers of the reservoirs is relatively insensitive to the particular assumptions used to determine organic matter loads in the models, and demonstrates that hypolimnetic hypoxia is primarily driven by stratification and reservoir morphology, rather than by external loads. The All-Forest Scenario demonstrates that current loads, and loads simulated under the TMDL Scenario, do not result in hypoxia that significantly exceeds that associated with natural conditions in the watershed. Low DO concentrations in the bottom layers of the reservoirs are therefore a naturally occurring condition, as described by the interim interpretation of Maryland's water quality standards. The TMDL Scenario thus meets water quality standards for DO under the interim interpretation.

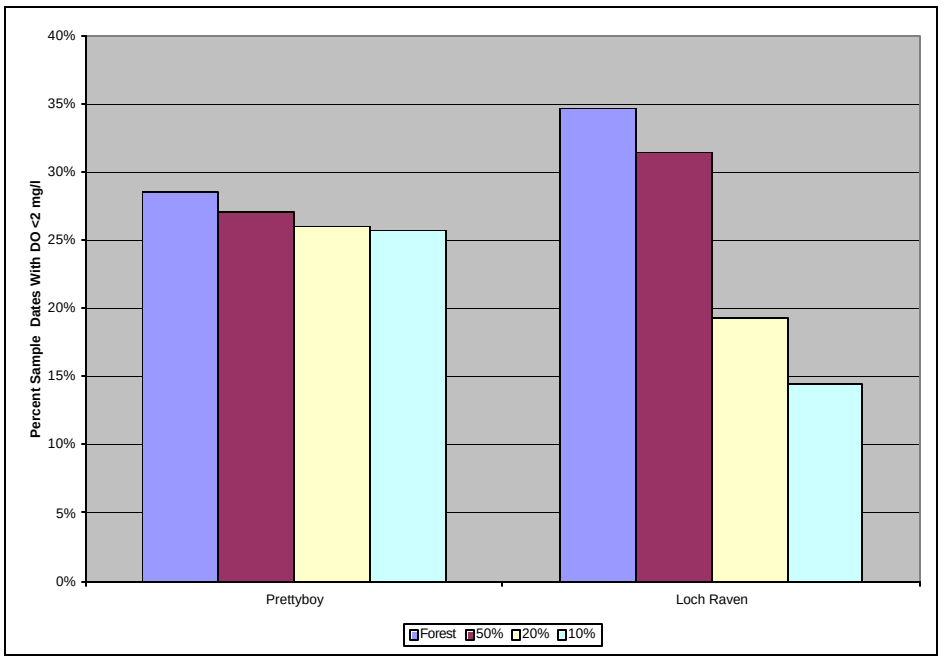

Figure 15: Percent of Sampling Dates on which DO < 2.0 mg/l as a function of proportion of All-Forest Scenario

4.4 TMDL Loading Caps

4.4.1 Phosphorus TMDL Loading Caps for Prettyboy and Loch Raven Reservoirs

This section presents the TMDLs for phosphorus for Prettyboy and Loch Raven Reservoirs. The TMDLs were estimated based on the phosphorus loadings as explained in Section 4.3 and the resulting water quality in the reservoirs for the simulated years 1992-1997. This period was selected to estimate the TMDLs because it covers a period that includes dry years as well as very wet years and thus takes into account a variety of hydrological conditions. Chla concentrations indicative of eutrophic conditions can occur at any time of year, and the simulation period encompasses the spectrum of observed seasonal concentrations (see Tables B3 and B4, Appendix B). Seasonal low DO concentrations in the hypolimnia that occur regularly each year are also represented in the simulation models.

TMDL loads were calculated on an average annual basis. The average residence time of Loch Raven Reservoir is approximately three to four months while the residence time of Prettyboy is approximately one year. Water quality conditions in both reservoirs are the cumulative result of loadings that span seasons, or even, in the case of hypolimnetic hypoxia, years. Average annual TP loads are therefore the appropriate measure in which to express nutrient TMDLs for Prettyboy and Loch Raven Reservoirs.

For Prettyboy Reservoir:

Total Phosphorus TMDL 23,192 lbs/year

For Loch Raven Reservoir:

Total Phosphorus TMDL 54,941 lbs/year

The TMDLs reflect a reduction of 54% from baseline TP loads in Prettyboy Reservoir and 50% from baseline loads in Loch Raven Reservoir. Load reductions are broken out by land use and jurisdiction in Appendix D.

Average Daily Loads:

In Prettyboy Reservoir, the average annual TMDL for TP will result in average daily TP loads of approximately 63.54 lbs/day. In Loch Raven Reservoir, the average annual TMDL for TP will result in average daily TP loads of approximately 150.95 lbs/day.

4.4.2 Sediment TMDL Loading Caps for Loch Raven Reservoir

Excessive sedimentation reduces a reservoir's storage capacity and therefore negatively impacts its ability to function as a water supply reservoir. Excessive sedimentation can

also negatively impact a reservoir's fishery and interfere with its recreational uses. Although the maximum sedimentation rates occur during wet weather events, it is the cumulative effect of sedimentation that impacts the reservoir. No single critical period can be defined for the water quality impact of sedimentation. An excessive sedimentation rate negatively impacts a reservoir regardless of when it occurs. Therefore, the efforts to reduce sediment loading to the lake should focus on achieving effective, long-term sediment control. Since some measures to control phosphorus from agriculture sources can also effectively reduce sedimentation, the expected sediment reduction can be estimated based on the degree of phosphorus control needed to improve the water quality of the reservoir.

To quantify the sediment reduction associated with this phosphorus reduction, the EPA Chesapeake Bay Program watershed modeling assumptions were consulted. For the agricultural best management practices (BMPs) that affect both phosphorus and sediments, EPA estimates a 1-to-1 reduction in sediments as a result of controlling phosphorus (EPA, Chesapeake Bay Program Office, 1998). However, this ratio does not account for phosphorus controls that do not remove sediments.

To estimate the applicable ratio, hence the sediment load reduction, it is necessary to estimate the proportion of the phosphorus reduction controls that remove sediments versus those that do not. In general, soil conservation and water quality plans (SCWQPs) remove sediments along with the phosphorus removal, while nutrient management plans (NMPs) do not. It has been assumed that 50% of the phosphorus reduction will come from SCWQPs and 50% from NMPs. This results in a 0.5-to-1 ratio of sediment reduction to phosphorus reduction. The net sediment reduction associated with a 50% NPS phosphorus reduction is about 25% (0.50 * 0.5 = 0.25).

It is assumed that this reduced sediment loading rate would result in a similar reduction in the sediment accumulation rate. The sediment accumulation rate predicted to result from this reduced loading rate would allow for the retention of 85% of the overall impoundment's original volume after 50 years. More important, it will reduce loss of volume in the upper reservoir, which otherwise would have less than 70% of its original capacity after 50 years. Under the TMDL loading cap, the upper reservoir may retain as much as 80% of its original capacity if the reduction in loading rates reduces volumetric loss at a rate proportionate to current capacity loss.

MDE believes that this volumetric retention will support the designated uses of Loch Raven Reservoir (Use III-P) for which it is protected: naturally-breeding trout and public water supply. This estimate is reasonably consistent with technical guidance provided by EPA Region III of a 0.7-to-1.0 reduction in sediment in relation to the reduction in phosphorus. (EPA, 1998) This rule-of-thumb would yield a 35% estimated reduction in sediment [100*(0.7 * 0.50) = 35%]

Assuming that a 50% reduction in total phosphorus load results in a 25% reduction in sediment load, the sediment loading cap for Loch Raven Reservoir is as follows:

For Loch Raven Reservoir:

Sediment TMDL	**28,925 tons/year**

Average Daily Loads:

In Loch Raven Reservoir, the average annual TMDL for sediment will result in average daily sediment loads of approximately 79.25 tons/day.

4.5 Total Load Allocations Between Point Sources and Nonpoint Sources

The allocations described in this section demonstrate how the TMDLs can be implemented to achieve water quality standards in Prettyboy and Loch Raven Reservoirs. Specifically, these allocations show that the sum of phosphorus loadings to the reservoirs from existing point and nonpoint sources can be maintained safely within the TMDLs established herein. The State reserves the right to revise these allocations provided such revisions are consistent with the achievement of water quality standards.

Phosphorus TMDL Allocations

- Nonpoint Source (NPS) Loads

  Nonpoint source loads including agricultural and forest loads are assigned to the TMDL as the Load Allocation (LA). The Calibration and Baseline Scenario loads were based on the HSPF model of the Gunpowder Falls Watershed. The modeling of the watershed accounted for both natural and human-induced components, including atmospheric deposition and septic loadings. Details on the HSPF model can be found in *Modeling Framework for Simulating Hydrodynamics and Water Quality in Prettyboy and Loch Raven Reservoirs* (ICPRB and MDE, 2006).

- Stormwater Loads

  In November 2002, EPA advised states that NPDES-regulated storm water discharges must be addressed by the wasteload allocation (WLA) component of a TMDL. See 40 C.F.R. § 130.2(h). NPDES-regulated storm water discharges may not be addressed by the load allocation (LA) component of a TMDL. EPA also provided guidance on ways to reflect the TMDL stormwater wasteload allocation (WLA). The stormwater phosphorus loads simulated in the TMDL scenario represent a 15% reduction in TP from baseline urban stormwater loads. Urban stormwater loads are now part of the WLA.

Current stormwater Phase I individual permits and new stormwater Phase II permits are considered point sources subject to WLA assignment in the TMDL, instead of LA assignment as in the past. EPA recognizes that limitations in the available data and information usually preclude stormwater allocations to specific outfalls. Therefore, EPA's guidance allows this stormwater WLA to be expressed as a gross allotment, rather than individual allocations for separate pipes, ditches, construction sites, etc. Available information for the Gunpowder Falls watershed allows the stormwater WLA for this analysis to be defined separately for Carroll, Baltimore and Harford Counties; however, these WLAs aggregate municipal and industrial stormwater, including the loads from construction activity.

Waste load allocations from point source dischargers are usually based on the relative contribution of pollutant load to the waterbody. Estimating a load contribution to a particular waterbody from the stormwater Phase I and II sources is imprecise, given the variability in sources, runoff volumes, and pollutant loads over time. Therefore, any stormwater WLA portion of the TMDL is based on a rough estimate.

- Wastewater Treatment Plant Loads

  In addition to nonpoint source loads and stormwater point sources, waste load allocations to the Hampstead and Manchester WWTP plus a 5% MOS, estimated as explained in the next section, make up the balance of the total allowable load. The Hampstead WWTP maximum allowable design flow of 0.9 MGD is used for this scenario. The total phosphorus limit at Hampstead is 0.3 mg/l year round. The Manchester WWTP maximum allowable current permit flow of 0.5 MGD is used for this scenario; discharges to surface water occur only from December through March. The total phosphorus limit at Manchester is 1.0 mg/l *when discharges occur*. All significant point sources are addressed by this allocation and are described further in the technical memorandum entitled *"Significant Nutrient and Sediment Point Sources in the Prettyboy and Loch Raven Reservoir Watersheds."*

The TMDL, including loads from stormwater discharges, is now expressed as:

TMDL = WLA [non-stormwater point sources + regulated stormwater point source] + LA + MOS

The phosphorus allocations for Prettyboy and Loch Raven Reservoirs are presented in Table 7.

Table 7: Total Phosphorus Allocations (lbs/yr) for Prettyboy and Loch Raven Reservoirs

	Prettyboy Reservoir	Loch Raven Reservoir
Nonpoint Source[1]	19,092	30,184
Point Source[2]	2,940	22,010
Margin of Safety[3]	1,160	2,747
Total Maximum Daily Load	23,192	54,941

[1] Excludng urban stormwater loads.
[2]Including urban stormwater loads.
[3]Representing 5% of baseline nonpoint source and urban stormwater loads.

4.5.1 Sediment Load Allocations for Loch Raven Reservoir

- Nonpoint Source (NPS) Loads

  Nonpoint source loads including agricultural and forest loads are assigned to the TMDL as LA. The Calibration and Baseline Scenario loads were based on the HSPF model of the Gunpowder Falls Watershed. The modeling of the watershed accounted for both natural and human-induced components. The LA to nonpoint sources below the Prettyboy Dam represents a decrease of approximately 25% from baseline loads. Sediment loads from Prettyboy Reservoir are less than 2% of total sediment load. Details on the HSPF model can be found in *Modeling Framework for Simulating Hydrodynamics and Water Quality in Prettyboy and Loch Raven Reservoirs* (ICPRB and MDE, 2006).

- Stormwater Loads

  The reduction in total phosphorus loads from stormwater discharges will result in a reduction in sediment loads, but because of the uncertainty in BMP efficiencies for developed land, no reduction is assumed for sediment loads from stormwater discharges, and their share of the WLA is set equal to baseline conditions.

- Wastewater Treatment Plant Loads

  The waste load allocation to the Hampstead WWTP makes up the balance of the total allowable load. The Hampstead WWTP maximum allowable current permit flow of 0.9 MGD is used for this scenario. The total suspended solids limit is 30.0 mg/l year round. All significant point sources are addressed by this allocation and are described further in the technical memorandum entitled *"Significant Nutrient and Sediment Point Sources in the Prettyboy and Loch Raven Reservoir Watersheds."*

- Permitted Industrial Facilities

  There are three industrial facilities with permits regulating the discharge of total suspended solids in the Loch Raven Reservoir watershed. Only one of them, the Lafarge Mid-Atlantic and Imerys facility, has even the potential to discharge significant sediment loads. The waste load allocation for the quarry was set as the product of maximum recorded average discharge at each of the two permitted outfalls and a suspended solids limit of 15 mg/l and 17 mg/l for the respective outfalls. The waste load allocation for the two other industrial facilities was also set as a product of the maximum recorded average flow and the permitted suspended solids concentration. All significant industrial point sources are addressed by this allocation and are described further in the technical memorandum entitled *"Significant Nutrient and Sediment Point Sources in the Prettyboy and Loch Raven Reservoir Watersheds."* Load reductions are broken out by land use and jurisdiction in Appendix D.

The TMDL for Suspended Sediment in Loch Raven Reservoir is as follows:

TMDL (tons/yr)	**=**	**LA**	**+**	**WLA**	**+**	**MOS**
28,925	**=**	**27,715**		**1,210**		**implicit**

4.6 Margins of Safety

A MOS is required as part of a TMDL in recognition of many uncertainties in the understanding and simulation of water quality in natural systems. For example, knowledge is incomplete regarding the exact nature and magnitude of pollutant loads from various sources and the specific impacts of those pollutants on the chemical and biological quality of complex, natural waterbodies. The MOS is intended to account for such uncertainties in a manner that is conservative from the standpoint of environmental protection.

Based on EPA guidance, the MOS can be achieved through two approaches (EPA, April 1991). One approach is to reserve a portion of the loading capacity as a separate term in the TMDL (*i.e.*, TMDL = Load Allocation (LA) + Waste Load Allocation (WLA) + MOS). The second approach is to incorporate the MOS as conservative assumptions used in the TMDL analysis. Maryland has adopted a MOS for nutrient TMDLs using the first approach. The reserved load allocated to the MOS was computed as 5% of the total loads for phosphorus. These explicit phosphorus margins of safety are **1,160 lbs/yr** for Prettyboy Reservoir, and **2,747 lbs/yr** for Loch Raven Reservoir.

In establishing a MOS for sediments, Maryland has adopted an implicit approach by incorporating conservative assumptions. First, because phosphorus binds to sediments, sediments will be controlled as a result of controlling phosphorus. This estimate of

sediment reduction is based on the load allocation of phosphorus (4,150 lbs/yr), rather than the entire phosphorus TMDL including the MOS. Thus, the explicit 5% MOS for phosphorus will result in an implicit MOS for sediments. This conservative assumption results in a difference of about 5,099 tons/yr (see Section 4.5 above for a discussion of the relationship between reductions in phosphorus and sediments). Secondly, as described in Section 4.4.2, MDE conservatively assumes a sediment-to-phosphorus reduction ratio of 0.5:1, rather than 0.7:1 sediment-to-phosphorus reduction ratio given in the technical guidance provided by EPA Region III. Table 8 compares the volumetric preservation under TMDL conditions in Loch Raven Reservoir with that of several other approved TMDLs.

Table 8: Volumetric Preservation of Various Impoundments Under Sediment TMDL Conditions

TMDL	VOLUMETRIC PRESERVATION (TMDL time-span)	VOLUMETRIC PRESERVATION (100 year time span)
Urieville Community Lake (MD)	76% after 40 years	40%
Tony Tank Lake (MD)	64% – 85% after 40 years	10% to 62.5%
Hurricane Lake (WV)	70% after 40 yrs	25%
Tomlinson Run Lake (WV)	30% after 40 yrs	Silted in
Clopper Lake (MD)	98% - 99% after 40 years	96% to 98%
Centennial Lake (MD)	68% - 87% after 40 years	20% to 69%
Lake Linganore (MD)	52% - 80% after 40 years	Silted in to 52%
Loch Raven Reservoir (MD)	85% after 50 years	80%

4.7 Summary of Total Maximum Daily Loads

The following equations summarize the nutrient TMDLs for Prettyboy and Loch Raven Reservoirs, and the sediment TMDL for Loch Raven Reservoir:

For Total Phosphorus in Prettyboy Reservoir:

TMDL (lbs/yr)	**=**	**LA**	**+**	**WLA**	**+**	**MOS**
23,192	**=**	**19,092**		**2,940**		**1,160**

For Total Phosphorus in Loch Raven Reservoir:

TMDL (lbs/yr)	**=**	**LA**	**+**	**WLA**	**+**	**MOS**
54,941	**=**	**30,184**		**22,010**		**2,747**

For Suspended Sediment in Loch Raven Reservoir:

TMDL (tons/yr)	=	LA	+	WLA	+	MOS
28,925	**=**	**27,715**		**1,210**		**implicit**

5.0 ASSURANCE OF IMPLEMENTATION

This section provides the basis for reasonable assurances that the phosphorus and sediment TMDLs will be achieved and maintained. For both TMDLs, Maryland has numerous well-established programs that may be drawn upon: the Water Quality Improvement Act of 1998 (WQIA); the Clean Water Action Plan (CWAP) framework; the Maryland Agricultural Water Quality Cost-Share (MACS) Program; the Low Interest Loans for Agricultural Conservation (LILAC) Program; the Maryland Agricultural Land Preservation Easement (MALPE) Program, and the Chesapeake Bay Agreement's Tributary Strategies for Nutrient Reduction. Also, Maryland has adopted procedures to assure that future evaluations are conducted for all TMDLs that are established. Additionally, the federal Safe Drinking Water Act requires states to develop and implement source water assessment programs (SWAPs) to study the safety and evaluate the vulnerability of drinking water sources to contamination.

The Hampstead WWTP will continue to meet the requirements of its NPDES discharge permit, which since 1997 requires an effluent phosphorus concentration below 0.3 mg/l and a total suspended solids concentration less than 30 mg/l. The Manchester WWTP will continue to meet the requirements of its NPDES discharge permit, which requires it to use spray irrigation to dispose of its wastewater discharge April through November, and to meet an effluent concentration limit of 1.0 mg/l TP and 30 mg/l TSS when discharging to surface water December through March.

Maryland's WQIA requires that comprehensive and enforceable nutrient management plans be developed, approved and implemented for all agricultural lands throughout Maryland. This act specifically requires that nutrient management plans for nitrogen be developed and implemented by 2002, and plans for phosphorus be completed by 2005. Maryland's CWAP has been developed in a coordinated manner with the State's 303(d) process. All Category I watersheds identified in Maryland's Unified Watershed Assessment process are totally coincident with the impaired waters list for 2002 approved by EPA. The State is giving a high priority for funding assessment and restoration activities to these watersheds.

In 1983, the States of Maryland, Pennsylvania, and Virginia, the District of Columbia, the Chesapeake Bay Commission, and the U.S. EPA joined in a partnership to restore the Chesapeake Bay. In 1987, through the Chesapeake Bay Agreement, Maryland made a commitment to reduce nutrient loads to the Chesapeake Bay. In 1992, the Chesapeake Bay Agreement was amended to include the development and implementation of plans to

achieve these nutrient reduction goals. Maryland's resultant Tributary Strategies for Nutrient Reduction provide a framework supporting the implementation of nonpoint source controls in the Upper Western Shore Tributary Strategy Basin, which includes the Gunpowder Falls watershed. Maryland is in the forefront of implementing quantifiable nonpoint source controls through the Tributary Strategy efforts. This will help to ensure that nutrient control activities are targeted to areas in which nutrient TMDLs have been established.

In November 1990, EPA required jurisdictions with a population greater than 100,000 to apply for NPDES permits for stormwater discharges. In 1983, the EPA Nationwide Urban Runoff Program found that stormwater runoff from urban areas contains the same general types of pollutants found in wastewater, and that 30% of identified cases of water quality impairment were attributable to stormwater discharges. The two Maryland jurisdictions where the majority of the Loch Raven and Prettyboy watersheds are located, Carroll County and Baltimore County, are required to participate in the stormwater NPDES program, and have to comply with the NPDES permit regulations for stormwater discharges. Several management programs have been implemented in different areas served by the counties. These jurisdiction-wide programs are designed to control stormwater discharges to the maximum extent practicable.

Since 1979, Baltimore City, Baltimore County and Carroll County have had in place a formal agreement to manage the reservoir watersheds and, since 1984, these agreements have been accompanied by an action strategy with specific commitments from the signatories. A revised Reservoir Watershed Management Agreement was signed in 2005, accompanied by a revised Action Strategy. Table 9 lists the parties to the 2005 agreement and some of their major commitments made in the Action Strategy.

In June 2005, the Baltimore County Department of Environmental Protection and Resource Management, in cooperation with MDE and other stakeholders in the region, began to develop a Watershed Restoration Action Strategy (WRAS) document for Prettyboy Reservoir. The purpose of the document is to present a strategy to reduce NPS pollution that contribute to impairments in the watershed, while at the same time conserving the unique, high quality natural resources. The strategy is developed through the combined efforts of the general public, watershed stakeholders, local and county governments, non-profit organizations, and state and federal agencies. The document outlines the conditions in the watershed, the potential sources of pollution and impairments, and actions that can be taken to address these issues. It is anticipated that this strategy, scheduled for completion in late 2006, will assure TMDL implementation for nonpoint sources.

Additionally, Maryland uses a five-year watershed cycling strategy to manage its waters. Pursuant to this strategy, the State is divided into five regions and management activities will cycle through those regions over a five-year period. The cycle begins with intensive monitoring, followed by computer modeling, TMDL development, implementation activities, and follow-up evaluation. The choice of a five-year cycle is motivated by the

five-year federal NPDES permit cycle. This continuing cycle ensures that every five years intensive follow-up monitoring will be performed. Thus, the watershed cycling strategy establishes a TMDL evaluation process that assures accountability.

Finally, it is noted that the baseline calibration scenarios inherently include the effects of some BMPs as of the time period affixed in the scenarios (*i.e.*, 1992 – 1997). Additional land use changes and BMP implementation efforts, potentially resulting in water quality changes of as-of-yet unknown type and magnitude, have occurred since then. It is likely that initial phases of the implementation process may include an assessment of these practices and their potential benefits (or detriments) to water quality.

Table 9: Signatories to the 2005 Reservoir Management Agreement and Their Major Commitments under the 2005 Action Strategy (RTG, 2005)

Maryland Department of the Environment	1. Use NPDES program to discourage significant phosphorus discharges in reservoir watersheds from package plants and new industrial dischargers.
Maryland Department of Agriculture	1. Enforce the provisions of Maryland Water Quality Improvement Act of 1998. 2. Offer assistance through the Maryland Agriculture Cost-Share Program. 3. Target assistance to farm operations having problems with the potential to cause water pollution.
Baltimore City	1. Continue water quality monitoring of reservoirs.
Baltimore County	1. Continued water quality monitoring of tributaries. 2. Maintain Resource Conservation zoning in the reservoir watersheds and maintain insofar as possible the Urban-Rural Demarcation Line. 3. Conduct programs of street-sweeping, storm drain-inlet cleaning, and storm pipe cleaning in urban areas.
Carroll County	1. Require enhanced stormwater management practices for all new development in reservoir watersheds. 2. Use master land-use plans to support Reservoir Management Agreement. 3. Limit insofar as possible additional urban development zoning with the reservoir watersheds.
Baltimore County Soil Conservation District Carroll County Soil Conservation District	1. Encourage farmers to participate in federal and state assistance programs that promote soil conservation and the protection of water quality. 2. Prepare Soil Conservation and Water Quality Plans for each farm in the reservoir watersheds, update plans where necessary, and assist operators in implementing them. 3. Encourage and assist operators to comply with nutrient management plans mandated under the Maryland Water Quality Improvement Act.
Baltimore Metropolitan Council	1. Provide staff for coordination and administration of the Reservoir Technical Program through the financial support of its member jurisdictions.

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APPENDIX I:

Total Maximum Daily Load of Mercury for Loch Raven Reservoir in Baltimore County, Maryland

Total Maximum Daily Load of Mercury for Loch Raven Reservoir in Baltimore County, Maryland

FINAL

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List of Abbreviations

AAWCC	Allowable Ambient Water Column Concentration
BAF	Bioaccumulation Factor
BMP	Best Management Practice
CAA	Clean Air Act
CWA	Clean Water Act
COMAR	Code Of Maryland Regulations
DE	Delaware
DNR	Maryland Department of Natural Resources
Eh	Oxidation Potential
EPA	U.S. Environmental Protection Agency
ESP	Electrostatic Precipitator
ft^3/s	Cubic feet per second
g	gram
Hg	Mercury
kg	kilogram
km^2	Square kilometers
LA	Load Allocation
L	liter
µg/L	micrograms per liter = ppm (parts per billion)
µg/kg	micrograms per kilogram = ppm (parts per billion)
MDE	Maryland Department of the Environment
MD	Maryland
MeHg	Methylmercury
MGD	Millions of gallons per day
M^2	Square meters
mm	millimeter
mi^2	Square miles
MOS	Margin of Safety
MRL	Mercury Load Reduction
m^3/s	Cubic meters per second
ng/L	nanograms per liter = ppt (parts per trillion)
NADP-MDN	National Atmospheric Deposition Program – Mercury Deposition Network
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
PCS	Permit Compliance System (An EPA database – *Envirofacts Warehouse* on the EPA website)
pH	The inverse logarithm of the hydrogen ion concentration
ppb	Parts per billion
ppm	Parts per million
PS	Point Source
RGM	Reactive Gaseous Mercury
TMDL	Total Maximum Daily Load

UMCES	University of Maryland Center for Environmental Science, Chesapeake Biological Laboratory
USGS	United States Geological Survey
WLA	Waste Load Allocation
WQS	Water Quality Standard
WQLS	Water Quality Limited Segments
WTP	Water Treatment Plant
WWTP	Waste Water Treatment Plant
yr	Year

EXECUTIVE SUMMARY

Loch Raven Reservoir is an impoundment in the Gunpowder River Watershed (sub-watershed code 02-13-08-05) in Baltimore County, Maryland. It lies in series below the Prettyboy Reservoir. Loch Raven Reservoir was identified on the State of Maryland's draft2002 list of Water Quality Limited Segments [303(d) list] as impaired by mercury contamination, based on data for mercury concentrations in fish tissue. Concentrations in the water are well below the threshold for concern in regard to drinking water. The Maryland water quality standards Surface Water Use Designation [Code of Maryland Regulations (COMAR 26.08.02.07)] for Loch Raven Reservoir is Use III-P – *Natural Trout Waters and Public Water Supply*. The Maryland Department of the Environment's (MDE) current public fish consumption advisory to eat limited amounts of fish from Loch Raven Reservoir is not supportive of the recreational fishing use. Therefore, this document proposes to establish a Total Maximum Daily Load (TMDL) for mercury in Loch Raven Reservoir.

The methodology used to compute this mercury TMDL consists of two broad steps, which have been modified to coordinate this analysis with the analysis of Prettyboy Reservoir. The first step is to determine a maximum Allowable Ambient Water Column Concentration (AAWCC) of mercury in the water column that ensures the bioaccumulation of mercury by fish will remain below a maximum fish tissue concentration. The second step is to determine a maximum allowable load that is consistent with the maximum water column concentration. The resultant TMDL includes a Load Allocation (LA), a Waste Load Allocation (WLA), a Future Allocation (FA) and a margin of safety (MOS). The TMDL methodology considers all sources, including direct atmospheric deposition to the surface of the lake, nonpoint source contributions from the watershed, point source loads and loads from the upstream Prettyboy Reservoir. Because no specific data was available to estimate point source contributions, literature information was used to estimate the potential point source contributions. These estimates were used to set aside a future allocation that may be used for point source waste load allocations after the results of future point source monitoring are available.

The TMDL for mercury to Loch Raven Reservoir is an average annual load of 843.5 grams per year (2.3109 grams per day). This is the total amount of mercury that can be assimilated by Loch Raven Reservoir without significantly increasing the risk from mercury in fish tissue. This TMDL includes a 14 % Future Allocation (FA) and an 86% nonpoint source allocation (LA). As better information is available from point sources, the future allocation may be shifted to them. For nonpoint sources, an estimate is provided of suballocations between direct atmospheric deposition to the surface of the lake and atmospheric loads to the watershed, which includes Prettyboy Reservoir watershed. The TMDL implementation through reduced atmospheric contributions is expected to be accomplished over time through existing and proposed regulatory controls (e.g., Clean Air Act (CAA)). These controls are expected to be implemented in phases.

1.0 INTRODUCTION

The federal Clean Water Act (CWA) and Maryland regulations require the State to maintain water quality that supports fish and aquatic life, and fishing as a recreational activity. The U.S. Environmental Protection Agency (EPA) interprets the "fishable" use under section 101(a) of the Clean Water Act to include, at a minimum, the protection of aquatic communities and human health related to the consumption of fish and shellfish. In other words, "fishable" means that not only can fish and shellfish survive in a waterbody, but when harvested, can also be safely eaten by humans and terrestrial wildlife. (OWOW Memorandum # WQSP-00-03, October 2000).

Based on mercury data in fish tissue from a subset of lakes across the State, the Maryland Department of Environment (MDE) announced a statewide fish consumption advisory for lakes this year. This advisory has been established statewide as a precautionary measure because the primary source of mercury is understood to be atmospheric deposition, which is widely dispersed. Based on additional fish tissue data, Maryland has verified that Loch Raven Reservoir is impaired due to mercury in fish tissue.

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 specific substance are inadequate to achieve water quality standards. The CWA requires the development of a Total Maximum Daily Load (TMDL) for all impaired waters on their Section 303(d) list. A TMDL reflects the maximum pollutant loading of an impairing substance a waterbody can receive and still meet water quality standards. A TMDL can be expressed in mass per time, toxicity or any other appropriate measure (40 CFR 130.2(i)). A TMDL must take into account seasonal variations, critical conditions and a margin of safety (MOS), to allow for uncertainty. Maryland's 2002 proposed 303(d) list prepared by MDE lists Loch Raven Reservoir as impaired for mercury in fish tissue.

Immediate public health benefits will be derived from the enhanced public awareness that will be generated through this TMDL process. The timely development of this TMDL will increase public awareness of the need for upgrading controls on the atmospheric emissions of mercury, which are anticipated to result in water quality improvements.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting and Source Assessment

Loch Raven Reservoir is an impoundment located near Timonium in Baltimore County, Maryland (Figure 1). The impoundment, which is owned by the Baltimore City Department Public Works, lies on the Gunpowder River. Prettyboy Reservoir lies in the Loch Raven Reservoir watershed and drains into Loch Raven Reservoir. The Prettyboy watershed comprises approximately 26% of the area of the Loch Raven watershed. The City of Baltimore Department of Public Works owns both water bodies and uses them in

a system to provide a major source of public water to the Baltimore metropolitan area. The Loch Raven Dam was constructed in 1923 and modified in 1986.

Inflow to the Reservoir is primarily via the Gunpowder River. The watershed map (Figure 2) shows that land use in the area draining to Loch Raven Reservoir is predominately mixed agricultural and forest/herbaceous. Land use distribution in this watershed is approximately 42% mixed agricultural, 37% forest/herbaceous, 19% developed and 2% water. (Figure 3) (Maryland Department of Planning, 2000 Land Use Data).

Table 1: Physical Characteristics for Loch Raven Reservoir

Location:	Baltimore County, Maryland Latitude 39.43 Longitude 76.54 (At the dam)
Surface Area:	9.7125 km^2
Normal Depth:	23.2 meters
Normal Volume	8.97×10^7 m^3
Drainage Area to Lake:	788.81 km^2 *
Average Annual Flow	8.6 m^3/s *

***** Includes contribution from Prettyboy Reservoir Watershed

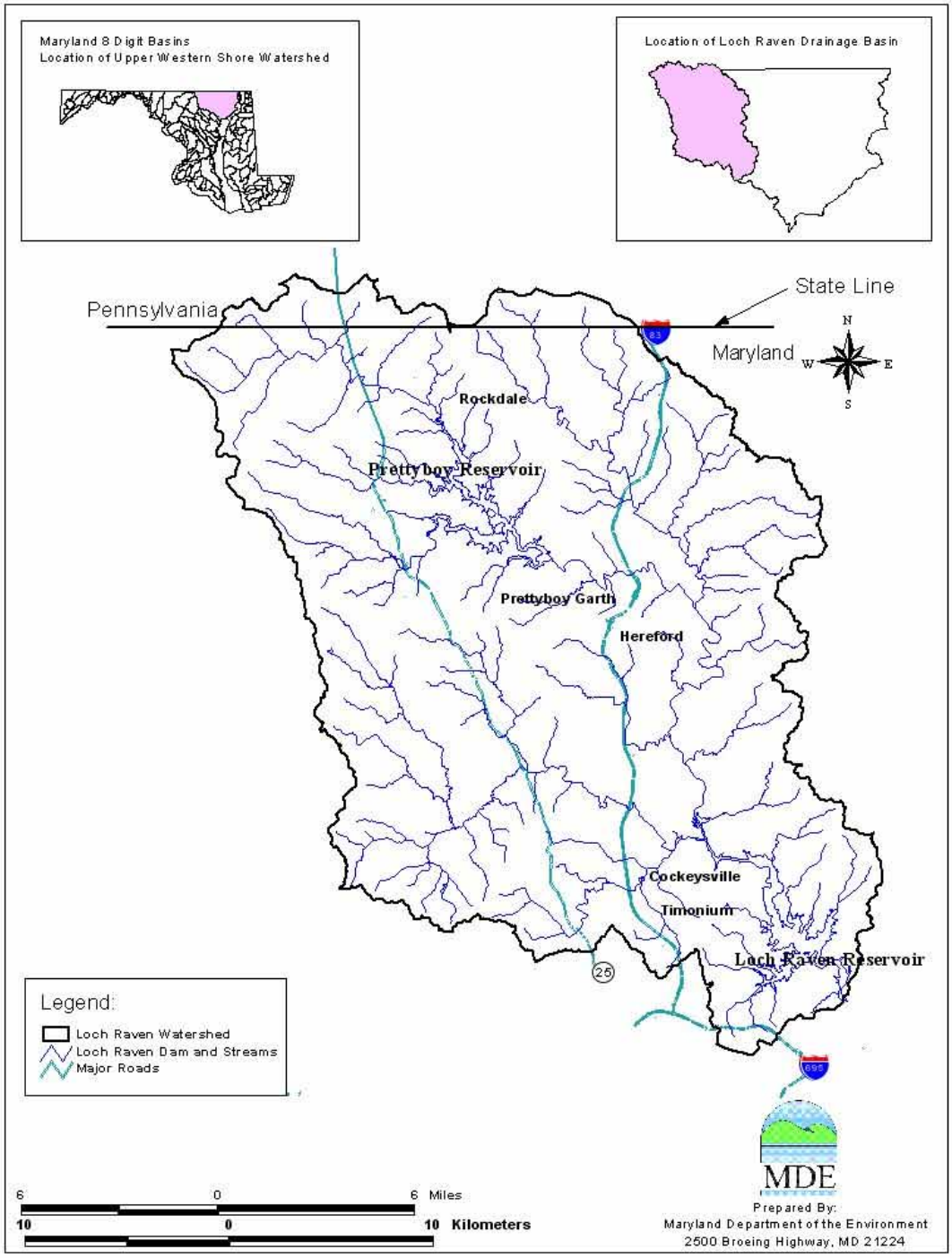

Figure 1: Location Map of Loch Raven Reservoir in Baltimore County, Maryland

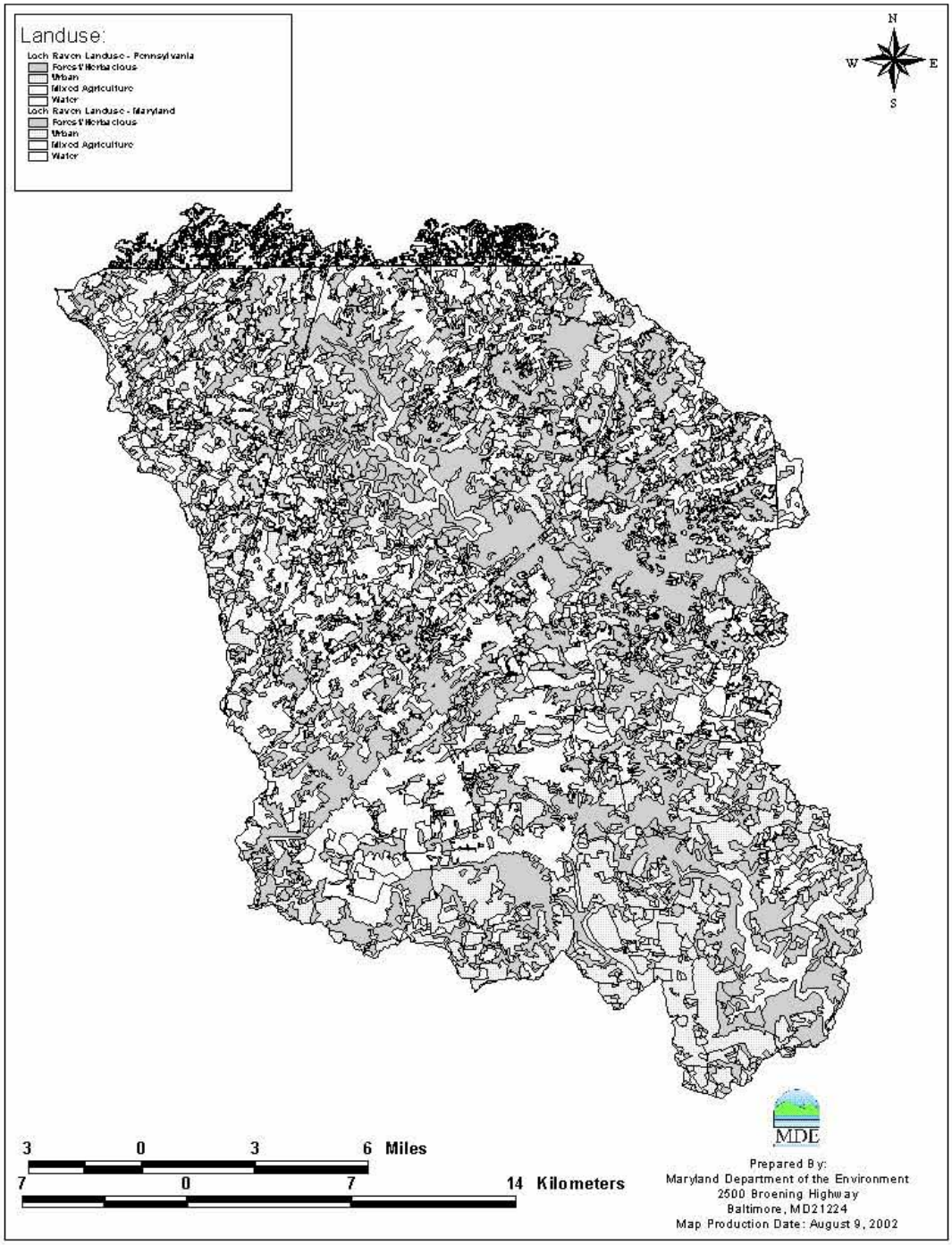

Figure 2: Predominant Land Use in the Loch Raven Reservoir Subwatershed

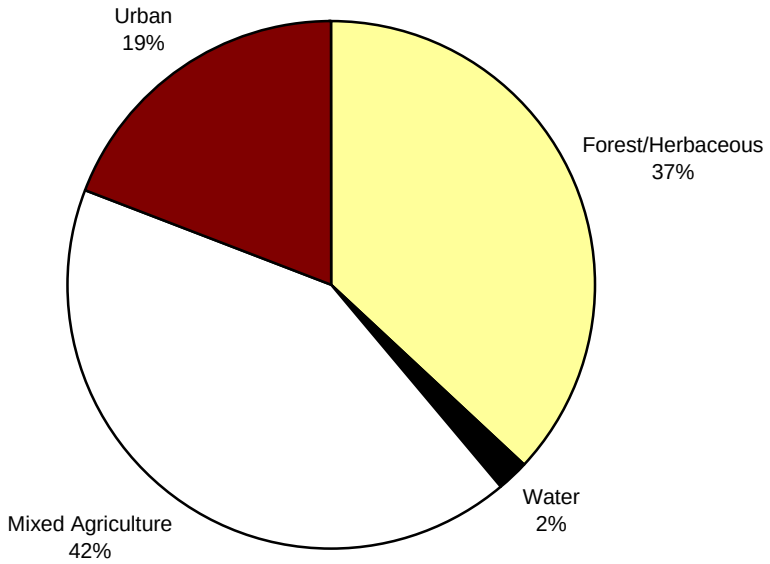

Figure 3: Land Use Distribution in the Loch Raven Reservoir Subwatershed

Loch Raven Reservoir is located in a watershed in which the mercury impairment is dominated by nonpoint source mercury contributions (via atmospheric deposition). The EPA considers coal-fired electric power generating plants to be the largest anthropogenic source of mercury emissions in the nation (EPA, 2000). Therefore an essentially one-to-one relationship between the Allowable Ambient Water Column Concentration (AAWCC) and atmospheric deposition of mercury is assumed.

The National Atmospheric Deposition Program – Mercury Deposition (NADP-MDN) was instituted in 1995 by federal, state, non-governmental research organizations and state agricultural experimental stations in order to monitor the amount of mercury deposited regionally in precipitation. Five sites of this network were used to estimate mercury air deposition rates in Maryland: Maryland (Wye), Delaware (Lewes), and Pennsylvania (Valley Forge, Arendtsville, Holbrook). Data obtained from this network was analyzed to estimate annual deposition rates (Appendix A). Estimates of current loads are included in Section 4.3.3.

In Maryland, the major sources of mercury air emissions are as follows: 43% attributed to power plants, 31% municipal waste combustors, 19% medical waste incinerators, 6% Portland Cement plants, and 1% other (e.g., landfills, oil-fired power plants, other industries).[1]

[1]www.mde.state.md.us/programs/landprograms/hazardous_waste/mercury/mercuryinfo.asp

US industrial demand for mercury dropped 75% from 1988 to 1997. This drop can be attributed to actions including:

- Federal bans on mercury additives in paint and pesticides;
- Industry efforts to reduce mercury in batteries;
- Increasing state regulation of mercury emissions and mercury in products;
- State-mandated recycling programs; and
- Voluntary actions by industry.[2]

The permitted point sources are summarized in Table 2. Although data exists to provide estimates of point source flows, mercury concentration data is not presently available to determine the mercury contributions from these dischargers[3]. To assess the potential influence of the point source contribution, relative to other sources, a sensitivity analysis was conducted. In the absence of observed mercury concentration data, literature values were considered for the analysis as presently described.

For the purpose of estimating potential loads from the point sources in Table 2, Lafarge/Imerys Quarry was addressed separately. The Lafarge Quarry functions like a reservoir that must be drained regularly. In the absence of other mercury concentration data, it was assumed that the concentration of mercury from the Lafarge Quarry would be similar to that of the current concentration in Loch Raven Reservoir (4.77 ng/l). An average flow of 3.0 mgd was used for Lafarge in the sensitivity analysis to determine the potential point source contribution.

Of the other point sources, the Hampstead WWTP makes up the vast majority of the flow. Additionally, by the nature of their operations, there is no reasonable potential that the small industrial sources are significant contributors of mercury. With these considerations in mind, the remaining discharges were assumed to have concentrations similar to municipal WWTPs.

To determine a potential concentration for these remaining point sources, data from the state of Maine was used. In Maine, 75 municipal WWTPs were analyzed using Mercury Method 1631, which has a detection level of 0.5 ng/l (Maine's information referenced by the State of Michigan, February 2000). The mean value of these samples was 11 ng/l. The maximum value was 59 ng/l (Waldoboro Sewer District). As a conservative assumption, a concentration of 60 ng/l was assumed for the remaining point sources.

Under the previous assumptions, in which the flow-weighted average concentration of mercury from all point sources was computed to be about 18 ng/l, the sensitivity analysis suggests that a high estimate of the current potential point source contribution would be

[2]Source: www.epa.gov/mercury/information.htm

[3] A program is under development to conduct periodic monitoring using a new analytical technique that will provide meaningful estimates of potential point source contributions. When this information becomes available, the future allocations developed in this analysis may be reallocated to point sources.

about 7% of the total load. If atmospheric mercury loads are reduced to achieve the allowable ambient water column concentration that is protective of fish tissue, the point source contribution would make up a greater proportion of the total load, which is estimated be about 12 %. Based on this analysis, a 14% future allocation has been set aside for potential use by point sources.

Table 2: NPDES Permit Holders in the Loch Raven Reservoir Subwatershed (02-13-08-05)

Permittee	NPDES Permit No.	County	Average Annual Flow (MGD)	Maximum Flow (MGD)
Hampstead WWTP	MD0022446	Carroll	0.539	0.9
Manchester WWTP*	MD0022578	Carroll	0.343	0.5
Exxon Service Station #2-5019	MDG916093	Baltimore	0.0009	None
Carroll Independent Fuel Company	MDG3444218	Baltimore	0.0001	None
Southern States Cooperative, Inc. – Cockeysville	MDG344461	Baltimore	0.000002	None
Gray & Son, Inc.	MD0063568	Baltimore	0.001	None
Lafarge/Imerys – Texas Quarry	MD0000175	Baltimore	3.0	None
Noxell Corporation - Baltimore	MD0002348	Baltimore	0.017	None
Teledyne Energy Systems	MD0065901	Baltimore	0.022	None

Flow Source: EPA's Permit Compliance System (PCS) Database
* Drains to Prettyboy Reservoir and is included in load from Prettyboy.

2.2 Water Quality Characterization

To characterize the water quality of Loch Raven Reservoir, two site-specific elements are addressed below: mercury residue in fish tissue data and mercury concentrations in the water column.

2.2.1 General Discussion

Trophic level 4 fish (Largemouth Bass) were harvested from Loch Raven Reservoir and were analyzed for mercury tissue concentrations. Water column samples were also taken and analyzed for mercury concentrations. A bioaccumulation factor was developed based on the above samples (see section 4.3.1 for details of the calculation). Samples were collected by the Maryland Department of Natural Resources (DNR) and the University of Maryland Center for Environmental Science, Chesapeake Biological Laboratory (UMCES) and were analyzed by UMCES.

In fish tissue, mercury is not usually found in concentrations high enough to cause fish to exhibit signs of toxicity, but the mercury in sport fish (trophic level 4) can present a potential health risk to humans. The health risk to humans represented by the mercury content in consumed fish tissue is due to methylmercury. Typically, almost all of the mercury found in fish tissue (90 to 95%) is in the methylmercury form. Mercury chemistry in the environment is complex and not totally understood. Mercury has the properties of a metal, specifically, persistence in the environment because it is not chemically broken down beyond the elemental mercury form (Hg^0) or its ionic forms

(Hg^{+} and Hg^{+2}). It also has properties similar to a hydrophobic organic chemical due to its ability to be methlyated through a bacterial process. Methylation of mercury can occur in water, sediment, and soil solution under anerobic conditions and, to a lesser extent, under aerobic conditions. In water, methylation occurs mainly at the water-sediment interface and at the oxic-anoxic boundary within the water column. Methylmercury is readily taken up by organisms and will bioaccumulate as it has a strong affinity for muscle tissue. It is effectively transferred through the food web, with tissue concentrations magnifying at each trophic level. This process can result in high levels of mercury in organisms high on the food chain, despite nearly immeasurable quantities of mercury/methylmercury concentrations in the water column.

For public health purposes, the MDE has the responsibility to monitor and evaluate the contaminant levels in Maryland fish, shellfish and crabs, and to determine if contaminant levels are within the limits established as safe for human consumption. In fulfillment of this public health responsibility, MDE has issued a statewide fish consumption advisory for mercury in fish. This advisory provides guidelines (Table 3) on fish consumption (allowable meals per month) for recreational anglers and their families (not including commercially harvested fish) and includes fish species in publicly accessible lakes and impoundments.

Table 3: Maryland Department of the Environment Fish Consumption Guidelines

Total mercury in Fish Tissue Range (μg/kg)	Fish Consumption: Maximum Recommended Meals per Month (based on an 8 oz. meal size)
117 – 235	7 - 4
236 - 322	3
322 – 409	2
410 – 939	1
> 939	< 1

These guidelines were developed, in part, to be protective for neurobehavioral effects during human fetal development and early childhood. An 8 ounce meal size is recommended for the general population. Recommended meal sizes for women of childbearing age and children (0-6 years) are 6 ounces and 3 ounces respectively. Thus levels of mercury in fish tissue above 235 μg/kg are an indication of impairment. When data for mercury concentrations in fish tissue is not available, data for methylmercury concentrations is used alternately for impairment decisions.

2.2.2 Mercury in Fish Tissue Data

Samples of fish were taken from Loch Raven Reservoir. Trophic level 4 fish (largemouth bass) were targeted in the collection because they represent the top of the bioaccumulation food chain and provide a conservative estimate of the mercury dose associated with fish consumption from this reservoir. The fish fillets obtained during the

sampling effort were analyzed for mercury concentrations and were measured for length and weighed. Appendix G lists the individual fish data.

Table 4: Summary of Mercury in Fish Tissue Concentrations from Loch Raven Reservoir

Trophic Level	Sample Count	Geometric Mean Methylmercury Concentration (μg/kg)
4	16	272.8

2.2.3 Water Column Mercury Concentrations

Water column samples were taken from Loch Raven Reservoir and were analyzed for total mercury and methylmercury concentrations using EPA Method 1631. Samples were analyzed for both constituents in both whole water and as dissolved (filtered).
The geometric mean value of total mercury in the water column is 4.95 ng/L. The geometric mean value of dissolved total mercury in the water column is 3.61 ng/L.
The geometric mean value of methylmercury in the water column is 0.170 ng/L. The geometric mean value of dissolved methylmercury in the water column is 0.155 ng/L.
Appendix G contains the individual data sets and a discussion of data reduction.

2.3 Water Quality Impairment

The Maryland water quality standards Surface Water Use Designation [Code of Maryland Regulations (COMAR) 26.08.02.07] for Loch Raven Reservoir is Use III-P designation – *Natural Trout Waters and Public Water Supply*. The water quality impairment of Loch Raven Reservoir being addressed by this TMDL analysis consists of a higher than acceptable level of mercury. Maryland water quality standards, under the federal CWA, require that water quality support public health and welfare for this designated use. An existing public health fish consumption advisory for Loch Raven Reservoir recommends significant limits on the consumption of fish from this impoundment. This is a violation of the State's narrative water quality standards, because the designated use of "fishing" is not fully supported. This loss of use results in Loch Raven Reservoir's identification on Maryland's 2002 303(d) list as impaired for mercury residue in fish tissue. Mercury concentrations in the water are well below the threshold for concern in regard to drinking water.

3.0 TARGETED WATER QUALITY GOAL

The objective of the TMDL established in this document is to reduce mercury loads to levels that are expected to result in meeting water quality criteria that support the Use III-P designation – *Natural Trout Waters and Public Water Supply*. See COMAR

26.08.02.02 B (1). Specifically, limiting the mercury loads is intended to ensure that concentrations in fish tissue are consistent with the protection of human health.

- MDE considers the term "suitable……. for fishing" (see COMAR 26.08.02.02 B (1) (c)) or "fishable" as the ability for the general population to eat at least 4 meals per month of any single common recreational fish species from the given waterbody. This upper threshold value for fish tissue is 235 μg/kg for methylmercury[4].

The fish tissue endpoint is designed to ensure that the general population can safely consume at least four meals per month. This is consistent with water quality standards, which must protect the overall population and do not have to be protective of more sensitive subpopulations. The risk assessment used by MDE to determine this concentration threshold incorporates the same risk level, Reference Dose and body weights and is consistent with the guidance adopted by the U.S. EPA for the protection of human health from methylmercury described in "Water Quality Criteria for the Protection of Human Health: Methylmercury" (EPA-823-R-01-001).

4.0 TOTAL MAXIMUM DAILY LOADS AND ALLOCATIONS

4.1 Overview

This section describes how the mercury TMDL and loading allocations were developed for Loch Raven Reservoir. The second subsection describes the analysis framework for developing the AAWCC and the TMDL calculation. The third subsection describes the steps in the TMDL calculation and the fourth subsection describes the TMDL allocations. This includes discussion of the relationship with the Prettyboy Reservoir TMDL. The fifth subsection addresses seasonal variations and critical conditions, and the sixth subsection explains the rational for the margin of safety (MOS). Finally, in the seventh subsection, the pieces of the equation are combined in a summary accounting of the TMDL.

4.2 Analysis Framework

The computational framework used for this TMDL calculation is a refinement of the methodology described in *" Total Maximum Daily Load for Total Mercury in Fish Tissue Residue in Big Haynes Reservoir,"* which was developed and proposed by the EPA, Region 4 for the State of Georgia, dated August 30, 2001. Maryland has refined the method by using a fish tissue threshold for mercury that is consistent with its fish consumption guidelines and more stringent than the EPA guidelines applied in Georgia. In addition, Maryland has estimated loads from air deposition and watershed sources

[4] To determine if a waterbody is impaired, the contaminant concentration from a sample of fish fillets of any single common species of recreational fish is compared to the established threshold. Generally, the geometric mean of 10 trophic level 4 fish make up the sample. If the threshold is exceeded, the waterbody's use is not met and the waterbody is considered impaired.

using mass balance calculations. Finally, the methodology was refined to address two reservoirs in series.

The TMDL analysis sets a maximum allowable ambient water column concentration (AAWCC), which ensures that bioaccumulation of the mercury concentration in fish tissue will remain below the threshold stated in Section 3.0. The AAWCC is computed using bioaccumulation factors based on site-specific fish tissue mercury concentration data and water column mercury concentration data. The TMDL is expressed in terms of an average annual load into the waterbody, which is computed from direct waterbody deposition and a watershed contribution. A future allocation of 14% is set aside, which may be used in the future if additional information indicates it is necessary to provide an explicit allocation to point sources.

The TMDL analysis framework can be summarized in the following steps:

(1) Determine the Biological Accumulation Factor (BAF) based on observed fish tissue data and observed water column concentrations.
(2) Using the BAF, calculate a maximum AAWCC that will ensure the targeted water quality goal of a mean fish tissue concentration of methylmercury remains below 235 μg/kg.
(3) Using a mass balance approach, estimate the TMDL that will result in the desired water quality target. This target consists of the AAWCC that is adjusted to account for particulate mercury, because the AAWCC is solely the dissolved component. (See Appendix H).
(4) This TMDL is coupled to the Prettyboy Reservoir TMDL so that both are consistent with each other. (Prettyboy Reservoir drains to Loch Raven Reservoir).

4.3 Total Maximum Daily Load Analysis

This section expands upon the three steps outlined immediately above.

4.3.1 Bioaccumulation Factor

A BAF is the ratio of the concentration of a chemical in fish tissue to the concentration of the chemical in the water column. As defined in Mercury Study Report to Congress (EPA 1997), the BAF is “The concentration of the methylmercury in fish divided by the concentration of total dissolved methylmercury in water.” When computing a BAF, MDE considered one of the three methods utilized in the Mercury Study report to Congress. Specifically this entails the direct estimation of BAF for trophic level 4 fish from site-specific criteria. The BAF calculated for this analysis is site specific, because it uses data from Loch Raven Reservoir. More details are given in the U.S. EPA technical support document for BAFs (EPA-820-B-95-005, March 1995). Also see, the EPA Science Advisory Board report, EPA-SAB-EPED/DWC-93-005, December 1992.

A food chain can be described in terms of trophic levels, in which higher levels represent species that are higher on the food chain.

$BAF = \{TL_4Fc_{(MeHg)} / Wc_{(MeHg)}\}$

Where:
(MeHg) means the particular concentration is for methylmercury
TL_4Fc = Trophic level 4 fish tissue concentration (μg/kg), from Table 4
Wc = Water column concentration (μg/L); from Appendix G, Table G5

The BAF calculation for Loch Raven Reservoir is expressed as:

BAF = 272.8 μg/kg /0.000155μg/L

BAF = 1,760,000 L/kg

4.3.2 Maximum Allowable Ambient Water Column Concentration

The maximum AAWCC is the concentration in the water that ensures that bioaccumulation will not exceed a fish tissue concentration that serves as the water quality endpoint. The water quality endpoint, stated in Section 3.0 is an average total mercury fish tissue concentration of 235 μg/kg for any trophic level.

The AAWCC uses the following equation from EPA guidelines (EPA, 2000):

$$AAWCC = \frac{\{(RfD-RSC)*BW*\text{Conversion Units}\}}{(CR*\ BAF*\text{Fraction MeHg})}$$

Where:

RfD = 0.1 μg/kg/day MeHg	Combined consumption rate: fresh + saltwater fish.
RSC = 0.027 μg/kg/day MeHg	Relative Source contribution (saltwater fish). This value is subtracted because the system under study is fresh water.
BW = 70 kg	Body weight (average of males and females).
CR = 29.8 g/day	Consumption rate (4 meal/month) based on MD fish consumption advisory risk analysis.
BAF= (L/kg)	Bioaccumulation Factor (site specific). See Section 4.3.1.

Fraction MeHg — Ratio of methylmercury to total mercury in the water column Appendix G.

Conversion units = 1,000,000 (ug/g) To convert the AAWCC to units of ng/L

Therefore:

$$AAWCC = \frac{(0.1-0.027) * 70 * 1{,}000{,}000}{29.8 * 1{,}760{,}000 * (0.155/3.61)}$$

AAWCC = 2.27 ng/L Dissolved Total Mercury

The fraction of methylmercury was calculated using the geometric mean values for dissolved concentrations for total mercury and methylmercury values (Table G3, and Table G5). Because the AAWCC accounts only for the dissolved component of the total mercury concentration, it is necessary to estimate the particulate mercury component expected to be present under conditions of a TMDL. To this end, a total mercury component, which is used in the load calculation for the TMDL, is computed in Appendix H.

4.3.3 Total Maximum Daily Load Calculation

The key finding in this overall analysis is the AAWCC, which is the water column concentration below which fish tissue concentrations will be protected to support human consumption. This section presents a computation of the estimated average annual load that corresponds to achieving the AAWCC. This annual load constitutes the TMDL.

The computation used to estimate the average annual load is a straightforward mass balance calculation. The computational procedure assumes a constant direct atmospheric deposition of mercury to the surface of the lake, and a constant loading from the watershed that feeds the lake. The contribution from the watershed is a combination of atmospheric loads that wash off the landscape and any other terrestrial sources. In this case, the contribution from Prettyboy Reservoir was also taken into consideration. A Future Allocation is set aside for future use in the event future data indicates an explicit allocation is necessary for point sources.

Briefly, the calculation involves an estimation of current loads that are necessary to produce the observed water column concentration. This is done using mass balance calculations. After the current loads are determined, reductions are calculated by using a load reduction factor. These steps are described in more detail below with values that apply to Loch Raven Reservoir.

<u>Current Load</u>: The calculation of the current total mercury load is performed in Appendix I. The current load includes the effect of direct atmospheric deposition to the surface of the reservoir and the nonpoint sources from the watershed, which includes

atmospheric mercury that is deposited to the surface of the land and is passed through the watershed.

Based on the mass balance estimates, which assumes steady state conditions, the current loads are summarized as follows:

Load from direct Air Deposition to the reservoir =	0.3759 g/day	(10.61 %)
Load from NPS from the Surrounding Watershed* =	1.9581 g/day	(55.24 %)
Load from Prettyboy Reservoir =	0.9672 g/day	(27.29 %)
Point Sources** =	0.2431 g/day	(6.86 %)
Current Daily Load =	3.5443 g/day	(100 %)

* Much of this is from atmospheric deposition to the land.
** The point source value is not based on observed data. Rather, it is the load that would occur assuming effluent concentrations discussed in Section 2.1.

Maximum Allowable Load: The maximum allowable load is calculated by adjusting the estimated current direct atmospheric load and watershed load downward until the target concentration is achieved (Appendix I). The target concentration is the adjusted AAWCC, which accounts for the particulate mercury (See Appendix H). Once the TMDL is determined, a Future Allocation is determined by adjusting the atmospheric and watershed contributions downward maintaining their relative proportions. The Future Allocation is determined on the basis for potential need for future point source allocations.

The results of the TMDL computation are summarized as follows:

Load from direct Air Deposition to the reservoir =	0.1643 g/day	(7.11 %)
Load from NPS from the Surrounding Watershed* =	0.8559 g/day	(37.04 %)
Load from Prettyboy Reservoir =	0.9672 g/day	(41.85 %)
Future Allocation =	0.3235 g/day	(14.00 %)
Total Maximum Daily Load =	2.3109 g/day	(100 %)

* Much of this is from atmospheric deposition to the land.

4.4 Total Maximum Daily Load Allocations

In a TMDL assessment, the total allowable load is divided and allocated to the various pollutant sources. The allocations described in this section demonstrate how the subject TMDL can be implemented to achieve water quality standards in Loch Raven Reservoir. Specifically, these allocations show that the sum of mercury loadings to the Loch Raven Reservoir from existing nonpoint sources can be maintained safely within the TMDLs established here.

The CWA and EPA regulations provide for flexibility in implementation of TMDLs, as long as the overall load is not exceeded. The allocations are generally classified as waste

load allocation (WLA) for point sources, load allocation (LA) for nonpoint sources, and a future allocation (FA). As future information becomes available, MDE expressly reserves the right to allocate this TMDL among different sources and land use categories in any manner that is reasonably calculated to achieve water quality standards. In particular, the future allocation of 14 % may be used in the future if additional information indicates that it is necessary to provide an explicit allocation to point sources.

4.5 Seasonal Variations and Critical Conditions

Seasonal Variations: This TMDL is effectively represented as an AAWCC level that is designed to reduce mercury concentrations in fish, thus protecting human health by minimizing exposure through fish consumption. The analysis is based on long-term averages. Although many factors might vary over a given year, the effect is averaged out over several years during which fish accumulate mercury. An analysis of the length and weight of individual fish used in the BAF calculation (Table G1) indicates they were of legal (keepable) size and the average age was approximately five years (DNR, 2000). The averaging effect of long-term bioaccumulation is reflected in the analysis and supports the use of an average annual AAWCC and average annual load. Specifically, the fish tissue concentration at the time of sampling is the result of long-term accumulation in fish that are several years old. The bioaccumulation factor is, in turn, computed on the basis of this long-term accumulation. An AAWCC is then calculated based on the relationship between the BAF, water column mercury concentration ratios and risk parameters related to fish consumption. Finally, the average annual loading values for the waterbody are calculated to meet the AAWCC.

Critical Conditions: Critical conditions concerns do not arise in this analysis because acute conditions are not a concern at the observed concentrations and the allowable concentrations of mercury are based on human fish consumption over a long time period, which averages out critical events. Also, the TMDL is protective of human health from fish consumption at all times, so that any “critical conditions” within that time frame are considered. Finally, the TMDL level established to be protective of human health is more conservative than the mercury levels to protect environmental resources, implying that critical conditions for environmental resources are also addressed by the previous logic that is applied to human health.

The annual average load is of primary significance because mercury bioaccumulation and the resulting risk to human health that results from mercury consumption is a long-term phenomenon. Therefore shorter seasonal inputs are less meaningful than total annual loads over many years. The use of annual loads allows for integration of short-term or seasonal variability.

The reader should also note that, although this analysis presents a loading limit, the fish tissue concentration depends on mercury water column concentration, not on load. Thus, annual loads are not highly relevant; that is, if a fish is exposed to the same concentration of mercury, but more water or less water of the same concentration passes through the reservoir due to seasonal differences in rainfall, the fish tissue accumulation will be the

same. This understanding is important when interpreting future information to evaluate the success of implementing controls to achieve the TMDL.

4.6 Margin of Safety

A margin of safety (MOS) is required as part of a TMDL in recognition of the fact that there are many uncertainties in scientific and technical understanding of water quality in natural systems. Specifically, knowledge is incomplete regarding the exact nature and magnitude of pollutant loads from sources and the specific impacts of those pollutants on the chemical and biological quality of complex, natural water bodies. The MOS is intended to account for such uncertainties in a manner that is conservative from the standpoint of environmental and human health protection.

Based on EPA guidance, the MOS can be achieved through one of two approaches (EPA, April 1991). One approach is to reserve a portion of the loading capacity as a separate term in the TMDL (i.e., TMDL = WLA + LA + FA+ MOS). The second approach is to incorporate the MOS as conservative assumptions in the design analysis. For purposes of this mercury TMDL methodology, Maryland has adopted margins of safety that make use of conservative assumptions, that is, a built-in MOS.

(1) When computing the bioaccumulation factor (BAF), it is assumed that anglers consume only trophic level four fish, which results in a larger BAF. Trophic level four fish are near the top of the food chain, and thus have the highest observable fish tissue concentrations due to bioaccumulation. Adopting the assumption that people eat only trophic level four fish represents a conservative assumption of exposure. This larger BAF is used in the denominator of the formula for computing the allowable ambient water column concentration (AAWCC), which makes the AAWCC tighter (a lower allowable water column concentration).

(2) EPA's recommended threshold for mercury in fish tissue is for 300 μg/kg, but MDE is using a value of 235 μg/kg. This lower threshold is based on a risk analysis used for Maryland's fish consumption procedures. The analysis assumes that some people consume more meals of fish over a given period of time than is assumed by EPA.

(3) The AAWCC formula includes the computation of the maximum allowable mercury in fish tissue, based on human health risk principles. Subtracting the relative source contribution (RSC), associated with mercury contribution to a typical diet due to marine fish, has the effect of allowing a maximum fish tissue concentration of about 172 μg/kg, rather than 235 μg/kg. This is a conservative assumption.

Items (2) and (3) immediately above result in a combined MOS of about 43%. The loss of mercury from the waterbody through reduction and volatilization is not accounted for

in the analysis. Therefore, credit for this phenomenon is taken as an additional margin of safety.

4.7 Summary of Total Maximum Daily Loads

The annual TMDL for mercury is calculated from the equation:

TMDL = WLA + LA + FA + MOS

Where: WLA = Waste Load Allocation
LA = Load Allocation
FA = Future Allocation
MOS = Margin of Safety

The TMDL for mercury (g/yr) is presented below in Table 5.

Table 5: Summary of Mercury TMDL for Loch Raven Reservoir

TMDL (g/yr)	Waste Load Allocation[a] (g/yr)	Load Allocation (g/yr)	Future Allocation (g/yr)	Margin of Safety
843.5	0.0	725.4	118.1	Implicit (Approximately 43%)

a. The future allocation may be used for point sources if warranted by future information.

On average, the TMDL will result in loads of approximately 2.3109 g/day.

The current total mercury load to Loch Raven Reservoir is the sum of the future allocation and NPS loads. MDE reserves the right to update the TMDL calculation and the TMDL source allocations as additional information from currently active or future programs becomes available and is analyzed.

5.0 ASSURANCE OF IMPLEMENTATION

Loch Raven Reservoir is located in a watershed in which the mercury impairment is dominated by nonpoint source mercury contributions (resulting from atmospheric deposition). The EPA considers coal-fired electric power generating plants to be the largest anthropogenic source of mercury emissions in the nation. As such, the TMDL implementation provisions may differ from the implementation of TMDLs from other pollutants (nutrients and toxics - other than mercury). EPA Region 4 and EPA Region 6 have indicated that reductions in atmospheric contributions will be accomplished over time through existing and proposed Clean Air Act regulatory controls that will ensure significant reductions in mercury loading on a nationwide basis by reducing atmospheric emissions. However, they believe it is too early to estimate the reductions in mercury emissions that may result from the future regulation of electric power generating utilities.

The EPA expects to see reduced emissions of mercury from this industry sector as a number of regulations are implemented to control sulfur dioxide emissions and nitrous oxide emissions, since some control technologies used to limit these pollutants collaterally reduce mercury emissions to some degree. .

EPA has taken a number of actions to reduce mercury pollution, including regulations for industries that contribute significantly to mercury pollution. These actions, once fully implemented, are expected to reduce nationwide mercury emissions caused by human activities by about 50% over 1990 levels. Examples include:

- Municipal waste combustors. EPA issued final regulations on October 31, 1995. These regulations were expected (by 2000) to reduce mercury emissions from these facilities by about 90%, from 1990 levels;
- Medical waste incinerators. EPA issued emission standards on August 15, 1997. These were expected (by 2002) to reduce mercury emissions from these facilities by about 94%, from 1990 levels.[5]

In addition to controls on mercury air emissions, proper management of mercury containing productions and source reduction are critical components to reducing mercury in the waste stream and to the environment. To this end, the following activities are examples of actions taken within Maryland:

- About 11 counties in Maryland have instituted household hazardous waste collection programs, where wastes including mercury containing products can be collected for safe management and disposal;
- Effective October 1, 2002, there is a prohibition on the sale and distribution of mercury fever thermometers in Maryland except by prescription (with certain exceptions, such as hospitals;
- Effective October 1, 2003, primary and secondary schools cannot use or purchase elemental or chemical mercury. MDE is required to provide outreach to schools on the management, recycle and disposal of mercury products.[6]
- Effective November 1, 2002, MDE will be implementing EPA's Universal Waste Rule which encourages the collection and recycling of wastes including mercury containing thermostats, lamps, and other products.
- Maryland is part of EPA Region 3's "e-cycling" project, which encourages the collection, refurbishment, and recycling of electronic devices. Four permanent sites in Maryland have been established for collection of computers, tv's, monitors, etc.
- Five sites in Maryland are partners and another MD company is a champion in the Hospitals for a Healthy Environment (H2E) program. Under this program, a Memorandum of Understanding was signed between USEPA and the American Hospital Association, calling for, among other things, virtual elimination of

[5]Source: www.epa.gov/mercury/information.htm

[6]Source: www.mde.state.md.us/assets/document/Retailers_Manu_web_version.pdf

mercury-containing hospital wastes by the year 2005. As of November 1, 2002, the program has 338 partners representing 1021 health care facilities.[7] The program's website, www.h2e-online.org/tools, provides additional tools to these facilities for waste management and pollution prevention.

As additional data and information are collected for the Loch Raven Reservoir watershed and as new legal requirements are imposed under the Clean Air Act and other environmental statutes, MDE will continue to evaluate the effectiveness of the regulatory and non-regulatory programs in achieving the water quality targets under this TMDL.

As part of Maryland's Watershed Cycling Strategy, follow-up monitoring and assessment will be conducted to evaluate the impairment status of Loch Raven Reservoir. For public health purposes, the MDE has the responsibility to monitor and evaluate the contaminant levels in Maryland fish, shellfish and crabs, and to determine if contaminant levels are within limits established as safe for human consumption. The currently issued fish consumption advisories are one result of the execution of this responsibility.

[7]Source: www.h2e-online.org

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U.S. EPA, Total Maximum Daily Load (TMDL) For Total Mercury in Fish Tissue Residue In Big Haynes Reservoir, EPA Region 4, Atlanta, Georgia, February 28, 2002.

U.S. EPA, “Water Quality Criterion for the Protection of Human Health: Methylmercury”, EPA-823-R-01-001, January 2001.

Appendix A

Mercury Air Deposition

Summary

Mercury air deposition data was utilized to quantify the contribution of nonpoint air sources to mercury loads in impaired water bodies. Air deposition data provided total annual loads of mercury to various water bodies.

Method

Five sites of the National Atmospheric Deposition Program – Mercury Deposition Network (NADP – MDN; http://nadp.sws.uiuc.edu/mdn/) were used to estimate mercury air deposition rates in Maryland: Maryland (Wye), Delaware (Lewes), and Pennsylvania (Valley Forge, Arendtsville, Holbrook). This network was instituted in 1995 by federal, state, non-governmental research organizations, and state agricultural experiment stations in order to monitor the amount of regional deposition of total mercury in precipitation. These sites spanned the western, northern, and central regions of Maryland (Figure A1). Data obtained from the network were converted to an annual basis (ug/m2-wk) and then plotted as a frequency histogram. Plots and estimates of kurtosis and skewness revealed non-normally distributed data. Geometric means were therefore calculated for each site. An average of the geometric means was then taken (8.43 ± 1.26 ug/m^2-yr) in order to estimate the statewide wet deposition of mercury (in precipitation) per year (Table A1).

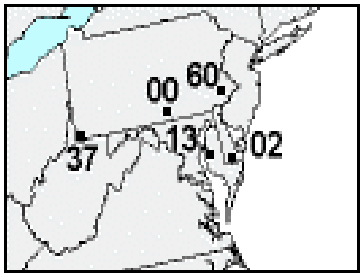

Figure A1: Mercury Deposition Network Monitoring Stations

Table A1: Wet Deposition of Total Mercury

Site	Location	Start Date	End Date	Geo Mean (ug/m2-yr)
DE02	Lewes, DE	03/14/95	10/08/96	7.71
MD13	Wye, MD	10/03/95	10/08/96	8.10
PA60	Valley Forge, PA	11/23/99	06/26/01	10.48
PA00	Arendtsville, PA	12/12/00	06/26/01	8.63
PA37	Holbrook, PA	06/22/99	11/21/00	7.21
			Average	8.43
			Stdev	1.26

Estimates for the amount of wet mercury deposition (8.43 ug/m^2-yr) were then applied to dry deposition estimates used in EPA-approved RELMAP air deposition analyses (http://www.epa.gov/region4/water/tmdl/georgia/index.htm). These analyses calculated the amount of mercury that is deposited from wet and dry sources in the United States using measured amounts of wet deposition and estimated proportions of dry deposition (RELMAP estimates; EPA, 1997).

Particulate, reactive gas (RGM; Hg^{2+}), and elemental (Hg0) mercury were considered for final depositional estimates in Maryland. Distinction was not made between locally deposited mercury species (RGM; Hg^{2+}) and those that deposit farther from source emitters (particulate and Hg^0), since all forms of mercury are ultimately incorporated into the food web. Final calculations determined that approximately 14.12 ug/m^2-yr of mercury is deposited in Loch Raven Reservoir (Table A2).

Table A2: Measured, Estimated, and Total Mercury Deposition

Total Wet Deposition in MD (ug/m^2-yr)[8]	RELMAP wet deposition	µg/m^2/yr[9]	Hg Species Ratios (EPA, 1997)[10]	Wet Deposition Total (ug/m^2/yr)[11]
8.43	Hg^{2+} (RGM) from US	2.65	0.267	2.25
	Particulate Hg from US	1.96	0.197	1.66
	Hg^0 from US sources	0.18	0.018	0.15

RELMAP dry/wet deposition ratio	0.676[12]

Dry deposition (RELMAP estimate; µg/m^2-yr)[13]	RELMAP dry deposition	µg/m^2/yr[14]	Hg Species Ratios (EPA, 1997)[15]	Dry Deposition Total (µg/m^2-yr)[16]
5.27	Hg^2+ (RGM) from US	4.10	0.98	5.59
	Particulate Hg from US	0.08	0.02	0.11
	Total	4.18	1.00	5.70

Total Deposition of Reactive Gas Mercury (Hg^{2+}; RGM; µg/m^2-yr)	7.84
Total Deposition of Particulate Mercury (µg/m^2-yr)	1.77
Total Deposition of Elemental Mercury (µg/m^2-yr)	4.51
Total Deposition of Mercury (µg/m^2-yr)	14.12

The wet deposition numbers are taken from the indicated monitoring data. The RELMAP modeled deposition numbers are used to estimate the wet/dry ratio, which is then used to determine dry deposition and then total deposition (wet + dry). The

[8]Average geomean from Table A1.
[9] Data from RELMAP model.
[10] Individual species divided by total RELMAP
[11]= footnote 8 x footnote 10
[12] Data from RELMAP model.
[13]= footnote 8 x footnote 12
[14] Data from RELMAP model.
[15] Individual species divided by total RELMAP
[16]= footnote 13 x footnote 15

RELMAP estimates are from a national model, so extrapolating to a finer watershed is important, as there are differences in deposition rates within Maryland, which should be considered important. The calculated mercury deposition rate for Loch Raven Reservoir (14.12 ug/m^2-yr) was multiplied by waterbody area (Table A3) to generate annual mercury loadings directly deposited to the waterbody.

Table A3: Mercury Deposition Estimates for a Select Waterbody

Lake/Impoundment	Area (km^2)	Direct Mercury Deposition to Waterbody (kg/year)
Loch Raven Reservoir	9.7125	0.1371

Uncertainty in Mercury Air Deposition Estimates

Quantification of the deposition of mercury from the air relies on many factors that are not derived empirically or from Maryland data. Four of the five mercury deposition network sites used in the estimation of atmospheric mercury deposition were in states adjacent to Maryland (PA and DE). These sites may be influenced by site-specific conditions, and therefore may alter overall deposition means used in subsequent calculations. Extrapolation from wet deposition means relies on modeling factors and estimates proposed in Savannah River TMDLs (EPA, 2000). Specifically, they rely on older regional-scale LaGrangian model (Regional LaGrangian Model of Air Pollution; RELMAP) output that may not represent smaller scales (Maryland) accurately (EPA, 2001). The output is also based on 1996 mercury emissions estimates and mercury speciation patterns that have not been rigorously investigated. Alteration of speciation ratios would change total depositional estimates directly. Modeling estimates for wet and dry deposition were also not quantified specifically for Maryland areas. Consideration of Maryland RELMAP isopleth model data could change the wet: dry deposition ratio, and hence the overall estimates of total mercury deposition.

Estimates of watershed area for some water bodies (e.g. Potomac River impoundments) could also be revised to include adjacent state estimates (VA, WV, and DE) of watershed areas calculated from GIS information (as was done for other Maryland watersheds).

Derivation of the total load relies in part on accurate estimation of the waterbody volume. Waterbody volumes were obtained from an inventory of Maryland dams and impoundments (PPRP, 1999). These were defined as the "volume of water stored below the normal operating pool elevation, excluding any flood storage" and the "impounding capacity in acre-feet, obtained from plans, design computations, or estimated". Waterbody volume estimates, therefore, may not represent current conditions that have been changed because of subsequent impoundment infilling by sediment or dredging and channelization.

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PPRP (Power Plant Research Project). 1999. PPRP Inventory of Maryland Dams (CD v1.2). Maryland Department of Natural Resources. Annapolis, MD.

Appendix B

Addendum For Toxics Methodology – MD 2002 303(d) List: Designated Use Impairments Based on Fish Tissue.

Background:

Section 101(a)(2) of the CWA establishes as a national goal "water quality which provides for the protection and propagation of fish, shellfish, and wildlife, and recreation in and on the water, wherever attainable." These are commonly referred to as the "fishable/swimmable" goals of the Act. Section 303(c)(2)(A) requires water quality standards to protect the public health and welfare, enhance the quality of water, and serve the purposes of the Act (EPA 2000). EPA, along with the Department, has interpreted these regulations to mean that not only should waters of the State support thriving and diverse fish and shellfish populations, but when caught, may also be safely consumed. Some water bodies may have elevated levels of contaminants, especially in the sediment. Some of these contaminants (especially mercury and PCBs) tend to bioaccumulate to elevated levels in the tissues of game fish and “bottom-feeders” (largemouth bass and catfish, respectively). When tissue levels of a contaminant are sufficiently elevated to increase the risk of chronic health effects if the fish is consumed regularly, the State has the responsibility to issue a fish consumption advisory to protect public health. Fish consumption advisories are designed to protect the general population as well as sensitive populations (i.e. young children; women who are or may become pregnant). If consumption advisory is issued for a waterbody, its designated use may not be supported and that waterbody may be listed as impaired for the contaminant(s) responsible for the fish consumption advisory.

The Department of the Environment has defined “fishable” as the ability to eat AT LEAST 4 meals/month (general population level) for common recreational fish species from a given waterbody. The tissue level corresponding to this will be the upper threshold at the 4 meal/month level for a given contaminant. In addition to this, if the tissue concentration is within 5% of the threshold, the water body’s designated use will be considered impaired. The 5% “safety factor” accounts for the uncertainty and spatial/temporal variability in monitoring data and sampling regimes. This safety factor is designed to protect and maintain the “fishable” designated use status of a waterbody. To determine if a waterbody is impaired, the appropriate measure of central tendency (i.e. geometric mean) for a contaminant from the fillet samples of common recreational fish species will be compared to the established threshold. If the threshold is exceeded, the water body’s designated use is not met, and the waterbody is considered impaired.

Data Requirements:

The data required to list a waterbody as impaired are similar to the data requirements for the development of a fish consumption advisory. The same decision rules are used to test data adequacy, and spatial and temporal representation. Consumption advisories based on the minimum required samples that resulted in an impairment decision will be

re-sampled prior to TMDL development to insure that the advisory was not due to a localized condition, and that the impairment is still temporally relevant. The data requirements for listing a waterbody are:

a. The advisory is based on fish and shellfish tissue data. All available data will be used.
b. The data are collected from the specific waterbody in question.
c. A minimum of 5 fish from a given species (individual or composite analysis)for a given waterbody.
d. Species used to determine impairment should be representative of the waterbody; migratory and transient species may be used if they are the dominant recreational species, but should only be used in conjunction with resident species, especially in the case of tidal rivers of the Chesapeake Bay.
e. Contaminant thresholds used will reflect concentrations used to set consumption recommendations for the general population. The general population is defined as women beyond the years of childbirth (~45); and adult males.

In some instances, it may be inappropriate to consider certain fish and shellfish consumption advisories in making an impairment determination. For example, a State may have issued a statewide or regional warning, based on data from a subset of water bodies and species or a higher consumption value may have been used in determining the need for an advisory to protect a specific sensitive population compared to the value used in establishing water quality criteria for the protection of human health. In such instances, these types of advisories were not considered for making an impairment determination. This approach is consistent with EPA's current recommendations regarding impairment determinations using contaminant data from fish advisories.

Appendix C

Mercury Chemistry

Mercury is a Group IIB (Periodic Table) element, as are zinc and cadmium. Elemental metallic mercury exists as a high luster silver-colored liquid at room temperature. Selected physical properties are listed in Table C1. Among the varied industrial and consumer uses of mercury are electrical apparatus, such as fluorescent light tubes, and control instruments - including thermometers and barometers. It is also used in the manufacture of pharmaceuticals, antifouling paints, mercury fulminate, electrolytic cells and dental amalgams. Mercury is a constituent of a number of antiseptics such as *mercurochrome, merthiolate and mercressin.* Mercury and all its compounds are toxic. Mercury fulminate, $Hg(CNO)_2$, is used as a detonator for initiating the explosion of smokeless powder and various high explosives (TNT, dynamite). Mercury fulminate is very unstable and can be exploded by shock; its explosion causes the main explosive to be detonated. Mercury electrolytic cells are used in a manufacturing process for chlorine/ alkali production. Liquid mercury dissolves many metals, especially the softer ones such as copper, silver, gold and the alkali elements. The resulting alloys, which may be solids or liquids, are called amalgams. Dental amalgam is an alloy of mercury and silver.

Table C1: Physical Properties of Metallic Mercury

Atomic Number	80
Atomic Weight	200.59
Density	13.5 g/cm^3 @ 25^{0}C
Melting Point	-39^{0}C
Boiling Point	357^{0}C
Water Solubility (molarity)	3.0 x 10^{-7} (mol/L) @25^{0}C
Water Solubility (mass basis)	60 μg/L @ 25^{0}C

Source: Dean, 1992.

Mercury exists in three oxidation states: the metallic, uncharged state (Hg^0); the mercurous state (Hg^{+1}); and the mercuric state (Hg^{+2}). These states are separated by only a small oxidation potential, and the metal readily participates in redox chemical reactions. In particular, Hg^{+1} salts disproportionate under many conditions to yield the Hg^{+2} salt and metallic mercury. Reduction of both the mercurous and the mercuric salts normally yields the metal state (PPRP).

Mercury in natural waters may assume any of the three oxidation states. The predominate state is determined by the hydrogen ion concentration (described as pH) and the oxidation potential (Eh) of the water. Since chloride and sulfide complex Hg^{+1} and Hg^{+2} ions, concentrations of these compounds also affect the relative species distribution (Gilmour, 1971, Gilmour and Henry 1991; Shimomora 1989). Ammonium, carbonate, bicarbonate and phosphate concentrations do not affect speciation (PPRP).

In natural systems, pH is generally in the range of 5 to 8 and the Eh is typically less than 0.5 Volts. For these systems, HgS and metallic mercury are the most likely solids to be found in equilibrium with saturated solutions of mercury salts at moderate Cl^{-1} and S^{-2} concentrations. The predominate species in the corresponding solutions will be $Hg(OH)_2$ and $HgCl_2$ in well oxygenated waters and Hg metal in poorly oxygenated waters (Gavis and Ferguson 1972) In reducing sediments, HgS will predominate the solid phase (PPRP).

Methylated forms of mercury, CH_3HgCl and $(CH_3)_2Hg$, are formed in both aerobic and anaerobic sediments through the action of bacteria. Methylated mercury is thought to be thermodynamically unstable in water; quantities of organic mercury found in surface waters are probably preserved through reaction barriers that prevent degradation. Methylation does not occur in the presence of moderate to high sulfide concentrations which immobilize the Hg^{+2} ion (PPRP).

In fish tissue, mercury is not usually found in concentrations high enough to cause fish to exhibit signs of toxicity, but the mercury in sport fish (trophic level 4) can present a potential health risk to humans. The health risk to humans represented by the mercury content in consumed fish tissue is due the chemical, methylmercury. Typically, almost all of the mercury found in fish tissue (90 to 95%) is in the methylmercury form. Mercury chemistry in the environment is complex and not totally understood. Mercury has the properties of a metal, specifically, persistence in the environment because it is not chemically broken down beyond the elemental mercury form (Hg^0) or its ionic forms (Hg^+ and Hg^{+2}). It also has properties similar to a hydrophobic organic chemical due to its ability to be methlyated through a bacterial process. Methylation of mercury can occur in water, sediment and soil solution under anerobic conditions and to a lesser extent under aerobic conditions. In water, methylation occurs mainly at the water-sediment interface and at the oxic-anoxic boundary within the water column. Methylmercury is readily taken up by organisms and will bioaccumulate as it has a strong affinity for fish muscle tissue. It is effectively transferred through the food web, with tissue concentrations magnifying at each trophic level. This process can result in high levels of methylmercury in organisms high on the food chain, despite nearly immeasurable quantities of mercury/methylmercury concentrations in the water column.

References

Gavis, J. and J.F. Ferguson. 1972. The cycling of mercury throughout the environment. Water Research 6: 986 – 1008.

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S. Shimomora. 1989. Analytical behaviour and some physical properties of mercury. A Review. Anal. Sciences 5: 633 – 639.

Appendix D

Details of Mercury Source Assessment

Appendix D presents background information regarding potential sources of mercury.

Table D1: Industrial and Consumer Uses of Mercury

U. S. Mercury consumption (10^3 kg) by end-use (based on Neme 1991)				
Use	1980	1985	1987	1989
Chlorine and Caustic Soda	326	234	310	380
Paint	298	168	198	191
Other Chemical Manufacturing Uses	104	74	78	58
Wiring and Switches	106	96	130	140
Batteries	958	950	532	250
Lighting and Other Electrical Uses	40	40	46	30
Dental Equipment/Instruments	174	128	118	126
Miscellaneous	28	20	34	36
Total	2,034	1,710	1,446	1,211
Sources: U.S. Department of the Interior (1983,1990,1991)				

In Maryland, the major sources of mercury air emissions are as follows: 43% attributed to power plants, 31% municipal waste combustors, 19% medical waste incinerators, 6% Portland Cement plants, and 1% other (e.g., landfills, oil-fired power plants, other industries).[17]

US industrial demand for mercury dropped 75% from 1988 to 1997. This drop can be attributed to actions including:

- Federal bans on mercury additives in paint and pesticides;
- Industry efforts to reduce mercury in batteries;
- Increasing state regulation of mercury emissions and mercury in products;
- State-mandated recycling programs; and
- Voluntary actions by industry.[18]

[17] www.mde.state.md.us/programs/landprograms/hazardous_waste/mercury/mercuryinfo.asp

[18] Source: www.epa.gov/mercury/information.htm

Table D2: Incineration Facilities

Major Municipal Solid Waste Incineration Facilities in Maryland			
Facility	Location	Total Waste Burned (kg/year)	Air Pollution Control Equipment
Waste Energy Partners	Edgewood	215×10^{6}	ESP
Pulaski Highway	Baltimore	491×10^{6}	ESP
Baltimore Refuse Energy System Co. (BRESCO)	Baltimore	$1,281 \times 10^{6}$	ESP

Electrostatic precipitators (ESP), which are widely used to control fine particulate matter, are ineffective at capturing gaseous emissions, including mercury vapor. The most efficient mercury controls include multi-stage wet scrubbers, high efficiency ESPs in series with wet scrubbers, activated carbon filters and removal of the waste stream prior to incineration.

Table D3: Maryland Estimated Mercury Emissions from Coal-burning Power Plants

Plant	Parent Company	City	Estimated* Total Mercury Released 1998 (pounds)	Estimated** Mercury Air Pollution 1998 (pounds)
Brandon Shores	Baltimore Gas & Electric Co.	Baltimore, MD	604	489
Morgantown	Potomac Electric Power Co.	Newberg, MD	645	404
Chalk Point	Potomac Electric Power Co.	Aquasco, MD	549	302
Dickerson	Potomac Electric Power Co.	Dickerson, MD	483	290
H. A. Wagner	Baltimore Gas & Electric Co.	Baltimore, MD	221	149
C. P. Crane	Baltimore Gas & Electric Co.	Baltimore, MD	225	117
R. Paul Smith	Allegheny Power System, Inc.	Williamsport, MD	45	28
State Total			2,774	1,781

*Estimated mercury in coal is calculated using plant specific coal contamination and coal consumption data. Release includes disposal in ponds and landfills as well as reuse applications such as fertilizer.

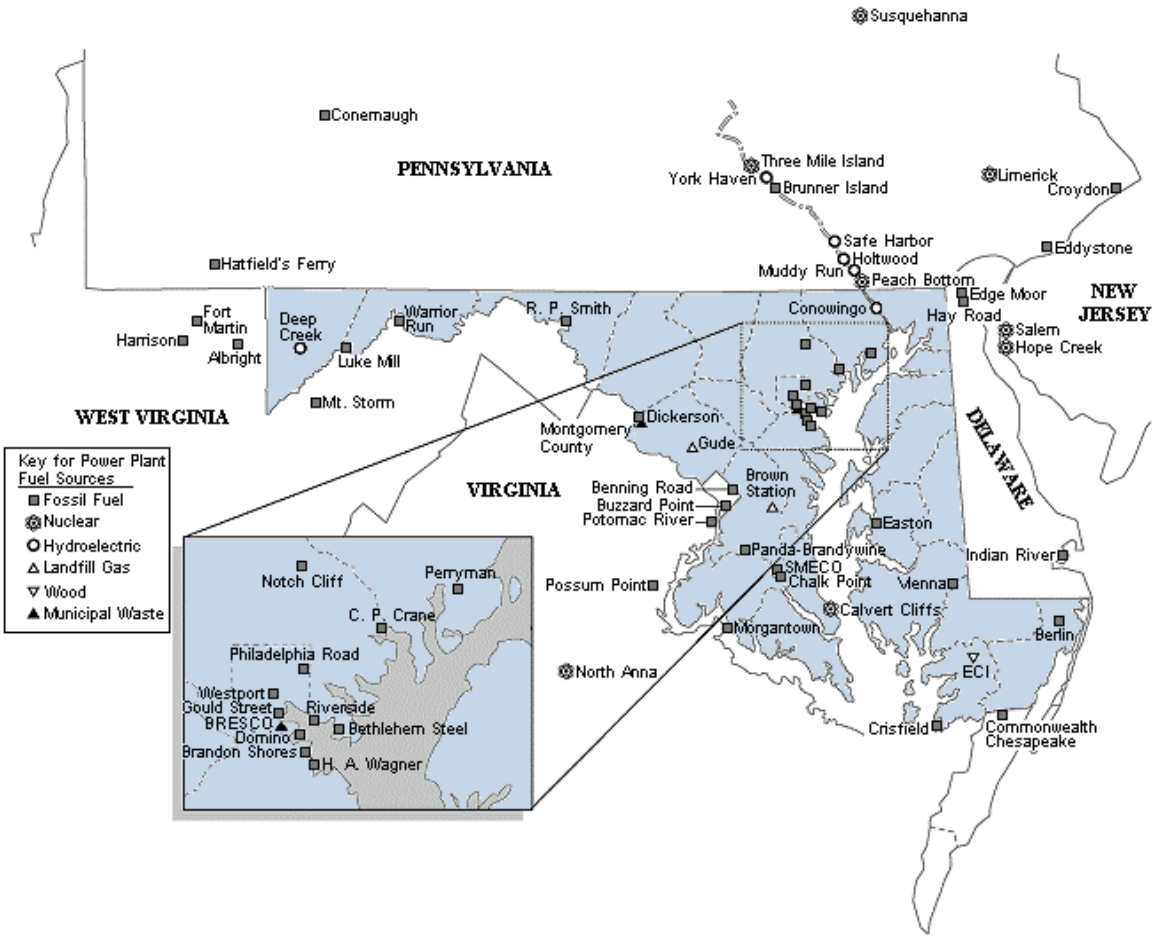


Figure D1: Power Plant Locations In and Around Maryland

** Total stack emissions are calculated by applying mercury released to plant specific modification factors.

Sources:
Environmental Working Group. Compiled from U. S. Department of Energy and U. S. Environmental Protection Agency databases. Plant ownership is attributed to the parent company of the plant as of January 1, 1999.

Source: Maryland Power Plant Research Program - Fact Book

Appendix E

Risk Assessment

Fish consumption advisory thresholds were determined by utilizing human health risk assessment procedures presented in EPA (1997) and modifications as in MDE (in prep, 2002). These advisories recommend that a certain number of meals per month of a particular fish species not be exceeded in order to avoid long-term health effects from exposure to methymercury.

Variables considered in the advisory risk assessment included: **meal frequency** (0, 1, 2, 4, 8, or unlimited meals per month), **meal size** (8 ounces for people 18-75 (GP) and women 18-45 (WOM) years of age, 3 ounces for children (CHD) 0-6 years of age), and **population weights** of 70 (GP), 64 (WOM), and 14.5 (CHD) kilograms. A **methylmercury reference dose** (RfD, 0.1ug/kg-day), based on neurological and developmental studies of infants chronically exposed to methylmercury through fish consumption, was also used in the risk analysis. These factors can be seen in Table E1

Table E1: Human Health Risk Assessment Parameters for MDE's Fish Consumption Advisories

RfD (ug/kg-day)	Body Weight (kg)	Meal Size (ounces/meal)	Fish Consumption Rate (kg/day)	Recommended Meal Frequency (meals/month)	Mercury Concentration in Fish Tissue (ppm)		
Men and Women 18 - 75 Years Old							
0.1	70	8	3.7	No Consumption		>	0.939
0.1	70	8	7.5	1	0.470	-	0.939
0.1	70	8	14.9	2	0.236	-	0.469
0.1	70	8	29.8	4	0.118	-	0.235
Women 18 - 45 Years Old							
0.1	64	8	3.7	No Consumption		>	0.858
0.1	64	8	7.5	1	0.430	-	0.858
0.1	64	8	14.9	2	0.216	-	0.429
0.1	64	8	29.8	4	0.108	-	0.215
Children 0 - 6 Years Old							
0.1	14.5	3	1.4	No Consumption		>	0.519
0.1	14.5	3	2.8	1	0.260	-	0.519
0.1	14.5	3	5.6	2	0.131	-	0.259
0.1	14.5	3	11.2	4	0.066	-	0.130

EPA. 2000. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories; Third Edition. Office of Science and Technology, Office of Water, U.S. Environmental Protection Agency, Washington, D.C.

Appendix F

UMCES Procedures

Sample Collection:

Clean double-bagged 2L Teflon bottles, partially filled with dilute trace metal grade HCl, were used for water collection. Prior to sampling, each bottle was emptied of the HCl downstream from the sampling location. Next, the bottle was rinsed three times with reservoir water and filled with water collected approximately 6 to 12 inches below the surface. After being filled with sample-water, the bottle was immediately recapped, double-bagged and stored in a cooler for transport back to the laboratory.

Sample filtration and storage:

Approximately 0.5 L of sample from each bottle was filtered through an acid cleaned AquaPrep 600 in line filter (0.45 um) into an acid washed and sample rinsed 500 ml Teflon bottle for dissolved Hg and MeHg. All equipment used for filtering was acid washed between samples and rinsed with Q-water. Both unfiltered and filtered water samples were spiked with Optima HCl acid (to 0.5%) and stored in a refrigerator until analysis for HgT and MeHg was performed.

<u>Total Mercury</u>
Based on U.S. EPA, *Method 1631, mercury in Water by Oxidation, Purge and Trap, and Cold Vapor Atomic Fluorescence Spectrometry*, October 2001.

<u>Methylmercury</u>
Bloom, NS (1992) Determination of picogram levels of methylmercury by aqueous phase ethylation, followed by cryogenic gas chromatography with cold vapor atomic fluorescence detection. Canadian Journal of Fisheries and Aquatic Sciences, vol 461131-1140; Bloom, NS.

<u>MeHg analysis</u>
Water samples were distilled with additions of a 50% sulfuric acid solution and a 20% potassium chloride solution (Horvat et al., 1993). The MeHg in the distillate was derivited with sodium tetraethylborate to convert it to volatile methyl-ethyl-mercury (Bloom, 1989). The volatile adduct was then purged from solution and collected onto a graphitic carbon trap. The MeHg was then thermally desorbed from the trap and analyzed by isothermal gas chromatography separation with CVAFS.

<u>Total Hg analysis</u>
BrCl was added to each sample at least 2 hours prior to analysis. Just prior to analysis, hydroxylamine hydrochloride was added to destroy any excess bromine in the sample. The samples were trapped by gold amalgamation after reduction with SnCl . The Hg

was then thermally desorbed from the trap and analyzed by CVAFS. (Mason et al., 1997; 1983; Bloom, 1989).

Chemical form of mercury in edible fish and marine invertebrates
Canadian Journal of Fisheries and Aquatic Sciences, vol. 49, 1010 – 1017.

Appendix G

Individual Sample Data and Analysis

This appendix presents all of the data for fish tissue samples and water column samples. The data reduction steps are also described.

Table G1: Individual fish sample data for mercury residue in fish tissue from Loch Raven Reservoir

Sample ID No.	Trophic Level	Species	Collection date	Methylmercury (µg/kg) wet weight	Length (mm)	Weight (gm)
LOR061201LMB1	4	Largemouth Bass	6/20/2001	461.5	378	647.0
LOR061201LMB2	4	Largemouth Bass	6/20/2001	162.3	369	758.0
LOR062001LMB3	4	Largemouth Bass	6/20/2001	462.0	386	789.2
LOR062001LMB4	4	Largemouth Bass	6/20/2001	497.6	420	911.0
LOR062001LMB5	4	Largemouth Bass	6/20/2001	145.8	347	559.1
LOR062001LMB6	4	Largemouth Bass	6/20/2001	241.1	305	382.2
LOR062001LMB7	4	Largemouth Bass	6/20/2001	258.4	307	375.0
LOR062001LMB8	4	Largemouth Bass	6/20/2001	164.5	320	463.3
LOR062001LMB9	4	Largemouth Bass	6/20/2001	172.1	312	399.9
LOR062002LMB10	4	Largemouth Bass	6/20/2001	210.2	308	387.0
LOR050602LMB1	4	Largemouth Bass	5/6/2002	290.4	390	703.8
LOR050602LMB2	4	Largemouth Bass	5/6/2002	61.7	396	691.4
LOR050602LMB3	4	Largemouth Bass	5/6/2002	595.2	420	1,004.9
LOR050602LMB4	4	Largemouth Bass	5/6/2002	430.6	431	1,040.0
LOR050602LMB5	4	Largemouth Bass	5/6/2002	267.7	455	1,198.3
LOR050602LMB6	4	Largemouth Bass	5/6/2002	824.4	455	1,185.3

An analysis of the length and weight of the fish used in the BAF calculation indicates that the fish were of legal (keepable) size and that the average age was approximately five Years (MDDNR, 2000).

It is recognized that there are not many samples of water column analyses, and that in some cases, the results from the same sample show a larger concentration for a dissolved concentration than a total concentration. Intuitively this does not seem reasonable. The analytical method used for these analyses (*U. S. EPA Method 1631*) has a minimum detection level of 0.5 ng/L. One nanogram per liter represents a detection level of one part per trillion. As all analytical methods have, *Method 1631* has an inherent +/- variability. All the data was subject to laboratory quality assurance/quality control procedures, (such as blanks, spiked samples, etc) prior to being released to MDE. However due to the sensitive nature of this test, a data reduction process was developed and employed.

Water Column Data Reduction Process

The TMDL analysis requires that we aggregate a number of samples into a single value that represents an estimate of the central tendency of the data. This data reduction process also must account for any data that we suspect is not valid.

Performing a laboratory analysis for trace elements is a very sensitive undertaking. The potential error in the measurements for mercury in the water column is about 15 % in either direction (over or under estimation). This implies that two samples that are within 30% of each other cannot be considered different.

The measurement of whole concentrations (dissolved plus particulate) is less subject to error than measurements of dissolved concentrations. This is because measuring whole concentrations does not require a filtration step, which can introduce error. In cases where the dissolved values are significantly greater than the whole sample (20% or more), it has been advised that the dissolved sample not be used due to the potential contamination during the filtration process (Mason, 2002, personal communications).

The data reduction process described below addresses pairs of water column samples of total mercury representing whole samples and dissolved samples. It is outlined in the form of decision rules to address all of the different cases that can be confronted.

For each pair of results from a given sample, whole and dissolved:

i. If the whole sample is more than 20% greater than the dissolved sample, keep both numbers as good, and interpret the difference as being the particulate fraction.

ii. If the whole sample and dissolved are within 20% of each other, compute the arithmetic mean of the two numbers. Use this average value to represent both whole and dissolved values in future calculations.

iii. If the dissolved number is more than 20% greater than the whole, discard the dissolved as being contaminated. Interpret the whole value as dissolved, and use this value to represent both whole and dissolved values in future calculations.

Table G2: Water Column Total Mercury Concentration Data from Loch Raven Reservoir

Sample Date	Sample Site	Total Mercury Concentration (Whole) ng/L	Total Mercury Concentration (Dissolved) ng/L	% Difference (whole-dissolved) / dissolved
4/30/2001	Downstream of Inflow	7.76	3.03	156
4/30/2001	Mid Reservoir	4.12	5.07	19
4/30/2001	Upstream of Outfall	3.39	8.81	62
	Geometric Mean Value	4.77	3.73	

Table G3 presents the reduced water column data for whole total mercury and dissolved total mercury. We check the percentage difference of each pair of samples presented in Table G2. For the Downstream sample the percentage difference is greater than 20 % (whole >dissolved) and thus the sample follows case i. For the Mid Reservoir sample the percentage difference is less than 20 % and thus the sample follows case iii. For the Upstream sample the percentage difference is greater than 20 % (whole < dissolved), thus the sample follows case ii. The results of the data reduction process are presented in Table G3. The value of 4.95 ng/L represents the expected whole water column concentration for total mercury. The value of 3.61 ng/L represents the expected water column concentration of dissolved mercury. The difference represents the expected particulate fraction.

Table G3: Data Reduction for Total Mercury Water Column Concentrations for Loch Raven Reservoir

Sample site	Total Mercury Concentration (Whole) ng/L	Total Mercury Concentration (Dissolved) ng/L
Downstream of inflow	7.76	3.02
Mid Reservoir	4.60	4.60
Upstream of Outfall	3.39	3.39
Geometric Mean Values	4.95	3.61

Table G4: Water Column Methylmercury Concentration Data from Loch Raven Reservoir

Sample Date	Sample Site	Methylmercury Concentration (Whole) ng/L	Methylmercury Concentration (Dissolved) ng/L	% Difference (whole-dissolved) / dissolved
4/30/2001	Downstream of Inflow	0.286	0.214	34
4/30/2001	Mid Reservoir	0.090	0.085	6
4/30/2001	Upstream of Outfall	0.209	0.182	15
	Geometric Mean Value	0.175	0.149	

Table G5 presents the reduced water column data for whole methylmercury and dissolved methylmercury. We check the percentage difference of each pair of samples in Table G3. For the Downstream sample the percentage difference is greater than 20 %, (whole > dissolved) so case i applies. For the Mid Reservoir sample the percentage difference is less than 20% and thus the sample follows case ii. For the upstream sample, the percentage difference is less than 20 %, so case ii applies again. The value of 0.170 ng/L represents the expected whole water column concentration for total mercury. The value of 0.155 ng/L represents the expected water column concentration of dissolved mercury. The difference represents the expected particulate fraction.

Table G5: Data Reduction for Dissolved Methylmercury Water Column Concentrations for Loch Raven Reservoir

Sample site	Methylmercury Concentration (Whole) ng/L	Methylmercury Concentration (Dissolved) ng/L
Downstream of inflow	0.286	0.214
Mid Reservoir	0.088	0.088
Upstream of Outfall	0.196	0.196
Geomean Values	0.170	0.155

Appendix H

TMDL Target Concentration (AAWCC Value Adjustment)

The AAWCC initially calculated in Section 4.3.2 is just the dissolved part of the total mercury in the reservoir. However when we compute a total load to the reservoir we are assuming that that both dissolved and particulate components are included in the load. That is, when we when we compute the TMDL via a mass balance calculation, we need the calculation target to be a whole value (dissolved + particulate). The dissolved component is the AAWCC; the particulate part is determined by the ratio of the dissolved and particulate that was observed for the existing data. Implied in this is the assumption that when the load is reduced, the ratio of dissolved to particulate total mercury remains constant. Therefore the formula for calculating the TMDL target concentration is expressed as:

$$\frac{\text{Observed whole total Hg value}}{\text{Observed dissolved total Hg value}} = \frac{X}{\text{AAWCC}}$$

Solving for X yields the TMDL target concentration:

$$\frac{4.95}{3.61} = \frac{X}{2.27}$$

$$X = 3.11 \text{ ng/L total mercury}$$

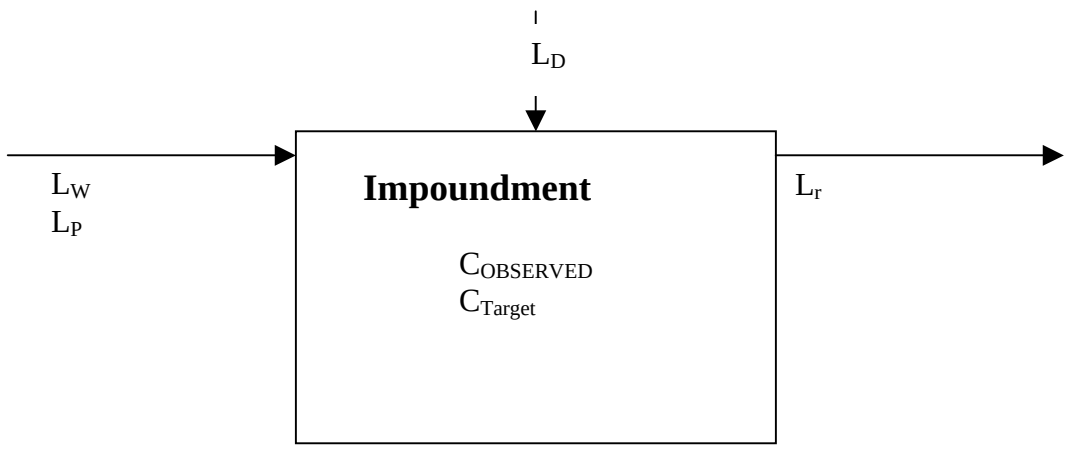
As explained, X – AAWCC equals the particulate fraction.

Appendix I

Steady State Mass Balance Calculations

This Appendix describes the mass balance calculations used to estimate the mercury loads into and out of the impoundment and is divided into four sections. The first section describes the mass balance equations. The second section describes parameters used, lists general definition of terms and identifies the location in the report to find data. The third and fourth sections show in detail the calculations for current loads and the total maximum daily loads, respectively.

Mass Balance Equations:



The assumptions for the Mercury TMDL calculation is that the system is in steady state and therefore the outflow load can be calculated from the impoundment discharge and a specified water column concentration. To calculate the current load, the observed water column concentration is used and to calculate the TMDL, the target water column concentration is used (see Appendix H for details on the target water column concentration). Therefore the following steady state mass balance equation can be used to determine current loads and future allocations.

$$\Sigma \text{ Load In} = \Sigma \text{ Load out}$$

The above equation can be further expanded to

$$L_P + L_D + L_W = L_r$$

It is important to note that if no point sources are present into the impoundment then L_P equals zero.

Definitions:

Point Source Information:

Parameter	Description	Source
Q_P	Point source flow into the impoundment	Table 2
C_P	Mercury concentration into the impoundment, attributed to point sources	Section 2.1
L_P	Mercury load into the impoundment, attributed to point source loads	Calculated
Q_{fp}	Future permitted maximum point source flow into the impoundment	Table 2
C_{fp}	Future permitted point source Mercury concentration into the impoundment (Same as C_P)**	Section 2.1
L_{fp}	Future mercury load into the impoundment, du to anticipated increased point source flows	Calculated
% Time Active	Percent of time point source is active during on year period.	Section 2.1

Reservoir Information:

Parameter	Description	Source
Qr	Average annual flow out of reservoir	Table 1
Cr	Observed reservoir water column total mercury concentration after data reduction	Appendix G
Lr	Current mercury load from reservoir	Calculated

Atmospheric Deposition:

Parameter	Description	Source
RSA	Reservoir surface area	Table 1
TDM	Total deposition of mercury	Appendix A
Ld	Mercury load due to direct atmospheric deposition to the impoundment	Calculated
Lda	Allowable mercury load due to direct atmospheric deposition to the impoundment	Calculated

* Point source contributions of mercury are currently unknown. All estimates are intentionally high to ensure that the future allocation developed in this TMDL is sufficient to address a future point source allocation if deemed appropriate.

** It is assumed that the concentration stays constant, although the point source flows may increase over time.

Definitions (Continued):

Watershed:

Parameter	Description	Source
Lw	Existing mercury load from the watershed to the impoundment	Calculated
Lwa	Allowable mercury load from the watershed to the impoundment	Calculated

TMDL Calculation:

Parameter	Description	Source
	Corrected Water Column Concentration Target	Appendix H
Fr	TMDL coefficient is the factor by which the atmospheric deposition and watershed loads mu be multiplied by to determine the allowable loa	Calculated
1-Fr	The percent reduction required from the atmospheric deposition and watershed loads.	Calculated
FA	The future allocation, which may be used to address point sources if warranted by future information	Calculated
LA	The load allocation is the sum of the atmospher deposition load and the watershed load after the TMDL reduction factor (Fr) is applied LA=Fr*(Ld+Lw)	Calculated

Location: Loch Raven

Point Source Contribution

Average Annual

%time active= 100%

Qp= 3.579 MGD *(3.785l/gal)*(1e6gal/1MGal)(%time)= 13,547,947 l/d

Note: Qp accounts for percent of time active

Cp= 17.9467 ng/l Flow-weighted average of Lafarge @ 4.77 ng/l and the remaining sources at 60 ng/l

Lp= 0.243141 g/day =Qp[l/d]*Cp[ng/l]*(1e-9g/ng)

Permit Maximum

%time active= 100%

Qfp= 3.94000 MGD *(3.785l/gal)*(1e6gal/1MGal)(%time)= 14,914,476 l/d

Note: Qp accounts for percent of time active

Cfp= 17.9467 ng/l

Lfp= 0.267666 g/day =Qp[l/d]*Cp[ng/l]*(1e-9g/ng)

Upstream Reservoir Information

Current

Qr= 2.9 m^3/s *(1000l/m^3)*(86400sec/1day)= 250,560,000 l/d

Cr= 3.86 ng/l

Lr= 0.9672 g/d =Qr[l/d]*Cr[ng/l]*(1e-9g/ng)

Future

Qr= 2.9 m^3/s *(1000l/m^3)*(86400sec/1day)= 250,560,000 l/d

Cr= 2.15 ng/l

Lr= 0.5387 g/d =Qr[l/d]*Cr[ng/l]*(1e-9g/ng)

Reservoir Information

Qr= 8.6 m^3/s *(1000l/m^3)*(86400sec/1day)= 743,040,000 l/d

Cr= 4.77 ng/l

Lr= 3.5443 g/d =Qr[l/d]*Cr[ng/l]*(1e-9g/ng)

Atmospheric Deposition

RSA= 9.7125 km^2 =Reservoir Surface Area

TDM= 14.127 ug/m^2/yr =Total Deposition of Mercury

Ld= 0.137208 kg/yr =RSA*TDM*((1000m/1km)^2)*(1g/1e6ug)*(1kg/1000g)

0.3759 g/d =Ld*(1000g/kg)*(1yr/365day)

Watershed

Lw=Lr-Ld-Lp

Lw= 1.9581 g/d

Summary-Current Daily Total Load

Lp=	0.243141	g/d	(6.86%)
Ld=	0.375914	g/d	(10.61%)
Lw=	1.958085	g/d	(55.25%)
Lpb=	0.967162	g/d	(27.29%)
Ld+Lw+Lp=	3.544301	g/d	(100.00%)

TMDL Calculation

Corrected Water Column Conc. Target= 3.11 ng/l

Reservoir Flow (Qr)= 743,040,000 l/d

TMDL=(Qr)[l/d]*(Ct)[ng/l]*[1e-9g/ng]= 2.3109 g/d Annual TMDL=2.3109g*365= 843.46 g/yr

Future Allocation

Future Point Source Contribution = 11.5830% =Lfp/TMDL Lfp= 0.267666 g/d

Total Future Allocation w/ ps~ 14.00% FA= 0.323520 g/d

Note: Total Future Allocation includes max permit point source Future Allocation=TMDL*(%contribution)

TMDL Reduction Factor

APPENDIX J:

Water Quality Management Plan for Loch Raven Watershed: Executive Summary and Stream Stability Assessment and Analysis

Water Quality Management Plan for Loch Raven Watershed

Final Plan

June, 1997

Submitted to:

Baltimore County

Dept. of Environmental Protection

and Resource Management

Submitted by:

Tetra Tech, Inc.

10306 Eaton Place, Suite 340

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Executive Summary

Introduction

This report presents a water quality and watershed management plan for the Loch Raven watershed study area in Baltimore County, Maryland. The Loch Raven watershed is a large and highly diverse watershed with many concerns typical of watersheds located in developing watersheds. The plan integrates stream assessment, modeling, spatial GIS information, and environmental data in an innovative fashion to develop a comprehensive and transferrable watershed management approach. To address the scale and complexity of the watershed, the management plan was developed at two levels. At the watershed-wide scale, the watershed is grouped into four management areas with similar characteristics. A set of ecologically based management actions, associated with each management area, are identified for ensuring the long-term integrity of the natural resources of the watershed (Figure ES-1). At the site-specific scale, a set of case studies representative of typical restoration needs are used to explore the procedures for identifying management needs in a more detailed fashion, including site-specific recommendations for stormwater management facilities or retrofits, and restoration of impacted streams. The plan prioritizes problems and management actions at both the management area and site-specific scales by integrating field indicators derived from assessments, water quality modeling, an evaluation of historical monitoring, soils, land use, and stormwater facility information. This comprehensive set of indicators collected during the field stream assessment process provide information valuable for supporting the prioritization and ranking steps. The final recommended management actions for each management area and case study site integrates structural stormwater and nonstructural management actions, and stream restoration in a comprehensive approach to restoration addressing both the short- and long-term impacts on the watershed.

The plan is designed to meet several distinct objectives of the Baltimore County Department of Environmental Protection and Resource Management (DEPRM). The first objective in the Loch Raven Watershed is to assist in the identification and evaluation of nonpoint source stormwater pollution and to provide a watershed restoration and management plan framework to be implemented through the Department's Capital Improvements Program as well as a variety of other programs. The water quality management plan will be used by the County in partial fulfillment of federal mandates under the National Pollutant Discharge Elimination System (NPDES) Municipal Stormwater Discharge Permit. In addition, the plan supports Baltimore County's Partnership Agreement with the State of Maryland in the Chesapeake Bay Program's Tributary Strategies for nutrient reduction.

The fundamental basis for evaluation of the watershed problems and identification of options is a clear set of goals for the watershed. The specific goals for the Loch Raven watershed, developed by Baltimore County DEPRM, are based on the historical and current watershed concerns, designated uses and water quality standards, ongoing programs such as the NPDES and Chesapeake Bay programs, and existing County programs and initiatives. The goals of the Loch Raven water quality management efforts include:

- Protection of the quality and quantity of the drinking water supplied by the Loch Raven Reservoir.
- Protection of the headwater subwatersheds to preserve a stable sediment production zone and high water quality inflow to stream orders 3 and higher.
- Protection of living resources, including aquatic and terrestrial habitat.
- Preservation of the rural character of the watershed.

The plan development process described in this report includes the following major elements:

- Watershed Characterization (Chapter 1)
- Pollutant Loading Estimates (Chapter 2)
- Stream Stability Assessment (Chapter 3)
- Problem Identification and Prioritization (Chapter 4)
- Management Planning Analysis (Chapter 5)
- Implementation Plan (Chapter 6)

The results of each of the elements of the study are summarized below. Figure ES-2 graphically displays the relationships between the various study elements and illustrates how the data and information gathered or developed under this project have been integrated into each step of the analysis. This figure also describes the prioritization and ranking steps, as well as the criteria used for each element of the study.

Watershed Characteristics and Background

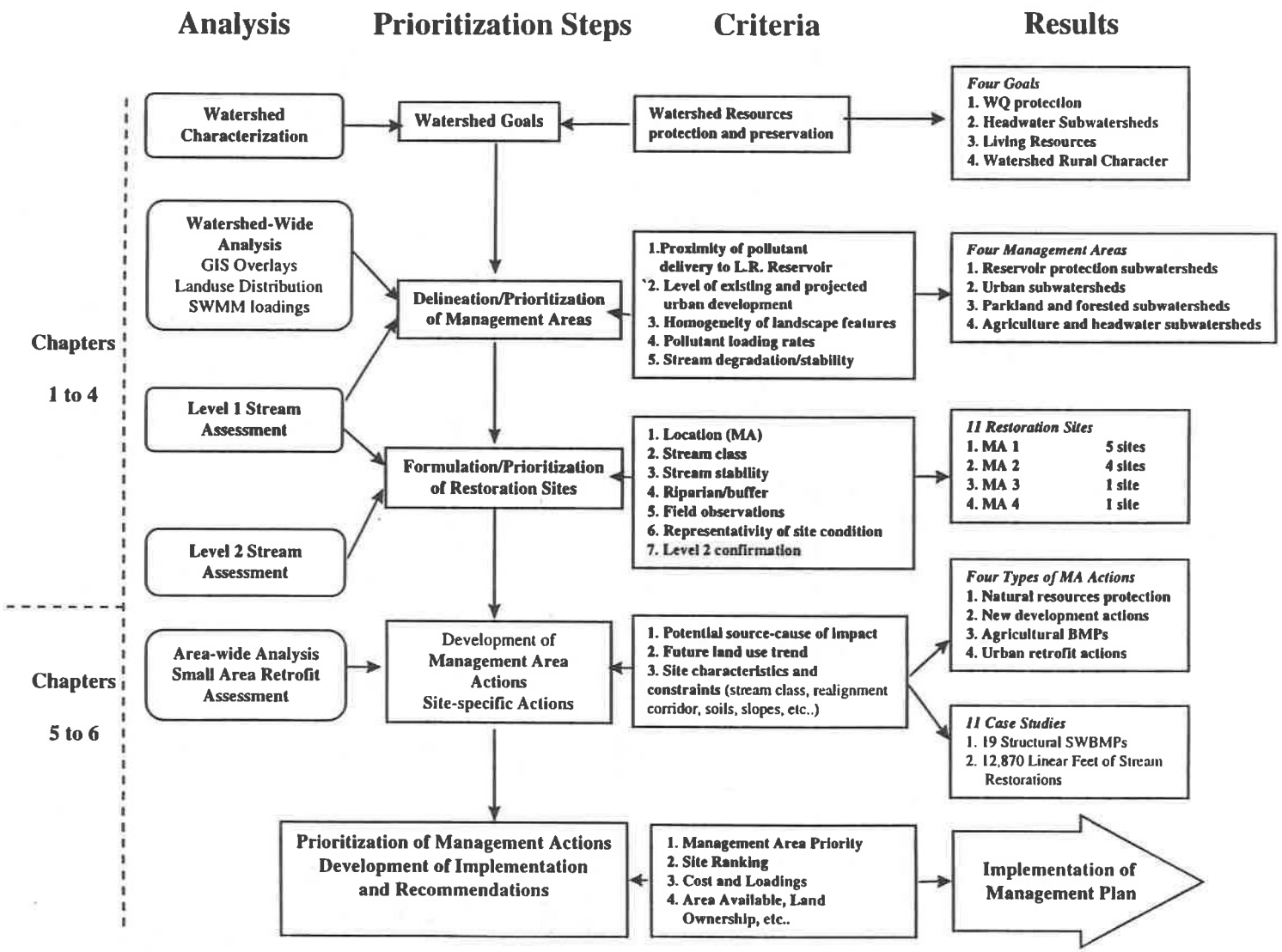
The Loch Raven Reservoir and its contributing watershed are located within the Gunpowder River subbasin. The watershed drains an area of approximately 140,000 acres. For the purpose of this water quality management planning study, the Loch Raven study area consists of the portion of the drainage area above the Loch Raven Reservoir lower dam to the dam at the Prettyboy Reservoir, bounded by the Maryland/Pennsylvania state line to the north, Harford County to the east, and Carroll County to the west. The watershed is characterized by urban land uses in the south and southeastern portions and forested and agricultural uses in the northern and western portions of the watershed. Historically, the primary water quality concern has been accelerated eutrophication in the reservoir due to nutrient loadings from both point and nonpoint sources

Because of the importance of the Loch Raven Reservoir as a public drinking water supply and natural trout habitat, all waters upstream of the Loch Raven dam have been designated by the Maryland Department of the Environment (MDE) as Class III-P, Natural Trout Waters and Public Water Supplies (COMAR 26.08.02.08I).

Loch Raven Study Area

Figure ES-1. Case Study Locations

Figure ES-2 Prioritization Process



The Loch Raven watershed has a long history of watershed management and water supply protection through the Reservoir Watershed Action Strategy. In 1979, local jurisdictions including Baltimore City, Baltimore County, Baltimore County Soil Conservation District, Carroll County, Carroll County Soil Conservation District, Regional Planning Council, Department of Agriculture, and the Department of Health and Mental Hygiene formulated and signed the Reservoir Agreement. In 1984, the cooperating jurisdictions signed a strengthened Reservoir Watershed Management Agreement. The Agreement, and its *1984 Action Strategy for the Reservoir Watersheds* (Action Strategy), provided a framework for improving water quality in the reservoir watersheds. In 1984, the Action Strategy established goals of preventing increased phosphorus and sediment loadings and restoring Loch Raven phosphorus loadings to pre-1970 levels as soon as possible. The 1990 Action Strategy eliminated this as a distinct goal because of lack of confidence in the estimated pre-1970 phosphorus load levels. The current reservoir protection goal defined by the Action Strategy for Loch Raven is the reduction of phosphorus loadings to acceptable levels as soon as possible.

Pollutant Loading Estimates

Pollutant loading estimates were developed to support the evaluation of waterbody conditions and a subsequent ranking and prioritization. The planning-level SWMM model, developed for a 10-year continuous simulation of existing land use distribution, was used as the fundamental framework for the various analyses of the Loch Raven land use condition and management alternatives. The SWMM model was used to estimate pollutant loadings for 10 pollutants and total suspended solids. Loadings were predicted for 55 subwatersheds for a 10-year period. The results of this continuous simulation were adequately validated through various comparative analyses between model results and available observed data or published values. The validation included an analysis of the overall watershed loading as well as an analysis of the spatial distribution of pollutant loadings at the subwatershed scale.

Based on a review of the watershed concerns, total phosphorus, total nitrogen, total suspended solids (TSS), and zinc were selected as indicators of watershed loading conditions from rural, developing, and urban areas. Average annual loadings of the indicator pollutants were used to identify high-priority subwaterheds under existing and future land use conditions. Three future land use scenarios were used to investigate the possible implications of various build-out conditions. The land use zoning categories that predominate in the watershed, RC2 and RC4, can be developed in a variety of fashions. RC2 build-out is not just a function of zoning, but also reflects changes in farming demographics and viability. The future conditions examined constitute a range of possible conditions. Conclusions of the SWMM analysis include designation of a set of high-priority subwatersheds based on average annual loading of the indicator pollutants. Evaluation of the existing stormwater management facilities identified subwatersheds with high loading potential and minimal controls under existing conditions.

Statistical analysis of monitoring data in the tributaries and the reservoir was performed to evaluate trends in loading over time. The tributary stations show a statistically significant increasing trend in nitrate concentrations and a decreasing trend in ammonia concentrations. Analysis of the reservoir monitoring stations showed a slight negative trend in total phosphorus concentrations at two of the sampling stations.

A simplified phosphorus model was developed and calibrated to the Loch Raven Reservoir. The reservoir model showed excellent representation of observed reservoir phosphorus conditions. The model was applied to a 10-year scenario of reservoir conditions. The longer-term simulation indicated that the reservoir would respond slowly to changes in phosphorus loading.

Releases of phosphorus from bottom sediments are likely contributing to the overall conditions in the reservoir. Over the longer term, reductions in phosphorus loading will occur as bottom sediment sources are slowly depleted, resulting in a system that is more responsive to changes in tributary inflows rather than bottom-sediment phosphorus fluxes.

Stream Stability Assessments

Streams are an important indicator of overall watershed health, and an assessment of the magnitude and extent of environmental impairment in the watershed stream network is a significant component of watershed characterization. The stream assessment process was designed to define potential in-stream sources of sediment, describe and assess the physical characteristics and condition of stream systems in the watershed, and identify opportunities for stream restoration and management.

For the Loch Raven watershed, a set of 14 subwatersheds and associated stream reaches were identified as representative of a cross section of the overall watershed condition. The Loch Raven watershed has over 822 stream miles, distributed among first, second, third, fourth, and higher order streams. Because of the size of the watershed and the large number of stream reaches, a subset of the total stream reaches, (80 miles total or approximately 10 percent), was selected. For the Loch Raven watershed, the traditional Level I approach (Rosgen, 1994) was enhanced to include additional parameters and more extensive field surveys. The stream assessment protocols developed for the Loch Raven watershed employed a combination of accepted techniques to describe stream type, stability, and riparian cover conditions. A fundamental expansion of the traditional approach was the use of in-field assessments to obtain basic parameters for all stream miles assessed rather than relying on estimates from topographic maps. The results of the field survey were evaluated in terms of classification (stream type), stream stability scores, and riparian condition. The stream assessment results were used to identify a set of high-priority reaches for additional investigation.

Problem Identification and Prioritization

The problem identification and prioritization process was structured to address the large size and diversity of the Loch Raven watershed. The watershed was first grouped into four large management areas. Each management area was selected to represent a different set of typical water quality and water resources management conditions and concerns. The plan development process was designed to consider management strategies on two implementation scales. Development of both management area-wide and site-specific management plans provided a comprehensive and integrated approach to restoration of problems at multiple scales.

Management area-wide analysis. A management area wide analysis was performed to address watershed-wide objectives. Water quality conditions, pollutant loading estimates, land use, and zoning designations were used to delineate and rank management areas. Management approaches and techniques were recommended for each area to address area-wide concerns.

Site-specific analysis. Management area-wide problems were further analyzed at the site level. Site-specific problem identification included identification of stream restoration sites and restoration alternatives and analysis of estimated pollutant loadings from each site to

select sites requiring additional or retrofitted stormwater management facilities. Site visits also identified areas requiring stabilization and velocity controls.

Management-Area Wide Analysis

Figure ES-2 describes the process used to select, prioritize, and rank water quality management opportunities. Information collected and analyzed during the watershed characterization and the watershed pollutant loading estimates were used to group Loch Raven subwatersheds into management areas (Figure ES-1). Each management area was ranked according to its impact on the four goals of reservoir protection. The management areas and their priority objectives are listed in Table ES-1.

Recommended management actions include source controls and nonstructural methods of regulating the impacts of urbanization and agricultural practices on the watershed and its receiving streams. They are intended to be applied on a broad scale throughout the management area as opportunities arise. Management actions can be grouped by categories of activities required for implementation as follows:

- Seven new development management actions
- Three urban retrofit management actions
- Seven natural resources protection management actions
- Five agricultural BMP management actions

Protection of reservoir drinking water quality and quantity has been given the highest ranking of importance for the overall Loch Raven watershed plan. Therefore, management actions addressing management area 1 are considered a priority for implementation.

Table ES-1. Management Areas

Number	Name	Priority Objective
1	Reservoir Protection Subwatersheds	Protection of drinking water supply of Loch Raven Reservoir.
2	Urban and Rapidly Urbanizing Subwatersheds	Retrofits in existing urban areas and management of new and projected urban sprawl.
3	Parkland and Forested Subwatersheds	Preservation of stable parkland and forested areas.
4	Agriculture and Headwater Subwatersheds	Agricultural management and protection of headwater streams.

Site-Specific Management Action Plan

The site-specific management action plan is a framework for addressing implementation of management actions at the site level. It is based on a set of 11 degraded that were identified from the information gathered on the assessed reaches in the 14 subwatersheds studied.

Restoration actions address site specific stream restoration as well as an identification of stormwater management practices within their drainage areas.

Site-Specific Stream Restoration Management Actions

A case study approach was used to illustrate the implementation of this framework. The case studies selected represent a cross section of the priority problems found in each of the management areas. Figure ES-1 also shows case study locations with respect to management areas and subwatersheds. Ranking of the stream restoration sites were based primarily on the following criteria:

- Degradation severity (Pfankuch ratings).
- Extent of the area impacted (linear feet impacted).
- Representativeness of typical sources/causes (urban, crop, pasture, forest).
- Opportunity for restoration (from field observations).
- Potential for recovery inferred from Level II and I classifications.

The majority of these stream restoration sites were found within Management Area 1, as shown in Table ES-2.

Table ES-2. Summary of Stream Restoration Sites

Case Study Site No.	MA	Subbasin	Length of Stream Restoration (linear feet)	Type of Restoration Proposed
1	2	Beaverdam Run	1,500	Bc
2	2	Goodwin Run	1,500	B
3	2	Oregon Run	1,870	fencing + Bc
4	2	Beaverdam Run	3,800	Bc or B
5	1	Loch Raven	500	B4c
6	1	Loch Raven	700	C
7	1	Loch Raven	600	B
8	1	Loch Raven	1,700	B
9	1	Carroll Branch	1,700	riparian buffer restoration
10	4	Blackrock Run	2,000	Bc
11	3	Panther Branch	500	Monitor for recovery

For each stream restoration site, an associated case study was developed to determine specific stream restoration and structural stormwater best management practices for source controls. Stream restoration recommendations were made based on the stream reach Rosgen classification, the recovery potential and the length of stream corridor available for realignment based on field observations. The cost of the proposed stream restoration was estimated to be $1,835,246 for 16,370 linear feet of restoration. More detailed information on these estimates is

provided in Chapter 5. The proposed restoration represents approximately 4 percent of the total stream miles assessed (using enhanced Level I). Opportunities for additional restoration most likely exist for other areas exhibiting stream degradation in the remainder of unassessed watershed streams.

Site-Specific Urban Stormwater Management Actions

Opportunities for structural and nonstructural stormwater best management practices (SWBMP) were evaluated for the 11 key case study areas exhibiting the most severe stream bank erosion conditions. Table ES-3 provides a summary of recommended site-specific management actions. A total of 19 structural SWBMPs are included in the stormwater management plan. At locations where no single BMP can manage the whole drainage area several BMP practices have been combined to address stormwater discharges from a single outfall. For example, for outfall CS-1-3B, an oil/grit separator will be used in conjunction with an extended detention pond to provide stormwater management for the whole contributing area. In another example, maximizing the stormwater treatment for outfall CS-1-4B required the use of both a bioretention area and an infiltration trench. Additional management actions are also suggested in the form of nonstructural source controls and in minimal impact requirements for new development, riparian forest protection, rezoning, and improved sediment and erosion controls.

The total design and construction costs associated with implementation of the structural SWBMPs is estimated at $1,260,831. Cost estimates were based on construction costs and the total water volume controlled. Further explanation on cost estimates procedures is provided in Chapter 5. These costs do not include costs of land acquisition or easements or maintenance costs. The cost per acre controlled provided by this suite of structural SWBMPs is approximately $3,109/acre controlled. The overall costs per pound per year controlled for nitrogen, phosphorous, and total suspended solids are $2,068, $9,129, and $43, respectively.

Implementation Plan

The following recommendations were identified in the implementation plan:

- Management Area 1 has been given highest priority due to its proximity to the reservoir, and the primary watershed management goal of drinking water protection. It is therefore recommended that implementation of management actions, structural SWMBPs, and stream restoration actions receive the highest priority here.
- Management Area 2 has been given high priority due to the potential for land conversion and impacts of future development on the watershed stream stability and reservoir total suspended solids and total phosphorus loadings.
- Within each management area, worst-case stream stability problems and associated stream restoration and SWBMPs should receive high priority.
- Within each subwatershed, implementation of structural management actions such as SWBMPs and stream restoration should occur in the headwater areas first and proceed downstream. This will avoid the impacts of upstream construction on downstream restoration projects.
- Within each case study area, stream restoration actions should generally be implemented after construction of upstream structural SWBMPs. This will avoid

impacts of subsequent erosion and deposition that may be caused during SWBMP construction.

- Some management actions can be implemented through minor changes in existing programs. Where this is possible, these actions should be given high priority to jump-start the watershed plan implementation process.
- The success of the watershed plan and its implementation to meet the watershed management goals should be monitored through a number of methods including biological monitoring, streambank stability studies, program implementation tracking, and reservoir quality improvement monitoring.
- Within the assessed study areas the overall cost of both the proposed stream restoration and SWBMP management actions were estimated at $3,096,077.

Recommendations for supplemental analyses and study include:

- Expansion of stream assessment data collection and analysis to a sample of stream reaches that is statistically representative of the watershed as a whole.
- Additional upland habitat data collection including habitat inventory, habitat classification, baseline species, and population assessments.
- Detailed analysis of on-site septic system siting and design, including determination of nitrogen loading impacts to the Loch Raven Reservoir.
- Continued and expanded monitoring to support evaluation of the results and progress and creation of a feedback mechanism to revise original goals and objectives.
- Development of a quantitative reservoir protection goal for phosphorus using an enhanced version of the PhosMod screening model.
- Evaluation of the build-out conditions and in-stream impacts from development in RC2-zoned areas. The application of RC4 performance criteria to RC2 areas should be considered throughout the Loch Raven watershed.

Selected special studies were identified to address areas with critical unknowns, including:

- Identify and monitor stable F channels.
- Further identify and implement agricultural BMPs that provide protection from stream degradation.
- Evaluate order 1 streams in the previously assessed watersheds. Previous stream surveys focused on stream orders 2 and 3, although significant impairments of order 1 streams were observed. Selection of the streams should be based on land use, ongoing activities, management area, and new development.
- Extend the Level I stream assessment to additional subwatersheds. Options for selection of field survey sites include high-loading subwatersheds (based on SWMM analysis) not previously analyzed and high-priority retrofit sites not included in the existing case studies.
- Perform a retrofit study to evaluate opportunities for additional management of water quality. The retrofit study should include field investigation and Level I assessment of the stream channel.

Table ES.3. Summary of Recommended Site Specific Management Actions

Case Study No.	MA	Subwatershed	Location	Drainage Area (Acres)	Dominant Land Use	Proposed BMP Type(s)	Proposed Stream Restoration Alternative	Additional Management Actions
1	2	Beaverdam Run	Padonia Road, Warren Road, York Road, west of reservoir	~500	MDR, HDR	1 Detention Pond (dry) 2 Extended Detention Ponds (wet) 2 Oil/Grit Separators	1,500 linear feet of restoration to Bc type channel	Source controls for SW from roofs and driveways in residential and commercial areas.
2	2	Goodwin Run	I-83, Padonia Road	~300	HDR, MDR	2 Extended Detention Ponds	1,500 linear feet of restoration to B type channel	Improve sediment and erosion controls. Riparian forest protection.
3	2	Oregon Run	Tufton Ave, Falls Road, Oregon Ridge Park	~350	Ag, LDR	Grassed Waterways Conservation tillage Gully Prevention 1,000 Riparian Fencing	Fencing to exclude cattle and 1,870 linear feet restoration to Bc channel	Rezone area from RC2 to RC4.
4	2	Beaverdam Run	Ridge Road, Greenspring Ave, Broadway Road, Berans Road	~400	LDR	3 Detention Ponds (dry) 1 Bioretention Area 1 Infiltration Basin 1 Wetland	3,800 linear feet of restoration to Bc/B type channel	Additional outfall stabilization and energy dissipation. Riparian reforestation as requirement for new development.
5	1	Loch Raven Reservoir	Northwest portion of reservoir	~25	LDR, MDR	2 Infiltration Trenches	500 linear feet of restoration to a B4c channel with grade control provided by vortex rock weirs	On-lot SWBMPs such as bioretention, infiltration trenches. Rock-lined step pools to stabilize headcuts.
6	1	Loch Raven Reservoir	Northwest portion of reservoir	~110	LDR, MDR	1 Extended Detention Pond 1 Bioretention Area	700 linear feet of restoration to a C type channel	On-lot SW source controls for roofs and driveways.
7	1	Loch Raven Reservoir	Eastern portion of reservoir	~70	LDR, Forest	None	600 linear feet of restoration to a B4 type channel	On-lot SW source controls for roofs and driveways.
8	1	Loch Raven Reservoir	Northeast portion of reservoir	~120	Ag, LDR	Ag BMPs to minimize erosion such as grassed waterways, diversion structures, and grassed buffer strips.	1,700 linear feet of restoration to a B type channel	Expansion of parkland to preserve riparian buffer.

Case Study No.	MA	Subwatershed	Location	Drainage Area (Acres)	Dominant Land Use	Proposed BMP Type(s)	Proposed Stream Restoration Alternative	Additional Management Actions
9	1	Carroll Branch	Carroll Road, Sparks Road, Glencoe Road	~230	Ag, LDR	None	Reestablish 1,700 feet of riparian buffer on both sides of stream	Monitor existing pond outfall and downstream channel for stability changes. Potential for existing pond retrofit. Maintain forested areas within Manor Loam soils. Develop areas with minimal impact. Limit imperviousness in new developments. Limit disturbance to existing vegetation. Improve sediment and erosion controls on new developments. Encourage woodlot management.
10	4	Blackrock Run	Carmel Road, Yeoho Road, Benson Mill Road, Pretty Boy Dam Road	~300	Ag	Potential for Ag Wet pond. Ag BMPs in form of diversion structures and grassed waterways.	2,000 linear feet of restoration to Bc type channel.	Develop areas with minimal impact. Limit imperviousness in new developments. Limit disturbance to existing vegetation. Maintain vegetated riparian buffers. Stabilize road crossings.
11	3	Panther Branch	Hereford High School	~37	Inst.	None	Monitor 500 linear feet of stream for recovery	None

Stream Stability Assessment and Analysis 3

3.1 Introduction

The Loch Raven watershed lies primarily within the Piedmont physiographic province and drains to the Loch Raven Reservoir. The reservoir provides a major drinking water supply for the Baltimore metropolitan area. The protection of the downstream drinking water supply, in terms of both preservation of the quality of water and protection of the storage capacity of the reservoir, is a major issue driving the various management and restoration initiatives taken by Baltimore County. The development of a watershed-wide management plan is also driven by the significant role of the water resources and stream systems in supporting the residents' needs and preserving the watershed's ecological balance. Water resources and streams in the Loch Raven watershed provide livestock watering, groundwater supplies, wastewater processing, streamside real estate, sportfish habitat, wildlife habitat, endangered species habitat, recreational and scenic benefits, and public education opportunities.

Natural processes and anthropogenic impacts can have a profound effect on the state of lotic systems within the watershed. The complexity of stream system processes, the difficulty in predicting the time element required for stream channel adjustments, and the tremendous resources required for environmental restoration can make watershed protection and management a challenging task. The first step in determining watershed management needs and defining appropriate management strategies is the characterization of environmental conditions and assessment of the physical and biological integrity of the stream systems within the watershed. Streams are an important indicator of overall watershed health, and an assessment of the magnitude and extent of environmental impairment in the watershed stream network is a significant component of watershed characterization. Stream assessment, together with the other components of the watershed study (i.e., characterization, SWMM modeling), can be used to identify problems areas, rank problems, and select management opportunities. The stream assessment process is designed to address the following general elements of the Loch Raven watershed planning study:

- Define potential in-stream sources of sediment.
- Describe and assess the physical characteristics and condition of stream systems in the watershed.
- Identify opportunities for stream restoration and management.

For the watershed stream assessment, the following specific analyses and objectives were defined as a means to achieving the widest range of conclusions and supporting information:

- Select representative streams in the Loch Raven watershed to provide an overall assessment of watershed conditions and status.
- Capture watershed variability and range of conditions for overall assessment.
- Categorize the stream conditions, problems, and level of impairment.
- Extrapolate to assess more complete watershed conditions, identify potential types and locations of problems, and support prioritization of problems and sources.

On a site-specific basis the stream assessment process was designed to provide the following analyses:

- Provide site-specific information to support problem identification.
- Characterize problem types (stream order and land cover/use).
- Identify opportunities for selection of restoration sites and management initiatives in the development of the final plan.

Stream assessments are useful in determining the location, nature, and eventually the source or cause of impairments and in identifying feasible control solutions and restoration alternatives. However, the large number of streams in even a moderate-sized watershed makes it impractical to carry out stream walk-based assessments for the entire stream network. Resource constraints will generally dictate that assessments be performed on only a sample of reaches within a watershed. However, it is important to ensure that the reaches selected for assessment are representative of conditions within the watershed and meet the objectives of the study. For the Loch Raven watershed, a set of stream reaches were identified as representative of a cross section of the overall watershed condition. The following sections describe the approach used to select stream reaches, explain the various field assessment techniques used, and present the assessment results.

3.2 Stream Assessment Approach

The Loch Raven watershed stream assessment procedure included the following:

- **Stream selection:** Subwatersheds and specific stream sections within the Loch Raven watershed were selected for assessment in this step.
- **Stream assessment techniques:** This step involved the selection of appropriate visual indicators and quantitative measures for assessing streams.
- **Field data interpretation:** Field data were analyzed to provide an assessment of stream condition at the watershed and subwatershed scale, and to identify specific impaired reaches.

3.2.1 Stream Selection

The Loch Raven watershed has over 822 stream miles, distributed among order 1, 2, 3, 4, and higher streams, as shown Table 3-1. Because of the size of the watershed and the large number of stream reaches, only a selected portion of the stream reaches was directly evaluated. A subset of the total stream reaches, 86.7 miles total (or approximately 10 percent), was targeted for assessment.

Table 3-1. Stream Miles and Order by Subwatershed

Subwatershed Number	Name	Order 1	2	3	>4	Total	
2	Second Mine Branch	11.31	4.28	2.38	0.00	17.97	LOW
3	Third Mine Branch	13.73	5.41	4.80	4.35	28.28	LOW
4	Forth Mine Branch	5.36	2.63	2.45	0.00	10.44	LOW
5	First Mine Branch	13.53	5.59	2.45	0.00	21.56	LOW
10	Little Falls	29.32	16.10	7.13	2.56	55.12	LOW
11	Beetree Run	11.80	7.70	3.87	0.00	23.37	LOW
19	Owl Branch	6.21	3.28	3.81	0.26	13.55	LOW
25	Gunpowder Falls (Below)	12.94	9.37	1.07	0.00	23.38	LOW
28	Buch Cabin	6.95	2.58	1.67	2.31	13.50	LOW
30	Mingo Branch	1.84	0.96	1.10	0.00	3.90	LOW
31	Panther Branch	3.11	1.31	1.05	0.00	5.46	LOW
32	Piney Run	18.22	11.13	3.61	5.11	38.08	LOW
33	Blackrock Run	19.95	8.96	3.60	7.45	39.96	LOW
34	Piney Creek	18.26	9.87	2.94	6.12	37.19	LOW
35	Charles Run	11.50	6.28	3.50	2.68	23.97	LOW
36	Little Piney Run	3.51	1.18	2.85	1.33	8.88	LOW
38	Indian Run - Loch Raven	4.34	4.67	2.49	0.00	11.49	LOW
39	Buffalo Creek	3.81	2.80	0.45	2.12	9.17	LOW
42	Carrol Branch	9.09	4.80	2.36	3.34	19.59	LOW
43	My Lady's Manor Br.	4.83	2.21	1.63	0.58	9.25	LOW
45	McGill Run	13.60	7.16	3.60	2.81	27.17	LOW
46	Western Run - Loch Raven	32.77	19.66	7.92	14.23	74.57	LOW
51	Greene Branch	13.07	5.49	4.26	3.01	25.83	MED
52	Gunpowder Falls	34.15	16.68	6.20	0.58	57.61	LOW
53	Slade Run	9.21	3.81	3.07	2.02	18.11	LOW
54	Quail Creek	1.47	0.90	0.70	0.00	3.06	MED
55	Delaware Run	8.26	3.19	1.84	1.96	15.25	LOW
56	Deadman's Run	4.03	1.77	0.86	1.54	8.20	MED
57	Oregon Run	8.79	4.15	0.39	3.61	16.95	MED
58	Overshot Run	5.70	2.84	3.48	0.00	12.02	LOW
61	Waterspout Run	2.86	1.06	2.09	0.00	6.01	LOW
62	Royston Run	1.20	0.47	0.47	0.00	2.14	LOW
63	Fitzhugh Run	4.20	2.01	0.84	1.68	8.74	HIGH
64	Dulaney Valley Branch	8.99	5.77	3.87	0.64	19.28	LOW
66	Councilman's Run	5.72	3.70	3.63	0.82	13.86	HIGH
67	Beaverdam Run	14.75	8.37	4.82	6.78	34.71	HIGH
68	Baisman Run	4.97	2.36	0.49	1.43	9.24	MED
73	Goodwin Run	6.93	2.95	2.72	1.39	13.99	HIGH
74	Merryman's Branch	1.18	1.30	0.00	0.00	2.48	MED
75	Jenkins Run	1.40	0.84	0.57	0.00	2.81	MED
82	Spring Branch	1.73	1.18	0.74	0.00	3.65	HIGH
89	Long Quarter Branch	1.48	1.81	0.16	0.00	3.45	HIGH
90	Rushbrook		1.00	1.00			
92	Hampton Branch	1.25	0.11	0.00	0.00	1.37	HIGH
100	Loch Raven Reservoir	16.00	9.42	1.89	0.00	27.31	HIGH
191	Lower Loch Raven Res.	1.03	0.28	0.25	0.00	1.57	MED
Total		**414.34**	**219.38**	**111.05**	**80.71**	**823.49**	

The stream selection process included two steps: (1) selection of representative subwatersheds and (2) selection of stream reaches within each subwatershed. The selection criteria for subwatersheds included the level of development within each subwatershed measured in terms of the percent imperviousness, percentage of urban land uses, results of past assessment of aquatic condition, percent forest, and local knowledge acquired by County watershed management personnel. Based on these criteria, a subset of 14 subwatersheds was identified (Figure 3-1). Within each selected subwatershed, stream reaches were identified for assessment based primarily on stream order and accessibility. Stream reaches were selected from within second- and third-order streams, which are generally zones of high sediment production. Table 3-2 presents a summary of stream miles selected within each subwatershed.

3.2.2 Stream assessment techniques

Stream assessments can be based on a variety of observations of stream degradation and stability indicators, habitat and riparian condition, and geomorphologic characteristics. A number of stream assessment protocols using both qualitative and quantitative measurements have been developed and documented in the literature (Pfankuch 1975, Rosgen, 1994). The stream assessment protocols developed for the Loch Raven watershed employ a combination of accepted techniques to describe stream type, stability, and riparian cover conditions.

3.2.2.1 Stream Stability Assessment Technique

Several field indicators have been used to assess channel stability and to infer the condition of the physical and biological components of the stream environment. Such indicators can provide insight into the degree of stream impact and assist in identifying reaches to prioritize for potential restoration. Table 3-3 presents a list of stream stability indicators used in the Loch Raven stream assessment and their associated weights. The weights range from 1 to 6, with scouring and deposition given the highest weight of 6. The steam stability indicators include those described by Pfankuch (1975).

3.2.2.2. Stream Geomorphologic Classification

Channel geomorphologic characteristics provide a useful means of identifying stable and unstable streams. The Rosgen stream classification system is an empirical methodology that can be used to describe a stream's behavior based on basic hydrologic and morphologic parameters, and it provides the basis for a consistent frame of reference when comparing streams.

For the Loch Raven watershed, the traditional Level I approach (Rosgen, 1994) was enhanced to include additional parameters, more extensive field surveys, and limited data collection. A fundamental difference is the use of in-field assessments to obtain basic parameters rather than relying on estimates from topographic maps. In addition, the procedure uses a simplified pebble count procedure, with a smaller sample of pebbles collected equally from a single pool and riffle, to determine dominant particle size. However, the procedure does not fully achieve the degree of accuracy obtained in a Level II classification because of rapid measurements required during the field assessment process. In the enhanced Level I procedure, slope is measured using a clinometer, and the cross section is defined by vertical measurements taken from a horizontal line stretched at the flood-prone width.

Loch Raven Study Area

Figure 3-1. **Subwatersheds with Stream Asssessments**

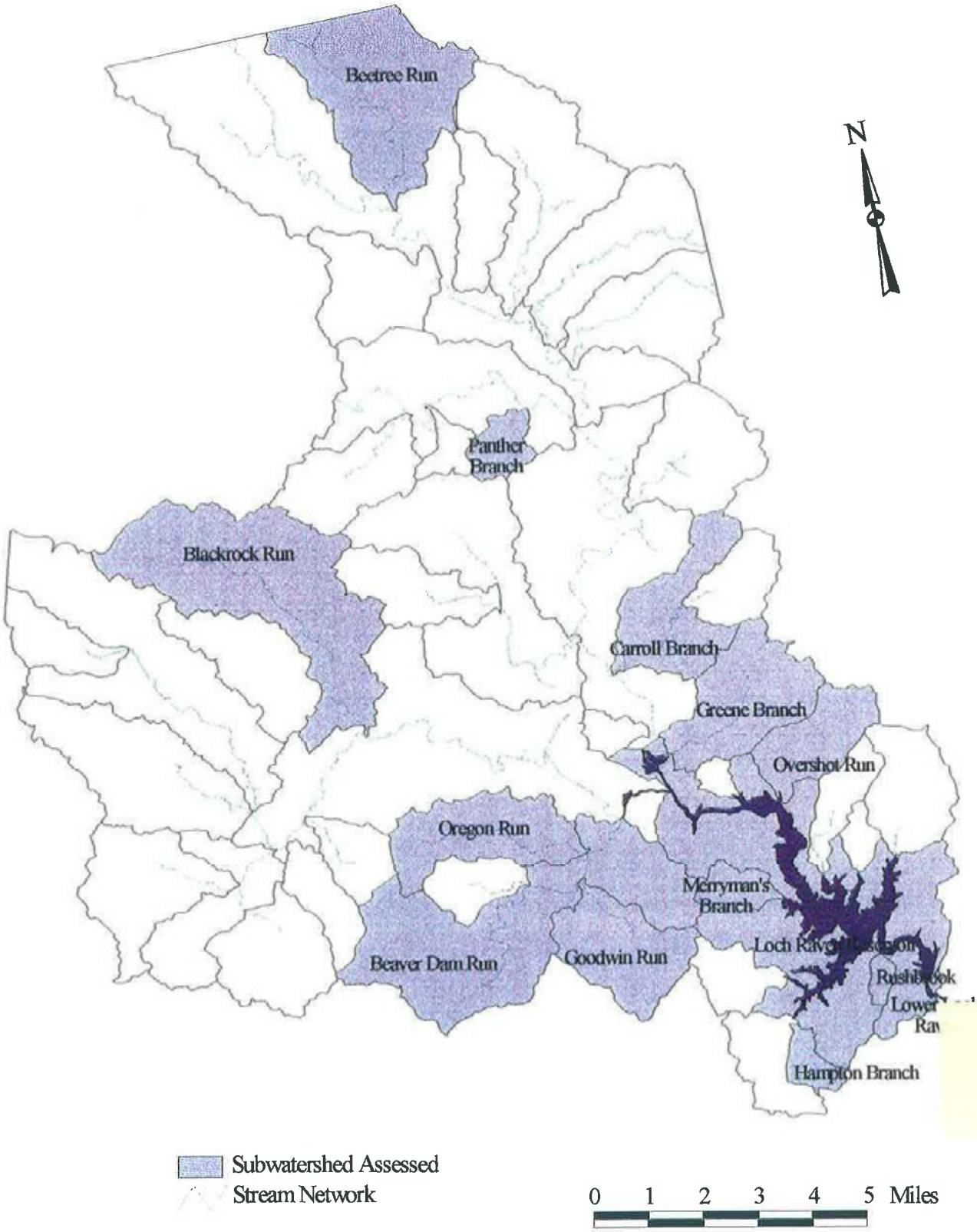


Table 3-2. Selected Stream Miles for Assessed Subwatersheds

Number	Subwatershed	Group	Order 2 (miles)	Order 3 (miles)	Total (miles)
11	Beetree Run	Ag-low	7.7	3.87	11.57
31	Panther Branch	Ag-low	1.31	1.05	2.36
33	Blackrock Run	Ag-medium	8.96	3.6	12.56
42	Carroll Branch	Ag-high	4.8	2.36	7.16
		Total Agriculture Miles	**22.77**	**10.88**	**33.65**
51	Greene Branch	Urban-medium	5.49	4.26	9.75 ✓
57	Oregon Run	Urban-low/medium	4.15	0.39	4.54
58	Overshot Run	Urban-high	2.84	3.48	6.32 ✓
67	Beaverdam Run	Urban-medium	8.37	4.82	13.19
73	Goodwin Run	Urban-high	2.95	2.72	5.67
74	Merryman's Run	Urban-medium	1.3		1.3
90	Rushbrook	Urban-medium/Forest-high	0.5		0.5
92	Hampton Branch	Urban-medium	0.11		0.11
100	Loch Raven Reservoir	Urban-low	9.42	1.89	11.31
191	Lower Loch Raven	Urban-medium	0.28	0.25	0.53
		Total Urban Miles	**35.4**	**17.81**	**53.2**
Total Miles			**58.1**	**28.69**	**86.7**

The value of an enhanced Level I classification in addition to the Pfankuch stability assessment outlined previously includes confirmation of stream reaches visually identified as unstable (G streams are generally inherently unstable), as well as identification of possibly impaired streams reaches that might not have been appropriately scored in the visual assessment. In addition, the stream class can be used for problem assessment and ranking, as well as for potential management and restoration recommendations.

3.2.2.3. Riparian Habitat Assessment

Comprehensive assessment and analysis of stream stability and restoration alternatives should also consider the riparian zone. The health of the riparian corridor directly affects and is inseparable from the physical characteristics and habitat value of a stream system. The overall condition of riparian corridors in a watershed reflects the viability of the watershed as a productive, diverse ecosystem. Degradation or elimination of riparian habitat may have severe consequences, adversely affecting water quality (in both the short term and long term), aquatic habitat, and property owners in areas subject to flooding, as well as those who depend on the watershed for domestic water supply. Removal of riparian vegetation may be the sole cause of stream reach impairment, while preservation and wise management will provide numerous positive results and may mitigate stresses placed on the system either upstream or downstream. For the Loch Raven watershed, a set of riparian indicators were collected during the field survey and they include the following:

- Riparian vegetation type
- Riparian buffer width
- Riparian buffer density

Table 3-3. Relative Weight of Indicators in Pfankuch Stability Rating

Visual indicator	Description	Relative weight
Landform slope	Steepness of the land adjacent to the stream channel.	2
Mass wasting or failure	Rates the existing or potential hazard for detachment of relatively large chunks of upper bank material into the stream.	3
Debris jam potential	Assesses the potential for floatable debris, such as tree trunks and limbs, to impede the natural direction and force of flow.	2
Vegetative bank protection	Provides an assessment of the degree of ground cover on the upper banks.	3
Channel capacity	Provides an assessment of how often overbank flows occur.	1
Bank rock content	Determines the relative resistance of bank material to detachment by flow forces.	2
Obstructions/flow deflectors/ sediment traps	Rates the ability of objects within the stream channel to produce adverse stability effects.	2
Bank cutting	Provides an assessment of the extent of lower bank scouring, undercutting, and vertical side failure.	4
Bank deposition	Provides an assessment of the extent and type of depositional processes occurring on lower bank areas.	4
Rock angularity	Relates to the relative extent of round and sharp edges of rocks on the channel bottom.	1
Brightness	Refers to the relative extent of bright (or polished) and dull (or stained) rocks on the channel bottom.	1
Consolidation or particle packing	Provides an assessment of the degree of particle packing and overlap.	2
Bottom size distribution and percent stable materials	Evaluates changes in bottom size distribution from natural variation and the overall percentage of channel bottom material that is rated to be stable.	4
Scouring and deposition	Provides an assessment of the extent to which scouring and deposition processes are actively taking place in the channel.	6
Clinging aquatic vegetation	Provides a measure of the degree of stabilization of soil-rock components by assessing the extent to which clinging plants can be seen on the channel bottom.	1

These indicators provide insight into the stream riparian habitat conditions, the ability of existing riparian areas to provide additional water quality treatment functions, the ability of existing riparian areas to provide added stability to stream banks, and the changes in riparian condition from one section of stream to another.

Additional indicators used in this assessment included water quality indicators to aid in identifying potential sources of nonpoint and point source pollution. The indicators were limited to those which could be identified within the confines of the stream and riparian area. Water quality indicators noted included:

- Storm drain outfalls
- Exposed sanitary sewer lines
- Visible illicit discharges
- Existing stormwater BMPs
- Evidence of trash and dumping

3.2.3 Field Data Interpretation

The field data were compiled and entered into a database for subsequent analysis. The interpretation of the field results was based on analysis of stability scores, stream classification, and riparian zones. The process uses channel stability scores as the initial selection criteria for the stream reaches with potential and existing problems. The channel stability scores are confirmed by comparison with the stream classification. A riparian zone analysis is then used to further describe and evaluate selected problem reaches. The riparian zone analysis is also used to identify a new set of reaches at risk for impairment due to lack of riparian zone cover. Supplemental, reach-specific information is also provided by the field observations of features such as localized uses, manmade structures, outfalls, and livestock access. The results from all analysis procedures are summarized at the watershed and subwatershed level in Section 3.3 of this report. The components of the analysis and scoring systems used are described in greater detail below.

3.2.3.1 Basis for summarizing and interpreting results

As noted previously, the Pfankuch channel stability scores were the primary means of identifying impaired reaches. The original scoring system uses the sum of individual indicator scores to rate an assessed reach as excellent, good, fair, or poor. To allow improved interpretation of reaches rated fair or poor, these categories were subdivided into three and two subcategories, respectively. The excellent and good categories were lumped into one class. A summary of the scoring system ranges and groups is shown in Table 3-4. The scores were used in conjunction with the Rosgen stream classifications to provide an assessment of overall stability. Stream classes were assigned based on parameters derived from direct field observations and interpretation of cross-sectional measurements and slope estimates.

Table 3-4. Channel Stability Rating Scores

Scoring System Ranges	Group Number	Interpretation
< 75	1	Good/excellent
75 -94	2	Fair
95 -104	3	Potentially impacted
105 -114	4	Slightly Poor Condition
115 -124	5	Poor Condition
> 124	6	Very Poor Condition

After selecting the most severely impaired reaches based on the stream stability and classification analysis, additional potentially impaired reaches were selected based strictly on the condition of the riparian vegetation. Areas with no riparian vegetation were assumed to be at higher risk for stream and aquatic life impacts.

A scoring method was developed to rate the riparian vegetation as good, fair, poor, or very poor. The "type" parameter recorded in the field allowed for an initial separation of existing riparian versus no riparian cover. Any segment with essentially no riparian cover (open space, pasture, and cropland type ratings) on either or both sides of the stream were automatically placed in a class of "very poor" riparian conditions. The remaining deciduous forest and shrub/scrub riparian vegetation types were rated based on the remaining two parameters recorded in the field: width and density of the riparian buffer, each given a score of 1 to 5 in the field (5 being the poorest condition). The width and density scores were weighted equally and added for combined scores ranging from 2 to 10. Table 3-5 outlines the scoring system used for the riparian area assessment.

These scores were used to determine the reaches with a forest corridor of less than 25 percent density and 25-foot width (D10) on either or both sides. These reaches were then added to the listing with no riparian cover and were given a "very poor" rating.

3.2.3.2. Data Processing and Analysis

A computerized system was developed for storing and processing field data and performing the interpretative analysis described above. This system allows rapid analysis of the data and identification of stream reaches where some degree of impairment is indicated and where further assessment may be necessary. Relational database tables were created using Microsoft Access to electronically store all raw data. A relational database structure allows more efficient querying of data and minimizes redundancy in data input. The data tables are described in Table 3-6.

Table 3-5. Riparian Assessment Categories (in terms of their stream stability function)

Cover Type	Good	Fair	Poor	Very Poor
Deciduous Forest	D2, D3	D4, D5	D6, D7	D8, D9, D10
Shrub/Scrub		SS2, SS3	SS4, SS5	SS6 or greater

Table 3-6. Summary of Data Tables in Stream Assessment Relational Database

Data table	Content	Primary Key Field or Relational Field
Basic information on data sheet	Field team and reach identifying information	Reach ID
Visual assessment data	Slope and visually assessed scores at 200-ft intervals	Reach ID
Pebble count data	Particle sizes recorded at various points on reach	Reach ID
Cross section information (basic)	Cross section location and values defining entrenchment	Cross section ID
Cross section information (detailed)	Cross section details (vertical measurements to channel bottom from bank to bank)	Cross section ID
Watershed/Stream information	General information about watershed and stream	Reach ID

3.3. Field Assessment Results

The stream assessment results are presented on a watershed-wide basis as well as for individual subwatersheds. The overall watershed results are examined in the context of the existing environmental setting including land use distribution and soil erosion hazard. Reaches within each subwatershed where significant impairment is indicated are identified. Potential sources/causes of impairment are reviewed and discussed.

3.3.1. Watershed-Wide Results

Among the 14 subwatersheds selected for this stream assessment study, the Blackrock Run, Carroll Run, Beetree Run, and Oregon Run subwatersheds have a significant percentage of agricultural land. The other watersheds are predominantly urban, with Greene Branch and Overshot Run having fairly large areas classified as low-density residential land use representative of "urban fringe" watersheds. Overall, the total area assessed included 41 percent urban land, 18 percent agricultural land, and 16 percent forested land, as shown in Table 3-7.

Table 3-7. Land Use Distribution Within Subwatersheds Selected for Assessment (1993 land use)

Watershed (number)	Total area (acres)	% Urban	% Parks	% Agriculture	% Forest
Blackrock Run (33)	7,110	10.4	0.0	54.8	34.7
Oregon Run (57)	2,720	35.5	16.5	39.8	8.2
Beetree Run (11)	5,144	16.5	0.8	45.9	36.8
Panther Branch (31)	740	31.1	40.0	15.7	13.1
Beaverdam Run (67)	7,144	67.2	4.4	13.4	14.9
Goodwin Run (73)	2,567	96.8	2.9	0.0	0.4
Hampton Branch (92)	527	97.5	2.7	0.0	0.0
Lower Loch Raven (191)	545	65.3	34.5	0.0	0.0
Merryman's Branch (74)	630	80.2	9.5	8.9	1.4
Carroll Branch (42)	2,565	20.3	0.0	59.9	19.8
Greene Branch (51)	3,000	51.8	11.7	23.0	13.5
Overshot Run (58)	1,784	52.6	13.7	24.6	9.1
Loch Raven Reservoir (100)	10,517	39.5	55.8	2.6	2.1
Rushbrook (90)	231	49.8	49.8	0.0	0.0
% of total area	45,224	41.4	17.7	25.2	15.6

The soil erosion hazard ratings for the subwatershed are summarized in Table 3-8. Erosion hazard refers to the potential for soil loss through various processes and incorporates soil erodibility and landscape slopes. Blackrock Run, Panther Branch, Lower Loch Raven, and Rushbrook have relatively large portions of their total land area classified as having a moderate to severe erosion hazard. Although the majority of the land area in the other watersheds does not have a severe erosion hazard, limited areas classified as having severe erosion hazard may be in close proximity to streams, providing for both a high erosion rate and high delivery of sediment to the stream system. The distribution of soil erosion hazard by subwatershed is presented in Table 3-8.

Table 3-8. Soil Erosion Hazard by Subwatershed

Watershed (number)	Total (acres)	Slight (%)	Moderate (%)	Severe (%)
Blackrock Run (33)	7,104	4,024 (56.6)	1,207 (17.0)	1,873 (26.4)
Oregon Run (57)	2,660	1,927 (72.4)	313 (11.8)	420 (15.8)
Beetree Run (11)	5,141	3,747 (72.9)	614 (11.9)	780 (15.2)
Panther Branch (31)	722	208 (28.8)	222 (30.7)	292 (40.4)
Beaver Dam Run (67)	6,881	4,973 (72.3)	852 (12.4)	1,056 (15.3)
Goodwin Run (73)	2,249	1,602 (71.2)	300 (13.3)	347 (15.4)
Hampton Branch (92)	524	405 (77.3)	119 (22.7)	0 (0.0)
Lower Loch Raven (191)	509	119(23.4)	108 (21.2)	282 (55.4)
Merryman's Branch (74)	625	511 (81.8)	71 (11.4)	43 (6.9)
Carroll Branch (42)	2,568	1,487 (57.9)	655 (25.5)	426 (16.6)
Greene Branch (51)	3,005	1,587 (52.8)	634 (21.1)	785 (26.1)
Overshot Run (58)	1,770	1,103 (62.3)	398 (22.5)	270 (15.3)
Loch Raven Reservoir (100)	8,270	4,466 (54.0)	1,662 920.10	2,146 (25.9)
Rushbrook (90)	231	108 (46.8)	44 (19.0)	79 (34.2)

Within the 14 subwatersheds selected, second- and third-order streams were assessed. Table 3-9 provides an inventory summarizing stream miles assessed. Overall, approximately 51 miles (65 percent) of order 2 streams and 28 miles (35 percent) of order 3 streams were assessed using the various techniques presented in Section 3.2. Stream reaches that could not be assessed included areas with dense overgrowth, dry streams, impounded streams, concrete channels, and restored reaches in addition to reaches to which access was denied by property owners (20.63 miles). Table 3-9 presents a summary of assessed streams by subwatershed.

It should be noted that the total miles for each subwatershed shown in Table 3-9 are based on distances estimated by pacing in the field, and may not correspond exactly to the total miles originally targeted utilizing GIS coverages (Table 3-2).

Table 3-9. Summary of Assessed Streams by Subwatersheds

Subwatershed	Total fully assessed (miles)	Channel - including concrete, riprap, gabion, piped (miles)	Not accessible-overgrown (miles)	Not accessible-private property (miles)	Ponded (miles)	Wetland (miles)	Dry (miles)	Total (miles)
Beetree Run (11)	10.20	0.08	0.40	0.77				11.45
Lower Loch Raven (191)	0.53							0.53
Panther Branch (31)	2.25						0.20	2.45
Blackrock Run (33)	5.68		1.02	4.67	0.21			11.58
Carroll Branch (42)	7.00			0.14	0.09		0.10	7.33
Green Branch (51)	5.07	0.04	1.67	3.11			0.08	9.97
Oregon Run (57)	2.79		0.76				0.99	4.54
Overshot Run (58)	3.35		0.30					3.65
Beaverdam Run (67)	7.91	1.14			0.19	0.08	0.09	9.41
Goodwin Run (73)	1.93	1.6	0.41	1.92				5.86
Merryman's Run (74)	0.72			0.57				1.29
Rushbrook (90)	0.50							0.50
Loch Raven Reservoir (100)	10.03							10.03
TOTAL	58.39	2.86	4.56	11.18	0.49	0.08	1.46	79.02

The results of the channel stability assessment by subwatershed are presented in Table 3-10 and Figure 3-2. Streams in five watersheds—Merryman's Run, Rushbrook, Overshot, Greene, and Beetree—were found to be in excellent to good condition since less than 2 percent of total stream miles assessed were found to have poor stability.

Five subwatersheds—Loch Raven Reservoir, Carroll, Oregon, Beaverdam Run, and Goodwin Run—were found to be the most degraded, with 16 to 23 percent of the stream miles assessed within the poor stability range. The Beaverdam Run and Goodwin Run subwatersheds have a high degree of urban development, whereas a significant portion of the total land area in the Carroll Branch and Oregon Run subwatersheds is classified as agriculture.

Table 3-10. Distribution of Stream Stability Ratings by Subwatershed

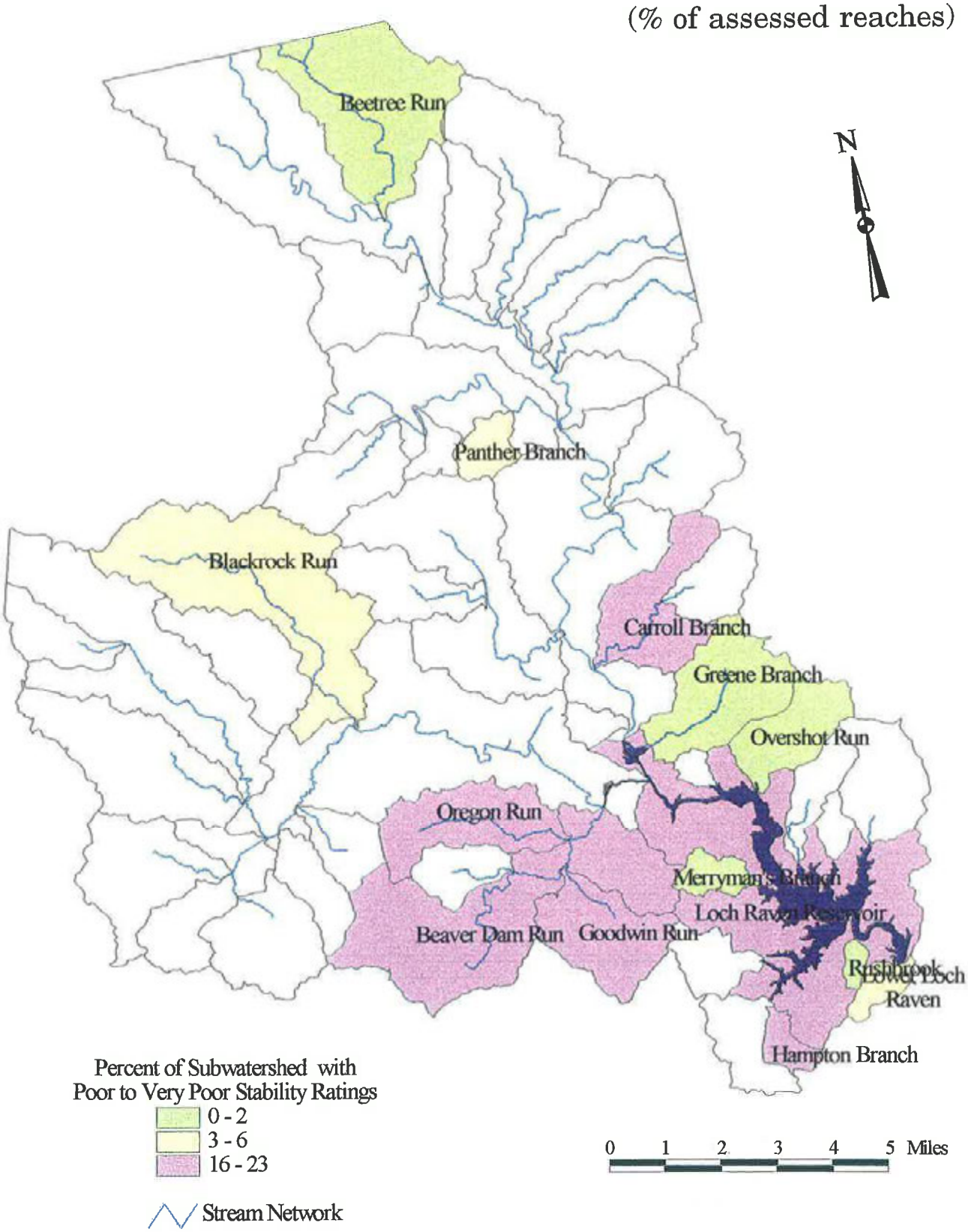
Watershed (number)	Total Feet Assessed	% with Poor to Very Poor Stability Ratings
Blackrock Run (33)	31,470	5.3
Oregon Run (57)	14,710	18.7
Beetree Run (11)	52,510	2.0
Panther Branch (31)	12,340	5.4
Beaver Dam Run (67)	42,205	22.5
Goodwin Run (73)	9,175	22.4
Lower Loch Raven (191)	5,350	3.6
Merryman's Branch (74)	3,820	0.0
Carroll Branch (42)	36,350	16.3
Greene Branch (51)	26,255	1.4
Overshot Run (58)	17,900	0.8
Loch Raven Reservoir/Hampton Branch (100)	52,544	20.5
Rushbrook (90)	2,140	10.0
Total	304,629	11.6

The remaining subwatersheds —Lower Loch Raven, Panther, and Blackrock— have a moderate level of degradation with only 3.5 to 5.5 percent of the stream reaches assessed found to be in the poor stability range. The overall distribution of channel stability ratings (expressed as a percentage of total miles assessed) is shown in Figure 3-3. If the assessed reaches are regarded as a representative sample, overall stream stability in the watershed can be inferred from Figure 3-3. The distribution of stream stability classes is clearly highly right-skewed, which indicates that while a significant number of reaches were rated to have good to excellent stability, overall watershed conditions may be considerably influenced by a relatively small number of reaches with poor stability. Frequency plots of stability ratings by subwatershed are presented in Figure 3-4. In general, these plots also show a right-skewed distribution.

Table 3-11 provides a summary of stream classes assessed to be F and G channels by subwatershed. In general, alluvial F and G channels are regarded as unstable. However, in humid regions with a long growing season (such as the northeast and southeast United States), relatively stable F channels can be found where stream banks are covered by extensive

Loch Raven Study Area

Figure 3-2. Subwatersheds with Poor to Very-Poor Stability Ratings (% of assessed reaches)



vegetation (Rosgen, 1996). The G channels in the watersheds are consistent with the results of the stream stability assessment, with Beaverdam Run having the largest number of G channels (expressed as a percentage of reaches classified), as well as the largest percentage of poor stream stability ratings. The distribution of F channels is more variable, and several F channels have been encountered in reaches with good to fair stability ratings. Due to overgrown conditions following the wet spring and summer period, bankfull determination was difficult in several stream reaches. The cross-sectional parameters (entrenchment and width-to-depth ratio) are extremely sensitive to the location of bankfull stage, and underestimation of bankfull stage can result in classifying B streams as F. In some cases, underestimation of bankfull stage may even result in misclassifying C streams as F. This situation has been noted especially in urban areas where streams are still adjusting to changes in hydrologic regime.

Table 3-11. Number of Reaches Classified as F and G Streams.

Watershed (number)	Number of Reaches Classified*	Number Classified as F	Number Classified as G
Blackrock Run (33)	26	3	3
Oregon Run (57)	12	8	1
Beetree Run (11)	41	14	5
Panther Branch (31)	24	15	0
Beaver Dam Run (67)	27	9	4
Goodwin Run (73)	3	3	0
Lower Loch Raven (191)	6	5	0
Merryman's Branch (74)	3	0	0
Carroll Branch (42)	32	8	3
Greene Branch (51)	21	17	0
Overshot Run (58)	19	5	1
Loch Raven Reservoir/Hampton Branch (100)	25	15	0
Rushbrook (90)	3	3	0

Table 3-12 shows the percentage of assessed reaches with poor riparian zone ratings. These were reaches with either no riparian zone (i.e., open space, pastureland, or cropland), as shown in Figure 3-5, or riparian zones with limited buffer and vegetation protection, as shown in Figure 3-6. The riparian zone is a critical component of a riverine ecosystem, and the health of the riparian corridor directly affects the physical characteristics and habitat value of a stream system. Poor riparian zone ratings are not necessarily correlated with poor channel stability ratings since multiple stressors can be responsible for stream degradation.

The riparian zone assessment provides an alternative means of gauging watershed conditions. When used in combination with channel stability ratings, it provides a combined measure of overall watershed conditions. In urban areas, riparian buffer may provide a limited flow attenuation function due to the routing of stormwater outfalls discharging directly to the stream system. Riparian areas may, however, still provide other ancillary benefits such as shading and habitat value. Limited resistance to erosive storms, the disturbances due to mass

grading and construction, and road crossings are precursors to initiation of localized stream instability. Hydrologic alterations that increase the frequency and duration of higher flows build on such localized disturbances, forcing the stream to adjust to such changes. Such adjustment occurs over a long period of time, leading to production of a large amount of sediment to the stream system.

Table 3-12. Percentage of Assessed Reaches with Poor Riparian Zone Ratings

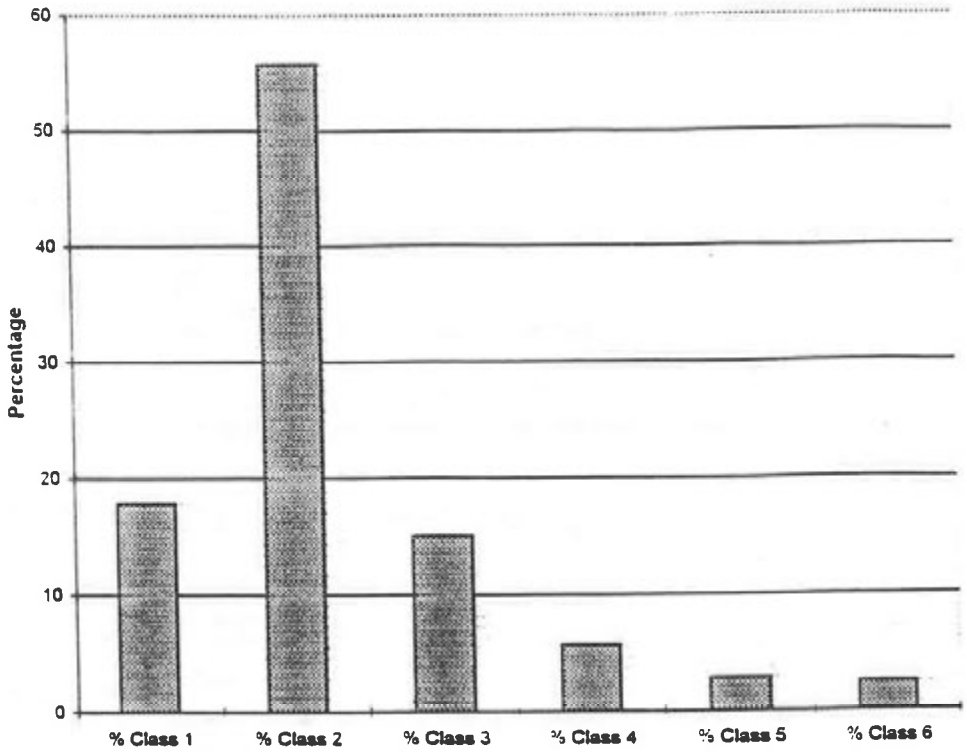
Watershed (number)	No Riparian Zone (% of assessed reaches)	Limited Buffer (% of assessed reaches)
Blackrock Run (33)	30.3	16.4
Oregon Run (57)	20.3	30.8
Beetree Run (11)	44.1	11.5
Panther Branch (31)	0.0	0.61
Beaver Dam Run (67)	26.2	6.0
Goodwin Run (73)	33.2	30.2
Lower Loch Raven (191)	0.0	0.0
Merryman's Branch (74)	11.0	89.0
Carroll Branch (42)	22.5	30.15
Greene Branch (51)	27.6	6.04
Overshot Run (58)	33.5	15.76
Loch Raven Reservoir/Hampton Branch (100)	21.0	15.7
Rushbrook (90)	0.0	0.0

The results of the riparian assessment show that riparian function may be limited in several subwatersheds. The greatest impacts are indicated in the Beetree Run, Blackrock Run, Merryman's Run, Goodwin Run, Oregon Run, and Beaverdam Run subwatersheds. While the last three subwatersheds were identified as impaired through the channel stability assessment procedure, there was no significant indication of impairment for the other watersheds. Thus, while channel instability may not be a major problem in the Beetree Run, Blackrock Run, and Merryman's Run subwatersheds, opportunities for riparian zone restoration should be explored in these subwatersheds. The Beetree Run and Blackrock Run subwatersheds have large agricultural land use components, which is probably the reason for the relatively large percentage of reaches with no riparian zone. The assessment results for Merryman's Run show that while relatively few reaches have no riparian zone, practically all the reaches have some degree of reduced riparian function.

3.3.2. Subwatershed summaries

In this section impairment summaries for 11 of the subwatersheds are provided. Summaries for three subwatersheds (Merrryman's Branch, Greene Branch, and Overshot Run) are not

Figure 3-3. Overall distribution of stability classes expressed in percent of total miles assessed (class 1: excellent, class 6: very poor)



included because in those subwatersheds less than 2 percent of the assessed reaches had poor or very poor stability ratings.

The subwatershed-level descriptions provide an overview of land use and the stream network in the subwatershed and details on specific impacted reaches. These details include stability, classification, riparian zone assessment, and an analyisis of the environmental setting of the reaches. Impacted reaches were identified primarily on the basis of stability scores, with consideration given to the continuous extent of poor stability (e.g., a single 200-foot section given a poor rating in a stream segment 2,000 feet long would not necessarily be selected as an impacted reach), the stream class (if available), and the riparian zone assessment.

The subwatershed summaries are organized as follows:

1. A brief description of land use and the stream network in the subwatershed, and details on actual linear feet of streams assessed; land use adjacent to assessed reaches; and, if certain targeted reaches were not assessed, reasons for this.
2. The distribution of channel stability assessment for the subwatershed by rating class, and a summary of the stability score, classification, and riparian zone assessment for selected impaired reaches.
3. Additional descriptions of selected reaches, their environmental setting, and maps showing land use, the stream network, and erosion hazard of soils in the subwatershed.

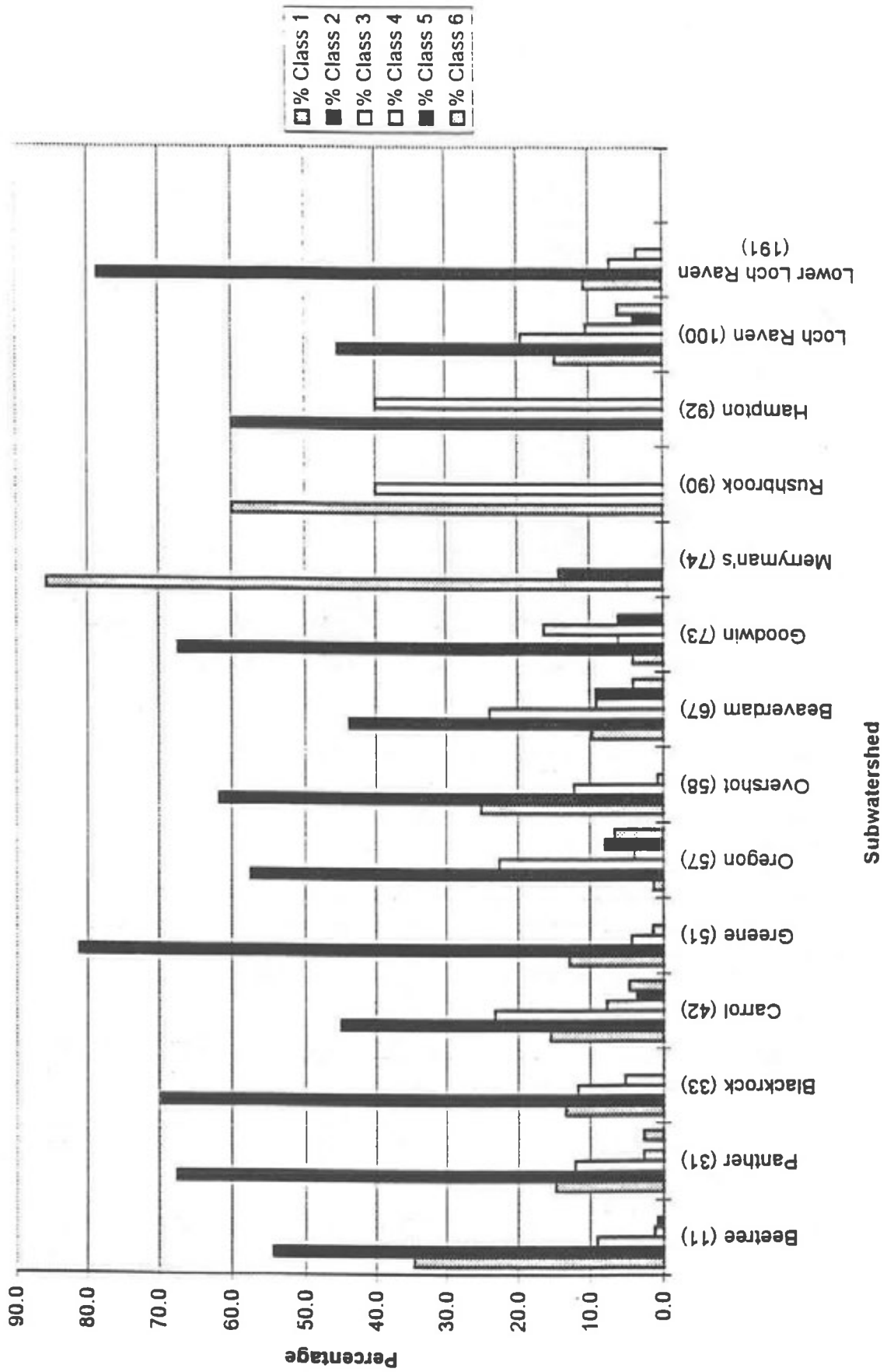
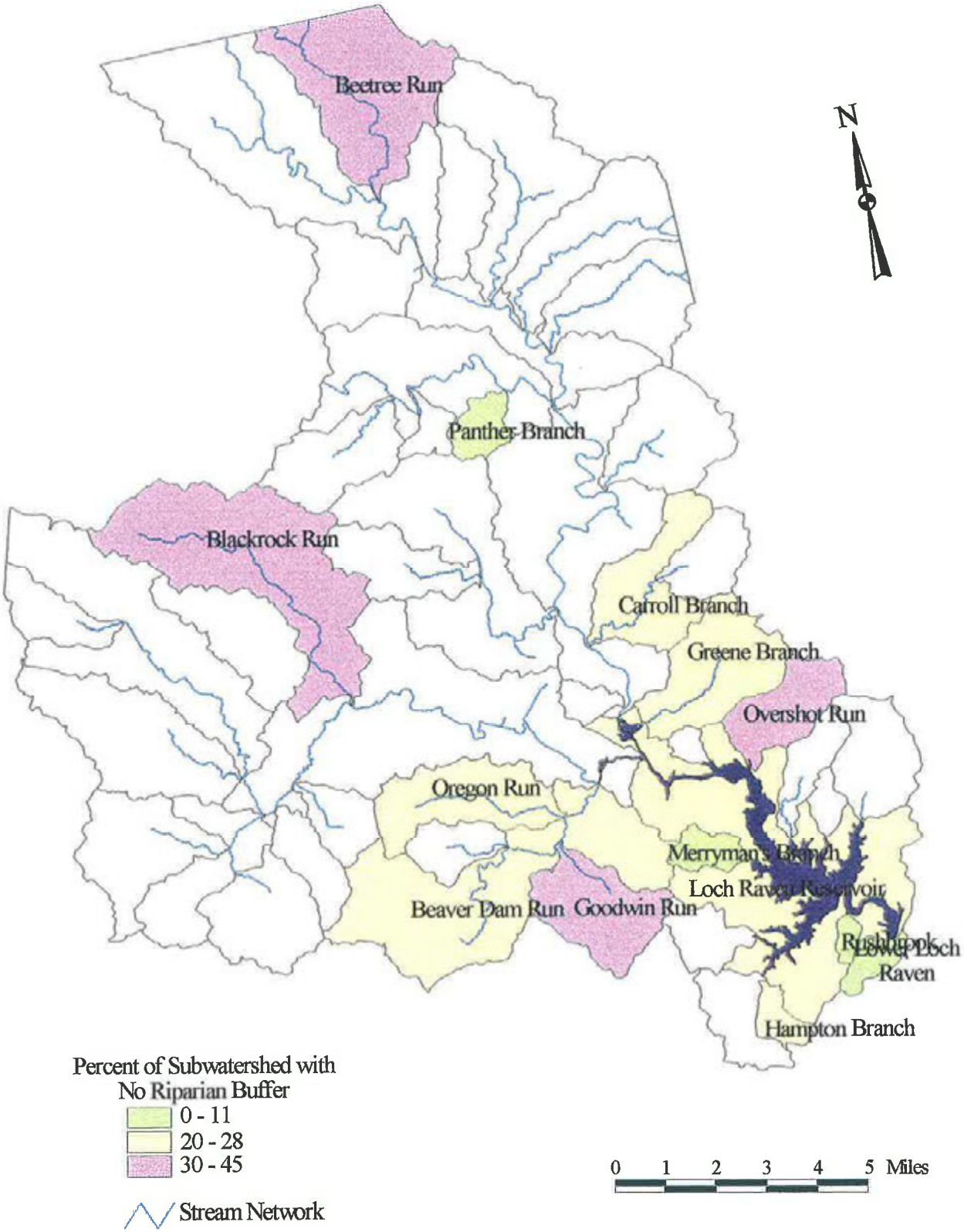


Figure 3-4. Frequency plots of channel stability scores by subwatershed

Loch Raven Study Area

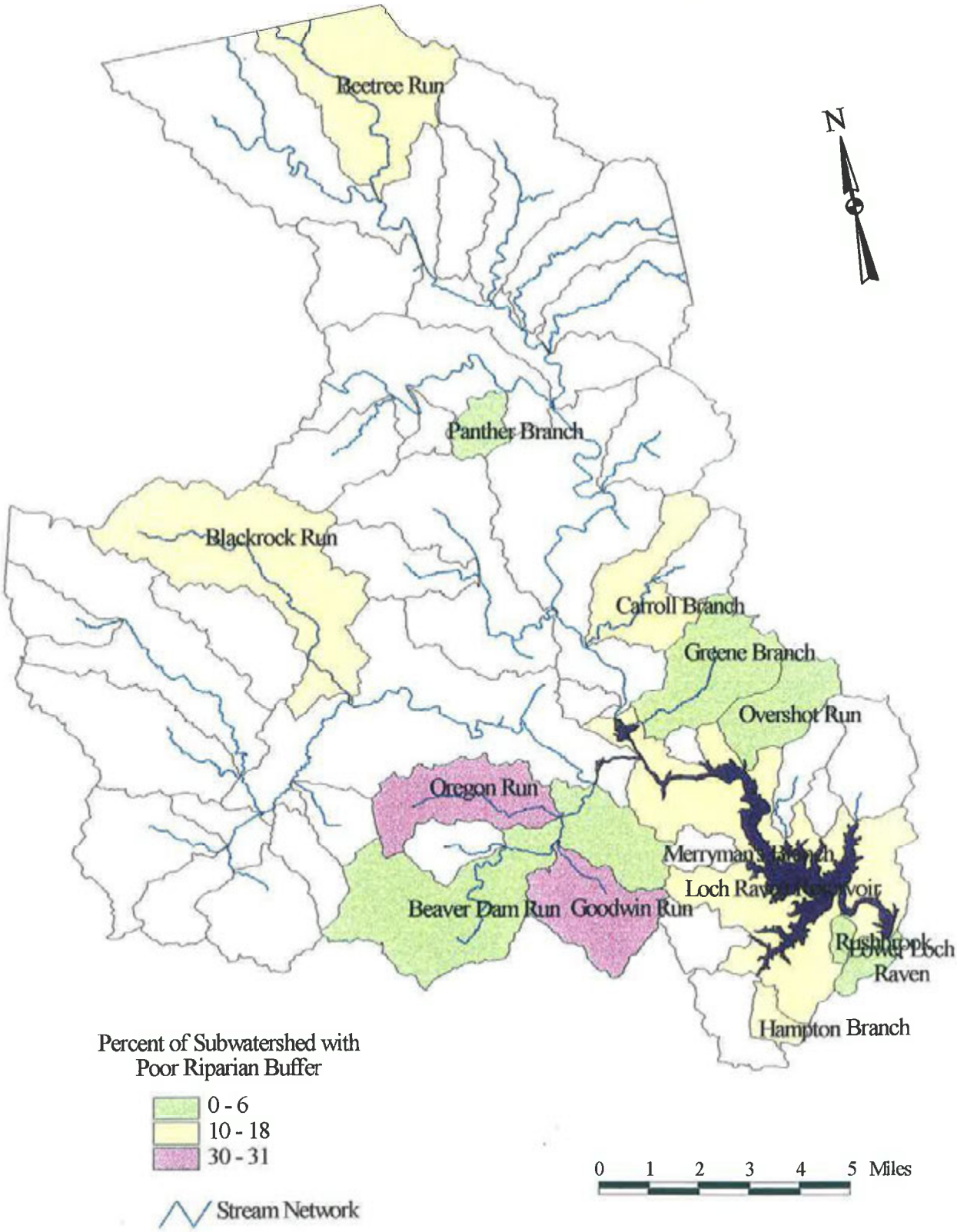
Figure 3-5. Subwatersheds with No Riparian Zone

(% of assessed reaches)



Loch Raven Study Area

Figure 3-6. Subwatersheds with Poor Riparian Buffers
(% of assessed reaches)



Watershed # 11 - Beetree Run

1. Stream Assessment Summary

Beetree Run subwatershed is located in the extreme northern portion of the Loch Raven watershed. The contributing drainage area is 5144 acres. For the most part, land use is split between agriculture and forest (46 percent and 37 percent respectively). Low density residential (15 percent) parkland (1 percent) and urban land uses (1 percent) comprise the remainder of the subwatershed (Figure 11.1.)

Streams draining Beetree Run subwatershed total about 23.37 miles, with 11.80 miles of stream order 1, 7.70 miles of stream order 2, and 3.87 miles of stream order 3. There are no higher order streams. A total of 11.57 miles of stream orders 2 and 3 were targeted for assessment. A total of 11.45 miles were walked in the stream, but it was not possible to access 1.25 miles because access was denied by property owners (0.77 miles), artificial c were present (0.08 miles), and land was overgrown (0.4 miles). The set of streams asses proportionally within the three dominant land uses: forest, low density residential, and agriculture. Figure 11.2 presents a map of the distribution of stream orders within the watershed. Stream segments used in this assessment are identified by their stream identification number.

↑ says "No higher order streams" but map 11.2 seems to show a good stretch of 8.

2. Identification of Impacted Stream Reaches

Overall Assessment: The stream stability ratings were used to identify potentially impaired stream reaches. The overall distribution of stream stability ratings in Beetree Run subwatershed is presented in Table 11.1. Among the 10.20 miles of streams assessed, 88.9 percent (9.07 miles) were rated as excellent to fair condition, 10.3 percent (1.05 miles) were assessed as moderately impaired, and 0.8 percent (0.08 miles) were assessed as substantially impaired.

Table 11.1. Distribution of channel stability assessment results for Beetree Run subwatershed

Rating Class	Rating Qualifier	Distribution	
		Feet	Percent
1	Good/Excellent	18,634	34.6
2	Fair	29,244	54.3
3	Potentially Impaired	4901	9.1
4	Slightly Poor Condition	646	1.2
5	Poor Condition	431	0.8
6	Very Poor Condition	0	0.0

Stability and Classification Assessment: Using the stability rating results and analyzing field data for the stream classification, three impaired stream reaches were identified. Table 11.2 presents the three stream segments and approximate location and linear distance of

impaired reaches within each segment. This table also presents the results of the stream classification results for each reach. Among the 1625 linear feet identified as impaired based on the stability ratings, 2/3 were classified as G streams. The remaining 1/3 were B streams.

Table 11.2. Stream stability ratings and classification of the selected impaired reaches

Stream Segment	Reach No.	Location (feet)		Length (feet)	Stream Order	Evaluation	
		From	To			Stability	Class
183	1	0	800	800	3	1-5	G4c
994	1	0	275	275	3	4	B5c
994	3	425	550	550	3	3-4	G4c

Riparian Buffer Assessment of Selected Stream Reaches: All of the selected stream reaches have little or no riparian buffer. Reaches 994-1 and 994-3 have no riparian buffer and therefore were rated very poor. Reach 183 received a slightly better rating because limited, sparse riparian vegetation exists on portions of the reach. Table 11.3 presents a summary of riparian buffer ratings for the three stream reaches selected as impaired. The lack of any significant riparian buffer indicates that impairment of the stream reaches may be due to severe local erosion resulting from riparian clearing and riparian zone disturbance.

Table 11.3. Riparian buffer ratings for the selected impaired stream reaches

Stream Segment	Riparian Ratings		Stream Segment	Riparian Ratings	
	Right Bank	Left Bank		Right Bank	Left Bank
183	Poor (D7/O)	Poor (D7/O)	994-3	Very Poor (O)	Very Poor (O)
994-1	Very Poor (O)	Very Poor (O)			

Description of Individual Reaches: The following presents additional descriptions of the selected streams and their environmental setting.

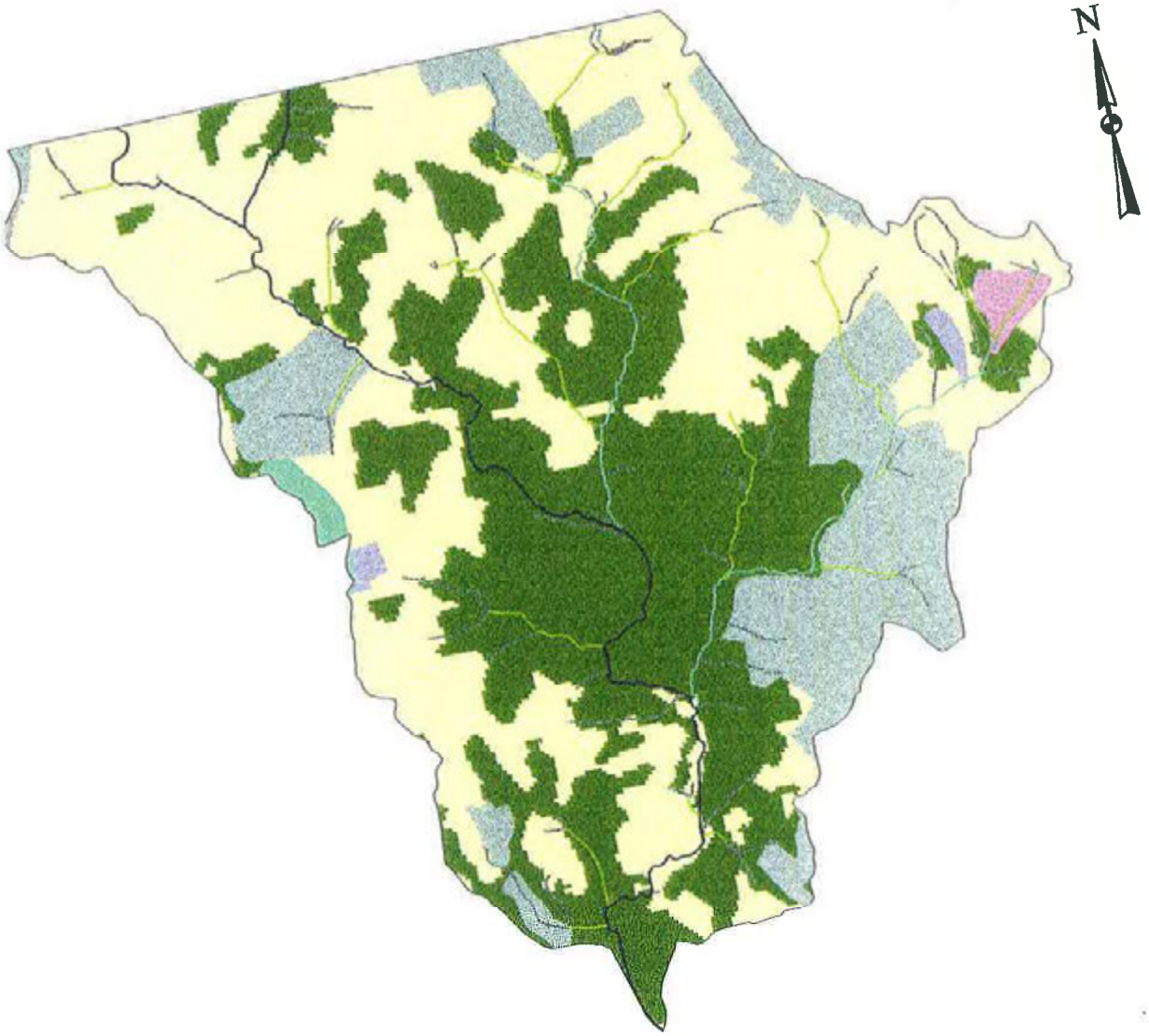
Stream reach 183: This type G4c reach is 800 feet long and has been given a stability rating ranging from stable to very unstable (Table 11.2). The very unstable portion is from 400 to 800 feet (400 feet total) and was rated as such due to high bank slope, small bank particle size, a large amount of obstructions within the channel, severe bank cutting and marked changes in particle size on the channel bottom. The type rating is a result of high entrenchment with a moderate to low slope, and moderate sinuosity. Deep rooted riparian vegetation was limited for 600 feet and absent for 200 feet (Table 11.3). According to the land use map (Figure 11.1) the reach is in an agricultural land use designation, however, field observations describe a series of three roads upstream; one of which is Highway 83. The drainage from the highway flows into the stream and is possibly causing the erosion problems indicated by the stability rating. Further upstream (above the reach) is industrial use area. This could also be causing increased flood flows due to impermeability.

Stream reach 994-1: Reach 994-1 is the first of three reaches which compose segment 994. Reach 994-3 is upstream and is significantly impaired as well (see Figure 11.2). Stream reach 994-1 has been rated somewhat unstable due to high bank slope, small sized bank particles, and a large amount of scour and deposition. The stream at this reach is type is B5c (Table 11.2). The lack of riparian vegetation (Table 11.3) and a high soil erosion hazard (Figure 11.3) both on the reach and immediately upstream could be partially responsible for the large amount of erosion and deposition. Land use surrounding the reach is designated as forest, with low density residential immediately to the west of the forest (refer to Figure 11.1). Field notes also indicate that there is a beaver dam just upstream from the reach, which has inundated the channel for 600 feet.

Stream reach 994-3: Reach 994-3 has been rated somewhat unstable as a result of steep bank slopes, small bank particle size, and numerous obstructions within the stream channel. This reach is type G4c due to low slope, moderate sinuosity, and high entrenchment. Although the land use indicates that the reach is surrounded by forest, there is no riparian buffer. Also, a low density residential land use designation is immediately to the west of the forest (Figure 11.1), and upstream portions flow through the low density residential areas. As a result of the residential areas, there is one minor storm water outfall approximately one mile upstream (see Figure 11.4).

Beetree Run

Figure 11.1 1993 Baltimore Office of Planning and Zoning



1993 Landuse

- Single Family Detached
- Single Family Attached
- Multi-Family
- Commercial
- Office
- Regional Commercial
- Industrial
- Institutional
- Park / Recreational
- Agriculture /Open Space
- Forest
- Undeveloped
- Pipe - Single Family Detached
- Pipe - Single Family Attached
- Pipe - Commercial
- Pipe - Office
- Water

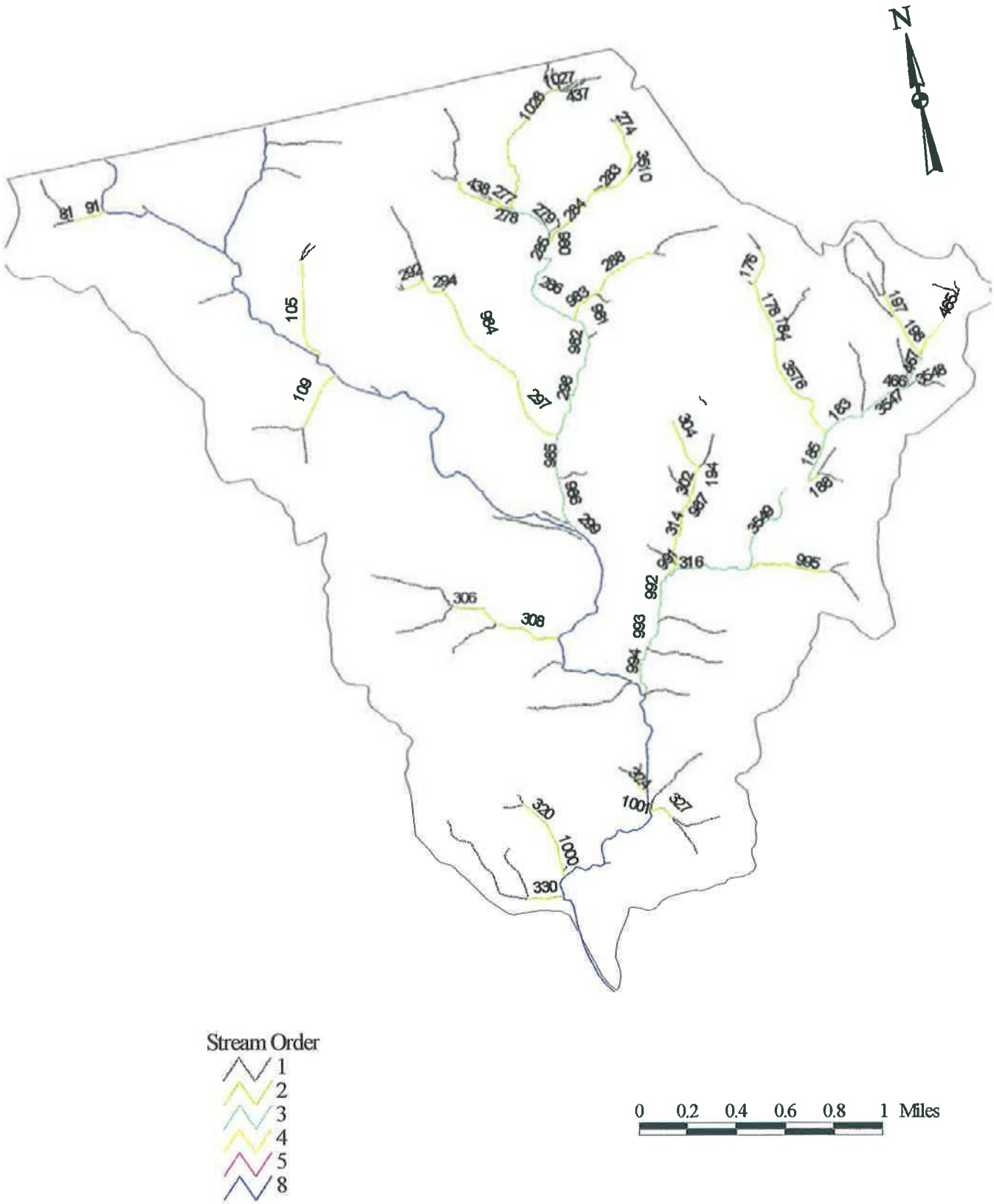
Stream Order

- 1
- 2
- 3
- 4
- 5
- 8

0 0.2 0.4 Miles

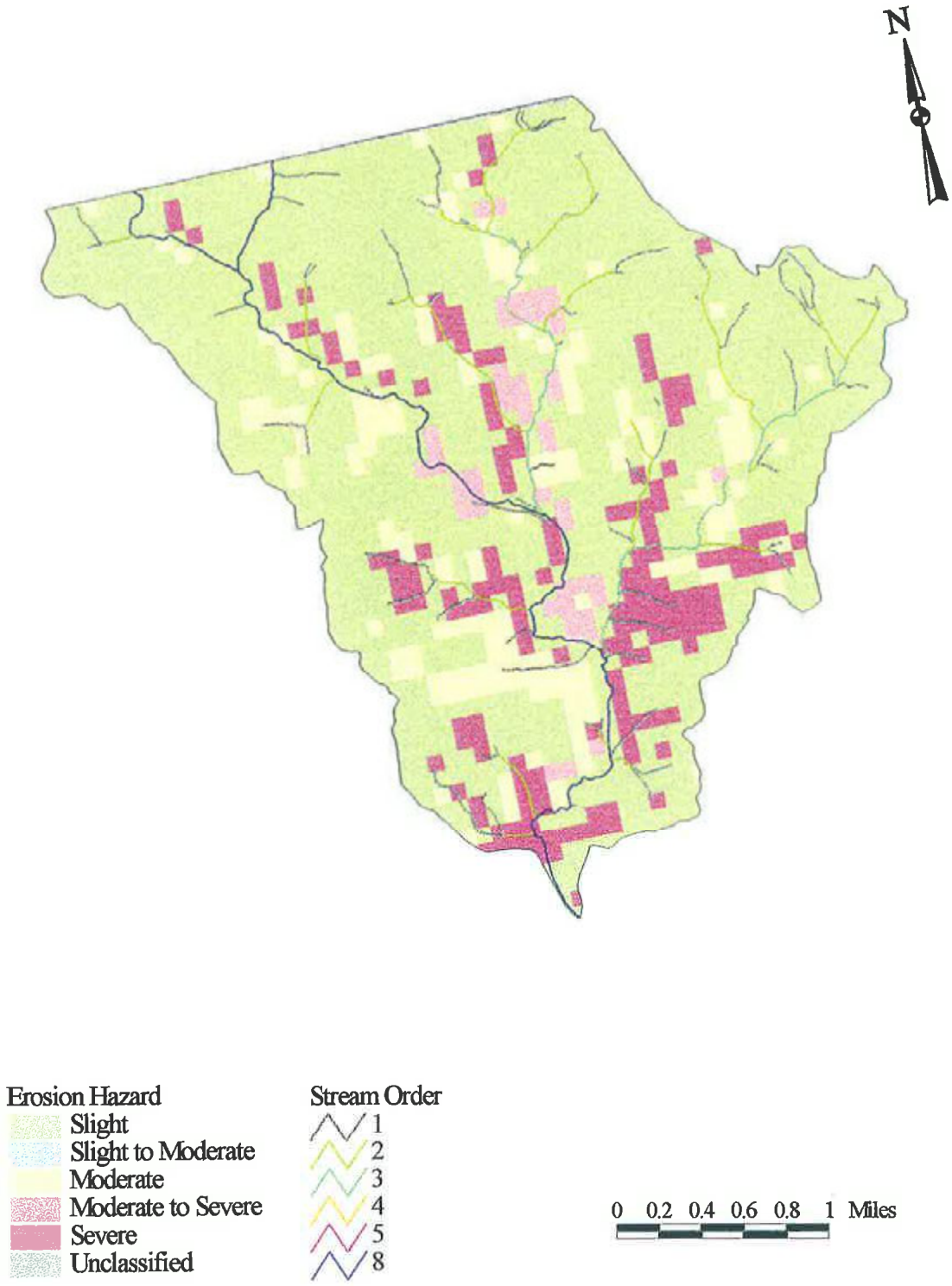
Beetree Run Subwatershed

Figure 11.2 Stream Order and Reach Segment ID



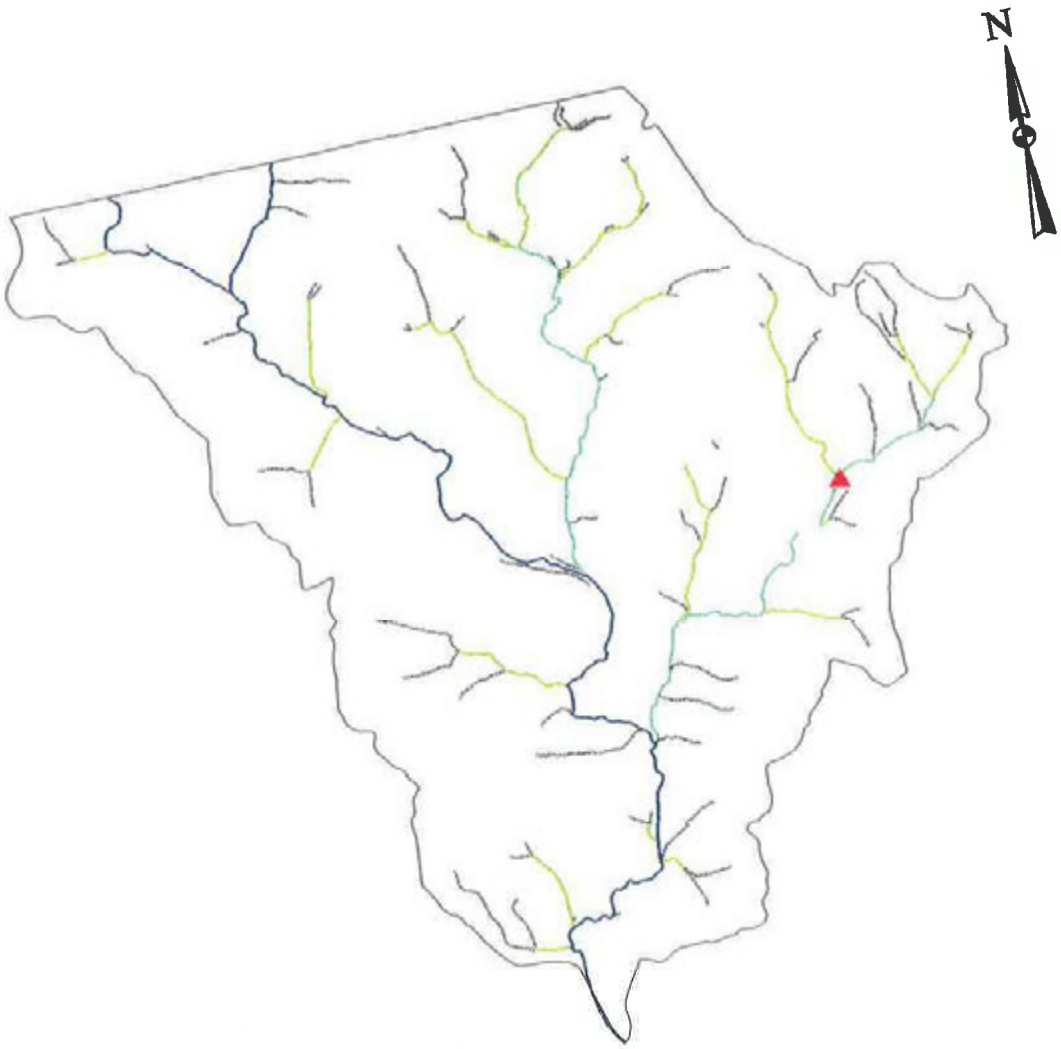
Beetree Run Subwatershed

Figure 11.3 Erosion Hazard



Beetree Run Subwatershed

Figure 11.4 Major and Minor Outfalls, SWM Facilities



Stormwater Management Facilities
Minor Outfalls
Major Outfalls

Stream Order
1
2
3
4
5
8

0 0.2 0.4 0.6 0.8 1 Miles

Watershed # 31 - Panther Branch

1. Stream Assessment Summary

The Panther Branch subwatershed is located in the central portion of the Loch Raven watershed, adjacent to the reservoir. The contributing drainage area is 740 acres. A large portion of this subwatershed has been designated as parkland (40 percent.) The remainder is fairly evenly split between agriculture (16 percent) forest (13 percent) low density residential (12 percent) and urban land uses (19 percent, Figure 31.1.)

Streams draining the Panther Branch subwatershed total almost 5.5 miles, with 3.11 miles o: stream order 1, 1.31 miles of stream order 2, and 1.05 miles of stream order 3. All of the stre: orders 2 and 3 were selected for this assessment, totaling 2.36 miles. A total of 2.45 stream miles were walked, with approximately 0.20 miles not fully assessed due to dry channel conditions. Land use within this watershed is varied. The set of stream reaches assessed refl this variation. Figure 31.2 presents a map of the distribution of stream orders within the watershed. Stream segments used in this assessment are identified by their stream identification number.

2. Identification of Impacted Stream Reaches

Overall Assessment: The stream stability ratings were used to identify potentially impaired stream reaches. The overall distribution of stream stability ratings in Panther Branch subwatershed is presented in Table 31.1. Among the 2.25 miles of streams assessed, 82.5 percent (1.84 miles) were rated as excellent to fair, 14.9 percent (0.33 miles) were assessed as having a moderately impaired condition and 2.7 percent (0.06 miles) were assessed as having a substantially impaired condition. Figure 31.3 presents a map of the distribution of erosion hazard within the watershed.

Table 31.1. Distribution of channel stability assessment results for Panther Branch subwatershed

Rating Class	Rating Qualifier	Distribution	
		Feet	Percent
1	Good/Excellent	1754	14.9
2	Fair	7959	67.6
3	Potentially impaired	1436	12.2
4	Slightly Poor Condition	318	2.7
5	Poor Condition	0	0.0
6	Very Poor Condition	318	2.7

Stability and Classification Assessment: Using the stability rating results and analyzing field data for the stream classification, two impaired stream reaches were identified. Table 31.2 presents the three stream segments and approximate location and linear distance of impaired reaches within each segment. This table also presents the results of the stream

classification results for each reach. Among the 491 linear feet identified as impaired based on the stability ratings, one reach was classified as a G4 and the other as F/B5.

Table 31.2. Stream stability ratings and classification of the selected impaired reaches

Stream Segment	Reach No.	Location (feet)		Length (feet)	Stream Order	Evaluation	
		From	To			Stability	Class
3558	4	400	775	375	2	6	G4
3558	5	775	891	116	2	6	F/B5

Riparian Buffer Assessment of Selected Stream Reaches: Both stream reaches 3558-4 and 3558-5 were rated fair because the riparian buffer width and density ranges from fairly extensive to very limited. Table 31.3 presents a summary of riparian buffer ratings for the two stream reaches selected as impaired. The variation of the riparian buffer indicates that potential causes of impairment could be a combination of local and upstream impacts.

Table 31.3. Riparian buffer ratings for the selected impaired stream reaches

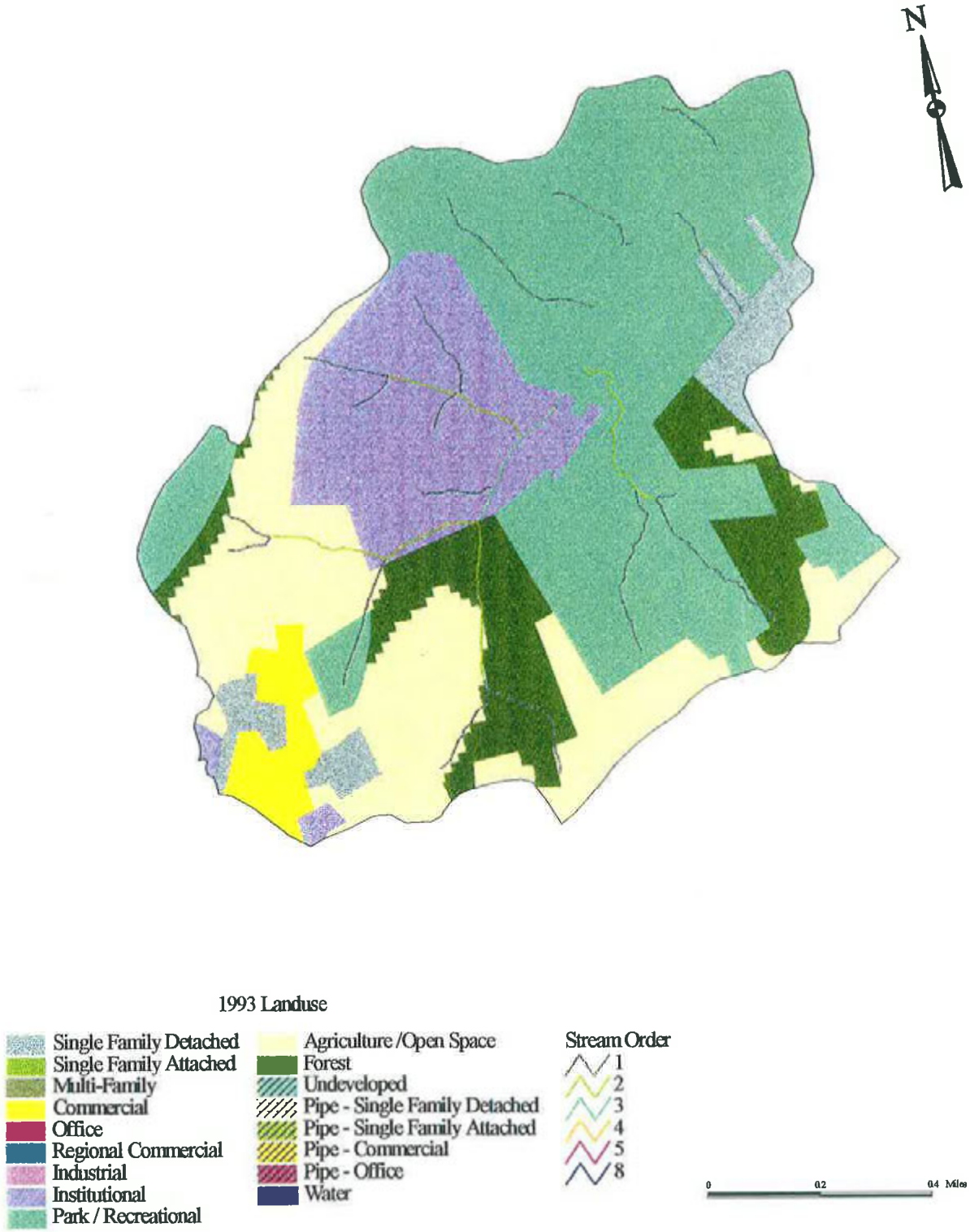
Stream Segment	Riparian Ratings		Stream Segment	Riparian Ratings	
	Right Bank	Left Bank		Right Bank	Left Bank
3558-4	Fair (D3/D10)	Fair (D3/D10)	3558-5	Fair (D3/D10)	Fair (D3/D10)

Description of Individual Reaches: The following presents additional description of the selected stream and their environmental setting.

Stream reaches 3558-4, 3558-5: Reaches 3558-4 and 3558-5 are both identified as very unstable (Table 31.2). They have been combined because the total length is only 491 feet. Multiple cross-sections were measured along this entire stream reach (3558), particularly in the most degraded sections. The cross-section show alternating G and F channels. The primary indicators responsible for the unstable rating are: a high potential for debris jams, numerous obstructions within the stream channel, failing banks, undercut tree roots, highly angular rocks with mostly bright surfaces. A stormwater management facility is located upstream of this reach (Figure 31.4). Riparian buffers range from a wide band to virtually no riparian buffer (D10) (Table 31.3). These stream reaches pass through an institutional land use designation (Figure 31.1) which continues upstream.

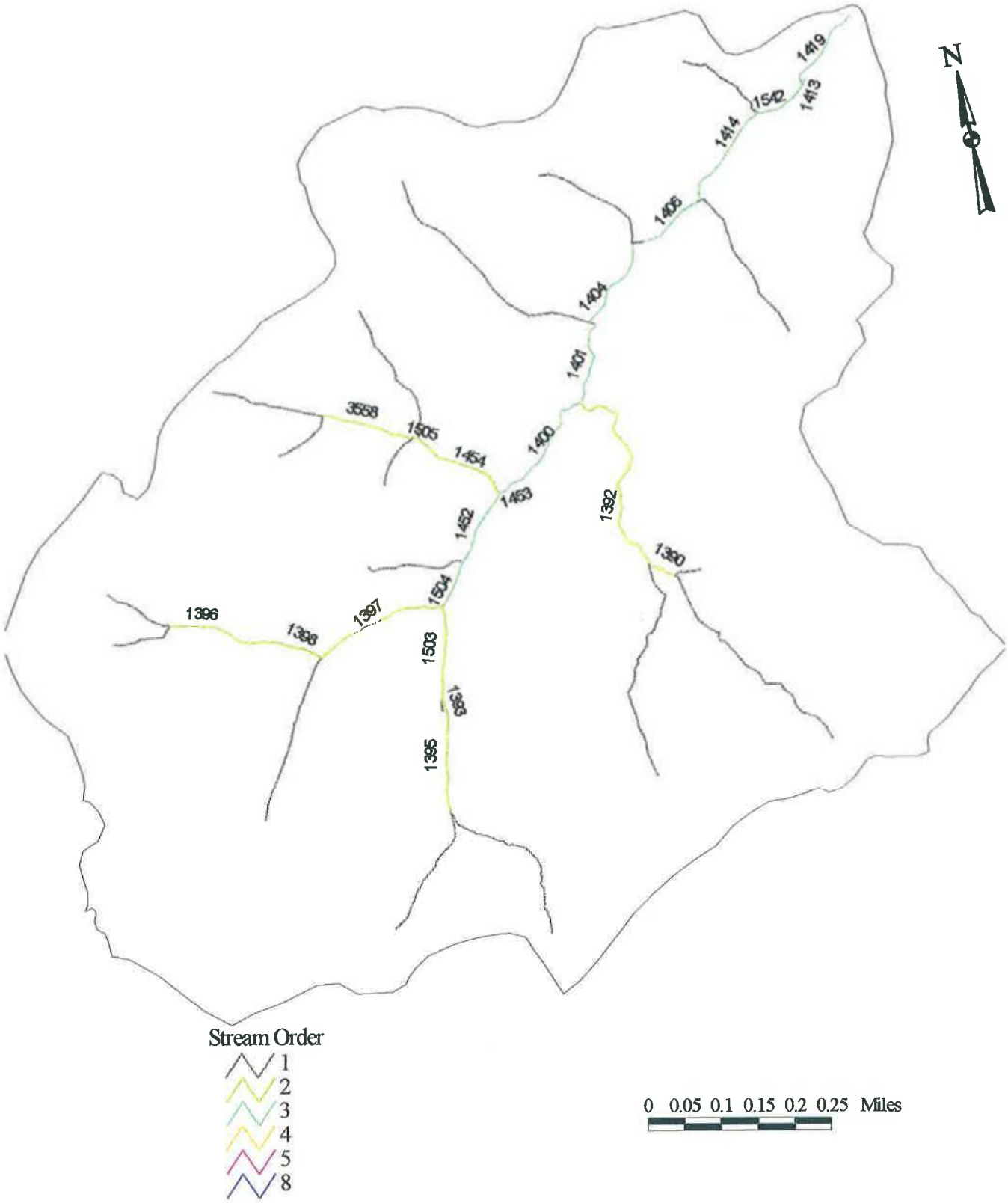
Panther Branch

Figure 31.1 1993 Baltimore Office of Planning and Zoning



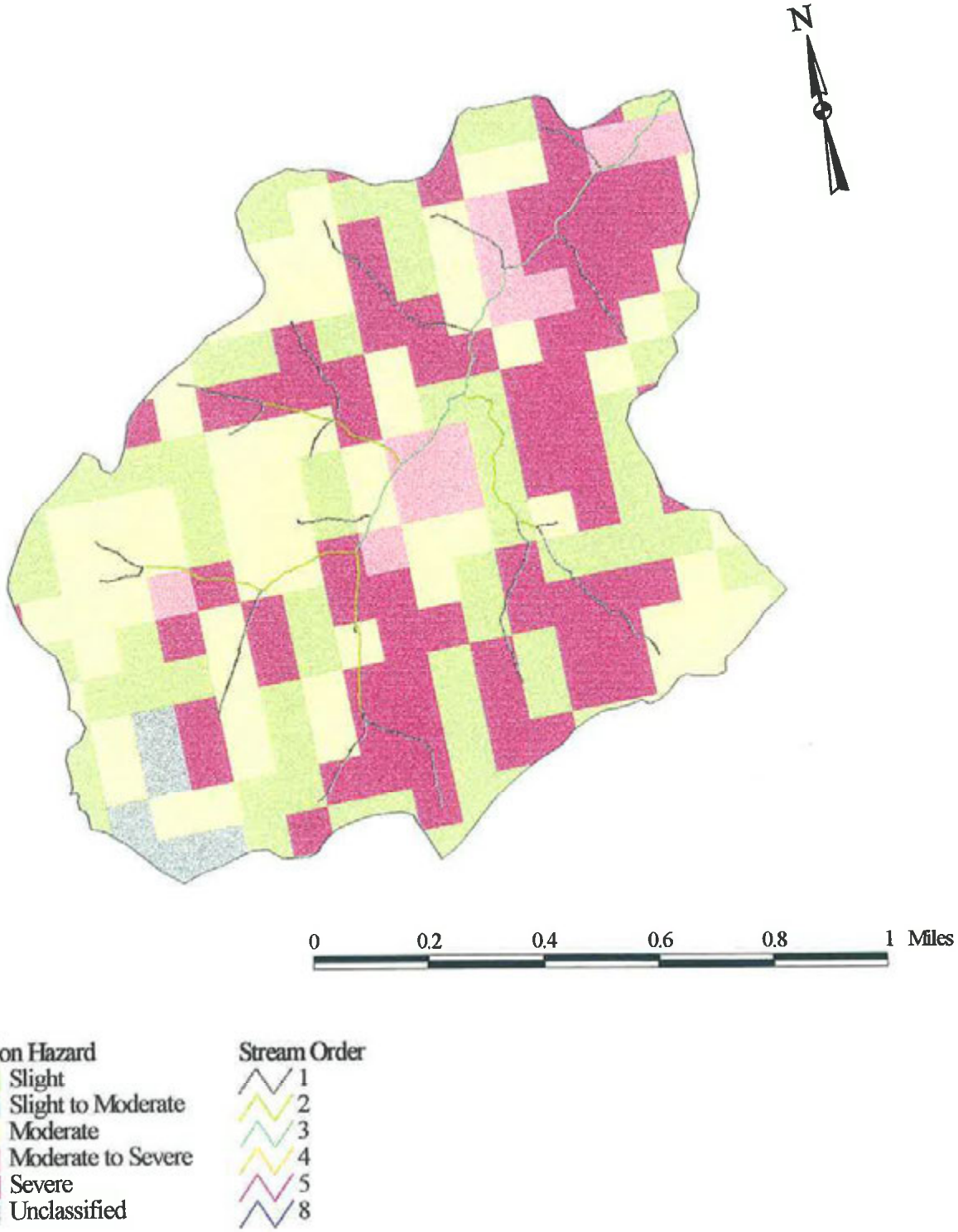
Panther Branch Subwatershed

Figure 31.2 Stream Order and Reach Segment ID



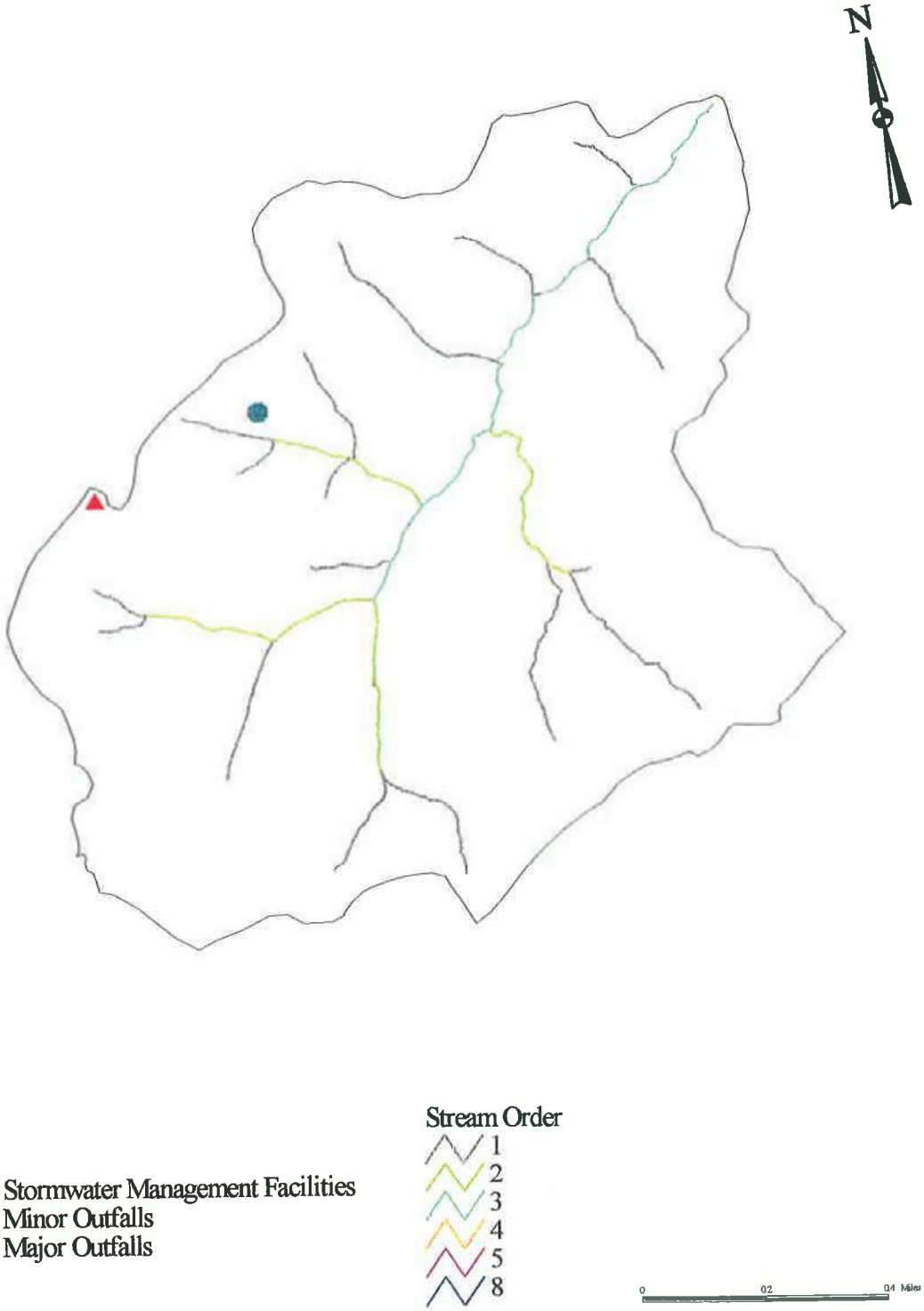
Panther Branch Subwatershed

Figure 31.3 **Erosion Hazard**



Panther Branch Subwatershed

Figure 31.4 Major and Minor Outfalls, SWM Facilities



Watershed # 42 - Carroll Branch

1. Stream Assessment Summary

Carroll Branch subwatershed is located in the central portion of the Loch Raven watershed. The contributing drainage area includes the 2565 acre Carroll Branch subwatershed as well as inflows from upstream headwater streams of the My Ladies Manor Branch (43) subwatershed. My Ladies Manor Branch has a drainage area of 1328 acres The Carroll Branch was selected for evaluation partially due to low forest coverage (20 percent) and intensive agricultural land uses (60 percent) representative of rural areas of the Loch Raven. Low density urban development represents a significant land use of the southern portion of the subwatershed as shown in Figure 42.1.

Over 19 miles of streams drain Carroll Branch subwatershed, with 9.11 miles of stream order 4.8 miles of stream order 2, 2.36 miles of stream order 3, and about 3 miles of higher order streams. All of the stream orders 2 and 3 (7.16 miles) were targeted for assessment. A total o 7.33 stream miles were walked, with a very limited portion (0.33 miles) not fully assessed due denied access by property owners (0.14 miles), dry stream bed (0.10), and impounded channel (0.09 miles). The set of stream reaches assessed lies proportionally within the three dominant land uses: agriculture, forest, and low density residential. Figure 42.2 presents a map of the distribution of stream orders within the watershed. Stream segments used in this assessmen are identified by their stream identification number.

2. Identification of Impacted Stream Reaches

Overall Assessment: The stream stability ratings were used to identify potentially impaired stream reaches. The overall distribution of stream stability ratings in Carroll Branch subwatershed is presented in Table 42.1. Among the 7 miles of streams assessed, over 60 percent were rated as excellent to good. However, over 16 percent (1.12 miles) were rated slightly to very poor and 23 percent (1.60 miles) were assessed as having a fair condition.

Table 42.1. Distribution of channel stability assessment results for Carroll Branch subwatershed

Rating Class	Rating Qualifier	Distribution	
		Feet	Percent
1	Good/Excellent	4250	15.5
2	Fair	16,669	45.1
3	Potentially impaired	8612	23.3
4	Slightly Poor Condition	2883	7.8
5	Poor Condition	1331	3.6
6	Very Poor Condition	1737	4.7

Stability and Classification Assessment: Using the stability rating results and analyzing field data for the stream classification, eight impaired stream reaches were identified. Table 42.2 presents the eight stream segments and approximate location and linear distance of impaired reaches within each segment. This table also presents the results of the stream classification results for each reach. Among the 11,200 linear feet identified as impaired based on the stability ratings, over 50 percent were classified as F streams. The remaining reaches were G and B streams.

Table 42.2. Stream stability ratings and classification of the selected impaired reaches

Stream Segment	Reach No.	Location (feet)		Length (feet)	Stream Order	Evaluation	
		From	To			Stability	Class
3061	1	0	350	350	2	6	F
3063	1	0	750	750	2	3-4	B5c
3081	1	0	650	650	3	3	F5b
3088	3			400	2	4	F4b
3297	1	0	2900	2900	3	3-6	F4b
3301	1	0	1700	1700	2	3-6	G5c
3402	1	0	2900	2900	3	3	B3/G3
3409	1	0	1550	1550	2	4	F4b

Riparian Buffer Assessment of Selected Stream Reaches: Most of the selected stream reaches have an excellent to fair riparian buffer. In fact, five out of the eight stream reaches selected (3061, 3081, 3088, 3297, and 3409), representing 50 percent of total linear feet of impaired reaches, have an excellent to good riparian cover. However, stream reaches 3301 and 3402 were rated very poor due to either absence or very limited rooted buffer. Table 42.3 presents a summary of riparian buffer ratings for the eight stream reaches selected as impaired. The existence of an appropriate riparian buffer indicates that potential causes of stream instability are due to inflows of sediment and/or increase in streamflow due to changes in the condition of the upstream drainage area.

Table 42.3. Riparian buffer ratings for the selected impaired stream reaches

Stream Segment	Riparian Ratings		Stream Segment	Riparian Ratings	
	Right Bank	Left Bank		Right Bank	Left bank
3061	Good (D2)	Good (D2)	3297	Good (D3)	Good (D2)
3063	Poor (D6)	Poor (D6)	3301	Very Poor (O)	Very Poor (O/D7)

Stream Segment	Riparian Ratings		Stream Segment	Riparian Ratings	
	Right Bank	Left Bank		Right Bank	Left bank
3081	Good (D2)	Good (D2)	3402	Poor (D7/SS3)	Poor (D6/SS4)
3088	Fair (D4)	Fair (D5)	3409	Fair (D4)	Fair (D4)

Description of Individual Reaches: The following section presents additional descriptions of the selected stream and their environmental setting.

Stream reach 3061: This 350 foot type F stream reach is very degraded as shown in the stability ratings in Table 42.2. Although the stream has an extensive riparian buffer (Table 42.3), the surrounding land is used for crops. The specific characteristics of the channel which led to the conclusion of instability are: steep bank slopes, small bank particle size, severe bank cutting, an unconsolidated channel bottom, marked particle size changes in the channel bottom, and a high amount of scour and deposition. High entrenchment combined with gradual slope resulted in the classification of the stream as type F. These indicators of channel instability combined with a high quality riparian zone indicate that upstream alterations to the riparian zone and stream channel may be contributing factors. Upstream pasture land on soils with a high erosion hazard could be a source of sediment and therefore impairment of this stream reach (Figures 42.1 and 42.3).

Stream reach 3063: Reach 3063 (750 feet) is relatively stable (type B5c, class 3-4; see Table 42.2) but has been chosen as a potentially impaired reach because of severe localized damage to the stream channel. The field observations indicate that there is locally severe bank erosion up to six feet high. The specific channel characteristics measured in the field which were the greatest factors in decreasing the stability rating are: steep bank slope, a high potential for debris jams, small bank particle size, and numerous obstructions in the stream channel. A failing culvert was also noted at the upstream end of the reach. Other potential sources of channel degradation include: limited riparian buffers, pastureland uses close to the stream reach, upstream land use of crop land, and soils with a high erosion hazards.

Stream reach 3081: This reach has also been given a relatively stable channel stability rating (class 3) but is a type F5b stream (Table 42.2), indicating channel degradation potential due to high entrenchment with a low slope. The reach, which is 650 feet long, is located in a forested area with a dense riparian zone (Table 42.3). Upstream the tributaries flow through agricultural and forested land, and the southern tributary is bounded on the left side by low density residential. A significantly impaired reach (3409) is on the northern tributary to 3081 (see Figure 42.2). Steep bank slope is noted as the greatest parameter contributing to a poor stability rating. The causes of the impairment in this reach could be a compounded result of the various land use practices in the upstream drainage area (Table 42.4).

Stream reach 3088: This relatively stable 400 foot stream reach is a type F4b channel (Table 42.2) due to relatively high entrenchment with shallow slopes. The riparian buffer zone is fairly extensive (see Table 42.3) with the exception of a stretch of riprap lined channel with no riparian vegetation through an easement. High bank slope and a high amount of bank deposition are the primary contributors to the stability rating of

class 4. Also, there is a high soil erosion hazard both on site and upstream. These conditions, plus the fact that the tributaries and a portion of the headwaters are in low density residential are possible causes of stream channel degradation. Also mapped (see Figure 42.4) are two storm water outfalls upstream from the reach within the residential area.

Stream reach 3297: This 2900 foot reach is located downstream from 3081 (described above) and 3409 (described last); see Figure 42.2. It is very unstable (Table 42.2) and has been classified as type F4b with small portions of type B. The surrounding riparian zone is substantial (Table 42.3), and is bordered by a forest land use designation (Table 42.3). Low channel slope with a high entrenchment, as well as high bank slope, a high debris jam potential, a large amount of bank deposition, marked changes in channel bottom particle sizes, and scour and deposition have resulted in the degraded stability and type ratings. Furthermore the soil erosion hazard is high (Figure 42.3) both in the immediate area and upstream. The only specific problem noted in the field is a stock crossing at 800 feet. The impairment of this stream is probably associated with upstream agricultural land uses and nearby low density residential land uses, as well as two significantly impaired upstream reaches.

Stream Reach 3301: Reach 3301 is 1700 feet long and is designated as very unstable (Table 42.2). It is a type G5c with little to no riparian buffer as described in Table 42.3. The slope of the stream is low but it is entrenched with moderate sinuosity. The primary factors resulting in the instability rating are: a large amount of mass wasting, little bank protection by vegetation, a high amount of bank cutting, and marked changes in particle sizes on the stream channel bottom. The reach is located entirely in a low density residential land use area (Figure 42.1) and the upstream reaches are also in this land use designation. The tributaries flow through agricultural land use areas. Field observations indicate that the lack of riparian habitat is a result of clearing for residential lawns. Also noted in the field is a pond which is 450 feet from the upstream end of the reach. As well as the conditions noted in the field, the causes of the impairment could be: soils with a high erosion hazard both immediately and upstream (Figure 42.3) and development in the residential areas.

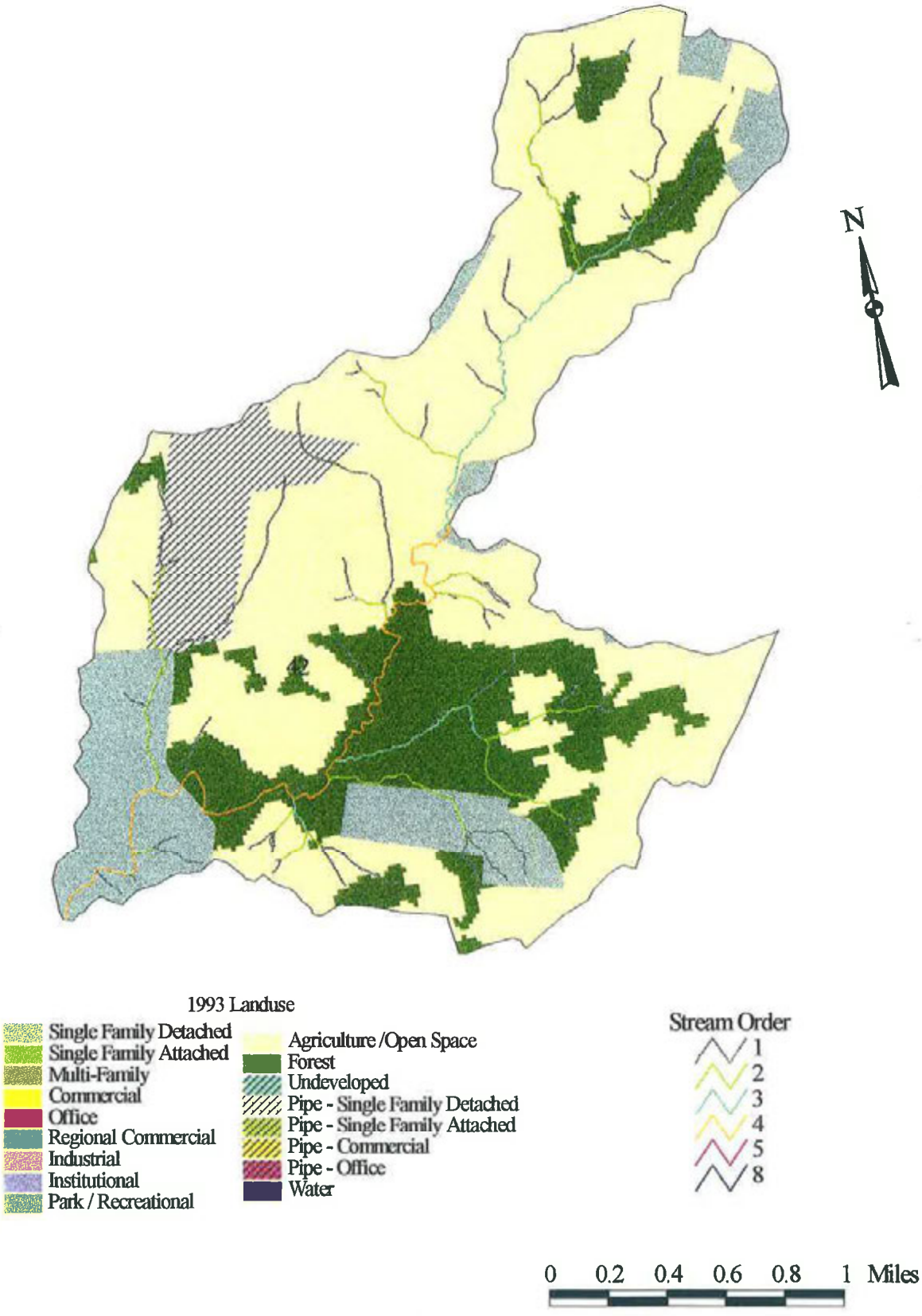
Stream reach 3402: This type B3/G3 stream reach which extends for 2900 feet is relatively stable (Table 42.2). The B3/G3 type rating indicates that the stream is actively degrading due to increasing entrenchment on a shallow slope. The riparian zone is significantly impacted, and has been rated poor (Table 42.3). Land use in the immediate area is pasture and the three contiguous upstream reaches (3403, 3404, 3405) are located in an agricultural area with feedlots and associated buildings (Figure 42.1). Also, immediately to the east of the reach is a low density residential area. The field observations indicate that there is stock access at 2000 feet and that the stream flows through a pasture and horse farm. Both the immediate and upstream conditions may be contributing to the impairment of this reach.

Stream reach 3409: Reach 3409 is 1550 feet long and is relatively stable, but has been classified as type F4b (Table 42.2), indicating low channel slope, high sinuosity, and high entrenchment. The riparian buffer is substantial and is surrounded by a forest land use designation mapped in Figure 42.1. The slightly decreased stability rating is a result of a steep bank slope and significant evidence of mass wasting. These poor stability rating parameters could be a result of a high soil erosion hazard within

the reach (Figure 42.3). Field comments indicate that there are two abandoned stream channels at 1200 feet, which could be evidence of stream migration or artificial channel alteration.

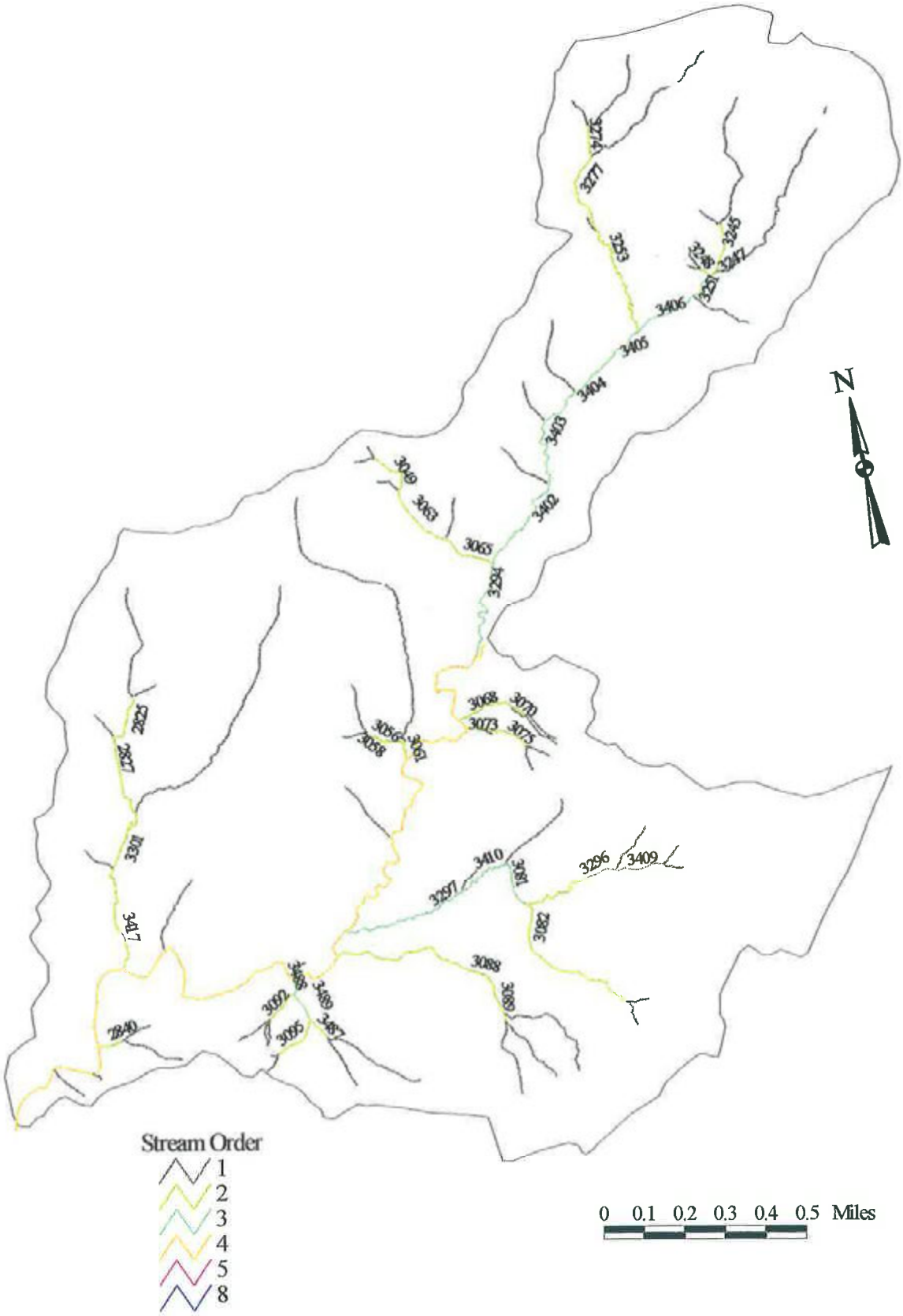
Carroll Branch Subwatershed

Figure 42.1 **1993 Baltimore Office of Planning and Zoning**



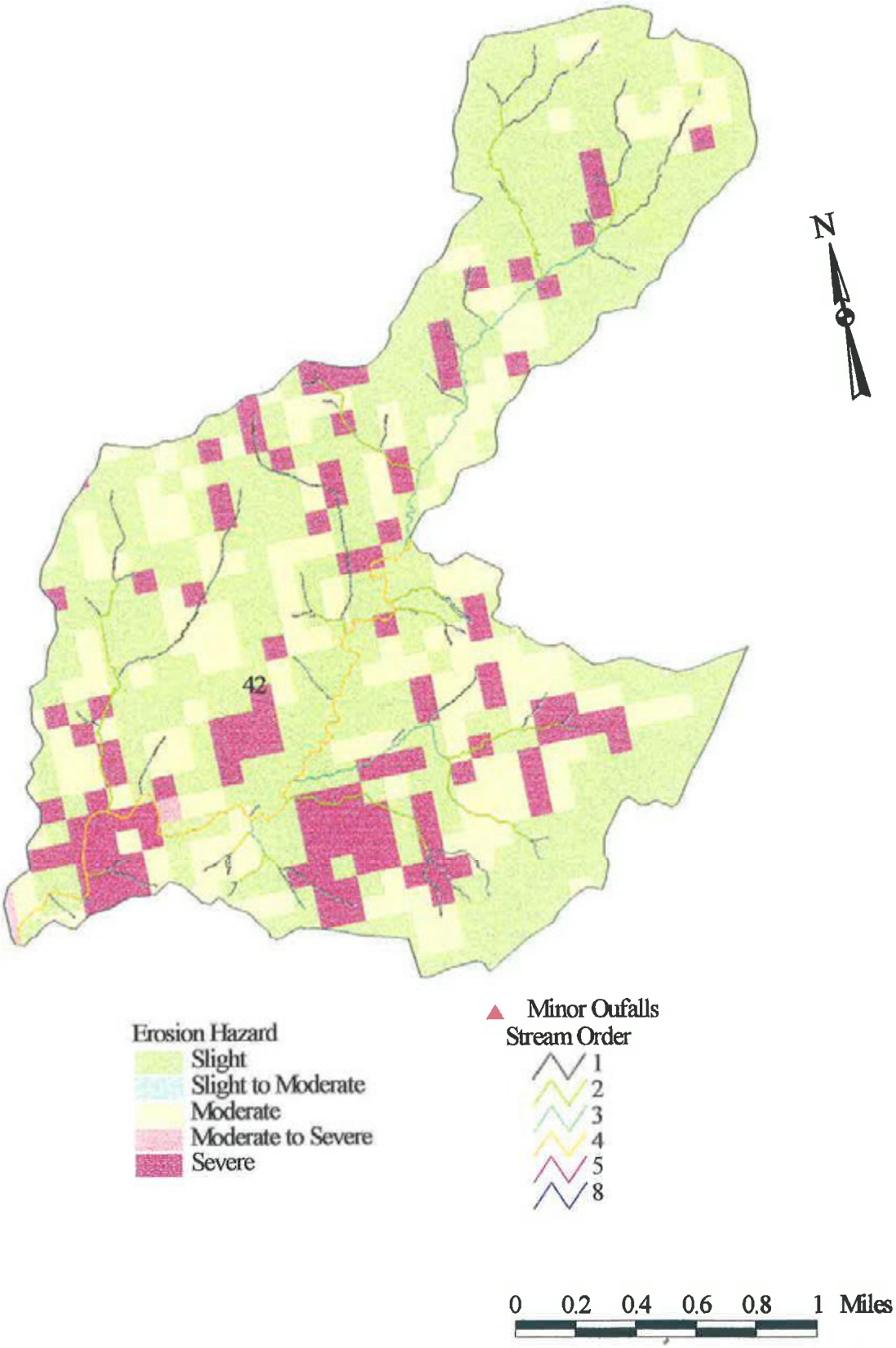
Carroll Branch Subwatershed

Figure 42.2 Stream Order and Reach Segment ID



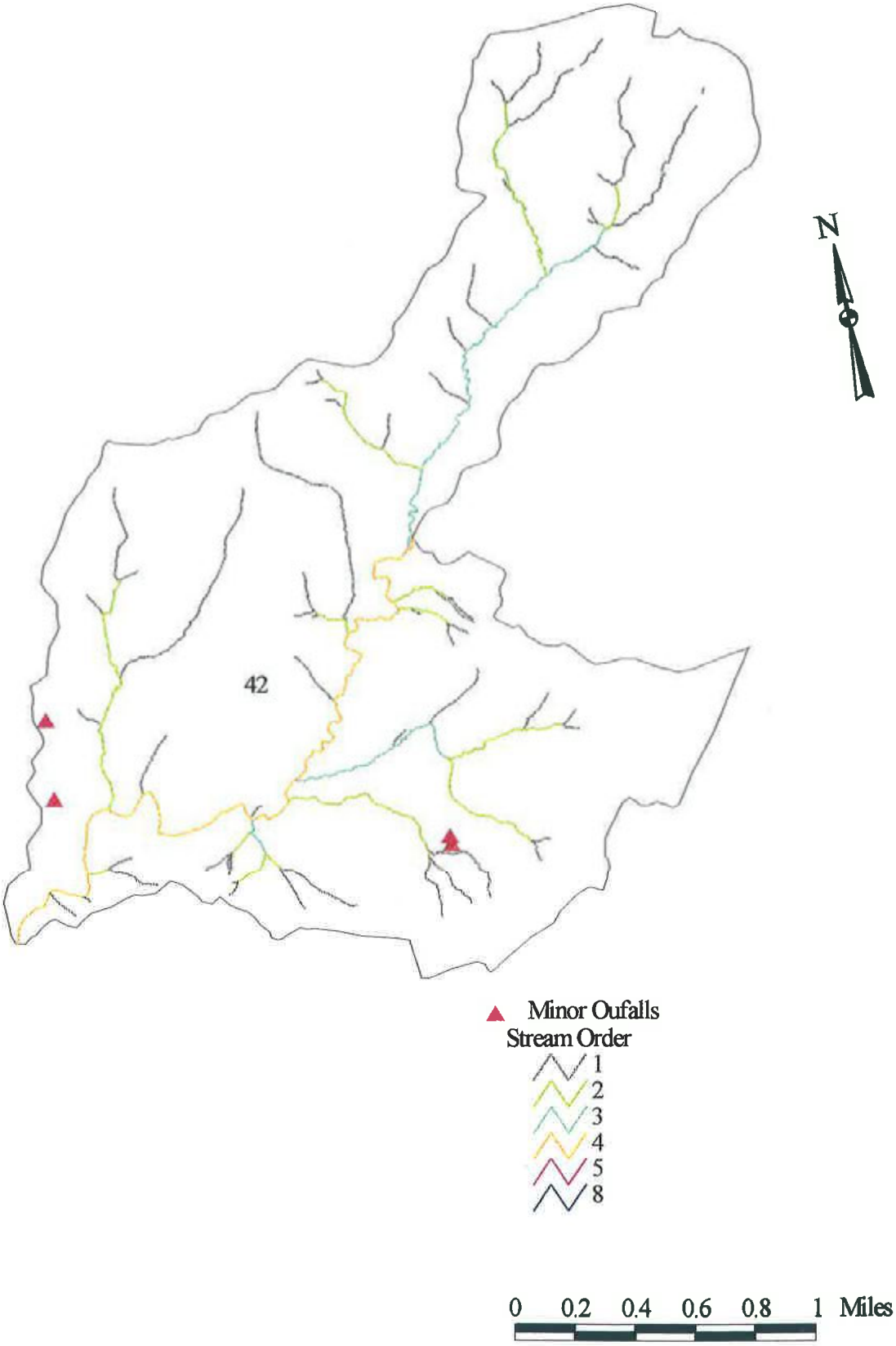
Carroll Branch Subwatershed

Figure 42.3 Erosion Hazard



Carroll Branch Subwatershed

Figure 42.4 Major and Minor Oufalls, SWM Facilities



APPENDIX K:

Water Quality Analysis of Heavy Metals for the Loch Raven Reservoir Impoundment in Baltimore County, Maryland

Water Quality Analysis of Heavy Metals for the Loch Raven Reservoir Impoundment in Baltimore County, Maryland

FINAL

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List of Abbreviations

As	Arsenic
Be	Beryllium
CBL	Chesapeake Biological Laboratory
Cd	Cadmium
cm	Centimeter
COMAR	Code of Maryland Regulations
Cr	Chromium
Cu	Copper
CWA	Clean Water Act
DOC	Dissolved Organic Carbon
EPA	Environmental Protection Agency
HAC	Hardness Adjusted Criteria
Hg	Mercury
MDE	Maryland Department of the Environment
mg	Milligram
mg/l	Milligrams per Liter
Ni	Nickel
NPDES	National Pollution Discharge Elimination System
Pb	Lead
PCB	Poly-chlorinated Biphenyl
Sb	Antimony
SCS	Soil Conservation Service
Se	Selenium
SSURGO	Soil Survey Geographic
TMDL	Total Maximum Daily Load
USGS	United States Geologic Survey
WER	Water Effects Ratio
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment
µg/l	Micrograms per Liter
Zn	Zinc

EXECUTIVE SUMMARY

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency (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 to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate that water quality standards are being met.

The Loch Raven Reservoir (basin code 02-13-08-05), located in Baltimore County, MD, was identified on the State's list of WQLSs as impaired by heavy metals (1996 listing), nutrients (1996 listing), suspended sediments (1996 listing), fecal coliform (2002 listing), evidence of biological impacts (2002 listing), polychlorinated biphenyls (PCBs) (2002 listing) and methylmercury (2002 listing). The heavy metal, nutrient, suspended sediment and PCB impairments were listed for the impoundment, and the biological and fecal coliform impairments were listed for the non-tidal streams. This report provides an analysis of recent monitoring data, including hardness data, which shows that the aquatic life criteria for heavy metals and the designated uses supported by those criteria are being met in the Loch Raven Reservoir. The non-tidal streams are not listed for heavy metals therefore they are not addressed in the water quality analysis (WQA). The analysis supports the conclusion that a TMDL of heavy metals is not necessary to achieve water quality standards in this case. Barring the receipt of any contradictory data, this report will be used to support the removal of the Loch Raven Reservoir from Maryland's list of WQLSs for heavy metals when the Maryland Department of the Environment (MDE) proposes the revision of Maryland's 303(d) list for public review in the future. A TMDL for methylmercury in fish tissue was completed in 2002. The nutrient, suspended sediments, bacteria and biological impairments will be addressed separately at a future date.

Although the waters of the Loch Raven Reservoir do not display signs of toxic impairments due to heavy metals, the State reserves the right to require additional pollution controls in the Loch Raven Reservoir watershed if evidence suggests that heavy metals from the basin are contributing to downstream water quality problems.

1.0 INTRODUCTION

Section 303(d) of the federal Clean Water Act (CWA) and U.S. Environmental Protection Agency's (EPA) 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. This list of impaired waters is commonly referred to as the "303(d) list". For each WQLS, the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate that water quality standards are being met.

A segment identified as a WQLS may not require the development and implementation of a TMDL if current information contradicts the previous finding of an impairment. The most common factual scenarios obviating the need for a TMDL are as follows: 1) more recent data indicating that the impairment no longer exists (i.e., water quality criteria are being met); 2) more recent and updated water quality modeling demonstrates that the segment is now attaining criteria; 3) refinements to water quality criteria, or the interpretation of those standards, which result in criteria being met; or 4) correction to errors made in the initial listing.

The Loch Raven Reservoir (basin code 02-13-08-05) was identified on the 1996 303(d) list submitted to EPA by the Maryland Department of the Environment (MDE) as impaired by heavy metals, nutrients and suspended sediments, with fecal coliform, methylmercury, polychlorinated biphenyls (PCBs) and biological impairments added to the list in 2002. The heavy metal, nutrient, suspended sediment and PCB impairments were listed for the impoundment and the biological, and fecal coliform impairments were listed for the non-tidal streams. The initial listing for heavy metals was questionable because: 1) no specific pollutants were defined; 2) the original listing was based on total recoverable metals (current standard is for dissolved metals); 3) inappropriate sampling techniques were applied (lack of filtration); 4) supporting data needed to interpret criteria was not available (hardness); and 5) a default hardness of 100 mg/l was used to convert and relate the total recoverable metals to the dissolved criteria, which superceded the total recoverable metals criteria. A water quality analysis (WQA) of heavy metals for the Loch Raven Reservoir impoundment was performed using recent water column and sediment toxicity data. Results show no impairment for heavy metals. The non-tidal streams are not listed for heavy metals therefore they are not addressed in the WQA. A TMDL for methylmercury in fish tissue was completed in 2002. The nutrient, suspended sediments, bacteria and biological impairments will be addressed separately at a future date.

The term "heavy metals" and "metals" are interchangeable and generally interpreted to include those metallic elements from periodic table groups IIA through VIA. At trace levels, many of these elements are necessary to support life. However, at elevated levels they become toxic, may build up in biological systems, and become a significant detriment to aquatic life. For the purposes of this WQA, metals are those priority pollutant metals that are commonly permitted in National Pollution Discharge Elimination System (NPDES) industrial or NPDES stormwater discharges. The following metals were sampled in the Loch Raven Reservoir impoundment: arsenic (As); cadmium (Cd); chromium (Cr); copper (Cu); nickel (Ni); lead (Pb); selenium (Se)

and zinc (Zn). Mercury (Hg), one of the priority pollutant metals, was addressed in the methylmercury fish tissue TMDL completed in 2002, therefore it will not be included in the WQA.

Basin geological conditions, land use, and past/present industrial practices did not indicate the potential for the presence of other priority pollutants, such as antimony (Sb) and beryllium (Be) - metals commonly found at Superfund sites.

If a specific water quality impairment exists that identifies specific metal(s) as impairing substances, sampling and analysis may be limited to those metal(s) of concern.

The remainder of this report lays out the general setting of the waterbody within the Loch Raven Reservoir watershed, presents a discussion of the water quality characterization process, and provides conclusions with regard to the characterization. The most recent data establishes that the Loch Raven Reservoir is achieving water quality criteria for metals.

2.0 GENERAL SETTING

Loch Raven Reservoir is an impoundment located near Timonium in Baltimore County, Maryland (see Figure 1). The impoundment is owned by the Baltimore City Department Public Works and is situated in the Gunpowder River watershed. The Loch Raven Reservoir is one of the major sources of raw water in the Baltimore area. Prettyboy Reservoir lies in the Loch Raven Reservoir watershed and drains into Loch Raven Reservoir. The Prettyboy Reservoir watershed comprises approximately 26% of the area of the Loch Raven watershed. The City of Baltimore Department of Public Works owns both water bodies and uses them in a system to provide a major source of public water to the Baltimore metropolitan area. In 1912, the dam for the Loch Raven Reservoir was built, and in response to additional water demand, the crest was raised in 1918 to its current 240 feet above sea level. The Loch Raven Dam was modified in 1986. Water is directed for treatment to the Montebello treatment plant, and from there, distributed to Baltimore City and the surrounding areas. Inflow to the Reservoir is primarily via the Gunpowder River. Table 1 lists the physical characteristics of the Loch Raven Reservoir.

Table 1: Physical Characteristics of the Loch Raven Reservoir

Location:	Baltimore County, Maryland Latitude 39.43 Longitude 76.54 (Dam)
Surface Area:	9.7125 km^2
Normal Depth:	23.2 meters
Normal Volume:	8.97×10^7 m^3
Drainage Area to Lake:	788.81 km^2
Average Annual Flow:	8.6 m^3/s

* Includes contribution from Prettyboy Reservoir Watershed

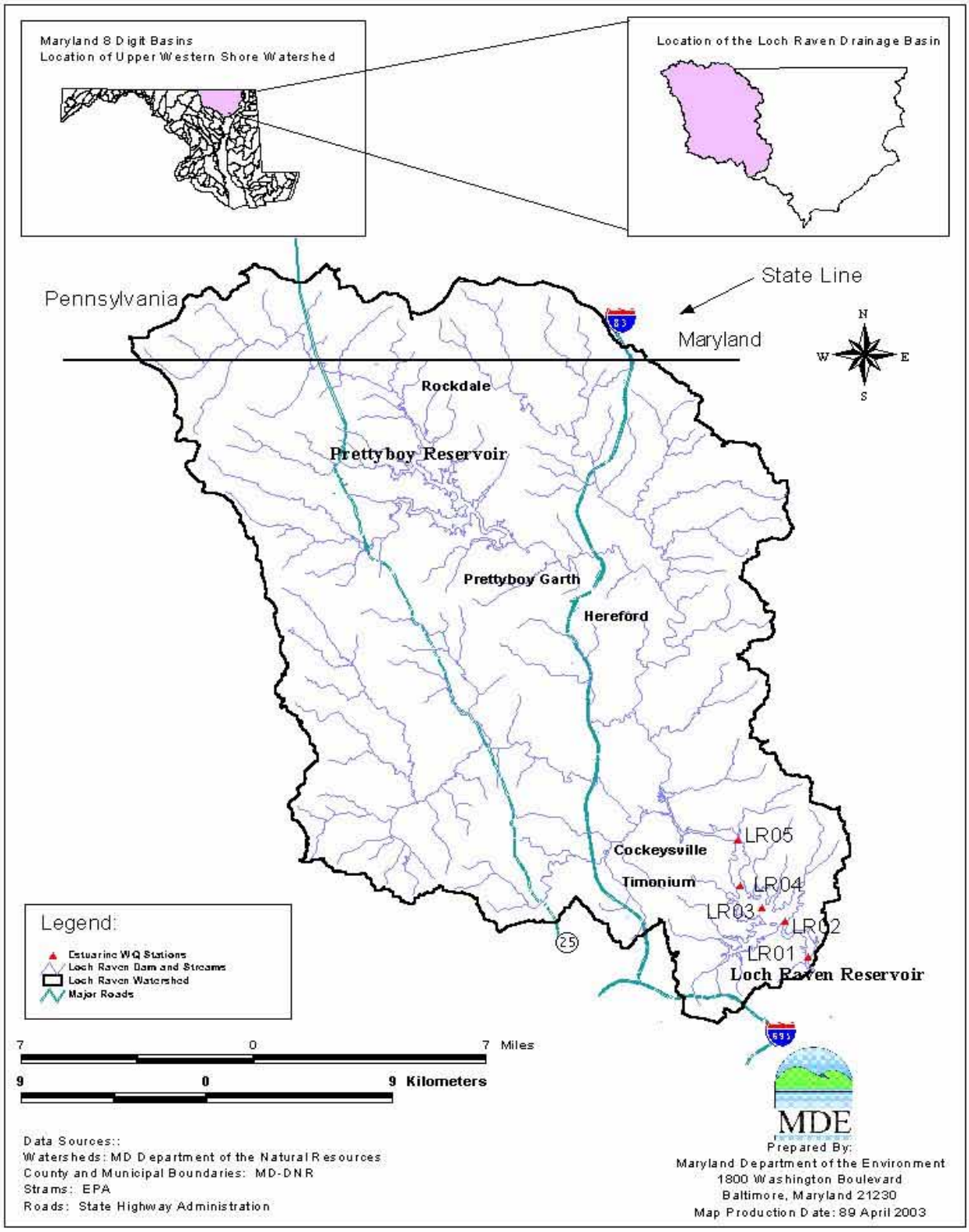

Figure 1: Watershed Map of the Loch Raven Reservoir

The majority of the watershed is in the Piedmont physiographic province. The highest elevation in the study area is 1,087 feet at the extreme northwestern boundary of the watershed in Pennsylvania. The Piedmont area is strongly dissected with rolling to steep topography. The Piedmont region in the watershed is underlain by metamorphic rock of Precambrian and Cambrian age. Deep, unconsolidated marine sediments of early Cretaceous and Pleistocene age overlie the metamorphic rock unconformably in the Coastal Plain province. The underlying metamorphic rock complex in the Piedmont region of the watershed consists mainly of crystalline schists and gneiss with smaller areas of marble. The underlying marble formations consist of Cockeysville Marble and Patuxent Formation. These formations are less resistant to weathering and occur primarily in valleys. Marble areas typically have higher infiltration rates and greater groundwater flow rates.

Soils overlying the bedrock in the Piedmont are seven to twenty feet deep. Soil formation is the result of the interaction of a variety of factors, including climate, parent material, relief, time, and biota. The humid continental climate has resulted in strong weathering and leaching of soils within the watershed. These processes have depleted free carbonates thereby acidifying the soils. The primary soil associations in the Piedmont area of the Loch Raven Reservoir Study area are Manor-Glenelg, Chester-Glenelg, Baltimore-Conestoga-Hagerstown, Beltsville-Chillum-Sassafras, and Glenelg-Chester-Manor.

The watershed is comprised primarily of B soils. Soil type is categorized by four hydrologic soil groups developed by the Soil Conservation Service (SCS). The definitions of the groups are as follows (SCS, 1976):

> Group A: Soils with high infiltration rates, typically deep well-drained to excessively drained sands or gravels.
> Group B: Soils with moderate infiltration rates, generally moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.
> Group C: Soils with slow infiltration rates, mainly soils with a layer that impedes downward water movement or soils with moderately fine to fine texture.
> Group D: Soils with very slow infiltration rates, mainly clay soils, soils with a permanently high water table, and shallow soils over nearly impervious material.

The soil distribution within the watershed is approximately 1.04% soil group A, 83.5% soil group B, 9.45% soil group C and 6.0% soil group D. Soil data was obtained from Soil Survey Geographic (SSURGO) coverages created by the National Resources Conservation Service.

The area draining to Loch Raven Reservoir is predominately mixed agricultural and forest/herbaceous (see Figure 2). Only one point source, the Noxell Corporation, located in Hunt Valley, MD, discharges metals (Cu) within the Loch Raven Reservoir Watershed. Land use distribution in this watershed is approximately 42% mixed agricultural, 37% forest/herbaceous, 19% developed and 2% water (Maryland Department of Planning, 2000).

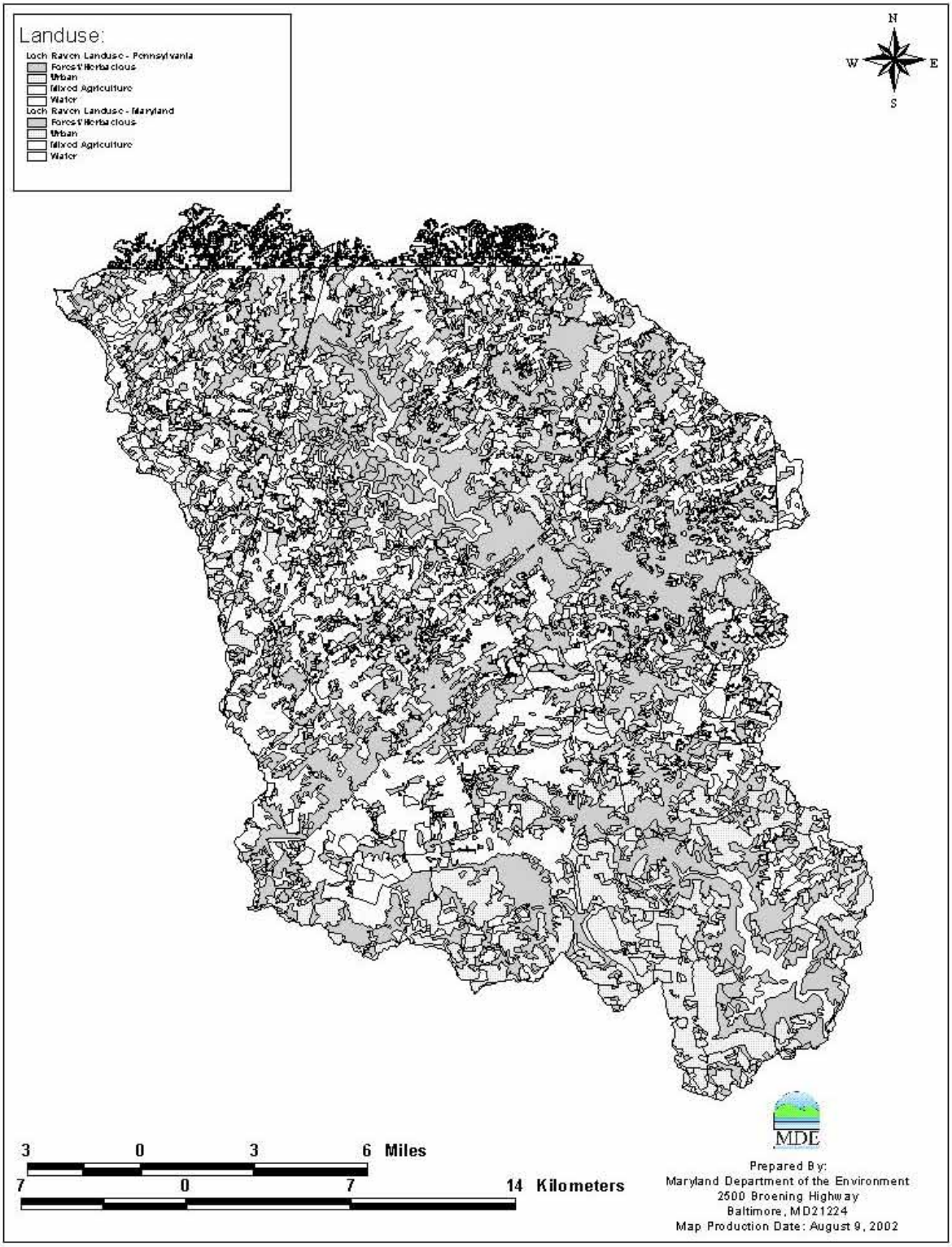

Figure 2: Land Use Map of Loch Raven Reservoir Watershed

3.0 WATER QUALITY CHARACTERIZATION

A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include support of aquatic life, primary or secondary contact recreation, drinking water supply, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. The criteria developed to protect the designated use may differ and are dependent on the specific designated use(s) of a waterbody. Maryland's water quality standards presently include numeric criteria for metals and other toxic substances based on the need to protect aquatic life, wildlife and human health. Water quality standards for toxic substances also address sediment quality to ensure the bottom sediment of a waterbody is capable of supporting aquatic life, thus protecting the designated uses.

The Maryland Surface Water Use Designation (Code of Maryland Regulations (COMAR) 26.08.02.08I) for the Gunpowder River and its tributaries (including Loch Raven Reservoir) is Use III-P – *natural trout waters and public water supply.* In addition, COMAR requires that all waterbodies in the State of Maryland support a Use I designation - *water contact recreation, fishing and protection of aquatic life and wildlife.* The applicable numeric aquatic life and human health (drinking water & fish consumption) criteria for dissolved metals in freshwater are described below in Table 2 (COMAR 26.08.02.03-2G). There are two species of chromium, trivalent Cr (III) and hexavalent Cr (VI). Cr (VI) has the highest toxicity of the Cr species, therefore the numeric criteria is more stringent. Total chromium concentrations were analyzed in the water column survey and are compared with the Cr (VI) numeric water quality criterion. The Loch Raven Reservoir is designated a public water supply therefore the human health (drinking water) criteria for metals must also be achieved. The water column data presented in Section 3.1, Table 6 through Table 10, shows that concentrations of metals in the water column do not exceed the aquatic life or human health (drinking water & fish consumption) criteria. An ambient sediment bioassay conducted in Loch Raven Reservoir establishes that there is no toxicity in the sediment bed of the impoundment (Fisher, 2002). Sediment chemistry analysis was not conducted because toxicity was not observed in the ambient sediment bioassay. The water column and sediment in the Loch Raven Reservoir impoundment is therefore not impaired by metals, thus the designated uses are supported and the water quality standard is being met for these substances.

Water column surveys conducted at five stations in the Loch Raven Reservoir from May 2001 to July 2001 were used to support these WQAs. For every sample, dissolved concentrations of the eight metals were determined. Sediment samples were also collected at all five monitoring stations for the sediment bioassay. Table 3 shows the list of stations with their geographical coordinates and descriptive location in the Loch Raven Reservoir watershed. Refer back to Figure 1 for station locations.

Water column sampling was performed four times for each station from May 2001 to July 2001 to capture seasonal variation. The sampling dates were as follows: 5/21/01 (spring wet weather); 6/11/01 (spring dry weather); 7/25/01 (summer dry weather) and 7/30/01 (summer wet weather).

Table 2: Numeric Water Quality Criteria (Metals)

Metal	Fresh Water Aquatic Life Acute Criteria (µg/l)	Fresh Water Aquatic Life Chronic Criteria (µg/l)	Human Health Criteria Drinking Water (µg/l)	Human Health Criteria Fish Consumption (µg/l)
As	340	150	50	41
Cd	4.3	2.2	5	-
Cr (VI)	16	11	100 *	-
Cu	13	9	1,300	1,300
Ni	470	52	100	4,600
Pb	65	2.5	15	-
Se	20	5	50	11000
Zn	120	120	-	69,000

* Human Health Criterion (drinking water) is designated for Cr

Table 3: Water Quality Analysis Stations for Loch Raven Reservoir

Station I.D.	GPS Coordinates	Station Description
LR01	39.431 76.543	Mouth of Loch Raven Reservoir.
LR02	39.446 76.555	Above LR01, off of Loch Raven Road in the Reservoir.
LR03	39.453 76.569	Above LR02, in the middle of the Reservoir, across from the Loch Raven Golf Course.
LR04	39.463 76.581	Above LR03, In the Reservoir, off of Dulaney Valley Road.
LR05	39.484 76.528	Above LR04, across from Springdale, MD, in the Reservoir.

For the water quality evaluation, a comparison is made between the water column concentrations of the metals and fresh water aquatic life chronic criteria, which is the more stringent of the numeric water quality criteria for metals except for As in which the human health criterion for fish consumption is more stringent and will be applied. Hardness concentrations were obtained for each station to adjust the fresh water aquatic life chronic criteria that are established at a hardness of 100 mg/l for metals. The State used the hardness adjustment to calculate fresh water aquatic life chronic criteria for those metals (Cd, Cu, Ni, Pb, and Zn) for which toxicity is a function of total hardness. The fresh water aquatic life chronic criteria are not adjusted for Cr (VI) and Se and because hardness either does not affect the bioavailability of these metals to aquatic life or there is significant uncertainty in the correlation between hardness and criteria. According to EPA's National Recommended Water Quality Criteria (EPA, 2002), allowable hardness values must fall within the range of 25 - 400 mg/L. MDE uses an upper limit of 400 mg/l in calculating the hardness adjusted criteria (HAC) when the measured hardness exceeds this value. Based on technical information, EPA's Office of Research and Development does not recommend a lower limit on hardness for adjusting criteria (EPA, 2002). MDE adopts this recommendation. The HAC equation for metals is as follows (EPA, 2002):

$$HAC = e^{(m[\ln(Hardness(mg/l)]+b)} * CF$$

Where,

HAC = Hardness Adjusted Criterion (µg/l)
m = slope
b = y intercept
CF = Conversion Factor (conversion from totals to dissolved numeric criteria)

The HAC parameters for metals are presented in Table 4.

Table 4: HAC Parameters (Fresh Water Aquatic Life Chronic Criteria)

Chemical	Slope (m)	y Intercept (b)	Conversion Factor (CF)
Cd	0.7852	-2.715	1.102 - ln(hardness)*0.0418
Cu	0.8545	-1.702	0.960
Pb	1.2730	-4.705	1.462 - ln(hardness)*0.146
Ni	0.8460	0.0584	0.997
Zn	0.8473	0.884	0.986

The State will perform a scientific review of all data submitted where a water quality criterion exceedance was the result of a hardness adjustment below 50 mg/l. This review is necessary because of the scientific uncertainty existing for hardness-toxicity relationships below 50 mg/l due to:

A. Paucity of toxicity test data below 50 mg/l that was used to develop the relationship between hardness and toxicity.
B. Presence/absence of sensitive species in the waterbody of concern.
C. Existence of other environmental conditions (e.g. high Dissolved Organic Carbon (DOC)), which might mitigate the toxicity of metals due to competitive binding/complexation of metals.

In instances where hardness data is not available, the State will calculate an average of existing hardness concentrations for each station. In applying average hardness, the sampling date for which hardness data is unavailable must not fall during a storm event substantially greater than the sampling dates used to calculate the average. A major rainfall event has the potential to reduce hardness below the average. An analysis of rainfall data from the National Weather Service (NWS) precipitation gauge (0180465) at Baltimore/Washington International Airport (BWI) shows no significant variation in storm events for the sampling dates, thus the average will apply. This is the closest gauge to Loch Raven Reservoir and is likely to be representative of the rainfall events that occur within the watershed.

3.1 WATER COLUMN EVALUATION

A data solicitation for metals was conducted by the MDE and all readily available data from the past five years was considered in the WQA. The water column data is presented in Table 6 through Table 10 for each station and is evaluated using the fresh water aquatic life chronic HAC, the more stringent of the numeric criteria for metals except for As in which the human health criterion is applied (Baker, 2002). Each table displays hardness (mg/l), sample concentrations (µg/l) and fresh water aquatic life chronic HAC (µg/l) by sampling date. For example, in Table 6 for the sampling date of 6/11/01 the hardness is 39.15 mg/l, the hardness adjusted criterion for Cu is 4.02 µg/l and the Cu sample concentration is 0.57 µg/l. The hardness concentrations reported in bold are for sampling dates in which hardness was not measured and an average value was applied. The detection limits for metals analysis are displayed in Table 5.

Table 5: Metals Analysis Detection Limits

Analyte	Detection Limit (µg/l)
As	0.09
Cd	0.001
Cr	0.03
Cu	0.01
Ni	0.01
Pb	0.003
Se	0.09
Zn	0.25

The range of concentrations for metals sampled in the field survey are as follows:

As = ND to 0.33 µg/l
Cd = ND to 0.01 µg/l
Cr = ND to 0.24 µg/l
Cu = 0.45 to 0.76 µg/l
Ni = 0.09 to 0.64 µg/l
Pb = ND to 0.02 µg/l
Se = ND to 0.51 µg/l
Zn = ND to 7.79 µg/l

Hardness ranges from 31.65 mg/l to 41.1 mg/l. The concentration ranges of all eight metals are well below their associated fresh water aquatic life chronic hardness adjusted criteria. The criteria were not exceeded by any of the eight metals sampled.

Table 6: Station LR01 Water Column Data

Sampling Date	5/21/01		6/11/01		7/25/01		7/30/01	
Hardness (mg/l)	40.5		39.15		36.9		**38.9**	
Analyte	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)
As	0.25	41	0.19	41	0.28	41	0.23	41
Cd	ND	1.15	0.01	1.12	ND	1.07	ND	1.12
Cr	0.13	11	0.12	11	0.06	11	0.16	11
Cu	0.74	4.14	0.57	4.02	0.57	3.82	0.49	4.00
Ni	0.46	24.21	0.65	23.52	0.13	22.38	0.30	23.40
Pb	ND	0.93	ND	0.89	0.01	0.84	ND	0.89
Se	0.27	5	0.22	5	0.45	5	ND	5
Zn	0.17	54.93	0.17	53.37	ND	50.8	ND	53.08

* Fresh Water Aquatic Life Chronic HAC

A) Cr (VI) criterion is applied
B) Hardness adjustment is unnecessary for Cr (VI) and Se
C) Human Health Criterion (fish consumption) is applied for As

ND - Not detected

Table 7: Station LR02 Water Column Data

Sampling Date	5/21/01		6/11/01		7/25/01		7/30/01	
Hardness (mg/l)	41.1		39.15		36.45		**38.9**	
Analyte	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)
As	0.25	41	0.18	41	0.20	41	0.32	41
Cd	ND	1.16	ND	1.12	ND	1.06	ND	1.12
Cr	0.14	11	0.11	11	0.03	11	0.17	11
Cu	0.76	4.19	0.57	4.02	0.55	3.78	0.49	4.00
Ni	0.47	24.51	0.64	23.52	0.09	22.14	0.3	23.40
Pb	ND	0.94	ND	0.89	ND	2.5	ND	0.89
Se	0.22	5	0.24	5	ND	5	ND	5
Zn	0.35	55.62	0.38	53.37	5.26	50.24	ND	53.08

Table 8: Station LR03 Water Column Data

Sampling Date	5/21/01		6/11/01		7/25/01		7/30/01	
Hardness (mg/l)	40.65		39.15		36.15		**38.7**	
Analyte	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)
As	0.24	41	0.17	41	ND	41	0.33	41
Cd	ND	1.15	ND	1.12	ND	1.05	ND	1.11
Cr	0.11	11	0.13	11	ND	11	0.17	11
Cu	0.75	4.15	0.54	4.02	0.55	3.75	0.45	3.98
Ni	0.49	24.28	0.64	23.52	0.16	21.99	0.28	23.29
Pb	ND	0.93	ND	0.89	0.01	0.82	ND	0.88
Se	0.19	5	0.21	5	0.51	5	ND	5
Zn	0.25	55.10	0.11	53.37	7.79	49.89	ND	52.85

* Fresh Water Aquatic Life Chronic HAC

A) Cr (VI) criterion is applied
B) Hardness adjustment is unnecessary for Cr (VI) and Se
C) Human Health Criterion (fish consumption) is applied for As

ND - Not detected

Table 9: Station LR04 Water Column Data

Sampling Date	5/21/01		6/11/01		7/25/01		7/30/01	
Hardness (mg/l)	40.65		39.15		36		**38.6**	
Analyte	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)
As	0.27	41	0.19	41	ND	41	0.29	41
Cd	ND	1.15	ND	1.12	ND	1.05	ND	1.11
Cr	0.11	11	0.14	11	0.04	11	0.17	11
Cu	0.73	4.15	0.56	4.02	0.55	3.74	0.47	3.97
Ni	0.48	24.28	0.63	23.52	0.16	21.91	0.28	23.24
Pb	ND	0.93	ND	0.89	0.01	0.81	ND	0.88
Se	0.26	5	0.24	5	ND	5	ND	5
Zn	0.20	55.10	0.22	53.37	4.39	49.71	ND	52.74

Table 10: Station LR05 Water Column Data

Sampling Date	5/21/01		6/11/01		7/25/01		7/30/01	
Hardness (mg/l)	39.75		38.25		31.65		**36.6**	
Analyte	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)
As	0.24	41	0.15	41	ND	41	0.20	41
Cd	ND	1.13	ND	1.10	ND	0.95	ND	1.06
Cr	0.24	11	0.12	11	0.02	11	0.16	11
Cu	0.68	4.07	0.56	3.94	0.57	3.35	0.47	3.79
Ni	0.48	23.83	0.64	23.07	0.12	19.65	0.42	22.22
Pb	ND	0.91	ND	0.87	0.02	0.71	ND	0.83
Se	0.29	5	0.23	5	0.40	5	ND	5
Zn	0.18	54.06	0.14	52.33	3.77	44.57	ND	50.41

* Fresh Water Aquatic Life Chronic HAC

A) Cr (VI) criterion is applied
B) Hardness adjustment is unnecessary for Cr (VI) and Se
C) Human Health Criterion (fish consumption) is applied for As

ND - Not detected

3.2 SEDIMENT TOXICITY EVALUATION

To complete the WQA, sediment quality in the Loch Raven Reservoir was evaluated using 10-day survival and growth whole sediment tests with the freshwater amphipod *Hyallela azteca.* This species was chosen because of its ecological relevance to the waterbody of concern. *H. azteca* is an EPA-recommended test species for assessing the toxicity of freshwater sediments (EPA, 2000). Five surficial sediment samples were collected using a petite ponar dredge (top 2 cm) by Chesapeake Biological Laboratory (CBL) from Loch Raven Reservoir. The sediment stations correspond to the five monitoring stations sampled in the water column surveys. Refer back to Figure 1 for station locations. Sediment toxicity test results are presented in Table 11. Ten amphipods were exposed to the sediment in each sample test. The table displays amphipod survival (#), amphipod weight (mg), average amphipod survival (%), and average amphipod weight (mg).

The test considers two performance criteria, which are survival and growth. For the test to be valid the average survival in control samples must be greater than 80% and there must be sufficient growth. Survival of amphipods in the field sediment samples was not significantly different than the 91.3 % average survival demonstrated in the control samples [$p < 0.05$]. Field sediment sample average survival results were 97.5, 93.8, 92.5, 91.3, and 95 percent. No sediment samples in the Loch Raven Reservoir exhibited toxicity contributing to mortality.

Table 11: Sediment Toxicity Test Results

Sample	Amphipod Survival (#)	Amphipod Weight (mg)	Average Amphipod Survival (%)	Average Amphipod Weight (mg)
Control A	9	0.159	91.3	0.172
Control B	9	0.181		
Control C	10	0.182		
Control D	10	0.183		
Control E	7	0.184		
Control F	9	0.156		
Control G	10	0.176		
Control H	9	0.157		
LR-01	10	0.229	97.5	0.22
LR-01	10	0.225		
LR-01	9	0.242		
LR-01	9	0.227		
LR-01	10	0.234		
LR-01	10	0.189		
LR-01	10	0.207		
LR-01	10	0.208		
LR-02	10	0.234	93.8	0.229
LR-02	10	0.212		
LR-02	10	0.188		
LR-02	8	0.261		
LR-02	9	0.247		
LR-02	9	0.232		
LR-02	10	0.221		
LR-02	9	0.234		
LR-03	10	0.23	92.5	0.232
LR-03	9	0.241		
LR-03	9	0.261		
LR-03	9	0.217		
LR-03	10	0.196		
LR-03	10	0.243		
LR-03	10	0.21		
LR-03	7	0.259		
LR-04	8	0.201	91.3	0.217
LR-04	8	0.239		
LR-04	10	0.221		
LR-04	10	0.223		
LR-04	10	0.18		
LR-04	10	0.231		
LR-04	10	0.213		
LR-04	7	0.224		
LR-05	10	0.219	95	0.206
LR-05	10	0.201		
LR-05	8	0.188		
LR-05	9	0.213		
LR-05	10	0.192		
LR-05	10	0.216		
LR-05	9	0.198		
LR-05	10	0.22		

Similarly, measured growth in the field sediment samples was not significantly different than in the control samples [$p < 0.05$]. In fact, growth in all of the reservoir samples was greater than in the control sediments. The weight of amphipods at the end of the growth period observed in the field sediment samples ranged from 0.206 g to 0.232 g while the weight observed in the control sample was 0.172 g. No sediment samples exhibited toxicity contributing to a reduction in growth.

4.0 CONCLUSION

The WQA shows that water quality standards for metals are being achieved. Water column samples collected at five monitoring stations in the Loch Raven Reservoir, from May 2001 to July 2001, demonstrate that numeric water quality criteria are being met. Bottom sediment samples collected at five monitoring stations, and used for bioassay toxicity tests, demonstrate no impacts on survival and growth. Barring the receipt of any contradictory data, this information provides sufficient justification to revise Maryland's 303(d) list to remove metals as impairing substances in the Loch Raven Reservoir impoundment.

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Appendix L:

Watershed Report for Biological Impairment of the Loch Raven Reservoir in Baltimore, Carroll, and Harford Counties, Maryland and York County, PA Biological Stressor Identification Analysis Results and Interpretation

Watershed Report for Biological Impairment of the Loch Raven Reservoir in Baltimore, Carroll, and Harford Counties, Maryland and York County, PA Biological Stressor Identification Analysis Results and Interpretation

FINAL

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List of Abbreviations

AR	Attributable Risk
BIBI	Benthic Index of Biotic Integrity
BMPs	Best Management Practices
BSID	Biological Stressor Identification
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
DO	Dissolved Oxygen
FIBI	Fish Index of Biologic Integrity
IBI	Index of Biotic Integrity
m	Meter
MDDNR	Maryland Department of Natural Resources
MDE	Maryland Department of the Environment
MBSS	Maryland Biological Stream Survey
mg/L	Milligrams per liter
NMPs	Nutrient Management Practices
RESAC	Regional Earth Science Applications Center
SSA	Science Services Administration
TP	Total Phosphorous
TMDL	Total Maximum Daily Load
µeq/L	Micro equivalent per liter
µS/cm	Micro Siemens per centimeter
USEPA	United States Environmental Protection Agency
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment

Executive Summary

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (USEPA) 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. A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. For each WQLS listed on the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report), the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate via a Water Quality Analysis (WQA) that water quality standards are being met.

The Maryland Department of the Environment (MDE) has identified the waters of the Loch Raven Reservoir watershed (basin number 02130805) has having multiple listings on the State's Integrated Report (Table E1) (MDE 2012).

Table E1. 2012 Integrated Report Listings for the Loch Raven Reservoir Watershed

Watershed	Basin Code	Non-tidal/ Tidal	Subwatershed	Designated Use	Year listed	Identified Pollutant	Listing Category
Loch Raven Reservoir	02130805	Non-tidal		Water Contact Sports	2008	Fecal Coliform	4a
				Aquatic Life and Wildlife	2002	Impacts to Biological Communities	5
		Non-tidal/ Impoundment		Aquatic Life and Wildlife	1996	TP	4a
						TSS	
					-	Arsenic	2
						Cadmium	
						Total Chromium	
						Copper	
						Lead	
						Nickel	
						Selenium	
				Fishing	2002	Mercury in Fish Tissue	4a
					-	PCB in Fish Tissue	2

In 2002, the State began listing biological impairments on the Integrated Report. The current MDE biological assessment methodology assesses and lists only at the Maryland 8-digit watershed scale, which maintains consistency with how other listings in the Integrated Report are made, how TMDLs are developed, and how implementation is targeted. The listing methodology assesses the condition of Maryland 8-digit watersheds with multiple impacted sites by measuring the percentage of stream miles that have an Index of Biotic Integrity (IBI) score of less than three, and calculating whether this is a significant deviation from reference condition watersheds (i.e., healthy stream, less than 10% stream miles degraded).

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the Loch Raven Reservoir watershed's tributaries are designated as Use III-P – *non-tidal cold water and public water supply*. The impoundment is designated as Use I-P – *water contact recreation, protection of aquatic life, and public water supply* (COMAR 2012 a, b). The Loch Raven Reservoir watershed is not attaining its designated use of protection of aquatic life because of biological impairments. As an indicator of designated use attainment, MDE uses Benthic and Fish Indices of Biotic Integrity (BIBI/FIBI) developed by the Maryland Department of Natural Resources Maryland Biological Stream Survey (MDDNR MBSS).

The current listings for biological impairments represent degraded biological conditions for which the stressors, or causes, are unknown. The MDE Science Services Administration (SSA) has developed a biological stressor identification (BSID) analysis that uses a case-control, risk-based approach to systematically and objectively determine the predominant cause of reduced biological conditions, thus enabling the Department to most effectively direct corrective management action(s). The risk-based approach, adapted from the field of epidemiology, estimates the strength of association between various stressors, sources of stressors and the biological community, and the likely impact these stressors would have on the degraded sites in the watershed.

The BSID analysis uses data available from the statewide MDDNR MBSS. Once the BSID analysis is completed, a number of stressors (pollutants) may be identified as probable or unlikely causes of poor biological conditions within the Maryland 8-digit watershed study. BSID analysis results can be used as guidance to refine biological impairment listings in the Integrated Report by specifying the probable stressors and sources linked to biological degradation.

This Loch Raven Reservoir watershed report presents a brief discussion of the BSID process on which the watershed analysis is based, and which may be reviewed in more detail in the report entitled "Maryland Biological Stressor Identification Process" (MDE 2009a). Data suggest that the Loch Raven Reservoir watershed's biological communities are influenced by anthropogenic development. There is an abundance of scientific research that directly and indirectly links degradation of the aquatic health of streams to development of natural landscapes, which often cause disturbances in stream habitat and

increased contaminant loads from runoff. The results of the BSID process, and the probable causes and sources of the biological impairments in the Loch Raven Reservoir watershed can be summarized as follows:

- The BSID analysis has determined that phosphorus is a probable cause of impacts to biological communities in the Loch Raven Reservoir watershed. Total phosphorus was identified as having significant association with degraded biological conditions. The BSID results thus confirm the development of the 2007 TMDL for nutrients was an appropriate management action to begin addressing the impacts of nutrient stressors on the biological communities in the Loch Raven Reservoir watershed.

- The BSID process has also determined that the biological communities in the Loch Raven Reservoir watershed are likely degraded due to inorganic pollutants (i.e., chlorides and sulfates). Chloride and sulfate levels are significantly associated with degraded biological conditions, and found in 26% and 23%, respectively, of the stream miles with poor to very poor biological conditions in Loch Raven Reservoir watershed. Runoff from roads, urban, and agricultural land uses causes an increase in contaminant loads from nonpoint sources by delivering an array of inorganic pollutants to surface waters. Discharges of inorganic compounds are very intermittent; concentrations vary widely depending on the time of year as well as a variety of other factors may influence their impact on aquatic life. Future monitoring of these parameters will help in determining the spatial and temporal extent of these impairments in the watershed. The BSID results thus support a Category 5 listing of chloride and sulfates for the 8-digit watershed as an appropriate management action to begin addressing the impacts of these stressors on the biological communities in the Loch Raven Reservoir watershed.

- The BSID process has also determined that biological communities in the Loch Raven watershed are likely degraded due to anthropogenic alterations of riparian buffer zones. MDE considers inadequate riparian buffer zones as pollution, not a pollutant; therefore, a Category 5 listing for this stressor is inappropriate. However, Category 4c is for waterbody segments where the State can demonstrate that the failure to meet applicable water quality standards is a result of pollution. MDE recommends a Category 4c listing for the Loch Raven watershed based on inadequate riparian buffer zones in approximately 36% of degraded stream miles.

- In 2007 a TMDL for total suspended sediments in the impoundment was developed and approved by EPA; however, the BSID analysis did not identify any sediment stressors in the non-tidal streams of the Loch Raven Reservoir watershed.

1.0 Introduction

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (USEPA) 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 listed on the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report), the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate via a Water Quality Analysis (WQA) that water quality standards are being met. In 2002, the State began listing biological impairments on the Integrated Report. Maryland Department of the Environment (MDE) has developed a biological assessment methodology to support the determination of proper category placement for 8-digit watershed listings.

The current MDE biological assessment methodology is a three-step process: (1) a data quality review, (2) a systematic vetting of the dataset, and (3) a watershed assessment that guides the assignment of biological condition to Integrated Report categories. In the data quality review step, available relevant data are reviewed to ensure they meet the biological listing methodology criteria of the Integrated Report (MDE 2010). In the vetting process, an established set of rules is used to guide the removal of sites that are not applicable for listing decisions (e.g., tidal or blackwater streams). The final principal database contains all biological sites considered valid for use in the listing process. In the watershed assessment step, a watershed is evaluated based on a comparison to a reference condition (i.e., healthy stream, less than 10% degraded) that accounts for spatial and temporal variability, and establishes a target value for "aquatic life support." During this step of the assessment, a watershed that differs significantly from the reference condition is listed as impaired (Category 5) on the Integrated Report. If a watershed is not determined to differ significantly from the reference condition, the assessment must have an acceptable precision (i.e., margin of error) before the watershed is listed as meeting water quality standards (Category 1 or 2). If the level of precision is not acceptable, the status of the watershed is listed as inconclusive and subsequent monitoring options are considered (Category 3). If a watershed is classified as impaired (Category 5), then a stressor identification analysis is completed to determine if a TMDL is necessary. A Category 5 listing can be amended to a Category 4a if a TMDL was established and approved by USEPA or Category 4b if other pollution control requirements (i.e., permits, consent decrees, etc.) are expected to attain water quality standards. If the state can demonstrate that the watershed impairment is a result of pollution, not a specific pollutant, the watershed is listed under Category 4c.

The MDE biological stressor identification (BSID) analysis applies a case-control, risk-based approach that uses the principal dataset, with considerations for ancillary data, to identify potential causes of the biological impairment. Identification of stressors

responsible for biological impairments was limited to the round two Maryland Biological Stream Survey (MBSS) dataset (2000–2004) because it provides a broad spectrum of paired data variables (i.e., biological monitoring and stressor information) to best enable a complete stressor analysis. The BSID analysis then links potential causes/stressors with general causal scenarios and concludes with a review for ecological plausibility by State scientists. Once the BSID analysis is completed, one or several stressors (pollutants) may be identified as probable or unlikely causes of the poor biological conditions within the Maryland 8-digit watershed. BSID analysis results can be used together with a variety of water quality analyses to update and/or support the probable causes and sources of biological impairment in the Integrated Report.

The remainder of this report provides a characterization of the Loch Raven Reservoir watershed, and presents the results and conclusions of a BSID analysis of the watershed.

2.0 Loch Raven Reservoir Watershed Characterization

2.1 Location

The Loch Raven Reservoir watershed is located both in Maryland and Pennsylvania, the Maryland 8-digit watershed total drainage area is approximately 140,900 acres. The majority of the watershed is in Maryland with a portion in York County, Pennsylvania. The Maryland portion is largely in Baltimore County, with small areas in Carroll and Harford Counties (see Figure 1). Gunpowder Falls, a major tributary of the Loch Raven Reservoir, drains into Chesapeake Bay north of the City of Baltimore. The watershed is located in the Eastern Piedmont Plain region, one of three distinct eco-regions identified in the MDDNR MBSS Index of Biological Integrity (IBI) metrics (Southerland et al. 2005a) (see Figure 2).

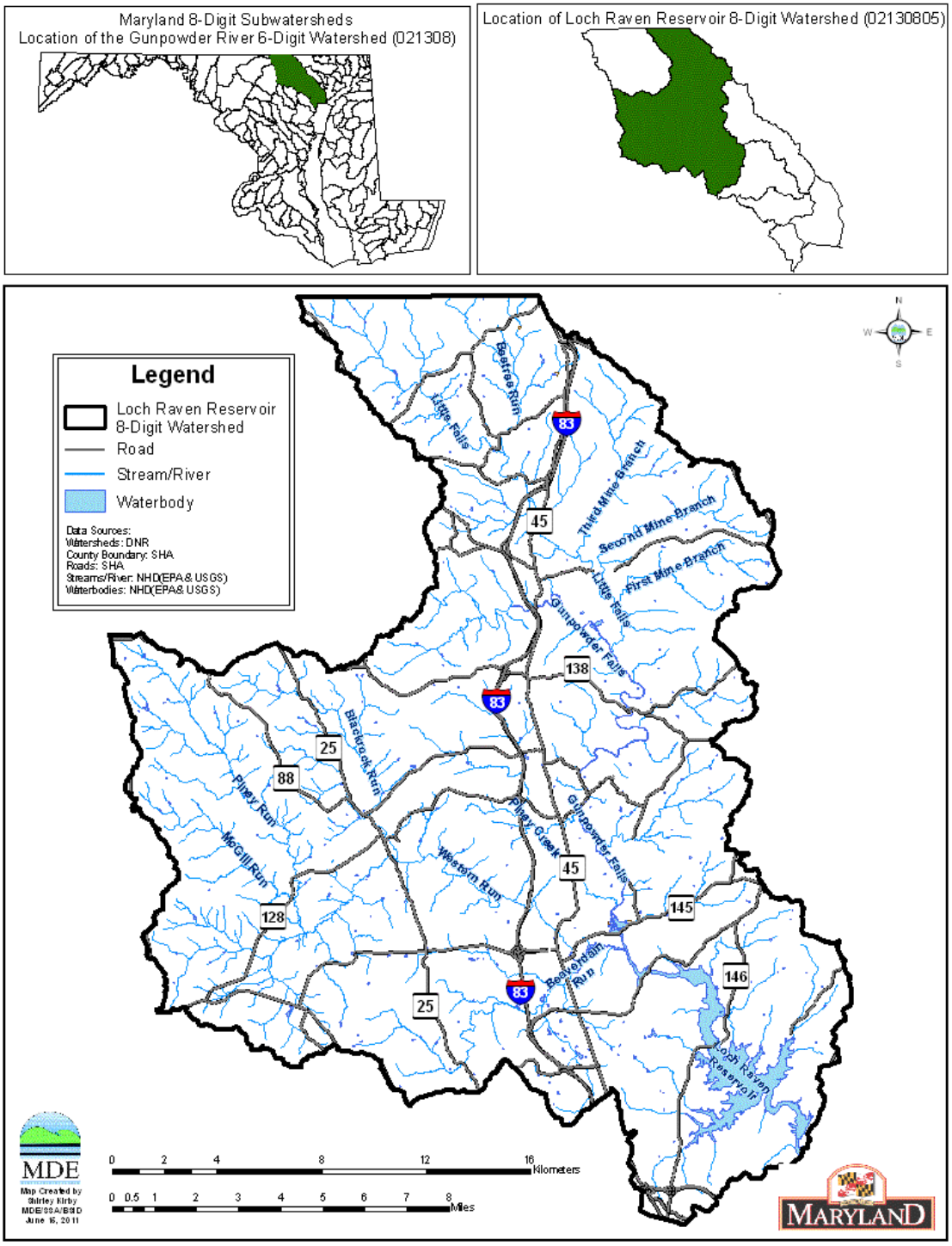

Figure 1. Location Map of the Loch Raven Reservoir Watershed

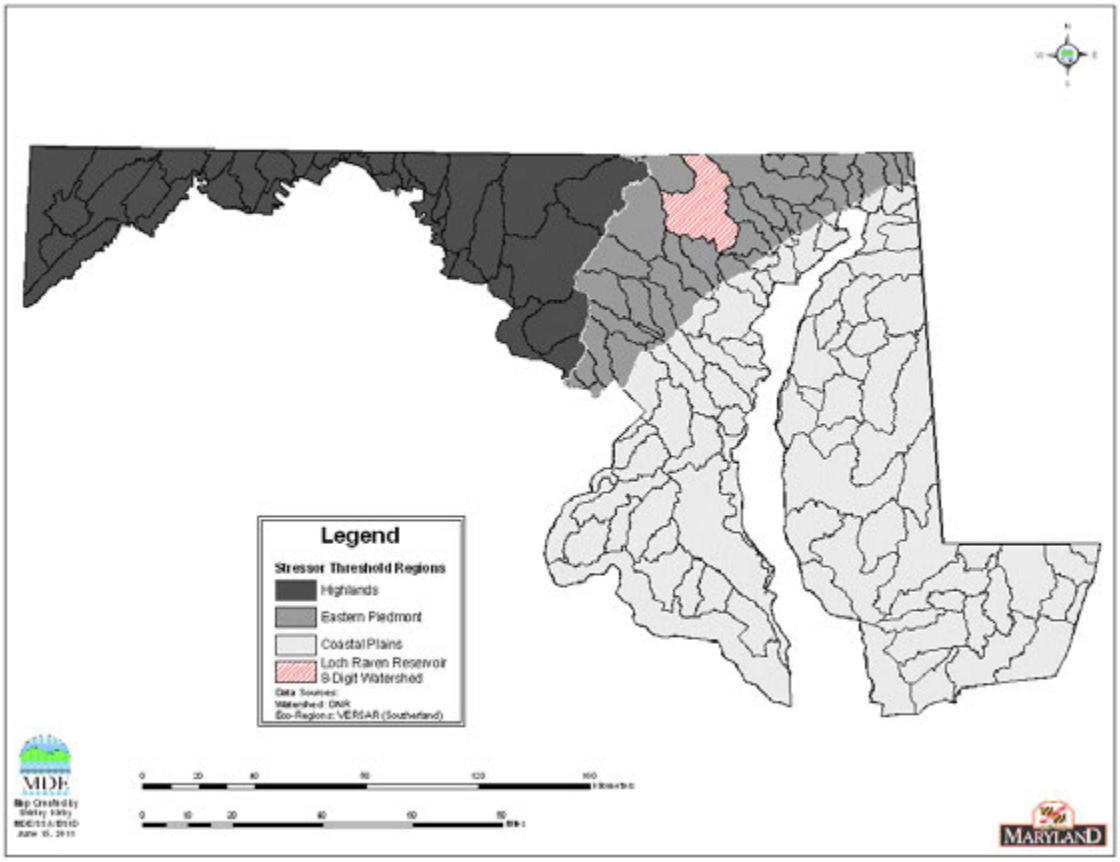

Figure 2. Eco-Region Location Map of the Loch Raven Reservoir Watershed

2.2 Land Use

Land use in the Loch Raven Reservoir watershed is primarily agricultural/pasture but also consists of forested and urban areas (see Figure 3). The forested areas are mainly along Gunpowder Falls and surrounding the reservoir. The urban areas are mostly in the southern part of the watershed. Regional Earth Science Application Center (RESAC) land use/land cover was used to estimate the land use for the Pennsylvania portion of the watershed. RESAC shows that the Pennsylvania portion is largely pasture and agricultural (MDE 2009b). The watershed includes the towns of Lutherville, Timonium, Cockeysville, Phoenix, Parkton, and Hampstead. State and county paved roads, such as Interstate 83, Routes 25, 45, 88, 128, 138, 145, and 146 and several minor roads interconnect points within the watershed. The tributaries to the reservoir include Beetree Run, Little Falls, Third Mine Branch, Second Mine Branch, First Mine Branch, Gunpowder Falls, Blackrock Run, Piney Run, McGill Run, Western Run and Beaverdam Run. Gunpowder Falls begins at the outlet of the Prettyboy Reservoir. A major tributary to Gunpowder Falls is Little Falls, which begins near the Pennsylvania border. Waters of the Loch Raven Reservoir watershed are designated as Tier II and they include Beetree

Run, First Mine Branch, Little Falls, Blackrock Run, Delaware Run, Indian Run, and Western Run (see Figure 5). The reservoir is part of the water supply system for Baltimore City and surrounding jurisdictions. Water supply intakes in Loch Raven Reservoir feed Baltimore City's Montebello Water Treatment Plant. The land use distribution in the watershed is approximately 37% agricultural/pasture, 37% forest/herbaceous, and 24% urban (see Figure 4) (MDP 2002). Urban impervious surface is 3% of the total land use in the watershed (USEPA 2010).

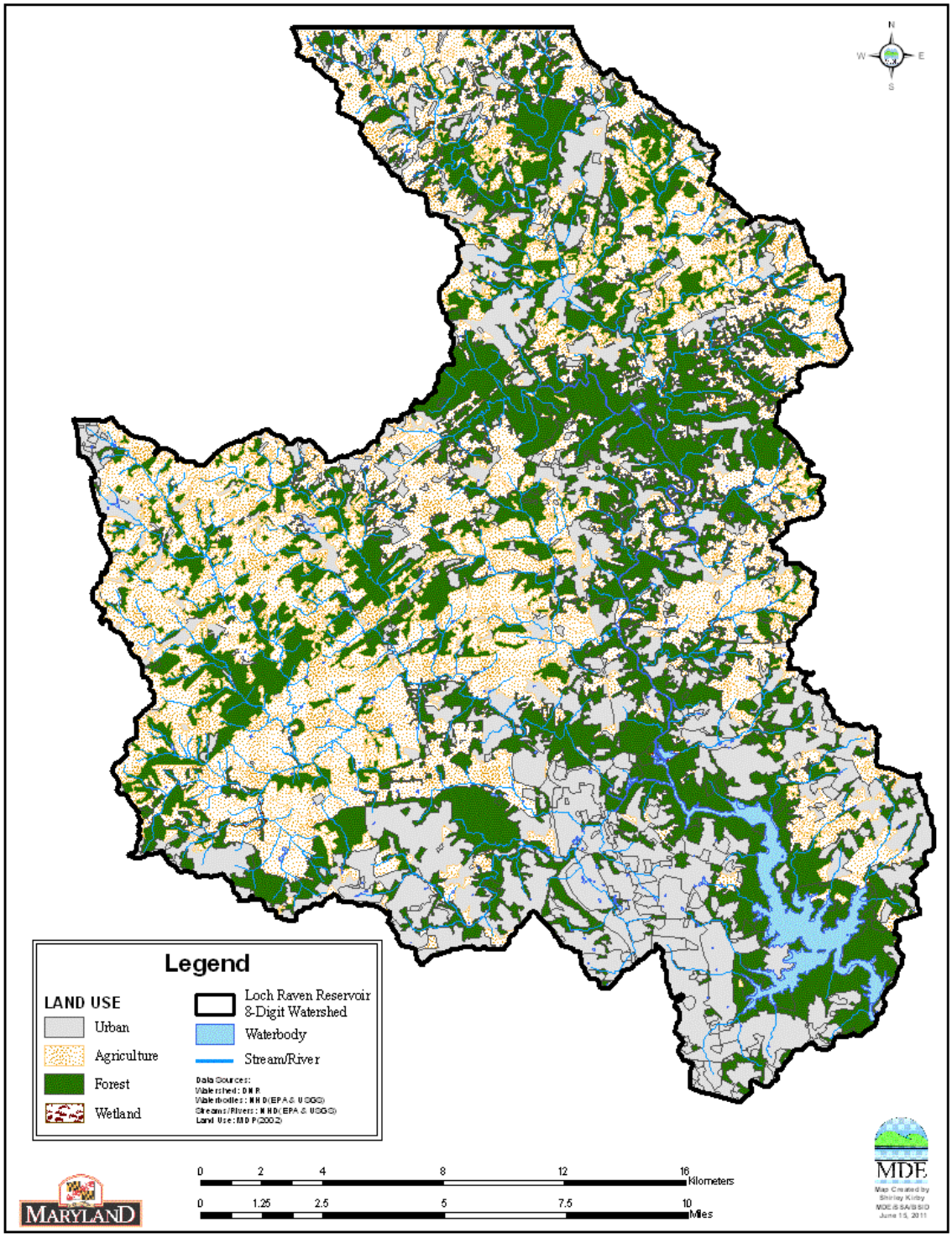

Figure 3. Land Use Map of the Loch Raven Reservoir Watershed

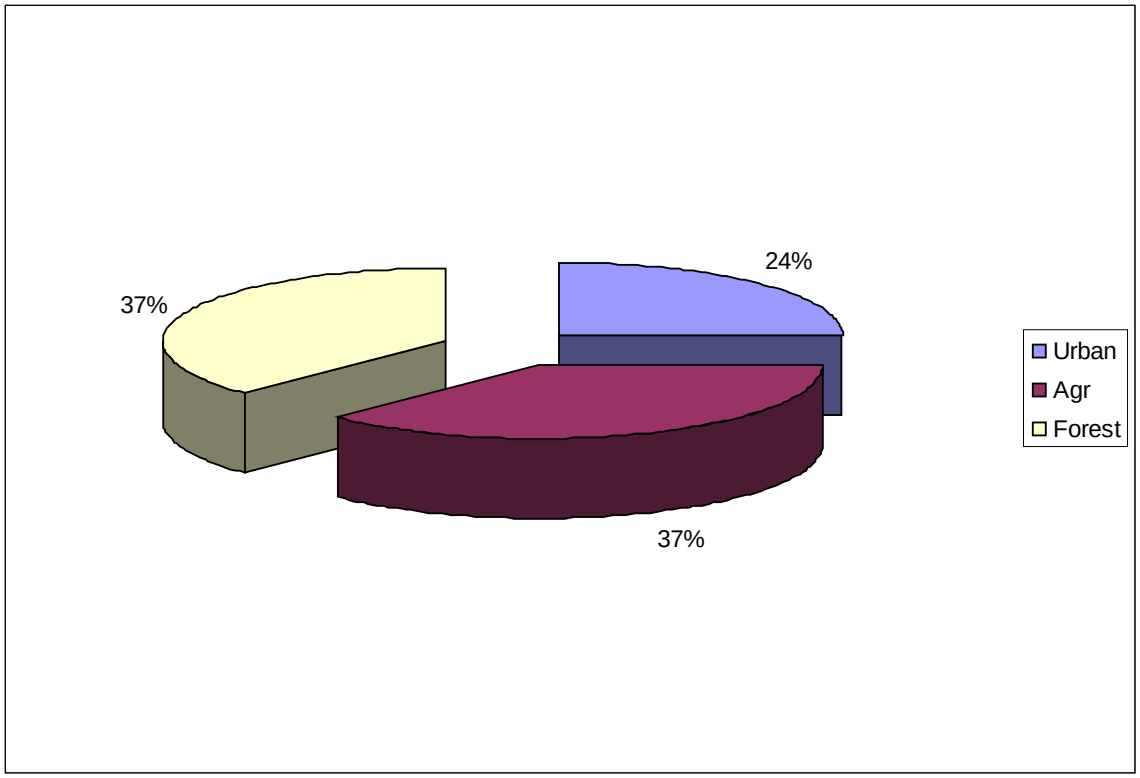

Figure 4. Proportions of Land Use in the Loch Raven Reservoir Watershed

2.3 Soils/hydrology

The Loch Raven Reservoir watershed is in the Piedmont Physiographic Province, which lies between the Blue Ridge and Coastal Plain physiographic provinces. Physiographic, or geomorphic, regions are broad-scale subdivisions based on terrain texture, rock type, and geologic structure and history (USGS 2013). The Piedmont surficial geology is characterized by metamorphic rock of Precambrian and Cambrian age (MDE 2004). The underlying metamorphic rock complex of the Loch Raven watershed downstream of Prettyboy Reservoir consists mainly of crystalline schists and gneiss with smaller areas of marble. The underlying marble formations, Cockeysville Marble and the Patuxent Formation, are less resistant to weathering than the schists and gneiss and consequently occur mainly in valleys. The primary soil associations in the watershed are the Manor-Glenelg, Chester-Glenelg, Baltimore-Conestoga-Hagerstown, Beltsville-Chillum-Sassafras, Glenelg-Chester-Manor, and Mt. Airy-Linganore associations. These soils are mainly deep and well drained to moderately well-drained. Within the stream floodplains, alluvial, Codorus and Hatboro soil series predominate (Reybold and Matthews 1976; Matthews 1969).

3.0 Loch Raven Reservoir Watershed Water Quality Characterization

3.1 Integrated Report Impairment Listings

The Maryland Department of the Environment (MDE) has identified the waters of the Loch Raven Reservoir watershed (basin number 02130805) has having multiple listings on the State's Integrated Report (Table 1) (MDE 2012).

Table 1. 2012 Integrated Report Listings for the Loch Raven Reservoir Watershed

Watershed	Basin Code	Non-tidal/ Tidal	Subwatershed	Designated Use	Year listed	Identified Pollutant	Listing Category
Loch Raven Reservoir	02130805	Non-tidal		Water Contact Sports	2008	Fecal Coliform	4a
				Aquatic Life and Wildlife	2002	Impacts to Biological Communities	5
		Non-tidal/ Impoundment		Aquatic Life and Wildlife	1996	TP	4a
						Sedimentation	
					-	Arsenic	2
						Cadmium	
						Total Chromium	
						Copper	
						Lead	
						Nickel	
						Selenium	
				Fishing	2002	Mercury in Fish Tissue	4a
					-	PCB in Fish Tissue	2

3.2 Biological Impairment

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the Loch Raven Reservoir watershed's tributaries are designated as Use III-P – *non-tidal cold water and public water supply*. The impoundment is designated as Use I-P – *water contact recreation, protection of aquatic life, and public water supply* (COMAR 2012 a, b). Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. The criteria developed to protect the designated use may differ and are dependent on the specific designated use(s) of a waterbody.

The Loch Raven Reservoir watershed is listed under Category 5 of the 2012 Integrated Report as impaired for impacts to biological communities. Approximately 27% of stream miles in the Loch Raven Reservoir watershed are estimated as having fish and/or benthic indices of biological impairment in the poor to very poor category. The biological impairment listing is based on the combined results of MDDNR MBSS round one (1995-1997) and round two (2000-2004) data, which include forty-five stations. Twelve of the forty-five stations have degraded benthic and/or fish indices of biotic integrity (BIBI, FIBI) scores significantly lower than 3.0 (i.e., poor to very poor). The principal dataset, i.e. MBSS round two, contains twenty sites; ten of the twenty sites have BIBI and/or FIBI scores lower than 3.0. Figure 5 illustrates principal dataset site and Tier II catchment locations for the Loch Raven Reservoir watershed.

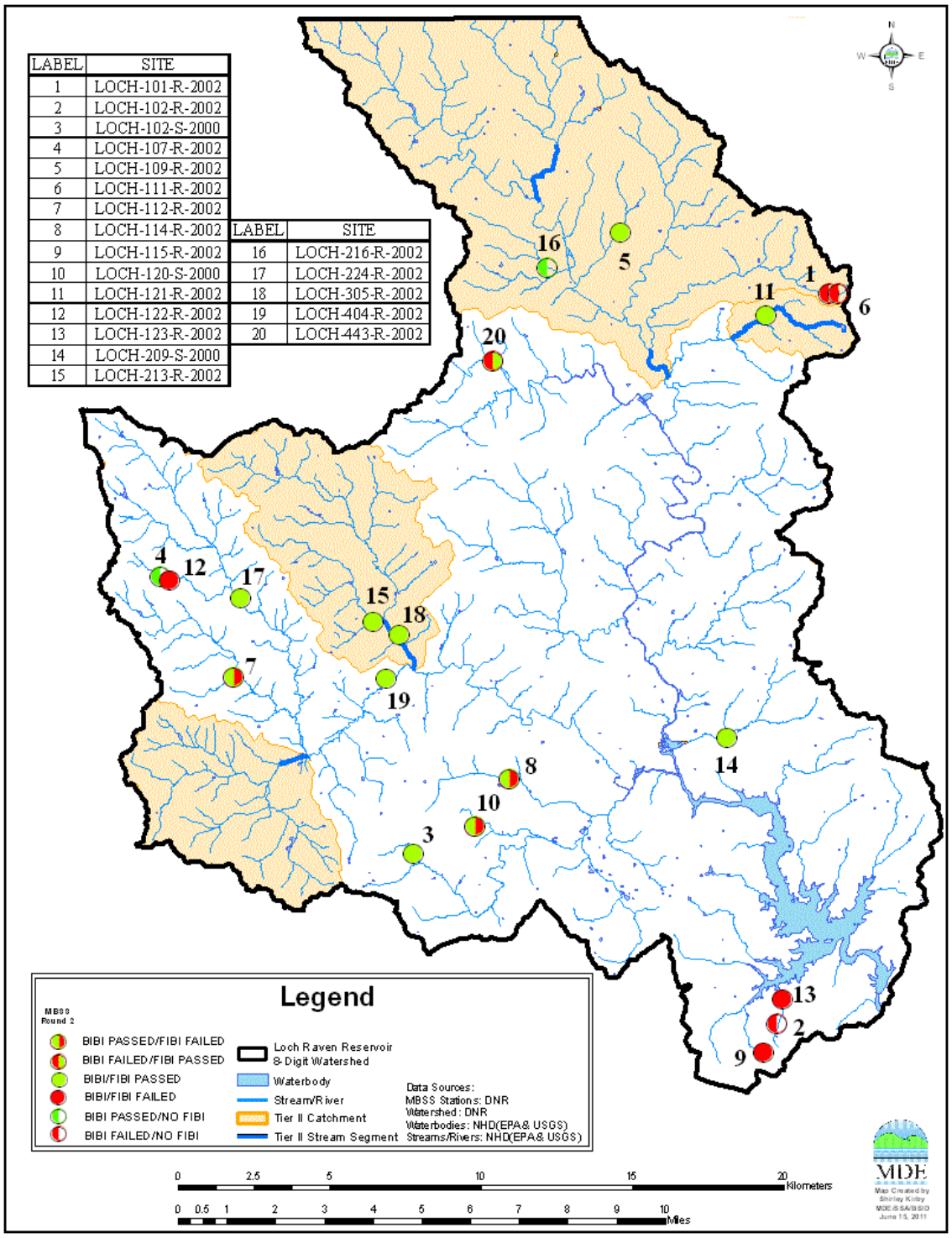

Figure 5. Principal Dataset Sites for the Loch Raven Reservoir Watershed

4.0 Stressor Identification Results for the Loch Raven Reservoir Watershed

The BSID process uses results from the BSID data analysis to evaluate each biologically impaired watershed and determine potential stressors and sources. Interpretation of the BSID data analysis results is based upon components of Hill's Postulates (Hill 1965), which propose a set of standards that could be used to judge when an association might be causal. The components applied are: 1) the strength of association which is assessed using the odds ratio; 2) the specificity of the association for a specific stressor (risk among controls); 3) the presence of a biological gradient; 4) ecological plausibility which is illustrated through final causal models; and 5) experimental evidence gathered through literature reviews to help support the causal linkage.

The BSID data analysis tests for the strength of association between stressors and degraded biological conditions by determining if there is an increased risk associated with the stressor being present. More specifically, the assessment compares the likelihood that a stressor is present, given that there is a degraded biological condition, by using the ratio of the incidence within the case group as compared to the incidence in the control group (odds ratio). The case group is defined as the sites within the assessment unit with BIBI/FIBI scores lower than 3.0 (i.e., poor to very poor). The controls are sites with similar physiographic characteristics (Highland, Eastern Piedmont, and Coastal region), and stream order for habitat parameters (two groups – 1st and 2nd-4th order), that have fair to good biological conditions.

The common odds ratio confidence interval was calculated to determine if the odds ratio was significantly greater than one. The confidence interval was estimated using the Mantel-Haenzel (1959) approach and is based on the exact method due to the small sample size for cases. A common odds ratio significantly greater than one indicates that there is a statistically significant higher likelihood that the stressor is present when there are poor to very poor biological conditions (cases) than when there are fair to good biological conditions (controls). This result suggests a statistically significant positive association between the stressor and poor to very poor biological conditions and is used to identify potential stressors.

Once potential stressors are identified (i.e., odds ratio significantly greater than one), the risk attributable to each stressor is quantified for all sites with poor to very poor biological conditions within the watershed (i.e., cases). The attributable risk (AR) defined herein is the portion of the cases with poor to very poor biological conditions that are associated with the stressor. The AR is calculated as the difference between the proportion of case sites with the stressor present and the proportion of control sites with the stressor present.

Once the AR is calculated for each possible stressor, the AR for groups of stressors is calculated. Similar to the AR calculation for each stressor, the AR calculation for a

group of stressors is also calculated over the case sites using the individual site characteristics (i.e., stressors present at that site). The only difference is that the absolute prevalence at each control site is estimated based on the stressor present at the site that has the lowest absolute prevalence among the controls.

After determining the AR for each stressor and the AR for groups of stressors, the AR for all potential stressors is calculated. This value represents the excess prevalence of all potential stressors in cases, sites in the watershed with poor to very poor biological conditions, beyond the prevalence in controls. The purpose of this metric is to determine if stressors have been identified for an acceptable proportion of cases (MDE 2009).

The parameters used in the BSID analysis are segregated into five groups: land use sources, and stressors representing sediment, in-stream habitat, riparian habitat, and water chemistry conditions. Through the BSID data analysis, MDE identified instream and riparian habitat, water chemistry, and potential sources significantly associated with degraded fish and/or benthic macroinvertebrate biological conditions. Parameters identified as representing possible sources are listed in Table 2 and include various agricultural and urban land use types. A summary of combined AR values for each source group is shown in Table 3. As shown in Table 5 and Table 6, parameters from the instream and riparian habitat and water chemistry groups are identified as possible biological stressors in the Loch Raven Reservoir watershed. A summary of combined AR values for each stressor group is shown in Table 7.

Table 2. Stressor Source Identification Analysis Results for the Loch Raven Reservoir Watershed

Parameter group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Benthic or Fish IBI)	Controls (average number of reference sites with fair to good Benthic or Fish IBI)	% of case sites with stressor present	% of control sites per stratum with stressor present	Statistical probability that the stressor is not impacting biology (p value)	Possible stressor (odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1)	% of case sites associated with the stressor (attributable risk)
Sources - Acidity	Agricultural acid source present	20	10	164	0%	2%	1	No	_
	AMD acid source present	20	10	164	0%	0%	1	No	_
	Organic acid source present	20	10	164	0%	0%	1	No	_
Sources - Agricultural	High % of agriculture in watershed	20	10	164	30%	7%	0.043	Yes	23%
	High % of agriculture in 60m buffer	20	10	164	20%	4%	0.086	Yes	16%
Sources - Anthropogenic	Low % of forest in watershed	20	10	164	20%	4%	0.086	Yes	16%
	Low % of wetland in watershed	20	10	164	60%	23%	0.016	Yes	37%
	Low % of forest in 60m buffer	20	10	164	20%	6%	0.144	No	_
	Low % of wetland in 60m buffer	20	10	164	0%	0%	1	No	_
Sources - Impervious	High % of impervious surface in watershed	20	10	164	20%	7%	0.186	No	_
	High % of impervious surface in 60m buffer	20	10	164	30%	8%	0.052	Yes	22%
	High % of roads in watershed	20	10	164	20%	4%	0.086	Yes	16%
	High % of roads in 60m buffer	20	10	164	10%	1%	0.164	No	_
Sources - Urban	High % of high-intensity developed in watershed	20	10	164	0%	1%	1	No	_
	High % of low-intensity developed in watershed	20	10	164	30%	9%	0.061	Yes	21%
	High % of medium-intensity developed in watershed	20	10	164	10%	2%	0.259	No	_
	High % of residential developed in watershed	20	10	164	20%	8%	0.208	No	_
	High % of rural developed in watershed	20	10	164	10%	4%	0.344	No	_
	High % of high-intensity developed in 60m buffer	20	10	164	0%	0%	1	No	_

Parameter group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Benthic or Fish IBI)	Controls (average number of reference sites with fair to good Benthic or Fish IBI)	% of case sites with stressor present	% of control sites per stratum with stressor present	Statistical probability that the stressor is not impacting biology (p value)	Possible stressor (odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1)	% of case sites associated with the stressor (attributable risk)
	High % of low-intensity developed in 60m buffer	20	10	164	10%	2%	0.212	No	_
	High % of medium-intensity developed in 60m buffer	20	10	164	0%	0%	1	No	_
	High % of residential developed in 60m buffer	20	10	164	20%	5%	0.105	No	_
	High % of rural developed in 60m buffer	20	10	164	30%	6%	0.029	Yes	24%

Table 3. Summary of Combined Attributable Risk Values for Source Groups in the Loch Raven Reservoir Watershed

Source Group	% of degraded sites associated with specific source group (attributable risk)
Sources - Agricultural	25%
Sources - Anthropogenic	57%
Sources - Impervious	35%
Sources - Urban	53%
All Sources	***81%***

4.1 Sources Identified by BSID Analysis

All the sources identified by the BSID analysis (Table 2), are the result of anthropogenic development within the Loch Raven Reservoir watershed. The watershed is comprised of 24% urban and 37% agricultural land uses; BSID results show that agricultural, urban and transportation development in the watershed and within the sixty meter riparian buffer zone has a significant association with degraded biological conditions. Due to the anthropogenic development there is a low percentage of forest and wetland in the watershed and the sixty meter riparian buffer zone. The land sources identified (a *high*

percentage of agriculture in watershed and riparian buffer, low percentage of forest, low percentage of wetlands, high impervious surfaces in riparian buffer, high percentage of roads in riparian buffer, high percentage of low intensity development in the watershed, and high percentage of rural development in the riparian buffer) are indicative of anthropogenic activities that result in altered natural landscapes, and increased inputs of nutrients and contaminants to streams.

Anthropogenic land development can also cause an increase in contaminant loads from point and nonpoint sources by adding sediments, nutrients, road salts, toxics, and inorganic pollutants to surface waters. In virtually all studies, as the amount of impervious area in a watershed increases, fish and benthic communities exhibit a shift away from sensitive species to assemblages consisting of mostly disturbance-tolerant taxa (Walsh et al. 2005).

Numerous studies have documented declines in water quality, habitat, and biological assemblages as the extent of agricultural land increases within catchments (Roth, Allan, and Erickson 1996; Wang et al. 1997; and Bis, Zdanowicz, and Zalewski 2000). Researchers commonly report that streams draining agricultural lands support fewer species of sensitive benthic and fish taxa than streams draining forested catchments (Wang et al. 1997). Agricultural land use degrades streams by increasing nonpoint inputs of pollutants, impacting riparian and stream channel habitat, and altering flows.

Agricultural land uses comprise 37% of the Loch Raven Reservoir watershed. Agricultural land use within the watershed, as well as within the sixty meter riparian zone, were found to be significantly associated with poor to very poor biological conditions in the watershed. The high percentage of agricultural land use within the 60 meter (m) buffer zone is indicative of the agricultural crops that are cultivated to the stream banks. Although nutrient management practices (NMPs) and best management practices (BMPs) are in place to control nutrient runoff in the watershed, the BSID analyses revealed that agricultural practices continue to create conditions in the watershed that are impacting biological resources. The excess nitrogen and phosphorus from fertilizer applications is leading to eutrophication in the watershed, as evidenced by the low dissolved oxygen stressors identified as significantly associated with degraded biological conditions in the watershed.

Streams in highly agricultural landscapes also tend to have poor habitat quality, reflected in declines in habitat indices and bank stability, as well as greater deposition of sediments on and within the streambed (Roth, Allan, and Erickson 1996; Wang et al. 1997). Sediments in runoff from cultivated land and livestock trampling are considered to be particularly influential in stream impairment (Waters 1995).

The BSID source analysis (Table 2) identifies various types of agricultural and urban land uses as potential sources of stressors that may cause negative biological impacts. The combined AR for the source group is approximately 81%, suggesting these land use

sources are the most prevalent sources of biological impairments in the Loch Raven Reservoir watershed (Table 3).

The remainder of this section will discuss the eight stressors identified by the BSID analysis (Table 4, 5, and 6) and their link to degraded biological conditions in the watershed.

Table 4. Sediment Biological Stressor Identification Analysis Results for the Loch Raven Reservoir Watershed

Parameter group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Benthic or Fish IBI)	Controls (average number of reference sites with fair to good Benthic or Fish IBI)	% of case sites with stressor present	% of control sites per stratum with stressor present	Statistical probability that the stressor is not impacting biology (p value)	Possible stressor (odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1)	% of case sites associated with the stressor (attributable risk)
Sediment	Extensive bar formation present	19	9	92	11%	13%	1	No	_
	Moderate bar formation present	19	9	92	56%	41%	0.496	No	_
	Channel alteration moderate to poor	19	9	92	56%	40%	0.491	No	_
	Channel alteration poor	19	9	92	11%	11%	1	No	_
	High embeddedness	19	9	92	11%	3%	0.311	No	_
	Epifaunal substrate marginal to poor	19	9	92	33%	14%	0.135	No	_
	Epifaunal substrate poor	19	9	92	11%	3%	0.28	No	_
	Moderate to severe erosion present	19	9	94	67%	60%	1	No	_
	Severe erosion present	19	9	92	22%	12%	0.337	No	_

Table 5. Habitat Biological Stressor Identification Analysis Results for the Loch Raven Reservoir Watershed

Parameter group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Benthic or Fish IBI)	Controls (average number of reference sites with fair to good Benthic or Fish IBI)	% of case sites with stressor present	% of control sites per stratum with stressor present	Statistical probability that the stressor is not impacting biology (p value)	Possible stressor (odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1)	% of case sites associated with the stressor (attributable risk)
Instream Habitat	Channelization present	20	10	94	10%	9%	1	No	_
	Concrete/gabion present	20	10	93	10%	1%	0.201	No	_
	Beaver pond present	19	9	92	0%	4%	1	No	_
	Instream habitat structure marginal to poor	19	9	92	33%	14%	0.128	No	_
	Instream habitat structure poor	19	9	92	11%	1%	0.15	No	_
	Pool/glide/eddy quality marginal to poor	19	9	92	44%	55%	0.719	No	_
	Pool/glide/eddy quality poor	19	9	92	11%	1%	0.15	No	_
	Riffle/run quality marginal to poor	19	9	92	67%	20%	0.004	Yes	47%
	Riffle/run quality poor	19	9	92	0%	1%	1	No	_
	Velocity/depth diversity marginal to poor	19	9	92	44%	55%	0.72	No	_
	Velocity/depth diversity poor	19	9	92	0%	0%	1	No	_
Riparian Habitat	No riparian buffer	20	10	93	60%	25%	0.023	Yes	36%
	Low shading	19	9	92	11%	4%	0.367	No	_

Table 6. Water Chemistry Biological Stressor Identification Analysis Results for the Loch Raven Reservoir Watershed

Parameter group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Benthic or Fish IBI)	Controls (average number of reference sites with fair to good Benthic or Fish IBI)	% of case sites with stressor present	% of control sites per stratum with stressor present	Statistical probability that the stressor is not impacting biology (p value)	Possible stressor (odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1)	% of case sites associated with the stressor (attributable risk)
Chemistry - Inorganic	High chlorides	20	10	164	30%	4%	0.013	Yes	26%
	High conductivity	20	10	164	50%	4%	0	Yes	46%
	High sulfates	20	10	164	30%	7%	0.043	Yes	23%
Chemistry - Nutrients	Dissolved oxygen < 5mg/l	19	9	163	11%	1%	0.15	No	_
	Dissolved oxygen < 6mg/l	19	9	163	22%	3%	0.045	Yes	19%
	Low dissolved oxygen saturation	19	9	163	44%	12%	0.023	Yes	32%
	High dissolved oxygen saturation	19	9	163	0%	1%	1	No	_
	Ammonia acute with salmonid present	20	10	164	0%	0%	1	No	_
	Ammonia acute with salmonid absent	20	10	164	0%	0%	1	No	_
	Ammonia chronic with early life stages present	20	10	164	0%	0%	1	No	_
	Ammonia chronic with early life stages absent	20	10	164	0%	0%	1	No	_
	High nitrites	20	10	164	20%	5%	0.105	No	_
	High nitrates	20	10	164	0%	3%	1	No	_
	High total nitrogen	20	10	164	0%	7%	1	No	_
	High total phosphorus	20	10	164	30%	8%	0.052	Yes	22%
	High orthophosphate	20	10	164	10%	5%	0.421	No	_
Chemistry - pH	Acid neutralizing capacity below chronic level	20	10	164	0%	1%	1	No	_
	Low field pH	19	9	163	11%	4%	0.318	No	_
	High field pH	19	9	163	0%	2%	1	No	_
	Low lab pH	20	10	164	10%	3%	0.303	No	_
	High lab pH	20	10	164	0%	2%	1	No	_

Table 7. Summary of Combined Attributable Risk Values for Stressor Groups in the Loch Raven Reservoir Watershed

Stressor Group	% of degraded sites associated with specific stressor group (attributable risk)
Instream Habitat	47%
Riparian Habitat	36%
Chemistry - Inorganic	46%
Chemistry - Nutrients	45%
All Chemistry	66%
All Stressors	***83%***

4.2 Stressors Identified by BSID Analysis

All eight stressor parameters identified by the BSID analysis (Tables 4 and 5), are significantly associated with biological degradation in the Loch Raven Reservoir watershed and are representative of impacts from anthropogenic development of natural landscapes.

Sediment Conditions

BSID analysis results for the Loch Raven Reservoir watershed did not identify any sediment habitat parameters that have a statistically significant association with poor to very poor stream biological condition, i.e., removal of stressors would result in improved biological community (Table 4).

Instream Habitat Conditions

BSID analysis results for the Loch Raven Reservoir watershed identified one instream habitat parameter that have a statistically significant association with poor to very poor stream biological condition, i.e., removal of stressors would result in improved biological community: *riffle/run quality (marginal to poor)* (Table 5).

Riffle/run quality was identified as significantly associated with degraded biological conditions and found to impact approximately 47% *(marginal to poor)* of the stream miles with poor to very poor biological conditions in the Loch Raven Reservoir watershed. Riffle/run quality is a visual observation including quantitative measurements

based on the depth, complexity, and functional importance of riffle/run habitat within the stream segment. An increase of heterogeneity of riffle/run habitat within the stream segment likely increases the abundance and diversity of fish species, while a decrease in heterogeneity likely decreases abundance and diversity. Marginal to poor and poor ratings are expected in unstable stream channels that experience frequent high flows.

The combined AR is used to measure the extent of stressor impact of degraded stream miles, poor to very poor biological conditions. The combined AR for the in-stream habitat stressor group is approximately 47% suggesting that this stressor group impacts a moderate proportion of the degraded stream miles in the Loch Raven Reservoir (Table 7).

Riparian Habitat Conditions

BSID analysis results for the Loch Raven Reservoir watershed identified one riparian habitat parameter that has a statistically significant association with poor to very poor stream biological condition, i.e., removal of stressors would result in improved biological community: *no riparian buffer* (Table 5).

No riparian buffer was identified as significantly associated with degraded biological conditions and found to impact approximately 36% of the stream miles with poor to very poor biological conditions in the Loch Raven Reservoir watershed. Riparian Buffer Width represents the minimum width of vegetated buffer in meters, looking at both sides of the stream. Riparian buffer width is measured from 0 m to 50 m, with 0 m having no buffer and 50 m having a full buffer. Riparian buffers serve a number of critical ecological functions. They control erosion and sedimentation, modulate stream temperature, provide organic matter, and maintain benthic macroinvertebrate communities and fish assemblages (Lee, Smyth, and Boutin 2004).

Riparian buffers are beneficial because they slow water runoff, trap sediment, and enhance infiltration. Often, the natural transition zone is altered through various land uses, and the protective nature of the riparian zone becomes ineffective or even detrimental to the health of the water body. Some typical quality problems for watersheds with anthropogenic disturbances in riparian buffer zones involve an influx of chemicals and excessive sediment from both agricultural and urban sources (Delong and Brusven 1994). Agricultural, rural, and impervious development within the riparian buffer zones was identified in the BSID analysis as significant sources.

The combined AR is used to measure the extent of stressor impact of degraded stream miles, poor to very poor biological conditions. The combined AR for the in-stream habitat stressor group is approximately 36% suggesting these stressors are associated with biological impairments in the Loch Raven Reservoir (Table 7).

Water Chemistry

BSID analysis results for the Loch Raven Reservoir watershed identified six water chemistry parameters that have statistically significant association with a poor to very poor stream biological condition (i.e., removal of stressors would result in improved biological community): *high chloride, high conductivity, high sulfates, dissolved oxygen <6 mg/L, low dissolved oxygen saturation, high total phosphorus* (Table 6).

High chlorides concentration was identified as significantly associated with degraded biological conditions and found in approximately 26% of the stream miles with poor to very poor biological conditions in the Loch Raven Reservoir watershed. Chloride can play a critical role in the elevation of conductivity. Chloride in surface waters can result from both natural and anthropogenic sources, such as run-off containing road de-icing salts, the use of inorganic fertilizers, landfill leachates, septic tank effluents, animal feeds, industrial effluents, irrigation drainage, and seawater intrusion in coastal areas. Smith, Alexander, and Wolman (1987), have identified that, although chloride can originate from natural sources, in urban watersheds road salts (i.e., sodium chloride) can be a likely source of high chloride and conductivity levels.

High sulfates concentration was identified as significantly associated with degraded biological conditions and found in 23% of the stream miles with poor to very poor biological conditions in the Loch Raven Reservoir watershed. Sulfates can also play a critical role in the elevation of conductivity. Other detrimental impacts of elevated sulfates are their ability to form strong acids, which can lead to changes of pH levels in surface waters. Sulfate loads to surface waters can be naturally occurring or originate from urban runoff, agricultural runoff, acid mine drainage, atmospheric deposition, and wastewater dischargers. When naturally occurring, they are often the result of the breakdown of leaves that fall into a stream, or of water passing through rock or soil containing gypsum and other common minerals. Sulfate in urban areas can be derived from natural and anthropogenic sources, including combustion of fossil fuels such as coal, oil, and diesel; discharge from industrial sources, and discharge from municipal wastewater treatment facilities. Typically sulfates derived from agricultural landscapes are associated with fertilizers, which often contain various types and concentrations of sulfate anions.

High conductivity levels were identified as significantly associated with degraded biological conditions and found to impact approximately 46% of the stream miles with poor to very poor biological conditions in the Loch Raven Reservoir watershed. Conductivity is a measure of water's ability to conduct electrical current and is directly related to the total dissolved salt content of the water. Conductivity can serve as an indicator that a pollution discharge or some other source of inorganic contaminant has entered a stream. Increased levels of inorganic pollutants can be toxic to aquatic organisms and lead to exceedences in species tolerances. Most of the total dissolved salts of surface waters are comprised of inorganic compounds or ions, such as chloride,

sulfate, carbonate, sodium, and phosphate (IDNR 2008). Urban and agricultural runoffs (i.e., fertilizers), septic drainage, as well as leaking wastewater infrastructure are typical sources of inorganic compounds.

Dissolved oxygen (DO) <6 mg/L concentration was identified as significantly associated with degraded biological conditions and found to impact approximately 19% of the stream miles with poor to very poor biological conditions in the Loch Raven Reservoir watershed. Low DO concentrations may indicate organic pollution due to excessive oxygen demand and may stress aquatic organisms. The DO threshold value, at which concentrations below 5.0 mg/L may indicate biological degradation, is established by COMAR (2012c).

Low (<60%) *DO saturation* concentration was identified as significantly associated with degraded biological conditions and found to impact approximately 32% of the stream miles with poor to very poor biological conditions in the Loch Raven Reservoir watershed. Natural diurnal fluctuations can become exaggerated in streams with excessive primary production. DO saturation levels less than 60% saturation are considered to demonstrate high respiration associated with excessive decomposition of organic material. Fluctuations of saturation concentration can be due to agricultural, forested, and urban land uses.

High total phosphorus (TP) concentrations were identified as significantly associated with degraded biological conditions and found to impact approximately 22% of the stream miles with poor to very poor biological conditions in the Loch Raven Reservoir watershed. This stressor is a measure of the amount of TP in the water column. Phosphorus forms the basis of a very large number of compounds, the most important class of which is the phosphates. For every form of life, phosphates play an essential role in all energy-transfer processes such as metabolism and photosynthesis. Excessive phosphorus concentrations in surface water can accelerate eutrophication, resulting in increased growth of undesirable algae and aquatic weeds. Eutrophication can potentially result in low dissolved oxygen and high pH levels, which can exceed tolerance levels of many biological organisms. TP input to surface waters typically increases in watersheds where agricultural and urban development are predominant.

Water chemistry is a major determinant of the integrity of surface waters that is strongly influenced by land use. Agricultural land uses comprise 37% of the Loch Raven reservoir watershed. Agricultural land uses within the watershed as well as within the sixty meter riparian zone were found to be significantly associated with poor to very poor biological conditions in the watershed. Developed landscapes, particularly the proportion of agriculture in the catchments and the riparian zone, often result in increased inputs of nitrogen, phosphorus, sulfates, and suspended sediments to surface waters. Although NMPs and BMPs are in place to control nutrient runoff in the watershed, the BSID analysis revealed that agricultural practices continue to create conditions that are negatively impacting biological resources. The excess phosphorus from fertilizer

applications is leading to eutrophication in the watershed, as evidenced by the *high total phosphorus* and *low dissolved oxygen* stressors identified as significantly associated with degraded biological conditions in the watershed. Also, sulfate loadings from fertilizers can potentially reach levels that are toxic to aquatic organisms.

Elevated concentrations of chloride, sulfate, and conductivity identified by the BSID analysis can also be indicative of urban developed landscapes. Anthropogenic activities associated with urban land uses degrade water quality by causing an increase in contaminant loads from various point and nonpoint sources especially during storm events. These sources can add inorganic pollutants to surface waters at levels potentially toxic to aquatic organisms.

In the Loch Raven Reservoir watershed there are several heavily traveled road routes, such as Routes 83, 45, 25 among others, connecting the urban areas of the watershed. Application of road salts in the watershed is a likely source of the chlorides and high conductivity levels. Although chlorides can originate from natural sources, most of the chlorides that enter the environment are associated with the storage and application of road salt (Smith, Alexander, and Wolman 1987). For surface waters associated with roadways or storage facilities, episodes of salinity have been reported during the winter and spring in some urban watercourses in the range associated with acute toxicity in laboratory experiments (EC 2001). These salts remain in solution and are not subject to any significant natural removal mechanisms; road salt accumulation and persistence in watersheds poses risks to aquatic ecosystems and to water quality (Wegner and Yaggi 2001). According to Forman and Deblinger (2000), there is a “road-effect zone” over which significant ecological effects extend outward from a road; these effects extend 100 to 1,000 meters on each side of four-lane roads. Roads tend to capture and export more stormwater pollutants than other land covers. On-site septic systems, sanitary sewage overflows, and stormwater discharges are quite frequent in the watershed and are also likely sources of elevated concentrations of chloride, sulfates, and conductivity.

Currently in Maryland there are no specific numeric criteria that quantify the impact of chlorides, sulfates, or conductivity on the aquatic health of non-tidal stream systems. Since the exact sources and extent of inorganic pollutant loadings are not known, MDE determined that current data are not sufficient to enable identification of the specific pollutant(s) causing degraded biological communities from the array of potential inorganic pollutants loading from urban development.

The combined AR is used to measure the extent of stressor impact of degraded stream miles with poor to very poor biological conditions. The combined AR for the water chemistry stressor group is approximately 66% suggesting these stressors are associated with biological impairments in the Loch Raven Reservoir watershed (Table 7).

4.3 Discussion of BSID Results

The BSID analysis results suggest that degraded biological communities in the Loch Raven Reservoir watershed are a result of increased urban and agricultural land uses causing alteration to stream habitat that eliminates habitat heterogeneity. High proportions of these types of land uses also typically results in increased contaminant loads from point and nonpoint sources by adding nutrients and inorganic pollutants to surface waters, resulting in concentrations that can potentially be toxic to aquatic organisms. Alterations to the physical habitat and water chemistry have all combined to degrade the Loch Raven Reservoir watershed, leading to a loss of diversity in the biological community. The combined AR for all the stressors is approximately 83%, suggesting the stressors identified by the BSID analysis would adequately account for the biological impairment in the Loch Raven Reservoir watershed (Table 7).

The BSID analysis evaluates numerous key stressors using the most comprehensive data sets available that meet the requirements outlined in the methodology report. It is important to recognize that stressors could act independently or act as part of a complex causal scenario (e.g., eutrophication, urbanization, habitat modification). Also, uncertainties in the analysis could arise from the absence of unknown key stressors and other limitations of the principal data set. The results are based on the best available data at the time of evaluation.

4.4 Final Causal Model

Causal model development provides a visual linkage between biological condition, habitat, chemical, and source parameters available for stressor analysis. Models were developed to represent the ecologically plausible processes when considering the following five factors affecting biological integrity: biological interaction, flow regime, energy source, water chemistry, and physical habitat (Karr 1991; USEPA 2013). The five factors guide the selections of available parameters applied in the BSID analyses and are used to reveal patterns of complex causal scenarios. Figure 6 illustrates the final casual model for the Loch Raven Reservoir watershed, with pathways bolded or highlighted to show the watershed's probable stressors as indicated by the BSID analysis.

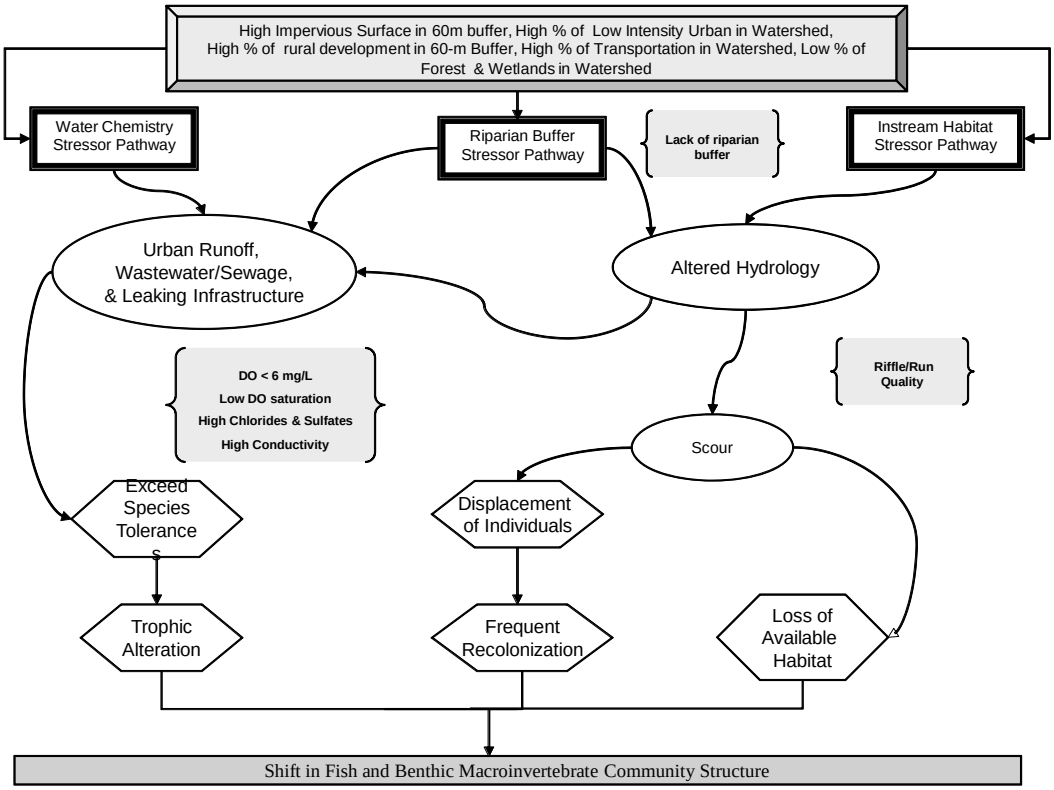

Figure 6. Final Causal Model for the Loch Raven Reservoir Watershed

5.0 Conclusion

Data suggest that the Loch Raven Reservoir watershed's biological communities are influenced by anthropogenic development. There is an abundance of scientific research that directly and indirectly links degradation of the aquatic health of streams to development of natural landscapes, which often causes disturbances in stream habitat and increased contaminant loads from runoff. Based upon the results of the BSID process, the probable causes and sources of the biological impairments of the Loch Raven Reservoir watershed are summarized as follows:

- The BSID analysis has determined that phosphorus is a probable cause of impacts to biological communities in the Loch Raven Reservoir watershed. Total phosphorus was identified as having significant association with degraded biological conditions. The BSID results thus confirm the development of the 2007 TMDL for nutrients was an appropriate management action to begin addressing the impacts of nutrient stressors on the biological communities in the Loch Raven Reservoir watershed.

- The BSID process has also determined that the biological communities in the Loch Raven Reservoir watershed are likely degraded due to inorganic pollutants (i.e., chlorides and sulfates). Chloride and sulfate levels are significantly associated with degraded biological conditions, and found in 26% and 23% respectively of the stream miles with poor to very poor biological conditions in Loch Raven Reservoir watershed. Runoff from roads, urban, and agricultural land uses causes an increase in contaminant loads from nonpoint sources by delivering an array of inorganic pollutants to surface waters. Discharges of inorganic compounds are very intermittent; concentrations vary widely depending on the time of year as well as a variety of other factors may influence their impact on aquatic life. Future monitoring of these parameters will help in determining the spatial and temporal extent of these impairments in the watershed. The BSID results thus support a Category 5 listing of chloride and sulfates for the 8-digit watershed as an appropriate management action to begin addressing the impacts of these stressors on the biological communities in the Loch Raven Reservoir watershed.

- The BSID process has also determined that biological communities in the Loch Raven watershed are likely degraded due to anthropogenic alterations of riparian buffer zones. MDE considers inadequate riparian buffer zones as pollution, not a pollutant; therefore, a Category 5 listing for this stressor is inappropriate. However, Category 4c is for waterbody segments where the State can demonstrate that the failure to meet applicable water quality standards is a result of pollution. MDE recommends a Category 4c listing for the Loch Raven watershed based on inadequate riparian buffer zones in approximately 36% of degraded stream miles.

- In 2007 a TMDL for total suspended sediments in the impoundment was developed and approved by EPA; however, the BSID analysis did not identify any sediment stressors in the non-tidal streams of the Loch Raven Reservoir watershed.

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