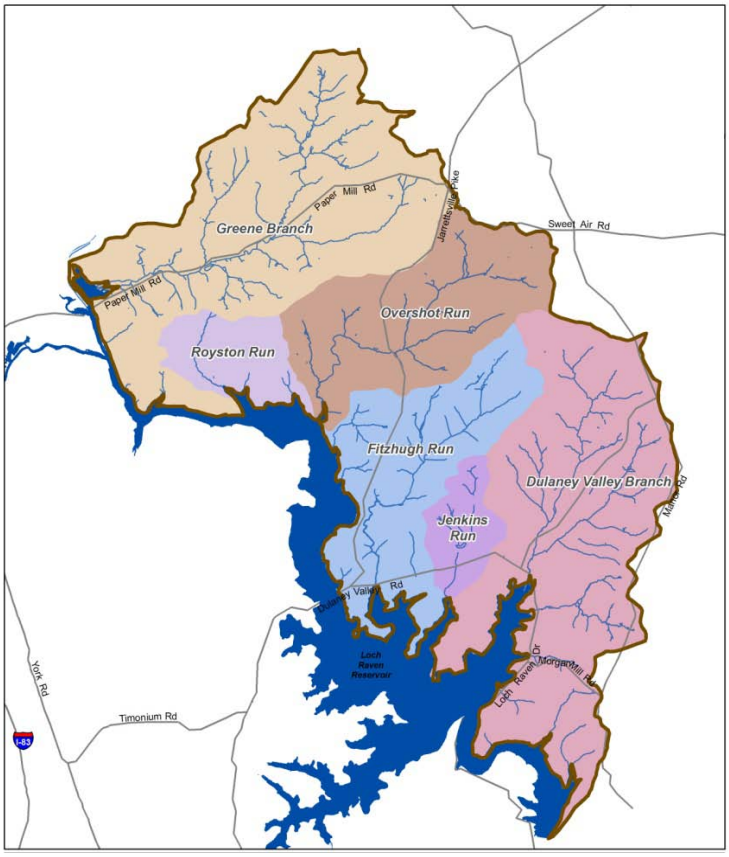
Appendix E

Loch Raven East
Watershed Characterization Report



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CHAPTER 1.0
Introduction

1.1 Purpose

The Loch Raven East Watershed Characterization Report has two primary objectives. First is to summarize the geomorphic, hydrological and biological natural resources in the watershed and to describe the current condition of these resources. The second objective is to describe the various human factors affecting these resources and identify restoration and preservation strategies which will help achieve the goals of the watershed. The information provided here will help to develop a Small Watershed Action Plan (SWAP) for the watershed.

1.2 Watershed Location and Scale

Loch Raven East (Planning Area R) lies in the Piedmont region of Maryland and is located in central Baltimore County. It is bounded on the southeast by Manor Road and on the south and southwest by Loch Raven Reservoir as shown on Figure 1-1. It encompasses 11,567 acres (18.1 square miles). This planning area was divided into six smaller drainage areas known as subwatersheds listed in Table 1- 1 and shown on Figure 2-1.

Loch Raven East is part of the Loch Raven Reservoir watershed, which is the largest of three area reservoir watersheds supplying water to Baltimore City and County. Baltimore City owns approximately 8,000 acres for forested buffer surrounding the reservoir Loch Raven, of which part is within this watershed. Loch Raven impounds the mainstem of Gunpowder Falls, with a watershed that extends upstream into Harford County, Carroll County, and York County, Pennsylvania. Below the reservoir, Gunpowder Falls flows southeast through Baltimore County to its confluence with the Chesapeake Bay near Joppatowne, MD.

Analysis was conducted at both the watershed (Loch Raven East) and subwatershed level. Analysis at the subwatershed level generally provides the detail required to make decisions about prioritizing restoration and preservation efforts. Restoration efforts are also more easily monitored at the subwatershed scale. This characterization report provides information at both levels, with analyses at the subwatershed level referring only to those portions of the subwatersheds within Loch Raven East.

Table 1- 1: Subwatershed Acreages

Subwatershed	Acres	Square Miles
Dulaney Valley Branch	3,577.2	5.6
Fitzhugh Run	1,772.3	2.8
Greene Branch	3,472.4	5.4
Jenkins Run	403.9	0.6
Overshot Run	1,782.9	2.8

Subwatershed	Acres	Square Miles
Royston Run	558.6	0.9
Total	**11,567.3**	**18.1**

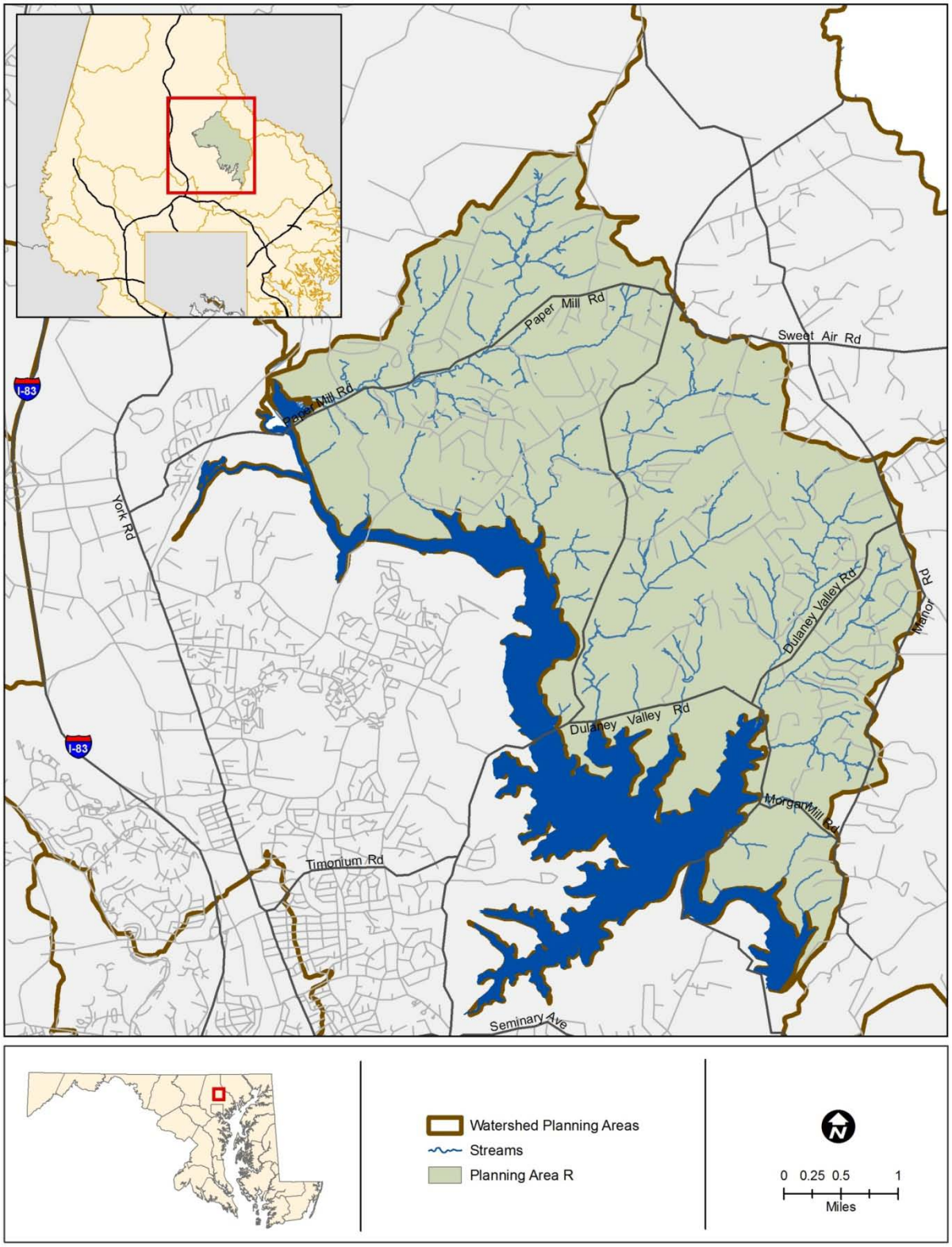


Figure 1-1: Loch Raven East Location

1.3 Report Organization

This report is organized into five chapters:

Chapter 1 explains the location of the study area and the purpose and scope of the characterization.

Chapter 2 summarizes watershed and subwatershed characteristics that may have an effect on water quality of streams, downstream receiving waters, groundwater, and other natural resources. This chapter includes information on climate, soils, geology, forest cover and streams within the watershed. It also includes information on human factors influencing these natural resources such as current land use, population, impervious cover, wastewater and storm water infrastructure.

Chapter 3 discusses water quality and quantity conditions based on available monitoring and stream assessment data.

Chapter 4 includes the upland assessment conducted to identify sources of pollution and potential restoration opportunities for neighborhoods, institutional land uses, pervious areas (open grass areas), and hotspots.

Chapter 5 summarizes potential preservation and restoration strategies appropriate for accomplishing watershed goals developed by the watershed stakeholders and Loch Raven East Steering Committee.

CHAPTER 2.0
Landscape and Land Use

2.1 Introduction

This chapter discusses land cover and land use in the Loch Raven East 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 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 is 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 because there is often 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 other watershed elements including water quality, natural resources, restoration and management.

This chapter will be presented in two parts: the first will document the natural characteristics of the watershed landscape, and the second will describe human activities that have altered the natural landscape.

2.2 The Natural Landscape

The natural landscape has characteristics relevant to watershed processes which are discussed in the following sections. These include climate, topography, geology, soils, forest cover, wetlands and the stream system within the watershed.

2.2.1 Climate

Climate influences soil formation and erosion processes, stream flow patterns and a significant part of the geomorphology of a watershed. Precipitation not only provides water to streams and plants, but the intensity, frequency and amount of precipitation can greatly influence watershed characteristics. Climate is a major factor determining the types of terrestrial and aquatic species that are present.

The climate of the region encompassing Loch Raven East is best described as humid continental with four well-defined seasons (USDA, 1976). The proximity of the Appalachian Mountains to the west and the Chesapeake Bay to the east provides a temperate climate with precipitation spread evenly throughout the year. Based on data from the National Oceanic and Atmospheric Administration (NWS, 2011), the average monthly rainfall from 1871 to 2011 is 3.49 inches in Baltimore with an average annual rainfall of 41.88 inches per year. Snowfall

generally occurs between January and March, with the heaviest snows occurring in January and February. The long-term average from 1981 to 2010 is 20.1 inches of snow per year.

Climate change will have an effect on watershed management in the future and may be included in future revisions of the SWAP.

2.2.2 Watershed Delineation

In order to implement a watershed approach to evaluate aquatic resources and water quality conditions it is necessary to delineate a boundary for the watershed, or drainage area. This is accomplished by selecting a specific water body or point along a stream and drawing a boundary that would encompass all land that would contribute runoff to the selected point. Watersheds vary greatly in size depending on the location of the point of interest. Watersheds can be nested within other drainage areas and can vary from a few acres for a headwater stream to several thousand square miles for large rivers and basins, such as the Chesapeake Bay.

Maryland divides its watersheds into 138 state-defined watersheds (also called 8-digit watersheds) averaging 75 square miles in size. The Loch Raven Reservoir is the 8-digit watershed that includes Loch Raven East. Baltimore County has further divided the 8-digit watersheds into 191 subwatersheds. Loch Raven East includes the Dulaney Valley Branch, Fitzhugh Run, Greene Branch, Jenkins Run, Overshot Run, and Royston Run subwatersheds and is shown in Figure 2-1.

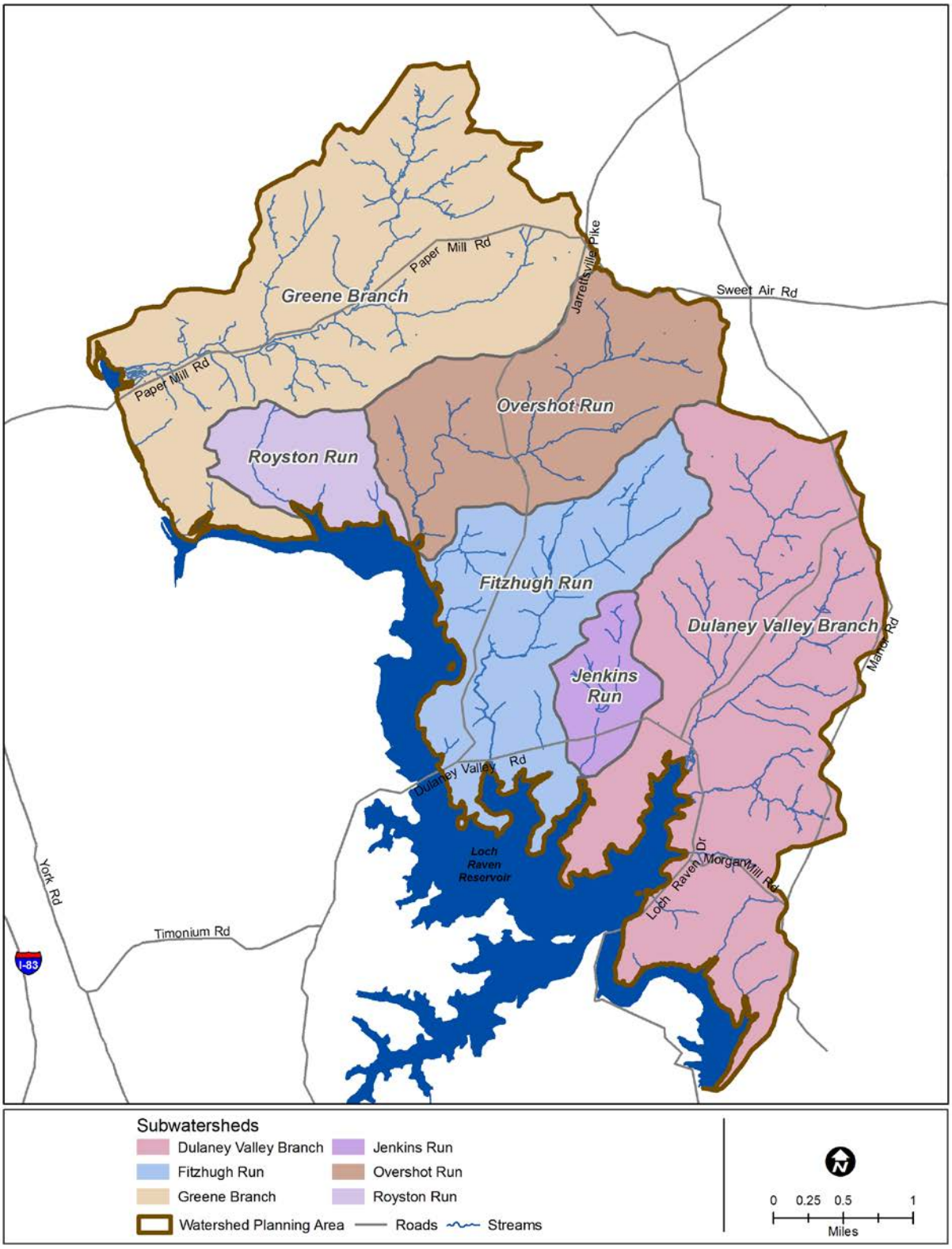


Figure 2-1: SWAP Planning Area

2.2.3 Topography

Topography describes the shape and features of the land surface, such as the elevation, steepness and concavity. Topography affects the flow of surface water, which in turn can have an effect on soil erosion and suitability for development. Steep and strongly sloping areas are generally associated with higher rates of erosion, with soil type and land use/land cover also playing a role. Topography also affects how pollutants are carried in a watershed, with steep slopes and erodible soils generally having a greater potential to carry more pollutants more rapidly to streams than flat slopes.

Topography in the Loch Raven East watershed typically follows what is generally seen in the Piedmont Physiographic Province, with rolling uplands and steep stream valleys. For Loch Raven East, the steepest slopes are associated with stream valleys and shoreline of Loch Raven Reservoir.

Slopes were determined using SSURGO soils data for Baltimore County (USDA, 2010) and classified into the following five categories:

- Nearly Level (0 – 3% slopes)
- Gently Sloping (3 – 8% slopes)
- Strongly Sloping (8 – 15% slopes)
- Moderately Steep (15 – 25% slopes)
- Steep (>25% slopes)

Table 2-1summarizes the percentage of area in each subwatershed for each slope category. Figure 2-2 provides a visual display of the slope categories within the watershed.

Table 2-1: Subwatershed Slope Characterization

Subwatershed	Slope Category (%)				
	Nearly Level (0-3%)	Gently Sloping (3-8%)	Strongly Sloping (8-15%)	Moderately Steep (15-25%)	Steep (>25%)
Dulaney Valley Branch	12.8	28.8	30.8	13.6	14.0
Fitzhugh Run	13.7	35.8	26.1	10.8	13.5
Greene Branch	10.9	25.8	27.9	16.0	19.5
Jenkins Run	23.3	41.0	14.5	9.3	12.0
Overshot Run	15.2	30.7	34.2	12.9	6.9
Royston Run	6.5	14.0	40.0	20.8	18.6
Total Watershed	12.8	29.0	29.6	14.0	14.6

As shown on Table 2-1 and Figure 2-2, strongly sloping to steep slopes make up 58.2% of the watershed. The most common category is strongly sloping (29.6 percent). Gently sloping (29.0 percent) and steep (14.6 percent) are the next most prevalent slope categories.

Royston Run has the highest percentage of steep, moderately steep, and strongly sloping land (18.6, 20.8, and 40.0 percent, respectively), which accounts for 79.5 percent of the subwatershed. Greene Branch, Dulaney Valley Branch and Overshot Run also have a high

percentage of steep, moderately steep, and strongly sloping land. The highest percent of gently sloping land (41.0 percent) and the highest percentage of nearly level land (23.3 percent) are both in Jenkins Run. Royston Run has the lowest percentage of gently sloping and nearly level land (14.0 and 6.5 percent, respectively).

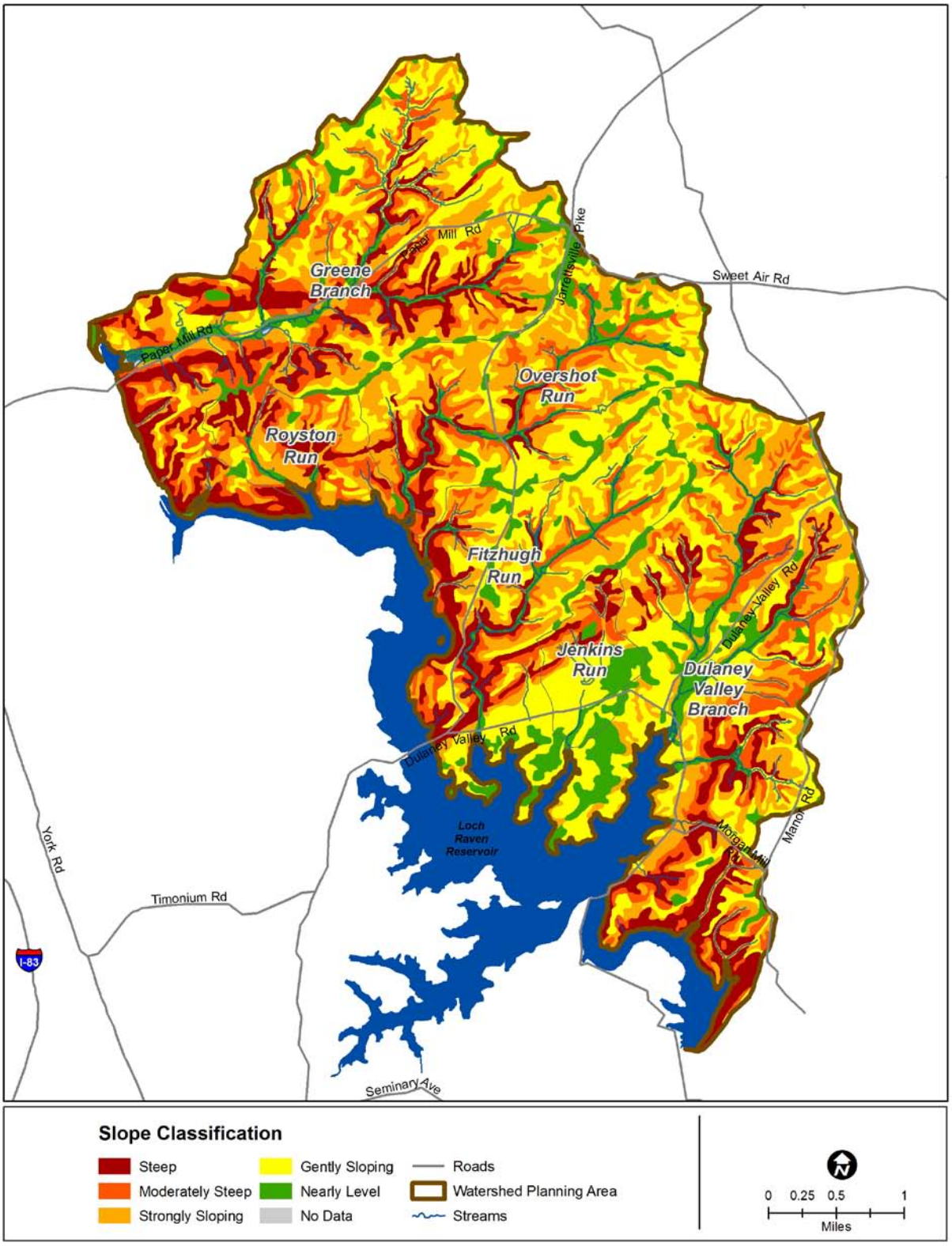


Figure 2-2: Loch Raven East Slope Classification

2.2.4 Geology

The geologic formations underlying a watershed have a significant effect on the water resources. Geology is a major determinant of the type of topography and surface features, discussed earlier. The chemical composition and minerals of the parent rock or unconsolidated sediments determines in large part the soil characteristics, including erodibility and infiltration rates. The underlying geology is a major factor in groundwater availability, which will be discussed in further detail in Section 2.3.4.

Loch Raven East lies within the Piedmont Physiographic Province, which is primarily underlain by metamorphic rock, that is, rock that has been changed over time due to heat and pressure. Five geologic formations are found in Loch Raven East, all of them of metamorphic origin. The oldest formation is Baltimore Gneiss, which is among the oldest rock in the eastern United States. Overlying this is the Cockeysville Marble. This formation is covered by another series of metamorphic rock formations, which in this location is identified as Loch Raven Schist (USDA, 1976). A small portion of Loch Raven Schist is covered by Setters Gneiss and Setters Schist. The Loch Raven Schist comprises the greatest majority of the area and underlies the entire Overshot Run subwatershed and almost the entirety of the Fitzhugh Run as well as high percentages of Dulaney Valley Branch and Royston Run. Setters Gneiss and Setters Schist formations underlie only one of the six subwatersheds – Greene Branch.

Table 2-2 shows the geologic composition in the six subwatersheds. This information is also displayed on Figure 2-3.

Table 2-2: Loch Raven East Geologic Composition by Subwatershed

Subwatershed	Geology (%)				
	Baltimore Gneiss	Cockeysville Marble	Loch Raven Schist	Setters Gneiss	Setters Schist
Dulaney Valley Branch	0.0	24.4	75.6	0.0	0.0
Fitzhugh Run	0.0	18.5	81.5	0.0	0.0
Greene Branch	32.5	11.5	45.4	7.4	3.2
Jenkins Run	0.0	63.7	36.3	0.0	0.0
Overshot Run	0.0	0.0	100.0	0.0	0.0
Royston Run	0.0	27.2	72.8	0.0	0.0
Total Watershed	9.8	17.4	69.7	2.2	1.0

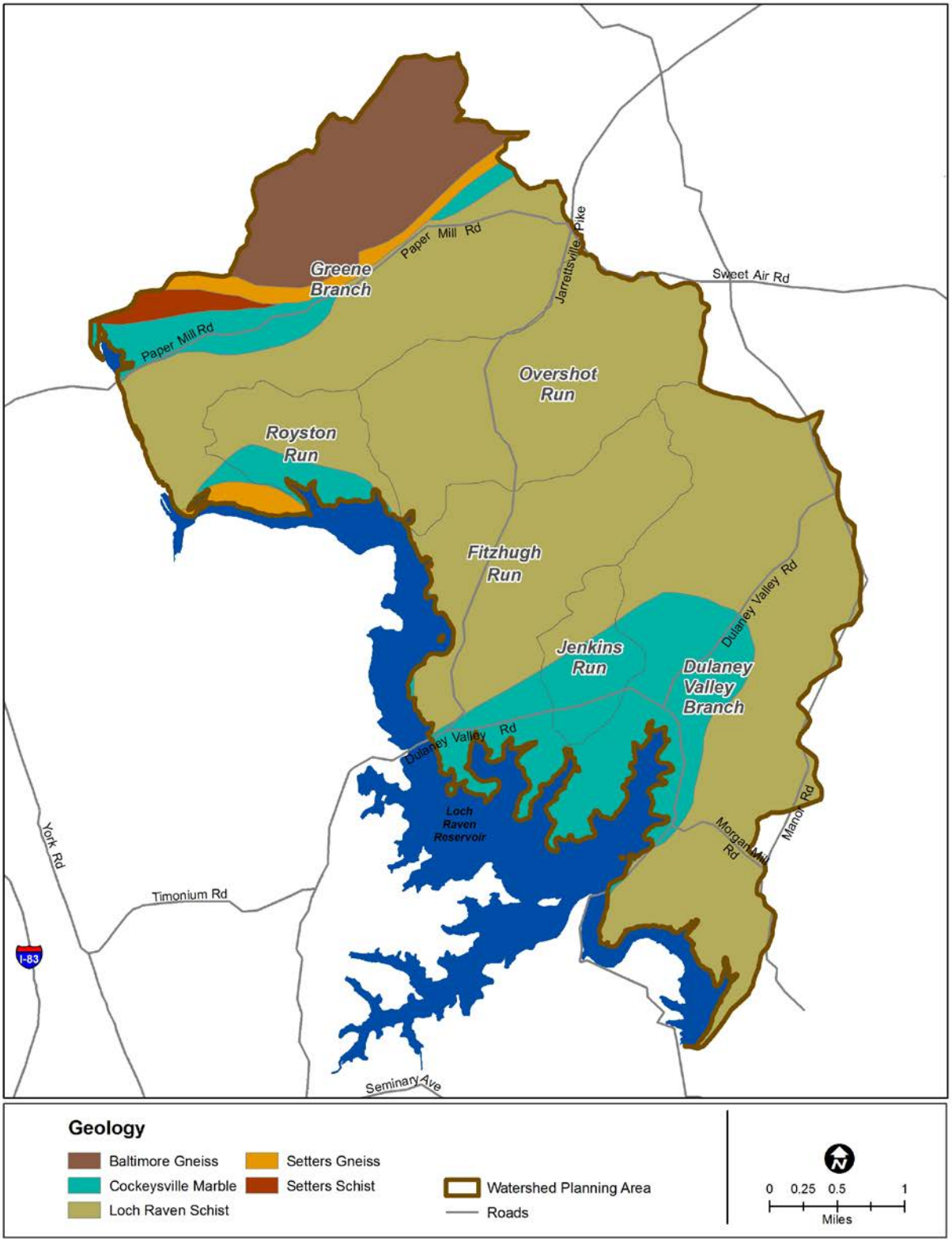


Figure 2-3: Loch Raven East Watershed Geology

2.2.5 Soils

Soil conditions are an important factor when evaluating water quantity and quality in streams and rivers. Soil type and moisture conditions greatly impact the amount and quality of runoff. Soils also affect how land may be used and its potential for vegetation and habitat. Soils are an important consideration in targeting projects aimed at improving water quality or habitat. The SSURGO soils data for Baltimore County was used for the soils data analysis (USDA, 2010).

All of the soils in Loch Raven East are derived from the parent metamorphic rock. Piedmont soils in upland areas are typically very erodible, with moderate infiltration rates. Piedmont alluvial soils, which are eroded soils deposited by flowing water, are found in stream valleys washed down from the upland areas and tend to be silts and clays which are far less permeable.

2.2.5.1 Hydrologic Soil Groups

The Natural Resources Conservation Service (NRCS) classifies soils into four hydrologic soil groups based on the soil's runoff potential which is a measure of how much precipitation will be converted to overland flow that runs off of the landscape downslope. Runoff potential is the opposite of infiltration capacity, which is the ability of the soil to absorb precipitation. Soils with high infiltration capacity will have low runoff potential, and vice versa. Infiltration rates are highly variable among soil types and are also influenced by disturbances to the soil such as cuts and fills associated with land development that can reduce infiltration and increase runoff potential. The four hydrologic soil groups are A, B, C, and D where Group A soils generally have the lowest runoff potential (highest infiltration) and Group D soils have the greatest runoff potential (lowest infiltration).

Each hydrologic soil group is described below. Additional information on hydrologic soil groups can be found in the Natural Resource Conservation Service's publication, *Urban Hydrology for Small Watersheds*, often referred to as Technical Release 55, or TR-55 (USDA, 1986):

- **Group A** soils are sand, loamy sand, or sandy loam soil types. These soils have high infiltration rates and low runoff potential even when thoroughly wetted. They consist mainly of deep, well-to excessively-drained sands or gravels with a high rate of water transmission.

- **Group B** soils are silt loam or loam soil types. These soils have moderate infiltration rates when thoroughly wet. They consist mainly of somewhat deep to deep, moderately-well to well-drained soils with moderately fine texture to moderately coarse texture with a moderate rate of water transmission.

- **Group C** soils are sandy clay loam soil types. These soils have a low infiltration rate when thoroughly wet. They typically have a layer that hinders downward movement of water and the soils have a moderately fine to fine texture. These soils have a low rate of water transmission.

- **Group D** soils include clay loam, silty clay loam, sandy clay, silty clay, or clay soil types. These soils have a very low infiltration rate and high runoff potential when thoroughly wet. They consist mainly of clays with high swell potential, soils with a permanent high water table, and soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material. These soils have a very low rate of water transmission.

One other classification is included in Table 2-3. There are small areas of open water or impermeable barren rock which are not included with the other hydrologic soil groups.

As shown on Figure 2-3 and Figure 2-4, the majority of soils in Loch Raven East are classified as Group B (81.5 percent) and C soils (16.1 percent), with moderate to low infiltration rates and moderate transmission of water through the soil. Only two subwatersheds, Greene Branch and Overshot Run, contain a small percentage of Group A soils. The small fraction of Group D soils in Loch Raven East with high runoff potential is associated with stream valleys.

Table 2-3: Loch Raven East Hydrologic Soil Categorization

Subwatershed	Hydrologic Soil Group (%)				
	A	B	C	D	Water /Impermeable
Dulaney Valley Branch	0.0	80.4	18.8	0.8	0.0
Fitzhugh Run	0.0	83.2	14.7	2.1	0.0
Greene Branch	0.9	81.1	16.1	1.8	0.1
Jenkins Run	0.0	85.1	12.8	2.1	0.0
Overshot Run	0.8	79.7	14.5	5.0	0.0
Royston Run	0.0	88.4	11.6	0.0	0.0
Total Watershed	0.4	81.5	16.1	2.0	0.0

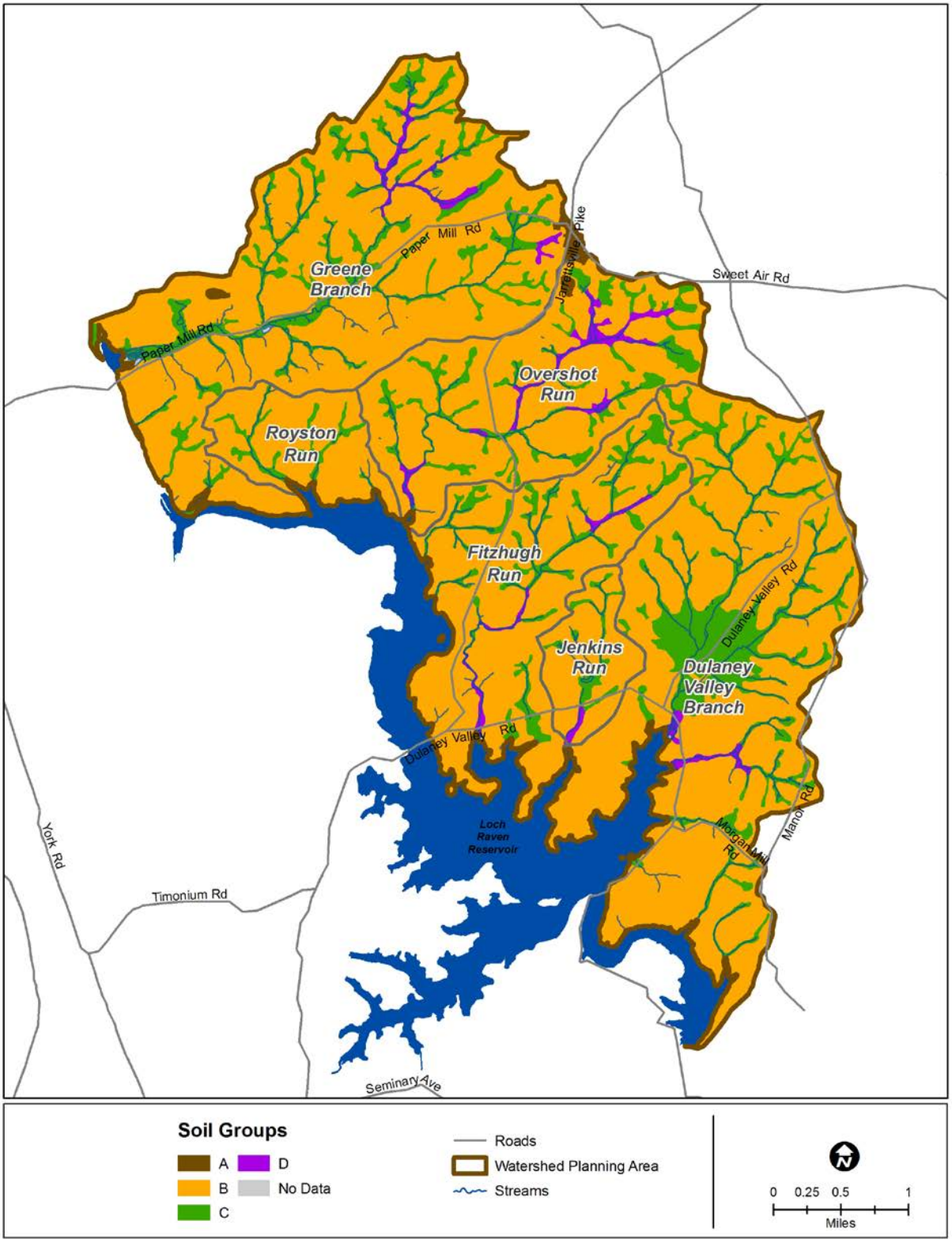


Figure 2-4: Loch Raven East Hydrologic Soil Groups

2.2.5.2 Soil Erodibility

Soil erodibility is a measure of the soil's susceptibility to erosion. The Universal Soil Loss Equation (USLE) developed by the United States Department of Agriculture (USDA) Agricultural Research Service is a model used to describe soil erosion processes. In the USLE, erodibility is described quantitatively using the K factor, which represents both the susceptibility of soil to erosion and its contribution to the rate of runoff. For example, clay soils have low K values because they are resistant to detachment. Coarse soils such as sand can also have low K values because even though they are easily detached, they infiltrate well and are therefore less susceptible to runoff. Silts have the highest K values because they detach easily and produce high rates of runoff (Institute of Water Research, 2002).

Subwatersheds with the largest percentage of highly erodible soils offer the greatest potential for addressing soil conservation with best management practices (BMPs) aimed at maintaining topsoil, such as cover crops and riparian buffer forestation. Combining this indicator with other information, such as cropland, slope steepness and distance to streams would help to determine where to retire highly erodible land from farming, a type of BMP. Additionally, a high K value helps to identify areas where urban development near streams, such as road construction or utility placement may have particularly adverse watershed impacts.

Soil erodibility was divided into three categories to match the classes used to classify sensitive areas in the Baltimore County Buffer Protection and Management Ordinance (Baltimore County, 2003).

- Low Erodibility (K factor < 0.24)
- Medium Erodibility (K factor 0.24 – 0.32)
- High Erodibility (K factor > 0.32)

Table 2-4 presents the soil erodibility categories based on K factors for subwatersheds in Loch Raven East.

Table 2-4: Loch Raven East Subwatershed Soil Erodibility Categories

Subwatershed	Soil Erodibility Category (%)			
	No Data	Low	Medium	High
Dulaney Valley Branch	0.0	0.0	86.7	13.3
Fitzhugh Run	0.0	0.0	85.5	14.5
Greene Branch	0.1	0.9	83.3	15.7
Jenkins Run	0.0	0.0	92.0	8.0
Overshot Run	0.0	0.8	80.5	18.7
Royston Run	0.0	0.0	88.4	11.6
Total Watershed	0.0	0.4	84.8	14.8

As shown on Table 2-4 and Figure 2-5, medium erodibility soils make up 84.8 percent of the watershed, with an additional 14.8 percent of highly erodible soils and 0.4 percent low erodible soils. All of the Loch Raven East subwatersheds have similar total amounts of medium and highly erodible soils. Overshot Run and Greene Branch have the highest percentages of highly erodible soils, with approximately 18.7 and 15.7 percent, respectively. Erosion across the watershed would at first appear to be problematic, with nearly 100 percent of the soils in the

medium to high erodibility categories and a high proportion of steep slopes. However, soil is largely protected by forest cover throughout several of these subwatersheds due to their location along the boundary of Loch Raven Reservoir. Greene Branch and Overshot Run are the only two subwatersheds with some low erodible soils.

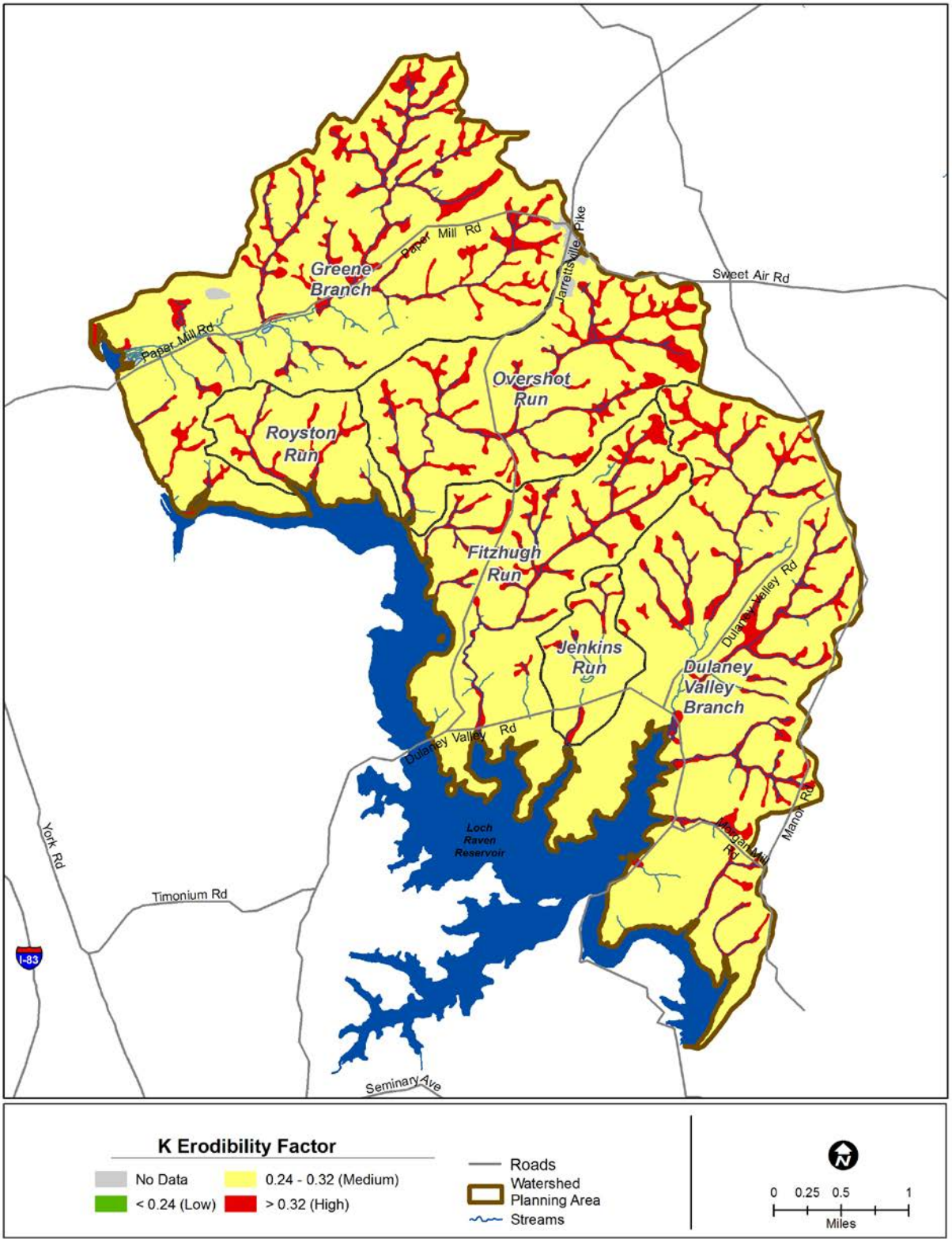


Figure 2-5: Loch Raven East Soil Erodibility Based on the K Factor

2.2.6 Forest Cover

Among land cover types, forest cover provides the greatest protection for soil and water quality. The entire Chesapeake watershed at the time of European settlement consisted primarily of old growth forest. In this type of pristine system, forest and soils co-evolve and shape the entire hydrologic cycle; these systems operate within a natural range of variability, assuring healthy habitat and water quality. In human-impacted systems, forest cover can still provide these same benefits and can help to protect water quality if judiciously planned and protected.

Table 2-5 shows the percentage of forested acres for each subwatershed in Loch Raven East. Figure 2-6 shows the distribution of forest cover.

Table 2-5: Loch Raven East Subwatershed Forest Cover

Subwatershed	Total Acres	Forested Acres	Forested (%)
Dulaney Valley Branch	3,577.2	1,817.1	50.8
Fitzhugh Run	1,772.3	837.9	47.3
Greene Branch	3,472.4	1,648.9	47.5
Jenkins Run	403.9	126.3	31.3
Overshot Run	1,782.9	790.2	44.3
Royston Run	558.6	376.1	67.3
Total Watershed	11,567.3	5,596.5	48.4

Since European settlement, forest cover in Loch Raven East has been greatly reduced through development for human uses. However, it remains relatively high when compared to many surrounding urban and suburban watersheds. Over 5,000 acres of forest remain in Loch Raven East, just under 50 percent of the total area and includes forested buffer land surrounding the reservoir owned, in part, by Baltimore City. Forest cover ranges from a low of 31.3 percent (Jenkins Run) to a high of 67.3 percent (Royston Run). Dulaney Valley Branch, Fitzhugh Run and Greene Branch also have relatively high percentages of forest cover with 50.8, 47.3, and 47.5, respectively. Data represented in the table and figure is derived from Baltimore County's forest GIS layer which differs from the Maryland Department of Planning's (MDP) 2010 land use/land cover data (which also contains forest data) presented in Section 2.3.1 Land Use and Land Cover. This layer was chosen because it was delineated from current higher resolution aerial photography and as a result is a more accurate representation of forest cover.

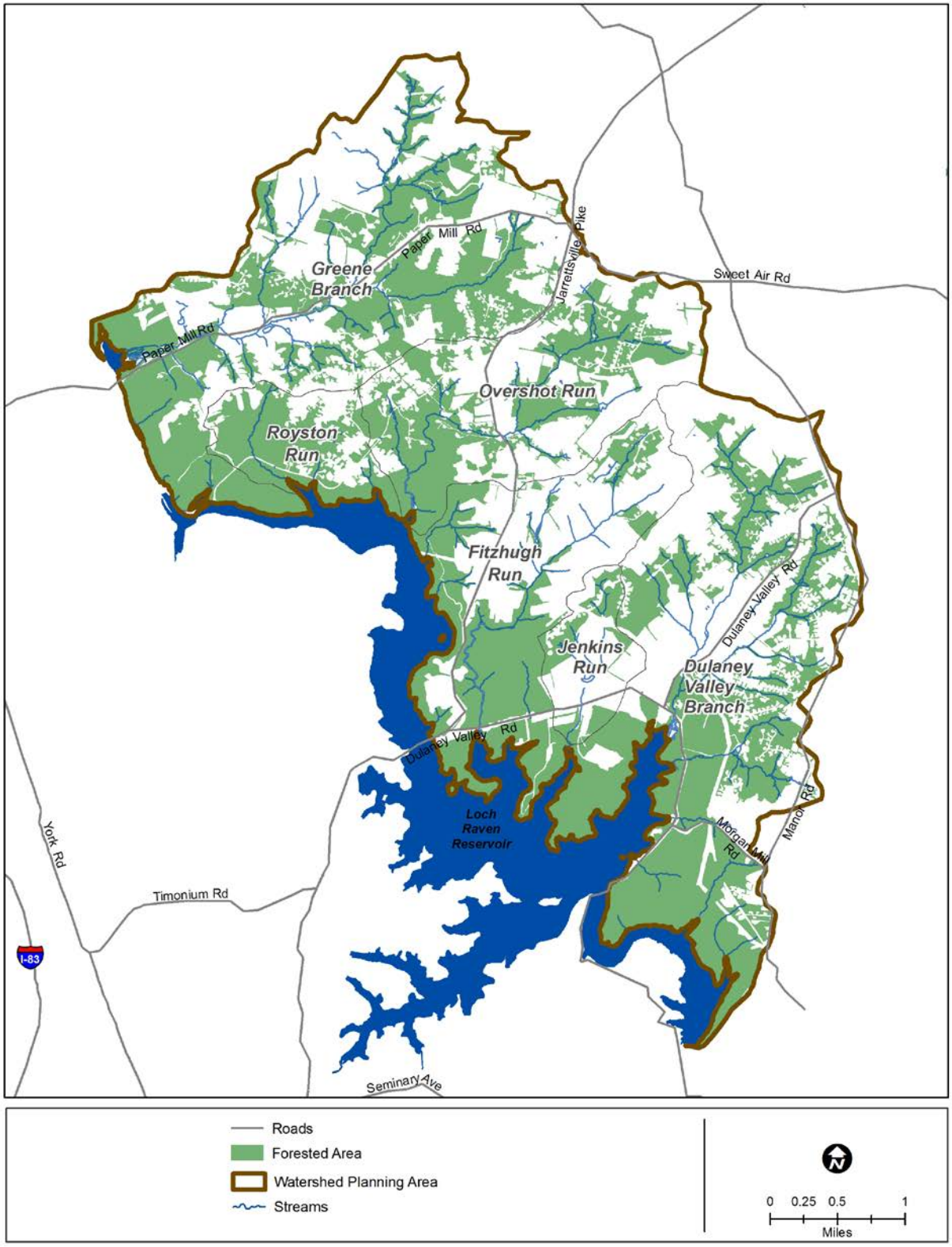


Figure 2-6: Loch Raven East Subwatershed Forest Cover

2.2.7 Stream Systems

Streams are the flowing surface waters within a watershed which are connected to groundwater through both baseflow and recharge as well as providing input to other water bodies such as ponds, lakes and wetlands. 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.

2.2.7.1 Stream Characteristics

As mentioned previously, Loch Raven East is part of the 8-digit Loch Raven Reservoir watershed and part of the Chesapeake Bay basin. There are approximately 84 miles of stream in this area that drain to the Loch Raven Reservoir and eventually the Chesapeake Bay. A summary of stream mileage and density in the subwatersheds is shown in Table 2-6. Figure 2-7 shows the streams and the six subwatersheds comprising Loch Raven East. Stream lines were photogrammetrically derived from 1:2400 scale aerial photography captured in 2008.

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

Subwatershed	Area (mi^2)	Stream Miles	Stream Density (mi/mi^2)
Dulaney Valley Branch	5.6	23.8	4.3
Fitzhugh Run	2.8	10.8	3.9
Greene Branch	5.4	31.3	5.8
Jenkins Run	0.6	3.2	5.0
Overshot Run	2.8	11.0	4.0
Royston Run	0.9	4.5	5.1
Total Watershed	18.1	84.4	4.7

The greatest stream lengths are located in Greene Branch (31.3 mi), Dulaney Valley Branch (23.8 mi), and Overshot Run (11 mi). Stream density is highest in Greene Branch with 5.8 miles per square mile of subwatershed (mi/mi^2).

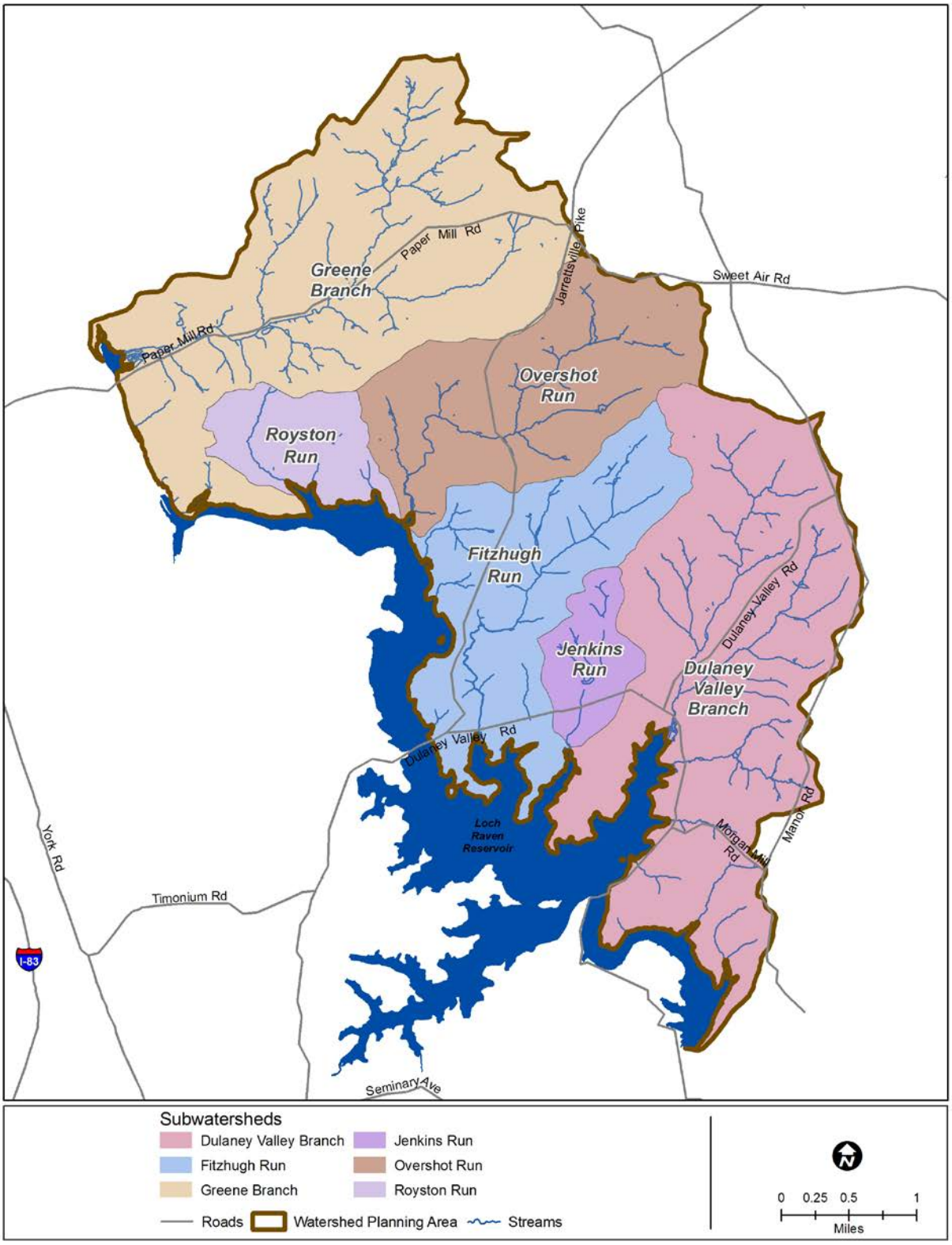


Figure 2-7: Loch Raven East Stream System and Subwatersheds

2.2.7.2 Stream Riparian Buffers

Riparian buffers are the vegetated areas adjacent to streams that serve the role of protecting water bodies from pollutant loads and providing bank stabilization and habitat for all types of stream life, including fish. Forested buffers along streams play a crucial role in improving water quality. Leaf litter from trees provide a needed energy source for soil microbes to decompose the organic matter where nutrients are consumed, taken up by plants and released back to the atmosphere, thus reducing the amount of nitrates available for runoff. Buffers mitigate flooding by reducing surface runoff, stabilizing stream banks, and trapping sediment. Tree roots capture and remove pollutants, such as excess nitrogen from shallow flowing water. The tree root structure also slows soil erosion and water flow thus reducing sediment load and flooding. Tree canopy shades streams, providing cooler water temperatures required for stream life, particularly cold-water species such as trout.

In smaller streams, such as those found at the subwatershed level, terrestrial plant material falling into the stream is the primary source of food for stream life. Seasonally, trees provide food in the form of leaves and plant parts for stream life at the base of the food chain (such as insects). Fallen tree branches and trunks provide a more consistent, slow-release food source throughout the year. Tree roots, snags and in-stream woody debris also provide important habitat for fish, insects and other aquatic life. Maintaining healthy streams and forest buffers are important for reducing the nutrient and sediment loads to the Loch Raven reservoir and the Chesapeake Bay. When stream riparian buffers are converted from forest to agriculture or other development, many of these benefits are lost and stream health declines. Riparian buffer zones can be replanted or preserved as a type of BMP to reduce impacts of developed land use.

The vegetative condition of the riparian buffer in Loch Raven East was analyzed based on a 100-foot buffer on either side of the stream system. Three land cover categories were used to classify stream buffer conditions: forested, open pervious (e.g. lawns, fields, cropland) and impervious (e.g. road and buildings). GIS was used to overlay the 100-foot stream buffer with impervious areas. Forested areas were determined in a similar manner (using Baltimore County's forest GIS layer). Remaining areas were classified as open pervious. Table 2-7 shows the percentages and acreages for stream buffer conditions. Figure 2-8 shows the 100-foot stream buffer classification distribution.

Table 2-7: Loch Raven East Land Cover in the 100-foot Stream Buffer

Subwatershed	Forested		Open Pervious		Impervious		Total	
	Acres	%	Acres	%	Acres	%	Acres	%
Dulaney Valley Branch	449.3	65.1	230.9	33.5	9.9	1.4	690.1	36.7
Fitzhugh Run	225.1	60.5	138.4	37.2	8.5	2.3	372.0	19.8
Greene Branch	529.5	65.9	259.2	32.3	14.6	1.8	803.4	42.7
Jenkins Run	27.8	38.4	43.1	59.5	1.5	2.1	72.4	3.8
Overshot Run	200.3	68.4	85.6	29.2	7.0	2.4	292.8	15.6
Royston Run	115.5	88.8	12.7	9.8	1.8	1.4	130.0	6.9
Total	1,547.5	65.6	770.0	32.6	43.3	1.8	2,360.8	100.0

Overall, stream buffers in Loch Raven East are in good condition with 65.6 percent forested. Only 1.8 percent of the 100-foot stream buffer is impervious cover. Open pervious area makes up the remaining 32.6 percent. It should be noted that much of the open pervious area

consists of the stream system itself because the stream is classified as open pervious area. An example is shown in Fitzhugh Run near the intersection of Dulaney Valley Road and Jarrettsville Pike (see Figure 2-8), where the stream is wide and the yellow line in the center of the stream buffer is the stream itself. Other areas of open pervious area are candidates for buffer forestation.

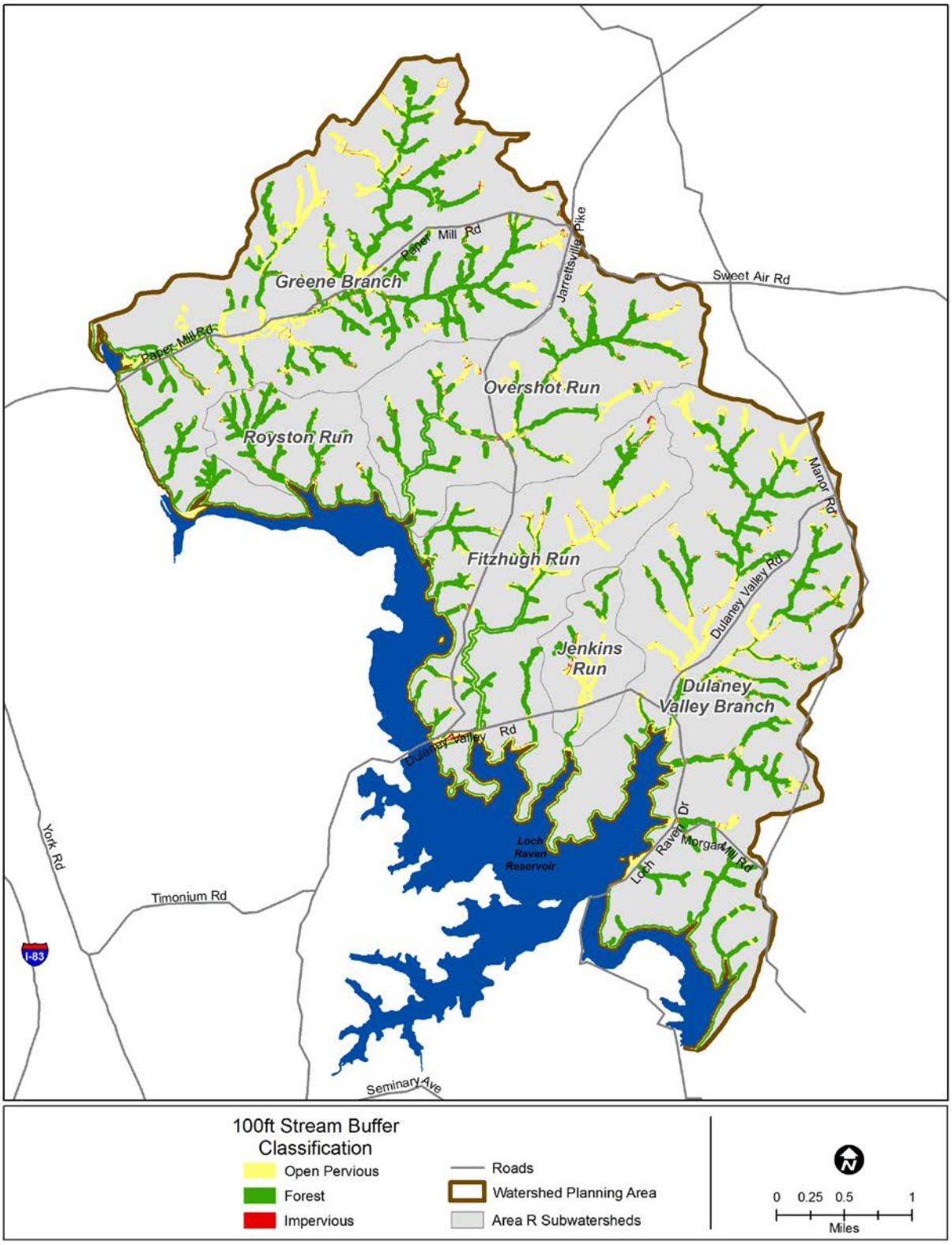


Figure 2-8: Loch Raven East 100-foot Stream Buffer Land Cover

2.3 The Human Modified Landscape

The natural landscape has been modified for human use over time. The intensity of development activities has increased, starting with the colonization of Maryland in the 1600s. This modification has resulted in environmental impacts to both terrestrial and aquatic ecosystems. This section will provide a characterization of the human modified landscape and how that modification is associated with impacts to the natural ecosystem. This includes a general description of land use and land cover followed by more specific issues such as population, impervious cover, drinking water and wastewater, storm water systems, discharge permits and zoning.

2.3.1 Land Use and Land Cover

Land use has pronounced impacts on water quality and habitat with land uses that generate different types and amounts of pollutants. As discussed previously, a forested watershed has the capacity to absorb pollutants and slow the flow of water into streams. Conversely, impervious surfaces such as roads, parking lots and roofs in developed areas block the natural seepage of runoff. These impervious surfaces tend to concentrate stormwater runoff, accelerate flow rates, and direct stormwater to the nearest stream. In addition, increased impervious cover transmits nutrients, pollutants, and increases water temperature in the stream. This can cause bank erosion and destruction of in-stream and riparian habitat. Watersheds with small amounts of impervious surface tend to have better water quality in local streams than watersheds with greater amounts of impervious surface (Schueler et al., 2009). Additionally, agricultural land, if not properly managed, can cause substantial increases in sediment, nutrients and pathogens in streams.

The Maryland Department of Planning develops land use/land cover data for the entire state of Maryland every five years. This data is created from aerial photography and satellite imagery. The most recent update available and the source of the data presented in this section is from 2010.

Loch Raven East contains 11,567 acres (18.1 square miles) of land consisting primarily of low-density residential uses and deciduous forest (30.8 percent and 28.0 percent, respectively). As mentioned previously, forest cover is high throughout the watershed with the highest percentage in Royston Run. Evergreen forest and mixed forest account for an additional seven percent of the total. Various agricultural practices (cropland, orchards, and pasture) make up another 17.5 percent of the total area, primarily in the Fitzhugh Run and Jenkins Run subwatersheds. Very low density residential uses, both forested and agricultural, collectively account for 10 percent of the watershed. Open urban areas, such as Hillendale Golf Course, Hunt Valley Inn Golf Course and Towson Golf and Country Club, make up four percent of the total. Commercial and institutional areas combined make up only one percent of the total area. One percent of Loch Raven East is water. All other land uses each comprise less than one percent of the total area.

Land use/land cover distribution within each subwatershed is varied. Dulaney Valley Branch, Greene Branch, Overshot Run, and Royston Run subwatersheds consist of primarily low density residential. Fitzhugh Run consists primarily of forest (deciduous and evergreen) and

agriculture uses (29.4 percent). Jenkins Run has the highest percentage of open urban land use (31.0 percent), largely due to the extent of the Towson Golf and Country Club.

A summary of the land use/land cover percentages by subwatershed is presented in Table 2-8, and shown in Figure 2-9.

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

Subwatershed	Brush	Commercial	Cropland	Deciduous Forest	Evergreen Forest	Institutional	Low-Density Residential	Medium-Density Residential	Mixed Forest	Open Urban Land	Orchards	Pasture	Very Low Density Residential (Agricultural)	Very Low Density Residential (Forested)	Water	Wetlands
Dulaney Valley Branch	0.0	0.0	11.9	24.7	6.2	0.2	36.6	0.0	3.8	0.1	0.0	4.3	5.2	5.0	2.0	0.1
Fitzhugh Run	0.2	0.0	18.0	38.2	7.8	0.0	11.7	0.0	1.2	1.6	0.0	11.4	6.1	2.2	1.6	0.0
Greene Branch	0.1	1.7	8.3	30.6	0.0	0.0	32.4	0.3	0.0	5.4	1.5	6.1	4.3	8.3	0.6	0.4
Jenkins Run	2.0	0.0	20.1	17.9	12.5	0.0	11.5	0.0	1.4	31.0	0.0	3.6	0.0	0.0	0.0	0.0
Overshot Run	0.0	0.7	8.6	23.3	0.0	2.3	34.1	3.4	3.8	6.8	0.0	7.1	3.8	6.0	0.1	0.0
Royston Run	0.0	0.0	0.0	23.1	0.0	0.0	44.1	0.0	22.0	0.0	0.0	0.0	0.1	7.6	3.1	0.0
Total Watershed	0.1	0.6	10.9	28.0	3.5	0.4	30.8	0.6	3.0	4.0	0.5	6.1	4.4	5.7	1.2	0.2

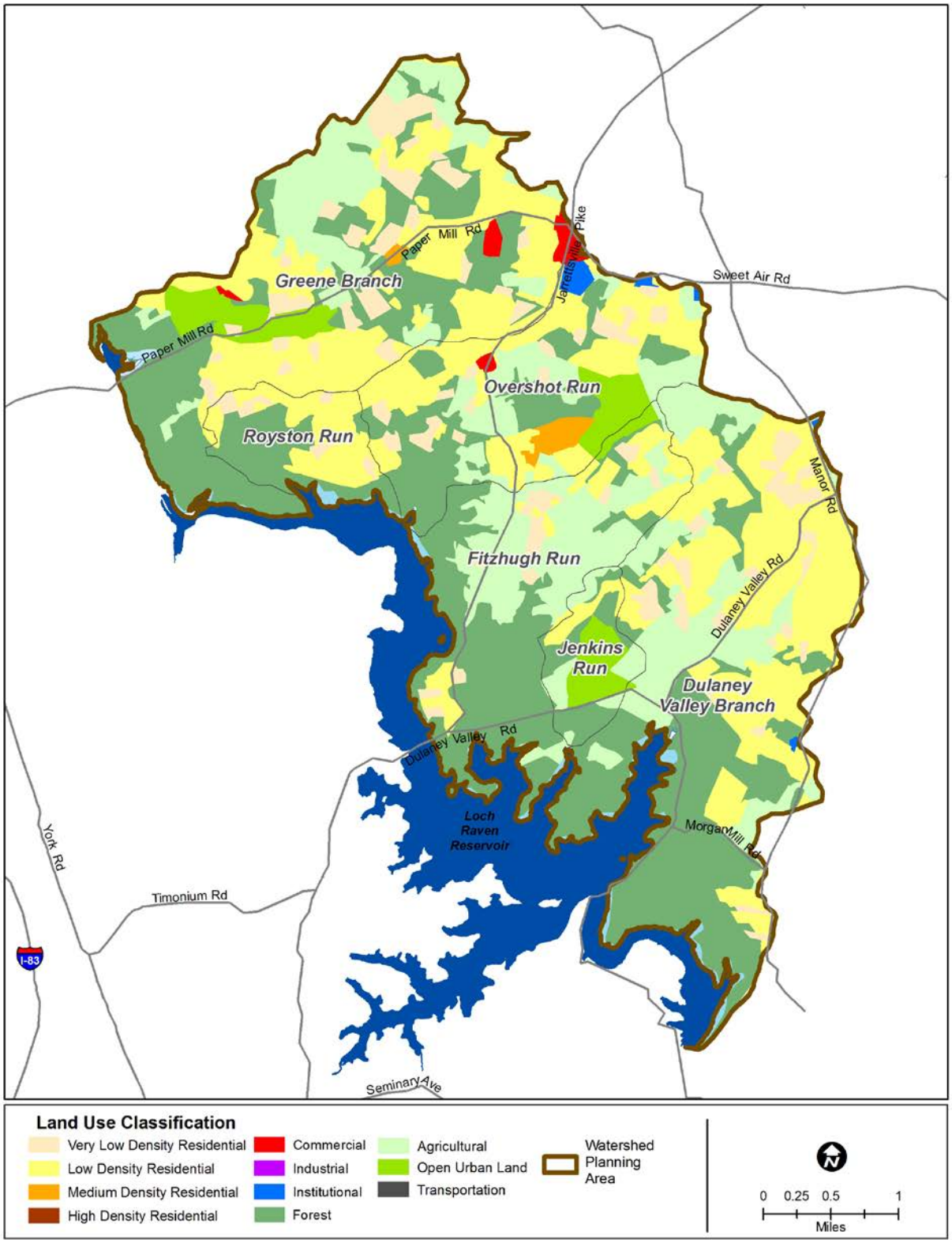


Figure 2-9: Loch Raven East Land Use/Land Cover

2.3.2 Population

Population data provides another way to evaluate the intensity of land use. For example, a higher population density (i.e. persons per acre) represents a more intense use of the land and increases the potential for environmental degradation. Much of the degradation from intensive land uses is related to the extent of impervious cover needed to support higher population densities, which results in the loss of land uses such as forest that protect water resources.

Smart growth principles are aimed at directing future growth to areas of existing services and to where development has already occurred. This will result in less land conversion to residential and supporting commercial areas, resulting in conservation of land uses with lower environmental impact such as forest and agriculture.

Population density in the watershed was estimated based on 2010 US Census data (U.S. Census Bureau, 2010). Table 2-9 summarizes the population data by subwatershed. Total population is provided as well as the calculated population density per acre and per impervious acre. Population density distribution is shown on Figure 2-10.

Table 2-9: Loch Raven East Population Data

Subwatershed	Total Population (2010 Census)	Total Area (acres)	Population Density (per acre)	Impervious Area (acres)	Population Density (per impervious acre)
Dulaney Valley Branch	2,026.0	3,577.2	0.6	165.1	12.3
Fitzhugh Run	420.5	1,772.3	0.2	55.2	7.6
Greene Branch	1,925.7	3,472.4	0.6	188.2	10.2
Jenkins Run	66.8	403.9	0.2	13.2	5.1
Overshot Run	1,192.6	1,782.9	0.7	109.3	10.9
Royston Run	368.8	558.6	0.7	30.0	12.3
Total Watershed	6,000.3	11,567.3	0.5	561.0	10.7

Population density across the watershed and within each subwatershed is low, with an average of 0.5 people per acre across the watershed. The parcels shown on the figure with higher population density (yellow and red parcels) are not actually highly populated acres but show up as high density because the census blocks are very small. The highest population density per impervious acre is in Royston Run and Dulaney Valley Branch. The lowest is in Jenkins Run, with an estimate of five people per impervious acre.

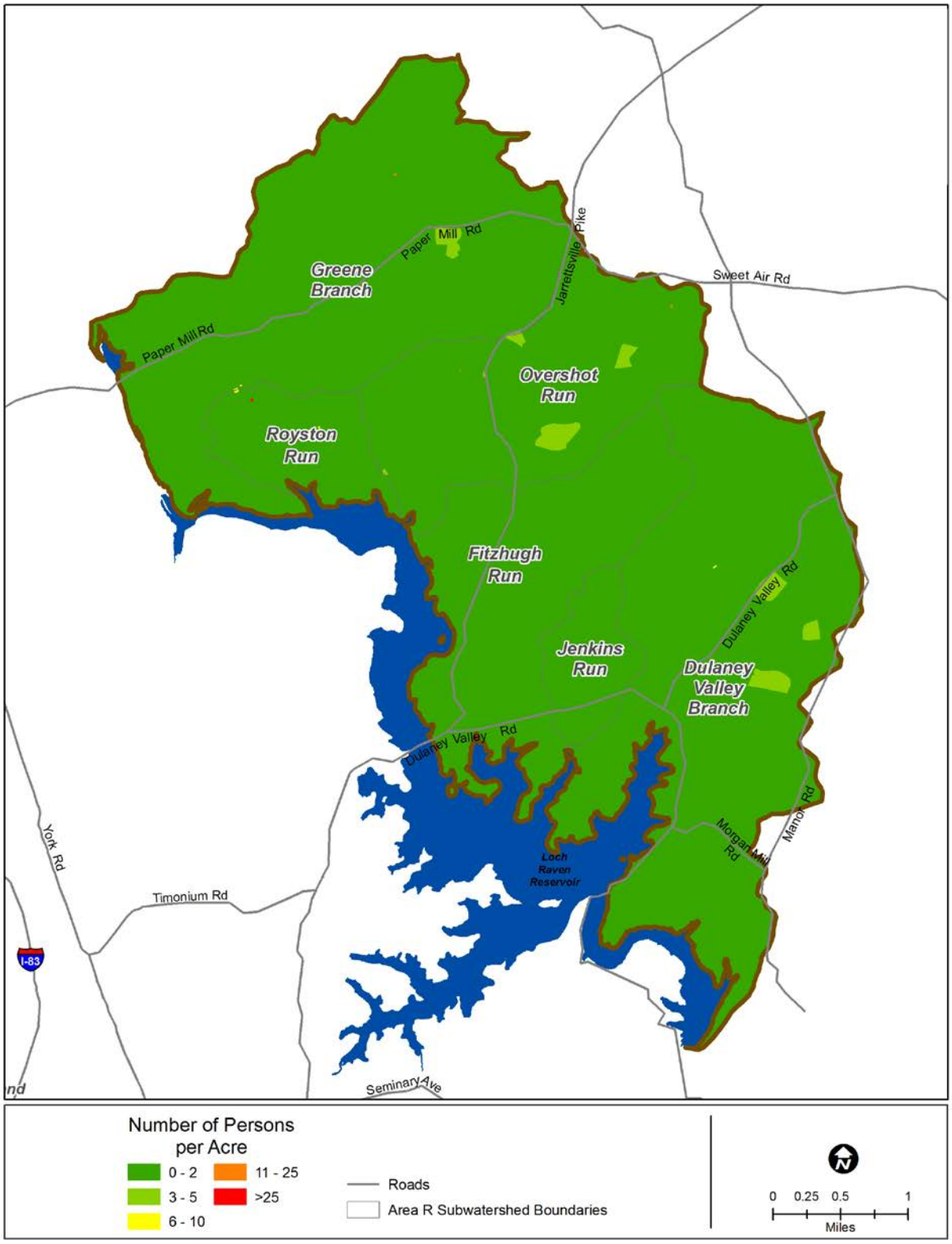


Figure 2-10: Loch Raven East Population Distribution (based on 2010 census data)

2.3.3 Impervious Surfaces

Impervious surfaces are materials that impede or prevent infiltration of water into the soil. While there are some naturally occurring impervious surfaces such as rock outcroppings, most impervious surfaces are man-made, and include roofs/ buildings, streets, sidewalks and parking areas.

The accelerated, concentrated runoff created by impervious surfaces can cause stream erosion and habitat destruction. Runoff from impervious surfaces picks up and washes off pollutants and is usually more polluted than runoff generated 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 loading in stormwater runoff. Research has been conducted to link the degree of urbanization (as measured by the amount of impervious cover) with various watershed-based indicators of water quality such as the diversity and abundance of aquatic and terrestrial life (Schueler et al., 2009).

The Center for Watershed Protection (CWP) compiled stream research conducted in various parts of the country and developed a simple impervious surface model that relates stream quality to percentage of impervious surfaces in a watershed. This model has been updated and is shown in Figure 2-11. The relationship is represented as a white ‘cone’ that is widest at low levels of impervious cover and decreases as impervious cover increases. This indicates that at low levels of impervious cover, other watershed metrics besides impervious cover such as forest cover, road density, riparian buffer and agricultural practices influence stream health and the resulting quality is more variable. As impervious cover increases, the relationship is stronger and the ‘cone’ is narrower indicating that the resulting stream quality is less variable and is most often degraded. Studies used to develop the impervious cover model measured stream quality based on a variety of indicators such as the number of aquatic insect species, stream temperature, channel stability, aquatic habitat, wetland plant density, and fish communities.

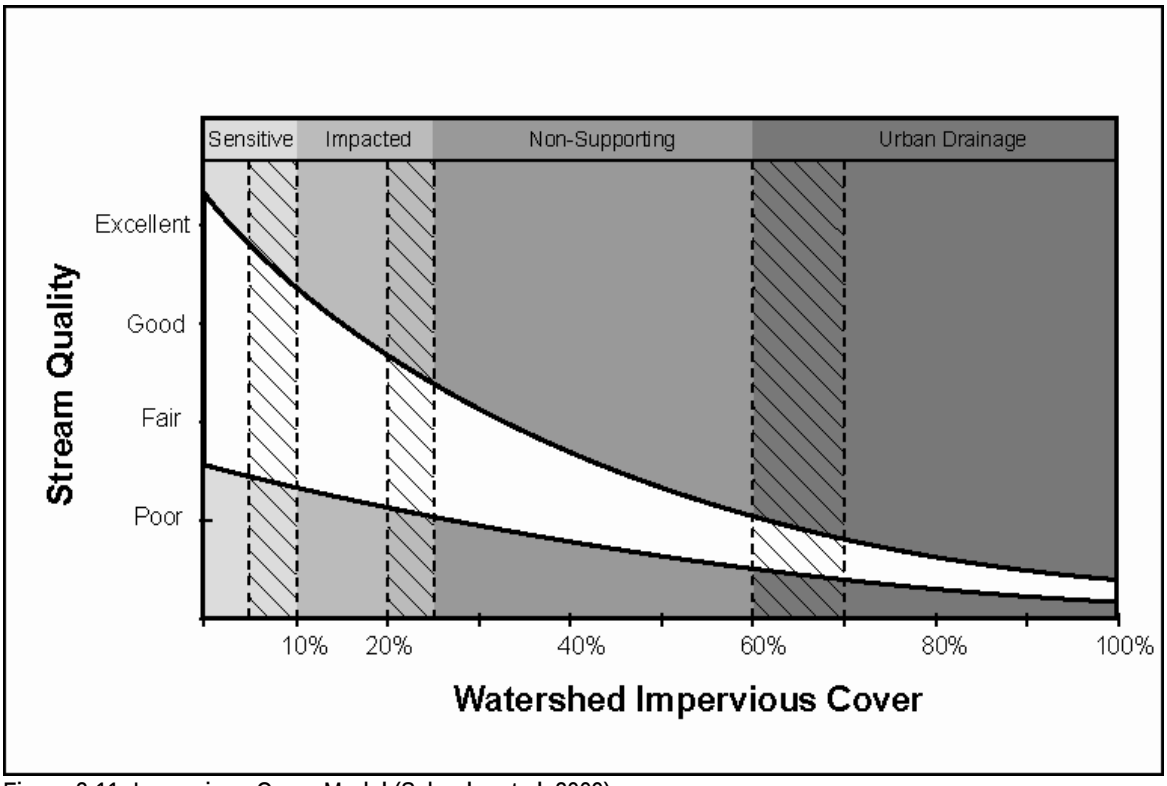


Figure 2-11: Impervious Cover Model (Schueler et al. 2009)

Based on the research compiled, CWP determined the following general categories to classify and predict stream quality in terms of impervious cover represented by bands in Figure 2-11. These 'bands' are colored in a gradation from least (light gray) to most (darker gray) amount of impervious cover.

- Sensitive – watersheds with less than 10 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. Sensitive watersheds are susceptible to environmental degradation with urbanization and increases in impervious cover.

- Impacted – watersheds with between 10 and 25 percent impervious cover show clear signs of degradation such as erosion, channel widening and decline in stream habitat. Stream restoration to a somewhat natural functioning system is still possible in these watersheds.

- Non-supporting – watersheds with between 25 and 60 percent of impervious cover are characterized by fair to poor water quality, unstable channels, severe erosion, and the inability to support aquatic life and provide habitat. Many streams in this category are typically piped or channelized.

- Urban drainage – in watersheds where impervious cover exceeds 60 percent, a watershed is classified as severely damaged which means that most of the natural stream system is gone, most often buried to flow in storm drains.

Management of damaged and severely damaged streams may focus on decreasing pollutant loads to downstream receiving waters but the ability to restore natural functions is debatable. Restoration efforts may also focus on making the remaining stream systems stable, aesthetically pleasing and an amenity to the community.

The roads and buildings GIS data layers from Baltimore County were used to determine the total impervious area within subwatersheds of Loch Raven East. Table 2-10 presents the results of this analysis and Figure 2-12 shows the distribution of impervious area in the study area.

Table 2-10: Loch Raven East Estimated Impervious Surfaces

Subwatershed	Total Area (ac)	Roads (ac)	Buildings (ac)	Impervious Area (ac)	% Impervious
Dulaney Valley Branch	3,577.2	109.5	55.5	165.1	4.6
Fitzhugh Run	1,772.3	42.6	12.6	55.2	3.1
Greene Branch	3,472.4	135.3	53.0	188.2	5.4
Jenkins Run	403.9	10.2	3.0	13.2	3.3
Overshot Run	1,782.9	71.4	37.9	109.3	6.1
Royston Run	558.6	19.6	10.4	30.0	5.4
Total	11,567.3	388.6	172.4	561.0	4.8

Impervious surfaces cover 4.8 percent of the total land surface in Loch Raven East, with all six subwatersheds below the ten percent of impervious area threshold to qualify as sensitive watersheds (Figure 2-13), according to CWP's impervious cover model. This is a low level of impervious area, especially when compared to more developed subwatersheds in Baltimore County.

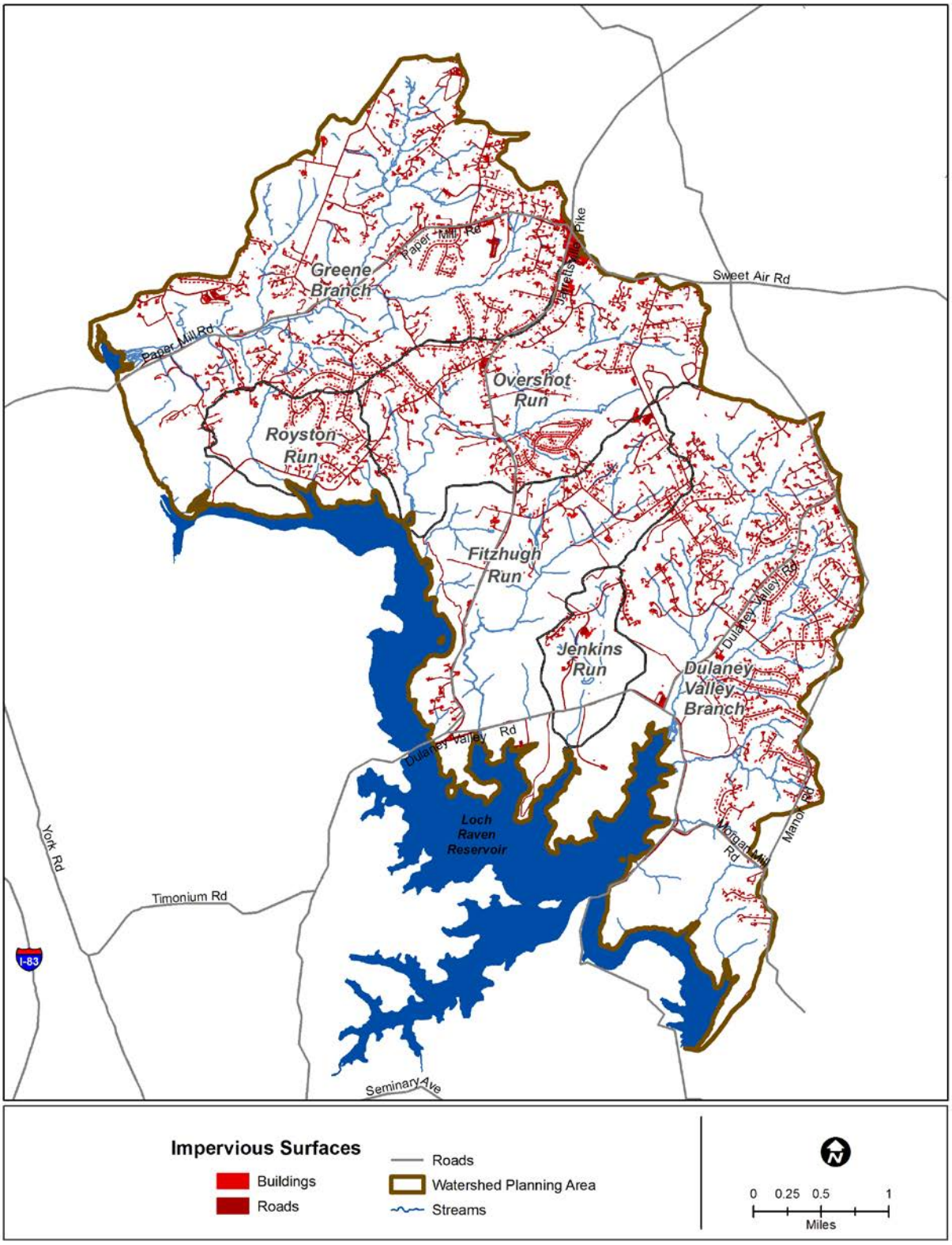


Figure 2-12: Loch Raven East Impervious Surfaces

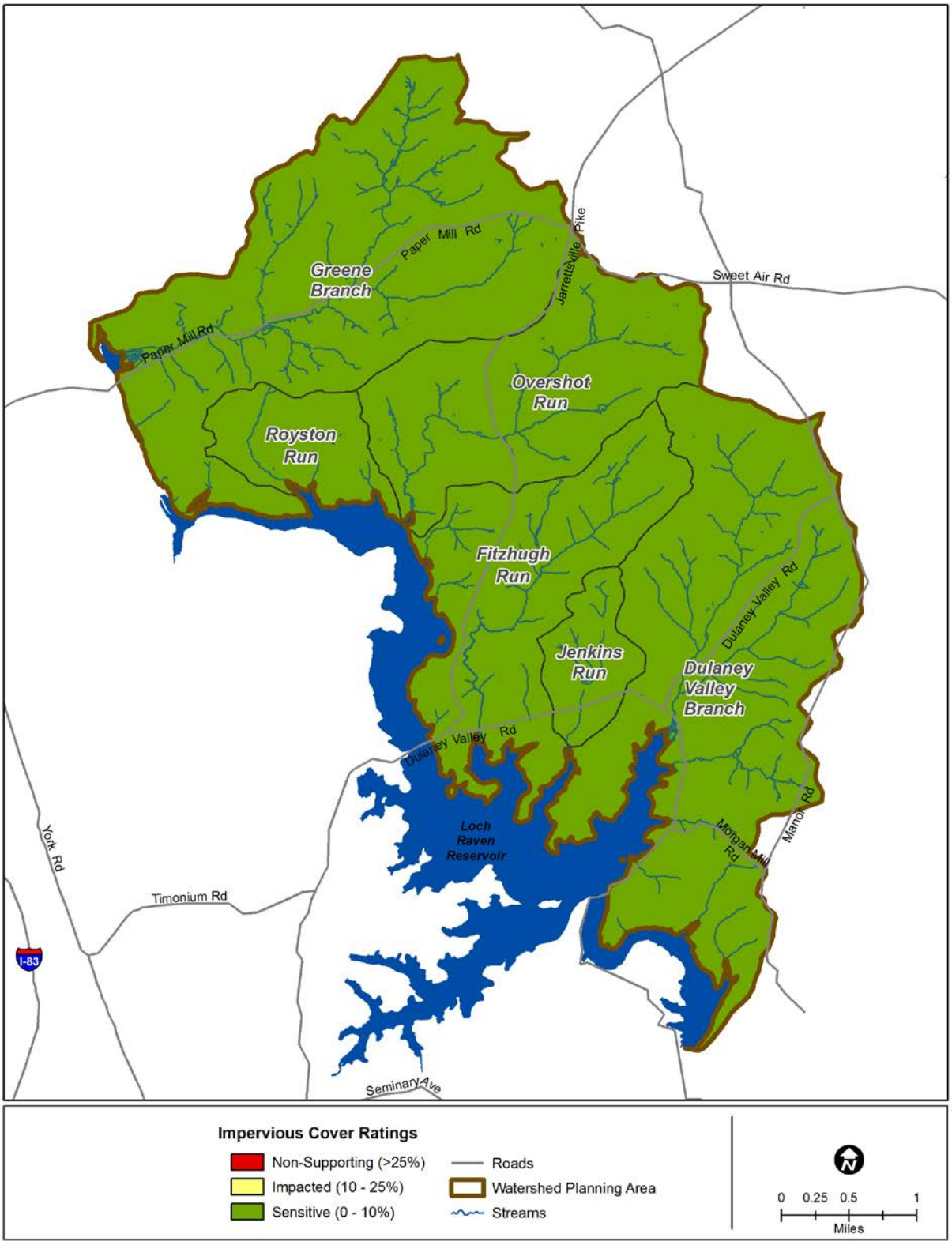


Figure 2-13: Loch Raven East Impervious Cover Ratings

2.3.4 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 properties. Having an adequate supply of drinking water is essential to maintaining the human population in a region. Loch Raven East streams flow into the Loch Raven Reservoir, a major source of public drinking water for the region.

2.3.4.1 Public Water Supply

Environmental impacts associated with public supply of water include the potential for increased residential development, associated impervious cover effects and the potential for leaks from the system. Loch Raven East lies outside of the area served by the Baltimore Metropolitan water supply, so the potential for leaks from the system are not an issue in this watershed. However, the effects associated with impervious cover and development in the watershed do have an impact on water quality and habitat in local streams and in the Loch Raven Reservoir.

2.3.4.2 Groundwater

Water supply in Loch Raven East is provided by groundwater wells. The underlying geology can cause well yield and water quality to be highly variable even in this small area. Wells in the Cockeysville marble, which underlie approximately 17 percent of the watershed, have some of the highest yields in Baltimore County due to fractures and cavities that have high capacities to hold and conduct water. Wells in areas underlain by Loch Raven schist, approximately 70 percent of the watershed, have been identified by the county as critical yield areas due to a lower degree of fracturing in the rock and may yield less flow than wells in other geology.

Groundwater quality is also affected by geologic formations. For example, naturally occurring radionuclides have been detected in groundwater at levels above the US EPA Drinking Water Standards in areas underlain by the Baltimore gneiss, which underlie almost 10 percent of the watershed. Hardness may be a problem in areas underlain by marble due to higher concentrations of calcium and magnesium. In addition, groundwater may be more acidic when obtained from aquifers in gneiss and schist while in marble formations ground water is usually alkaline (Baltimore County DEPRM, 2006a).

2.3.5 Wastewater

Wastewater produced through human use must be treated. This is accomplished either through public conveyance to a wastewater treatment facility (not applicable in this watershed) or through individual wastewater treatment systems such as septic systems. Residential wastewater consists of all water typically used by residents including wash water, bathing water, human waste disposal water, and any other rinse water (e.g., paint brush, floor washing, etc.). Industrial and commercial facilities must also dispose of any water used as part of their operations. Depending on the operation, the water could contain any number of contaminants, including metals, organic compounds, detergents, or synthetic compounds. All of these wastes have the potential to harm the natural environment and drinking water sources.

2.3.5.1 Septic Systems

Properly functioning septic systems provide treatment for pathogens and phosphorus present in wastewater, but can discharge nitrogen in the form of nitrates. Depending on the location of the system, the nitrates may either be reduced or eliminated through denitrification as the water passes through riparian buffers, particularly forested riparian buffers. Failing and improperly maintained systems can release nitrogen, phosphorus, and other chemicals, contaminating the aquatic environment. They can also result in increased bacterial contamination of nearby streams and are therefore a human health concern.

There is no public sewer in use in Loch Raven East and therefore septic systems are numerous. According to Baltimore County Bay Restoration Fund tracking there are approximately 2,500 septic systems in Loch Raven East. Table 2- 11shows the distribution of these septic systems among the six subwatersheds.

Table 2- 11: Approximate Number of Septic Systems in Loch Raven East

Subwatershed	Number of Septic Systems (estimated)
Dulaney Valley Branch	826
Fitzhugh Run	147
Greene Branch	799
Jenkins Run	32
Overshot Run	551
Royston Run	145
Total	2,500

2.3.5.2 Public Sewer

A public sewer system conveys wastewater from individual residences and businesses to a facility that treats the wastewater prior to discharge. Loch Raven East lies outside of the area served by the Baltimore County public sewer system, and therefore issues such as leakage or overflows are not applicable in this watershed.

2.3.6 Stormwater

Stormwater is surface water or snowmelt resulting from precipitation. Stormwater that does not infiltrate into the ground, evaporate, or transpire through plants becomes surface runoff that flows directly to streams, with or without being directed to a storm drainage system. Stormwater runoff is affected by the amount and intensity of rainfall, soil characteristics, surface slope and land use/land cover. Runoff is higher in areas with greater impervious surfaces and on agricultural land than on undeveloped land. Certain types of agricultural uses such as row crops can dramatically increase runoff especially compared to low density development. This can lead to flooding and stream erosion, resulting in the destruction of habitat and a reduction of a stream’s natural ability to remove pollutants.

Stormwater runoff can also carry various contaminants and contribute to thermal impacts on streams. Pollutants deposited on impervious surfaces and other developed lands from daily human activities are washed off into stream systems by stormwater. Runoff from agricultural operations and residential areas can carry pollutants such as nutrients, pathogens, and chemicals to receiving water bodies.

2.3.6.1 Storm Drainage System

The storm drainage system commonly consists of curb and gutter with associated inlets (road drains), and a piping system, or drainage swales (e.g., roadside ditches) which may or may not be connected to storm drain pipes. The purpose of these systems is to remove water quickly from roadways to prevent flooding and potentially hazardous situations. However, the environmental impacts from the two systems are different. The curb and gutter system quickly and efficiently removes water from impervious surfaces and routes that water to low spots in the topography, usually directly to the stream. This type of system delivers not only increased volumes of water, but pollutants associated with impervious surfaces are carried untreated directly to the stream system or other receiving water body (bypassing any existing buffer).

Grass drainage swales do not move the water as quickly as curb and gutter systems and may allow the water to slow somewhat prior to entering the stream system, or in some cases storm drain pipes. Drainage swales also allow some infiltration into the soil thus reducing the amount of water eventually delivered to the receiving water body. The infiltration and slower movement of water also provide some filtering of pollutants.

Table 2-12 shows the components of the storm drain system by subwatershed. There are only two major (> 3 feet in diameter) storm drain outfalls in Loch Raven East. The minor (< 3 feet in diameter) storm drain outfalls and corresponding pipe lengths are shown. The length of pipe for which cross-sectional size is unknown is also shown. Table 2-13 shows the percentage of area served by the storm drain system.

Table 2-12: Loch Raven East Storm Drain System Components

	Major (>3ft)			Minor (<3ft)			All Outfalls		
Subwatershed	Outfalls (#)	Inlets (#)	Pipe (ft)	Outfalls (#)	Inlets (#)	Pipe (ft)	Total Outfalls (#)	Total Inlets (#)	Total Piping (ft)
Dulaney Valley Branch	-	-	-	32	82	11,160	32	82	11,160
Fitzhugh Run	-	-	-	-	-		-	-	-
Greene Branch	1	7	980	37	90	13,048	38	97	14,028
Jenkins Run	-	-	-	3	8	855	3	8	855
Overshot Run	-	-	-	12	29	3,955	12	29	3,955
Royston Run	1	4	1,120	7	18	3,125	8	22	4,245
Total	2	11	2,100	91	227	32,143	93	238	34,243

Table 2-13: Loch Raven East Stormwater System Coverage

Subwatershed	Stormwater System Drainage Area (acres)	Area Covered by Stormwater System (%)	Number of Inlets (#)	Inlet Density (# / mi^2)
Dulaney Valley Branch	210.9	5.9	82.0	14.7
Fitzhugh Run	-	-	-	-
Greene Branch	189.4	5.5	97.0	17.9
Jenkins Run	9.3	2.3	8.0	12.7
Overshot Run	61.2	3.4	29.0	10.4
Royston Run	48.4	8.7	22.0	25.2
Total	519.3	4.5	238.0	13.2

2.3.6.2 Stormwater Management Facilities

Starting in the mid-1980s the Maryland Department of Environment (MDE) began requiring new development to implement stormwater management to control the quantity of stormwater runoff. This continues to be a significant consideration for development across the state. Stormwater management systems, such as stormwater ponds, can reduce erosion, sedimentation, pollution, and flooding. Increased importance of water quality and water resource protection led to the development of the Maryland Stormwater Design Manual (MDE, 2000) which provided BMP design standards that endeavored to mimic natural hydrologic processes to preserve pre-development conditions. The subsequent Maryland Stormwater Management Act of 2007 expanded on the 2000 manual regulations by requiring that environmental site design (ESD) techniques be implemented in new development via nonstructural BMPs and/or other better site design techniques. Full implementation of onsite ESD can in some cases eliminate the need for downstream stormwater management (SWM) facilities.

There are many types of BMPs available for managing stormwater runoff and providing stormwater quality treatment, all with differing pollutant removal capabilities. Several considerations are taken into account when selecting appropriate stormwater treatment measures such as space, maintenance, cost, and community acceptance.

Table 2-14 and Figure 2-14 summarize and display the location of the 27 public and private stormwater management facilities in Loch Raven East. Both Greene Branch and Overshot Run have the most facilities (eight each) which are widely distributed throughout the subwatersheds. Dulaney Valley Branch has seven facilities, followed by Fitzhugh Run with three facilities, and Jenkins Run with one facility. Royston Run does not have stormwater management. Filtration practices are the most numerous across the entire watershed (14 facilities). Although Greene Branch and Overshot Run have the same number of stormwater management facilities (8), facilities in Overshot Run treat more area (134 acres) which means that 55.4 percent of the treated area in Overshot Run drains to SWM facilities. With the exception of the detention ponds, designed largely for peak flow control, these stormwater management facilities provide water quality treatment.

Table 2-14: Loch Raven East Stormwater Management Facilities

SWM Facility Type	Dulaney Valley Branch	Fitzhugh Run	Greene Branch	Jenkins Run	Overshot Run	Total
Detention (#)		1	3		1	5
Drainage Area (ac)		5.5	7.6		3.4	16.5
Extended Detention (#)	2		1	1	1	5
Drainage Area (ac)	14.9		4.6	5.3	54.3	79.1
Filtration (#)	5	2	2		5	14
Drainage Area (ac)	51.9	6.7	13.3		74.2	146.1
Infiltration (#)			2		1	3
Drainage Area (ac)			2.3		2.2	4.5
Total (#)	7	3	8	1	8	27
Total Area Treated (ac)	66.8	12.2	27.8	5.3	134.1	246.2

Table 2-15 shows the percentage of urban land use area treated by stormwater management. This was calculated by locating SWM facilities in the following MDP land uses: very-low, low- and medium-density residential, commercial, industrial, institutional, open urban and transportation and calculating the area treated by each of these SWM facilities. Table 2-15 shows that 2.4 percent of the urban land uses in Loch Raven East are treated by SWM, with Overshot Run receiving the highest area of urban land treated at 87.1 acres, or 9.9 percent. Jenkins Run and Royston Run currently have urban land use that is not treated by stormwater management. Locations of urban land use where there is no current stormwater management are good candidates for implementing BMPs. Locations for implementing BMPs will be further discussed in Chapters 3 and 4.

Table 2-15: Loch Raven East Urban Land Uses Treated by Stormwater Management

Subwatershed	Total Area (ac)	Urban Land Use (ac)	Urban Acres Treated by SWM	Urban Land Use Treated by SWM (%)
Dulaney Valley Branch	3,577.2	1,669.0	0.9	0.1
Fitzhugh Run	1,772.3	361.9	11.1	3.1
Greene Branch	3,472.4	1,817.0	27.7	1.5
Jenkins Run	403.9	171.5	-	-
Overshot Run	1,782.9	881.5	87.1	9.9
Royston Run	558.6	287.8	-	-
Total	11,567.3	5,188.7	126.8	2.4

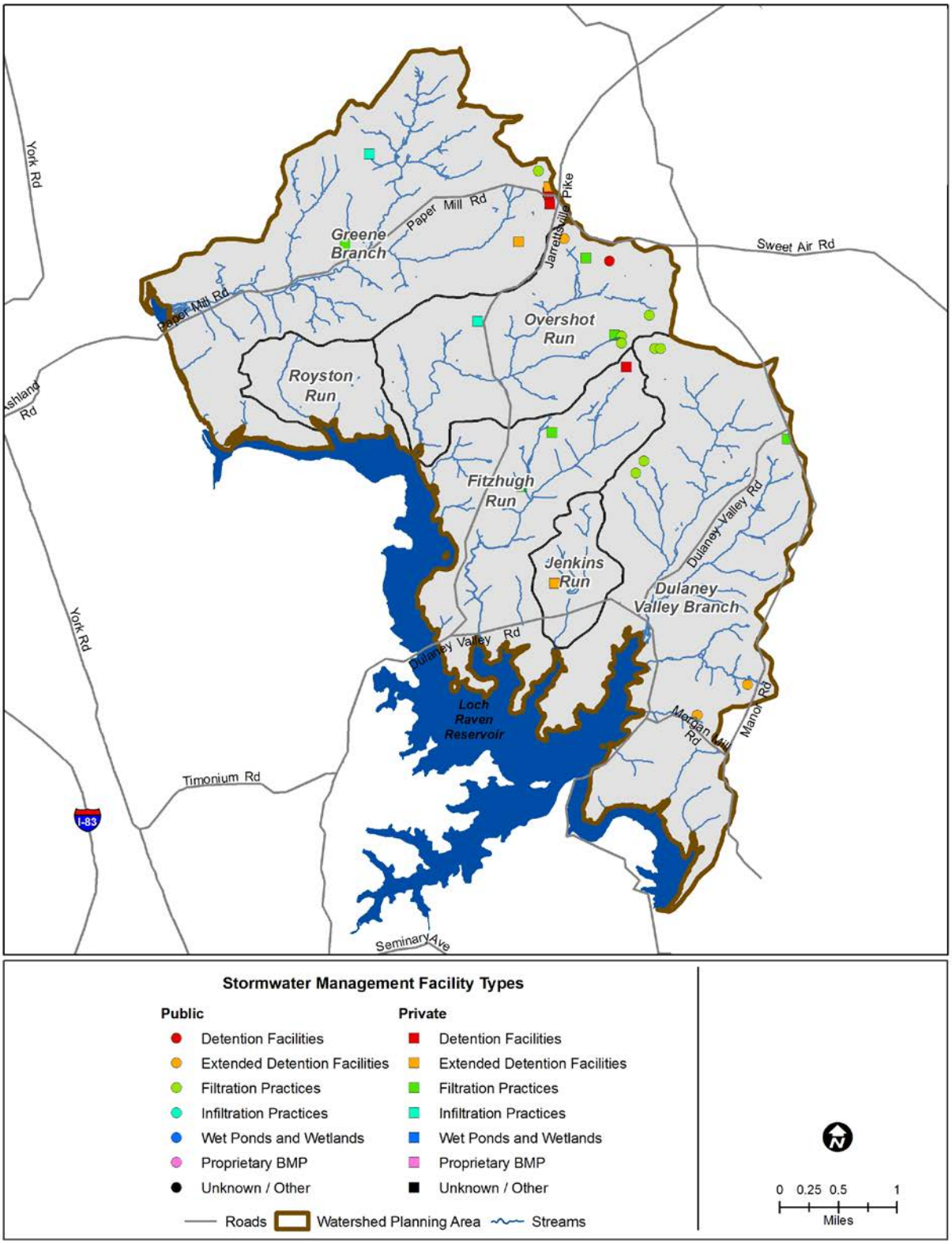


Figure 2-14: Stormwater Management Facility Types

2.3.7 NPDES Permits

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 number and type of NPDES-permitted facilities within the watershed is summarized in Table 2-16.

There are three permitted facilities: two golf courses located in Greene Branch and Jenkins Run and a commercial swimming pool discharge located in Overshot Run.

Table 2-16: NPDES Permits in Loch Raven East

Subwatershed	# Industrial	# General	# Pools	# of Permits
Greene Branch	-	1	-	1
Jenkins Run	-	1	-	1
Overshot Run	-	-	1	1
Total	-	2	1	3

2.3.8 Zoning

The Baltimore County Office of Planning (2009) defines zoning as “a system of land use regulation that controls the physical development of land. It is 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.” Zoning controls development patterns throughout the county over time.

The Comprehensive Zoning Map Process (CZMP) takes place every four years as specified in the County Code. The most recent rezoning started in the fall of 2011 and is currently underway.

In 1967, Baltimore County established the Urban Rural Demarcation Line (URDL) as part of its smart growth management policy. This line identified areas of Baltimore County that had or would receive public water and sewer infrastructure, thus allowing for commercial and residential development. Limits on infrastructure growth effectively ensured limited development in areas outside of the URDL, including all of Loch Raven East.

The current zoning for the watershed is summarized in Table 2-17 and shown on Figure 2-15, along with the location of the URDL. There are many zoning categories in Baltimore County. Only those most applicable to this watershed are shown on the legend. The majority of zoning categories within the watershed are resource conservation (‘RC’) categories with a few business and office zoning categories. There are also several properties that are in agricultural or conservation easements. These are discussed later in section 2.3.8.1 Conservation Easements.

The greatest percentage of land in the watershed is zoned ‘RC 6’ or rural conservation and residential (52.4 percent), followed by areas zoned ‘RC 7’, or resource preservation (30.3 percent) that are associated with protecting cultural, historical, recreational, and environmental resources. Agricultural zoning (‘RC 2’; 7.1 percent), mainly in northern Greene Branch, and

watershed protection ('RC 4'; 5.7 percent) comprise the other significant zoning areas. There are no areas zoned for commercial use in Loch Raven East.

Table 2-17: Loch Raven East Zoning (Baltimore County Office of Planning, 2012 and 2006b)

Zoning Code	Zoning Description	Total (Acres)	% of Watershed Area
BL	Business Local – Small-scale commercial	34.1	0.3
BM	Business Major – Large-scale commercial	12.6	0.1
BR	Business Roadside – Most permissive commercial classification	0.8	0.0
RC 2	Agricultural Protection – Foster and protect agriculture	826.3	7.1
RC 4	Watershed Protection – Protect the watersheds of the three regional reservoirs	658.9	5.7
RC 5	Rural Residential – Provide for residential development in appropriate rural areas	461.6	4.0
RC 6	Rural Conservation and Residential – Provide greater protection for resource areas	6,060.8	52.4
RC 7	Resource Preservation – Protect cultural, historical, recreational and environmental resources	3,505.4	30.3
RO	Residential Office – Permits house conversions to office buildings.	3.0	0.0
ROA	Residential Office – Permits house conversions to office buildings. Small conventional office buildings are permitted by special exception.	3.9	0.0
	Total	11,567.4	100.0

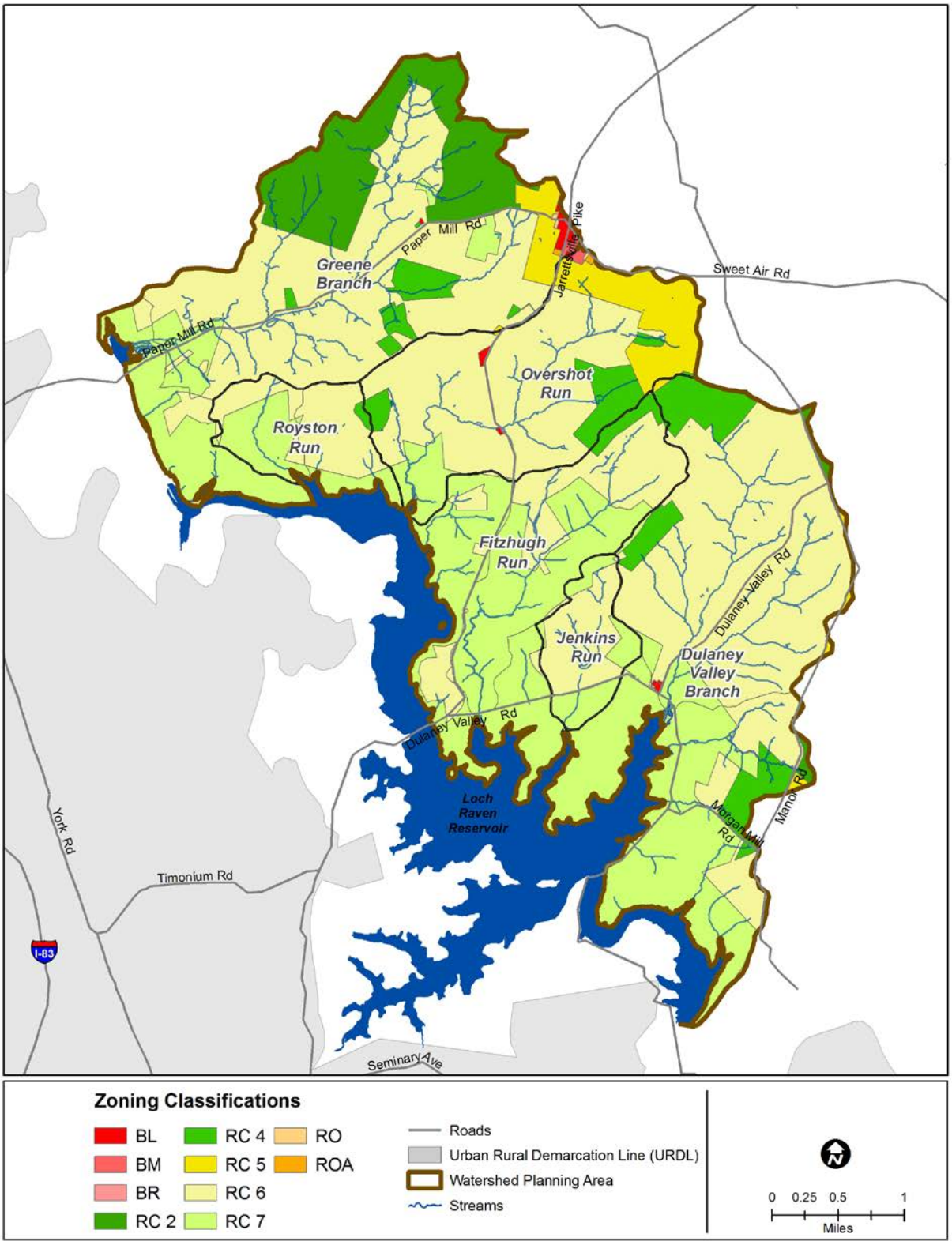


Figure 2-15: Loch Raven East Zoning

2.3.8.1 Conservation Easements

A conservation easement ensures the protection of significant natural resources on a property. Placing a property under easement may allow the landowner to receive income, or estate and property tax benefits while still maintaining ownership of the property.

Loch Raven East contains several conservation easements held under various preservation programs. These include properties held under local land trusts, Maryland Agricultural Land Preservation Foundation, Rural Legacy or Baltimore County Agriculture Land Preservation, Forest Conservation and open space on properties that are situated in areas zoned by Baltimore County as watershed protection (RC-4) or rural conservation and residential (RC-6 primary and secondary). These categories are discussed in more detail below. Table 2-18 summarizes the area within each subwatershed held in easement and Figure 2-16 shows the location of these properties.

Table 2-18: Conservation Easements (Acres)

Subwatershed	County Agriculture Land Preservation	Forest Conservation	Local Land Trust Proper-ties	Maryland Agricultural Land Preservation Foundation Properties	Watershed Protection Zoning (RC-4)	RC6 Primary	RC6 Secondary	Rural Legacy	Total
Dulaney Valley Branch	0.0	129.2	107.7	0.0	205.5	0.0	0.0	27.0	469.5
Fitzhugh Run	0.0	3.3	0.0	42.6	26.0	0.0	0.0	247.2	319.1
Greene Branch	28.9	29.7	3.0	202.8	85.9	9.5	10.7	46.2	416.5
Jenkins Run	0.0	6.9	0.0	0.0	0.0	0.0	0.0	31.6	38.5
Overshot Run	0.0	55.9	0.0	84.2	54.7	0.0	0.0	261.6	456.3
Royston Run	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0
Total	28.9	230.0	110.7	329.5	372.1	9.5	10.7	613.6	1705.0

Properties protected by the Maryland Rural Legacy program make up the largest portion of easement properties with 613.6 acres, primarily in Overshot Run and Fitzhugh Run. The Rural Legacy program was created in 1997 by the Maryland General Assembly to protect large, contiguous tracts of rural lands to preserve natural and scenic resources (EPS, 2011). This program is jointly funded through Maryland Program Open Space dollars and the State of Maryland. Local jurisdictions, including Baltimore County, also contribute funding. Individual parcels are administered by local land trusts.

There is open space on several properties that are held under easement in areas zoned by Baltimore County as Watershed Protection Areas (RC-4 zoning designation). In Loch Raven East, there are 372.1 acres located in Dulaney Valley Branch, Fitzhugh Run, Greene Branch, and Overshot Run. Residential development in the Watershed Protection Area (RC-4) requires the allocation of an open space (unbuildable area) of 70% of the total tract acreage. The 70% includes forest stands, farm fields, steep slopes, and/or wetlands (EPS, 2011). Watershed Protection Areas are established to provide for the protection of the water supplies of

metropolitan Baltimore. These areas prevent contamination of the water supply by limiting unsuitable types or levels of development in the watershed.

The Maryland Agricultural Land Preservation Foundation (MALPF) properties make up 329.5 acres of the watershed, with 202.8 acres in Green Branch. The MALPF program was created in 1979 and jointly funded by Baltimore County and the State of Maryland. The program is dedicated to preserving farmland and promoting commercial agriculture. To qualify for this program, a farm must be a minimum of 50 acres or located adjacent to a preserved property. Landowners receive cash payments for participating in this easement program (EPS, 2011).

Forest Conservation easements in Baltimore County provide for the protection of forests as required by the State of Maryland's Natural Resources Article 5-1601-1613, Forest Conservation Act. A forest, as defined by the County Code for this purpose, is an area 1-acre or more in size with at least 50 percent of the trees having a 2-inch or greater diameter at 4.5 feet above the ground. Forested buffers specifically refer to wooded areas that are adjacent to and protect a stream. Buffers can include trees, shrubs or herbaceous vegetation and are not restricted by minimum size requirements (Baltimore County Code Article 33 Title 5). Forest conservation areas in the watershed often overlap other conservation easements. The 230 acres of Forest Conservation easements shown in Table 2-18 are those areas of forest that are not also held in other easements.

There are 110.7 acres, primarily in Dulaney Valley Branch held in the Long Green Land Trust, a land trust made up of local concerned citizens that seeks to preserve open space, farm land, natural resources and historic sites. Local land trusts are preservation programs created in 1967 by the Maryland General Assembly to protect Maryland's natural environment. Larger properties (greater than 50 acres) are preferred for preservation under these programs, but local land trusts are often willing to work with smaller properties (EPS, 2011).

In addition to the easements described above, there are parcels in the Greene Branch subwatershed zoned by Baltimore County as Rural Conservation and Residential (RC-6 zoning designation) which require primary and secondary conservancy areas. In Greene Branch there are 9.5 acres zoned as primary conservancy areas and 10.7 acres zoned as secondary conservancy areas. One parcel in Greene Branch is also protected under the Baltimore County Agricultural Land Preservation Program, which was created in 1994 to preserve working family farms. A farm must be at least 20 acres, located in the Agricultural Preservation Protection Areas (APPA), and meet certain soil criteria to be eligible for this program (EPS, 2011).

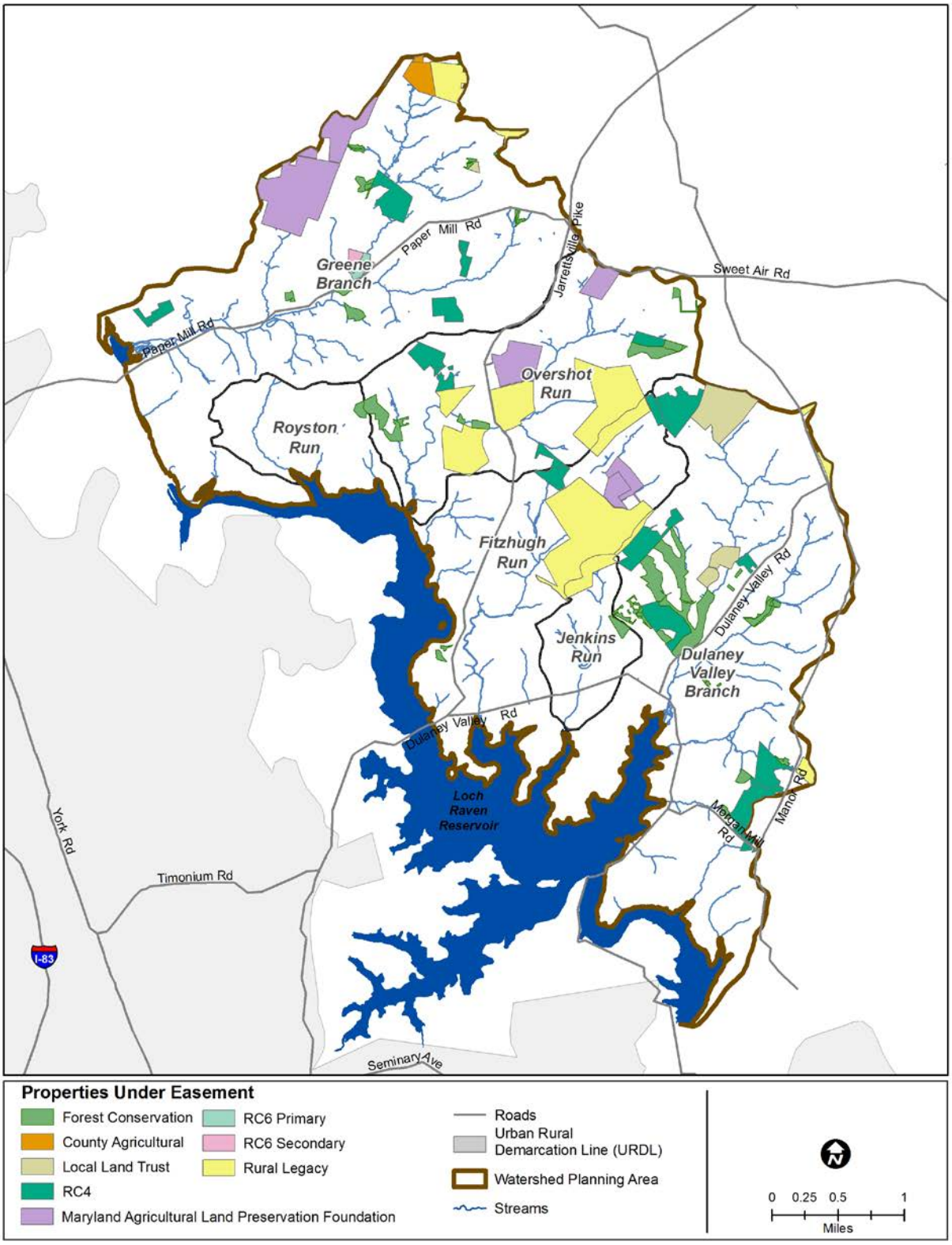


Figure 2-16: Loch Raven East Properties Under Easement

2.3.9 Historical Development

Historical development within the watershed began before 1900 with the almost half of the development occurring from the 1950s to the 1970s. Table 2-19 provides a summary of the number of units within each subwatershed and the decade built. Figure 2-17 and Figure 2-18 shows the decade each parcel was developed using the GIS shapefile "HistoricalDevo2005" provided by Baltimore County.

As discussed in section 2.3.6.2, in the mid-1980s the Maryland Department of Environment (MDE) began requiring new development to implement stormwater management to control the quantity of stormwater runoff. In 2007, the Maryland Stormwater Management Act of 2007 expanded on the 2000 manual regulations by requiring that environmental site design (ESD) techniques be implemented in new development via nonstructural BMPs and/or other better site design techniques. As a result of the development patterns, most of the watershed was built prior to the requirement for stormwater management.

Table 2-19: Decade Built and Number of Units

Decade Built	Before 1900	1900 to 1919	1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000 - 2010	After 2010	No Data	Undeveloped
Dulaney Valley Branch	25	7	4	8	14	120	205	264	48	67	60	6	175	69
Fitzhugh Run	6	2	4	1	7	12	32	25	11	13	5	1	29	38
Greene Branch	22	5	5	10	9	52	65	141	261	96	59		123	58
Jenkins Run								32	3				10	7
Overshot Run	10	4	7	4	6	104	131	85	82	32	36	4	129	42
Royston Run	4		1	1	1	16	68	33	12	2	7		12	13
Total	67	18	21	24	37	304	501	580	417	210	167	11	478	227

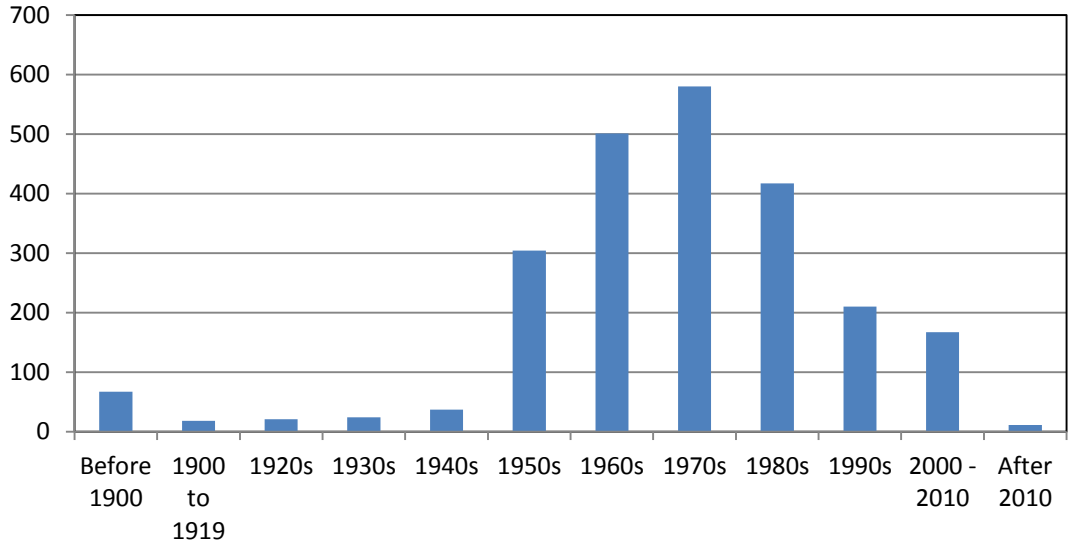


Figure 2-17: Number of Units Built by Decade

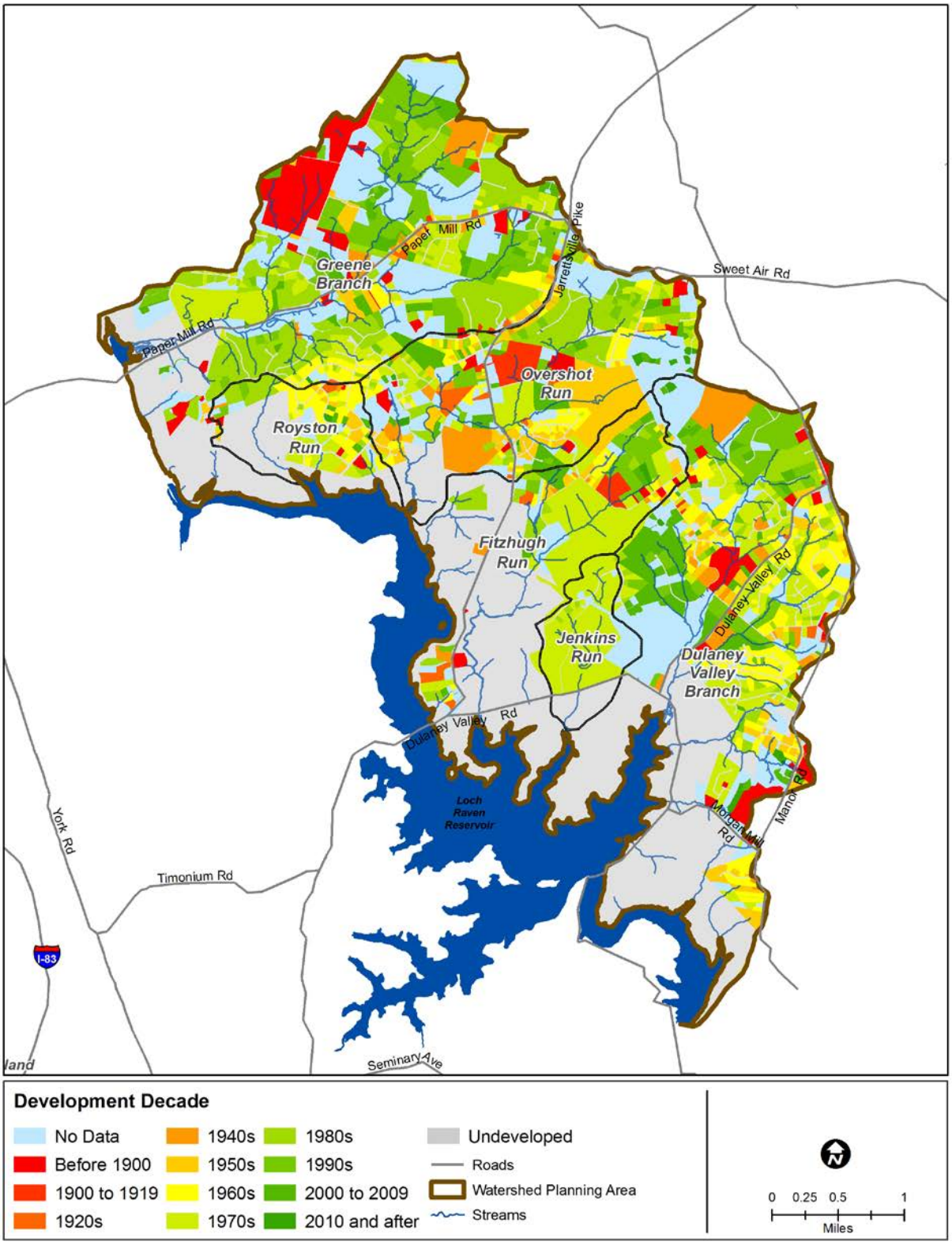


Figure 2-18: Decade Built

CHAPTER 3.0
Water Quality and Living Resources

3.1 Introduction

The Loch Raven East subwatershed (Area R) is located in the Loch Raven Reservoir watershed and includes Greene Branch, Royston Run, Overshot Run, Fitzhugh Run, Jenkins Run, Dulaney Valley Branch, and several unnamed tributaries that drain directly to the reservoir. Area R is in the southeastern part of the watershed, east of Interstate 83 and the Loch Raven Reservoir impoundment. The Area R subwatersheds account for approximately 8.2% of the Loch Raven Reservoir watershed drainage area (Table 3-1).

Chapter 3 describes the water quality, living resources, and habitat for Area R based on existing watershed conditions. In addition to water quality maintenance and improvement strategies, the SWAP aims to provide a plan for the support of plants, animals, and their habitat. Species living in natural communities require many habitat characteristics for survival including land, water, and biological conditions that provide for their needs of food, water, shelter and reproduction.

Water is an integral part of the habitat of all species. Animals and plants require water to survive; their populations are intimately connected to water's availability and its quality. They respond to changes in water quality and habitat conditions in ways that reflect the health of water bodies, the local geomorphology and activities occurring in the watershed. In some cases, water quality is measured in terms of its ability to support living resources such as trout or shellfish. Information on living resources is presented in this chapter as an indicator of water quality health and of overall habitat conditions in the watershed. A baseline assessment such as this can help to determine if current and future watershed management practices are adequately providing for the needs of natural communities.

Existing water quality data was reviewed for the SWAP and was generally representative of the entire Loch Raven Reservoir watershed. The data review included: impairments from Maryland's 303(d) listing, pollutant loadings analysis for total nitrogen and total phosphorus, water quality monitoring data available to date, stream corridor assessments, and stormwater management facility assessments.

Table 3-1: Percent of Area R Watershed Within the Loch Raven Watershed

Subwatershed	Total Area (Acres)	% of Loch Raven Watershed
Dulaney Valley Branch	3,577	2.5
Fitzhugh Run	1,772	1.3
Jenkins Run	404	0.3
Greene Branch	3,472	2.5
Overshot Run	1,783	1.3
Royston Run	558	0.4
Loch Raven Reservoir Watershed	140,931	100
Area R Total	11,566	8.2

3.2 Designated Water Uses, the 303(d) Listings and Total Maximum Daily Loads (TMDLs)

Area R contributes 8.2% of the drainage area to the Loch Raven Reservoir watershed which is part of the area covered under the 2005 Reservoir Watershed Management Agreement and Action Strategy. This section provides a summary of water quality impairments for the Loch Raven Reservoir watershed as reported by the Maryland Department of the Environment (MDE). MDE has designated Gunpowder Falls and all tributaries above the Loch Raven Reservoir as Use III-P, defined as Nontidal Cold Water and Public Water Supply. The designated uses include water contact sports, leisure activities involving direct contact with surface water, fishing, growth and propagation of trout and other fish, aquatic life and wildlife, agricultural water supply, industrial water supply, and public water supply.

Section 303(d) of the 1972 Clean Water Act requires states to develop, and periodically update, a list of impaired waters that fail to meet applicable state water quality standards which are defined by their designated uses. States must also establish priority rankings and develop Total Maximum Daily Loads (TMDLs) for waters on the 303(d) list. 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. TMDLs can be developed for a single pollutant or group of pollutants of concern (e.g. sediment, metals, bacteria, nutrients, and pesticides).

The Loch Raven Reservoir watershed (8-digit watershed) is listed as impaired in the Maryland 303(d) list of impaired waters for various pollutants of concern including: fecal coliform, methylmercury, sedimentation and siltation, total phosphorus and impacts to benthic/fish communities (MDE, 2008). The Loch Raven Reservoir impoundment is impaired for sedimentation and siltation, methylmercury, and total phosphorus. The Loch Raven Reservoir watershed streams are impaired for impacts to benthic and fish communities (1st through 4th order streams) and fecal coliform (mainstem river). Table 3-2 provides a summary of the impairment listings and status. Impairment listings reflect the inability to meet water quality standards for the designated uses discussed above.

Four TMDLs have been completed and approved for the Loch Raven Reservoir watershed (Table 3-2). In Area R, the impairment that is most relevant is the impact on benthic/fish communities in first through fourth order streams. According to MDE the stream biological community impairment listing has a low priority and a TMDL will be developed at some point in the future (MDE, 2008). While the impairment documented in Area R subwatersheds is a lower priority, it may also be contributing to the downstream impairments in the river mainstem and the reservoir impoundment. In addition, it is important that measures are taken in Area R to help meet the TMDL's for phosphorus, sediment and fecal coliform which are a problem in the reservoir and mainstem river.

Table 3-2: Water Quality Impairment Listing and Status

Impairment (Year Listed)	Water Type	TMDL Status	Applicable Designated Use
Sedimentation/siltation (1996)	Reservoir	TMDL Approved (2007) [1]	Drinking Water Supply
Total Phosphorus (1996)	Reservoir	TMDL Approved (2007) [1]	Aquatic Life and Wildlife
Impacts to Benthic and Fish Communities (based on completed bioassessments (2002))	Streams (1st – 4th order streams)	TMDL Required	Aquatic Life and Wildlife
Methylmercury-fish tissue (2002)	Reservoir	TMDL Approved (2004)	Fishing
Fecal Coliform (2008)	Streams (Mainstem River)	TMDL Approved (2009)	Water Contact Sports

[1] TMDLs for both total phosphorus and sediment were set simultaneously and are dependent on each other.

With the completion of a number of TMDL analyses for impaired waters, target load reductions for phosphorus, sediment and fecal coliform have been determined. Load reductions for methylmercury focus on targeting air deposition. Table 3-3 summarizes the reductions required for the Loch Raven Reservoir watershed for each waterborne pollutant of concern. Even though the yet to be determined TMDL for impacts to benthic/fish communities is relevant for Area R, measures must be taken in Area R to help meet the TMDLs for phosphorus, sediment and fecal coliform, which are a problem in the reservoir and mainstem river.

Table 3-3: TMDL Reduction Requirements for Urban Stormwater (EPS, 2010a)

Watershed	Total Phosphorus	Sediment	Fecal Coliform
Loch Raven Reservoir	50%	25%	80.2%

3.2.1 Sediment and Nutrients

A single TMDL was developed for total phosphorus and sedimentation/siltation that was approved by MDE in 2007 and is included as Appendix K. Sources of total phosphorus include surface runoff from urban and agricultural land uses in addition to discharge from small industrial sources and the Hampstead Municipal Waste Water Treatment Plant (WWTP). Excess total phosphorus in the aquatic environment leads to algal blooms. When the algae die, they consume oxygen from the reservoir that decreases the available oxygen to support aquatic life. In order to meet the water quality standards, a 50% target reduction of total phosphorus was established.

Sources of sediment in the Loch Raven Reservoir include urban, agricultural, and stream erosion. Sediment accumulation within the reservoir limits the storage capacity and therefore impacts its ability to function as a water supply reservoir. Excessive sedimentation can also negatively impact the fish population and recreational uses. Some of the total phosphorus control measures will also control sediment as phosphorus often enters the reservoir attached to sediment particles. In order to meet the water quality standards, a target reduction of sediment was established as a 25% reduction.

In the Loch Raven Reservoir and other Baltimore City water supply reservoirs (i.e. Prettyboy Reservoir and Liberty Reservoir) historical trends from an extensive water quality monitoring effort show that total phosphorus concentrations in monitored streams and from wastewater treatment plants have been declining. Likewise, algal levels in all three reservoirs have gradually improved during the past 15-18 years. Steadily increasing nitrate levels over this period appear to be stabilizing. All three reservoirs are still in various states of eutrophication and need further improvement and continued protection. Sedimentation is monitored periodically to assess the practical storage capacity of these impoundments. Each reservoir was reported as losing storage capacity: Loch Raven Reservoir has lost about 11 percent of its original volume, Prettyboy Reservoir has lost 7.5 percent, and Liberty Reservoir has lost 3.3 percent (BMC, 2004).

The Chesapeake Bay Program's draft Watershed Model Phase 5.3 was made available in late 2010. The Chesapeake Bay TMDL for nutrients and sediment is based on this model, as well as the Airshed Model and the Estuarine Model. The Chesapeake Bay TMDL was finalized on December 29, 2010. Subsequent to the completion of the Chesapeake Bay TMDL, the State of Maryland allocated load reductions to each source sector and to each local jurisdiction. These load reduction targets supersede the targets listed in the Tributary Strategies. All of the Baltimore water supply reservoirs are "treated" as nutrient traps by the Chesapeake Bay model and a reduction credit will be applied.

3.2.2 Fecal Coliform

The Maryland Department of the Environment (MDE) has identified the tributaries of Loch Raven Reservoir as impaired for fecal coliform bacteria (MDE, 2008). Fecal bacteria are

microscopic single-celled organisms (primarily fecal coliform and fecal streptococci) found in the wastes of warm-blooded animals. Excessive amounts of fecal bacteria in surface water used for recreation are known to indicate an increased risk of pathogen-induced illness to humans.

Bacteria in the reservoir tributaries are identified with domestic (pets and human associated animals), human (human waste), livestock (agriculture-related animals), and wildlife (mammals and waterfowl) source categories. In order to meet the water quality standards for the Loch Raven Reservoir, a load reduction of 77% in Maryland and 13% in Pennsylvania are required (MDE, 2009). A TMDL developed for fecal bacteria was developed in 2009 and is included as Appendix J.

3.2.3 Mercury

Based on early mercury data in fish tissue from a subset of lakes across the state, MDE announced a statewide fish consumption advisory for lakes. This advisory was 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. A TMDL for methylmercury in fish tissue was approved in 2004. Methylmercury is formed from inorganic mercury by the action of anaerobic organisms that live in aquatic systems including lakes, rivers, wetlands, sediments, soils and the open ocean. This methylation process converts inorganic mercury to methylmercury in the natural environment. Limited options exist to address a methylmercury TMDL through stormwater discharge regulations or practices because the pollution is transported through the air from Maryland and other states. 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) (MDE, 2002). A TMDL developed for mercury was approved in 2004 and is included as Appendix I.

3.2.4 Water Quality Analyses (WQA) with EPA Concurrence of MDE's Findings

In addition to mercury, the Loch Raven Reservoir watershed was initially identified on the 1996 303(d) list as impaired by other heavy metals. The heavy metal impairments were listed for the non-tidal streams. The original listing for heavy metals was questionable because: 1) no specific pollutants were defined; 2) the original listing was based on total recoverable metals and current standard is for dissolved metals; 3) inappropriate sampling techniques were applied (e.g., lack of filtration); 4) supporting data needed to interpret criteria was not available (e.g., hardness); and 5) a default hardness of 100 mg/l was used to convert and relate the total recoverable metals to the dissolved metals criteria, which superseded 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. The conclusions of the WQA indicate no impairment for heavy metals currently exists (MDE, 2003).

3.3 Pollutant Loading Analysis - Total Nitrogen and Total Phosphorus

Pollutant loading analyses are intended to assess the impacts of current and future development on water quality. For the Loch Raven East watershed, a pollutant loading analysis was completed based on land uses and the presence of septic systems 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 (CBP) July 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 East watershed are summarized in Table 3- 4.

Table 3- 4: Annual Pollutant Loading Rates for Loch Raven East (lbs/acre/year)

WRE Land Use	Total Nitrogen Per Acre	Total Phosphorus Per Acre
Urban Impervious	17.4	1.5
Urban Pervious	11.6	0.3
Cropland	23.1	1.3
Pasture/Orchards/Agricultural Buildings	7.8	0.7
Livestock	162.7	23.9
Forest	2.8	0.04
Water	10.3	0.6

3.3.2 Septic System Pollutant Loading

Total nitrogen loads from septic systems were calculated for each subwatershed using the equation below. Table 3-5 provides a summary of the number of people and septic systems in each subwatershed. The nitrogen load from septic discharge passes through the soil and reaches the stream through groundwater. A portion of the nitrogen load will be attenuated by the soil. The pass-though rate is defined as the percent of the septic nitrogen load that reaches the stream through groundwater (i.e., is not attenuated). Results are provided in Table 3-8 .

Pounds of total nitrogen from septic systems=
(Number of people) x (Pounds of nitrogen/person/year) x (Pass-Through Rate)

Where:
# of people = provided in Table 3-5
Pounds of nitrogen/person/year = 8.92 (from CBP, 2012)
Pass-through rate = 0.4 (60% of the septic nitrogen load is attenuated by the soil as per CBP, 2012)

Table 3-5: Number of People and Septic Systems in Each Subwatershed

Subwatershed	# People	# Septic Systems	# People/Septic System
Dulaney Valley Branch	2,025.9	826	2.5
Fitzhugh Run	420.5	147	2.9
Greene Branch	1,925.7	673	2.9
Jenkins Run	66.8	32	2.1
Royston Run	368.8	145	2.5
Overshot Run	1192.6	551	2.2
Total	6,000.3	2,364	

Table 3-6: Relationship Between MDP Land Use/Land Cover Categories to WRE Land Cover Categories

MDP Land Use/Land Cover Categories	WRE Land Cover Categories
191 Large Lot Subdivision (Agriculture)	See Table 3-7
192 Large Lot Subdivision (Forest)	See Table 3-7
11 Low Density Residential	Urban
12 Medium Density Residential	Urban
13 High Density Residential	Urban
14 Commercial	Urban
15 Industrial	Urban
16 Institutional	Urban
17 Extractive	Urban
18 Open Urban	Urban
21 Cropland	Cropland
22 Pasture	Pasture/Orchards/Ag. Building
23 Orchards	Pasture/Orchards/Ag. Building
24 Feeding Operations	Livestock
25 Row and Garden Crops	Cropland
41 Deciduous Forest	Forest
42 Evergreen Forest	Forest
43 Mixed Forest	Forest
44 Brush	Forest
50 Water	Water
60 Wetlands	Forest
72 Bare Rock	Urban
80 Transportation	Urban
242 Ag. Buildings	Pasture/Orchards/Ag. Building

Table 3-7: Recommended Load Group Composition for Large Lot Subdivision Type (Hirsch, 2011)

MDP Land Use/Land Cover Categories	Proportion of Area by Loading Rate Groups			
	Cropland	Urban	Forest	Pasture
191 Large Lot Subdivision (Agriculture)	14.2%	16.1%	27.6%	42.1%
192 Large Lot Subdivision (Forest)	5.4%	9.6%	78.4%	6.6%

The total acreage for each WRE land cover category was calculated. These were multiplied by the corresponding pollutant loading rates in Table 3- 4. The resulting annual pollutant loads for total nitrogen and total phosphorus for Loch Raven East are summarized in Table 3-8.

Table 3-8: Total Annual Nutrient Loads from Area R

WRE Land Cover	Area (Acres)	Nitrogen		Phosphorus	
		Rate (lbs/acres/yr)	Load (lbs/yr)	Rate (lbs/acres/yr)	Load (lbs/yr)
Cropland	1,352	23.08	31,193	1.32	1,781
Forest	4,639	2.77	12,871	0.04	182
Pasture/Orchards/Ag. Building	1,119	7.76	8,677	0.72	800
Impervious Urban	561	17.36	9,739	1.51	849
Pervious Urban	3,741	11.55	43,201	0.30	1,110
Livestock	0	162.74	0	23.92	0
Water	156	10.26	1,604	0.61	95
Septic Systems	--	8.92	21,409	--	--
Total	11,567		128,694		4,817

Table 3- 9: Loch Raven East WRE Land Cover Categories

WRE Land Cover	Dulaney Valley Branch (acres)	Fitzhugh Run (acres)	Jenkins Run (acres)	Greene Branch (acres)	Overshot Run (acres)	Royston Run (acres)
Cropland	464	316	81	323	166	2
Forest	1,436	859	136	1,347	576	285
Pasture/Orchards/Ag. Building	242	323	15	344	191	3
Urban Impervious	165	55	13	188	109	30
Urban Pervious	1,194	187	158	1,243	739	219
Water	76	32	0	28	2	19
Totals	3,577	1,772	404	3,472	1,783	559

Table 3-10: Annual Total Nitrogen Loads by Subwatershed

	Subwatershed	Dulaney Valley Branch	Fitzhugh Run	Jenkins Run	Greene Branch	Overshot Run	Royston Run	Total (Watershed)
	Total Area (acres)	3,577	1,772	404	3,472	1,783	559	11,567
Annual Total Nitrogen	Cropland	10,701	7,296	1,878	7,443	3,821	55	31,193
	Forest	3,984	2,383	379	3,737	1,598	791	12,871
	Pasture/Orchards/Ag. Building	1,881	2,508	113	2,670	1,481	24	8,677
	Urban Impervious	2,866	957	229	3,268	1,898	521	9,739
	Urban Pervious	13,784	2,162	1,828	14,356	8,540	2,531	43,201
	Water	784	324	0	284	17	196	1,604
	Septic Systems	7,228	1,500	238	6,871	4,255	1,316	21,409
	Total Nitrogen (lbs/yr)	41,228	17,131	4,665	38,628	21,610	5,432	128,694
	Total Nitrogen Loading Rate (lbs/acre/yr)	11.5	9.7	11.6	11.1	12.1	9.7	11.1

Table 3-11: Annual Total Phosphorus Loads by Subwatershed

	Subwatershed	Dulaney Valley Branch	Fitzhugh Run	Jenkins Run	Greene Branch	Overshot Run	Royston Run	Total (Watershed)
	Total Area (acres)	3,577	1,772	404	3,472	1,783	559	11,567
Annual Total	Cropland	611	417	107	425	218	3	1,781
	Forest	56	34	5	53	23	11	182
	Pasture/Orchards/Ag. Building	173	231	10	246	137	2	800
	Urban Impervious	250	84	20	285	165	45	849
	Urban Pervious	354	56	47	369	219	65	1,110
	Water	46	19	0	17	1	12	95
	Septic Systems							0
	Total Nitrogen (lbs/yr)	1,491	840	190	1,395	763	138	4,817
	Total Nitrogen Loading Rate (lbs/acre/yr)	0.42	0.47	0.47	0.40	0.43	0.25	0.21

3.4 Water Quality Monitoring Data

Baltimore County conducts chemical, biological, and illicit discharge and elimination monitoring within Area R. Section 3.4.1 summarizes the chemical data available for Area R. Section 3.4.2 summarizes the biological monitoring program. Section 3.4.3 discusses the illicit discharge detection and elimination program. In addition, Baltimore County conducted a synoptic sampling survey that is included in Appendix H.

3.4.1 Chemical Data

A baseflow monitoring program was initiated by Baltimore County in 2003. Baseflow is groundwater seepage into the stream channel and baseflow conditions exist when groundwater provides the entire flow of a stream. Typically after three days of no rain the flow in the channel is provided by groundwater. The County's baseflow monitoring program monitors sites in the Patapsco/Back River Basin in odd-numbered years, while the Gunpowder Basin/Deer Creek are monitored in the even-numbered years. Area R is located in the Gunpowder Basin and is therefore monitored in even numbered years. The sampling sites were chosen to maximize the number of subwatersheds monitored. In 2007, the sampling sites were divided into two tiers: Tier 1 sites are regular sampling sites, while Tier 2 sites are only to be sampled if a Small Watershed Action Plan (SWAP) or other project begins in the area. Fifty three (53) Tier 1 and 22 Tier 2 sites are in the Gunpowder Basin/Deer Creek watershed (Baltimore County EPS, 2011). All of the baseflow data sites presented for Area R are Tier 1 sites.

Due to the limited number of samples that were being collected for the baseflow monitoring program, it is being replaced with the trend monitoring program. Baseflow synoptic surveys will still be completed in support of SWAPs. The synoptic survey data are presented in Appendix H. Baseflow site LR 19 is being sampled as one of the trend monitoring sites. The trend monitoring program was initiated in January 2011. All sites in the trend monitoring program will be visited once per month regardless of weather. This will increase the number of samples per site to twelve per year.

There is one monitoring point for each of the baseflow sites in Area R. Figure 3-1 shows the locations of the baseflow monitoring sites, including LR 19 which represents a trend monitoring site.

The standard set of monitored pollutants for baseflow and trend sites includes total suspended solids (TSS), total solids (TS), total Kjeldahl nitrogen (TKN), nitrate/nitrite, total phosphorus, ortho-phosphorus, cadmium, copper, lead, zinc, biochemical oxygen demand (BOD), chemical oxygen demand (COD), chlorides, sodium, hardness, magnesium and calcium as well as temperature and pH determined *in situ*. A minimum of three days of dry weather is required prior to monitoring any baseflow site.

Table 3-12 shows the baseflow sampling results for each site. In addition, metals (i.e. copper, cadmium, lead, and zinc) were analyzed and found not to exceed the chronic and acute aquatic life, or the drinking water standards for either total or dissolved metals.

Figure 3-1: Area R Baseflow Monitoring Site Locations

Table 3-12: Summary of Baseflow Monitoring Data for Area R

Parameter (mg/l)		Site			
		LR 19 (Overshot Run)	LR 18 (Greene Branch)	LR 03 (Dulaney Valley Branch)	LR 02 (Fitzhugh Run)
Chloride	No. Samples	9	11	14	14
	Min.	42.13	37.89	27.35	16.35
	Max.	77.18	62.09	71.17	46.79
	Mean	58.20	49.90	39.90	25.09
	St. Dev.	13.09	8.00	14.60	7.87
	Median	57.83	49.63	35.55	23.07
Nitrate/Nitrite	No. Samples	8	10	13	20
	Min.	1.87	1.06	1.35	1.19
	Max.	2.66	2.51	3.04	4.70
	Mean	2.29	1.63	2.01	2.34
	St. Dev.	0.25	0.43	0.46	0.84
	Median	2.25	1.53	2.03	2.37
Total Kjeldahl Nitrogen	No. Samples	10	10	15	21
	Min.	0.10	0.10	0.10	0.01
	Max.	0.52	0.42	0.49	2.50
	Mean	0.18	0.17	0.16	0.41
	St. Dev.	0.14	0.11	0.13	0.63
	Median	0.10	0.10	0.10	0.10
Total Nitrogen	No. Samples	8	10	13	20
	Min.	1.97	1.28	1.45	1.29
	Max.	2.76	2.61	3.14	5.80
	Mean	2.42	1.80	2.18	2.77
	St. Dev.	0.25	0.39	0.44	1.23
	Median	2.45	1.77	2.20	2.59
Total Phosphorus	No. Samples	10	12	15	21
	Min.	0.01	0.01	0.01	0.01
	Max.	0.06	0.06	0.10	0.09
	Mean	0.03	0.02	0.03	0.02
	St. Dev.	0.02	0.02	0.02	0.02
	Median	0.03	0.02	0.02	0.02
Temperature (°C)	No. Samples	10	12	13	18
	Min.	4.60	5.30	-0.80	3.10
	Max.	21.67	23.22	19.50	20.70
	Mean	13.80	15.98	13.49	12.53
	St. Dev.	5.55	5.77	5.67	1.23
	Median	15.72	17.60	15.60	2.59

Chloride is important because it is linked to chronic toxicity in urban streams and the Loch Raven Reservoir watershed is 303(d) listed for biological impairment. The USEPA

National Recommended Water Quality Criteria (USEPA, 2013) lists the chronic aquatic life criterion for chloride as 230 mg/l and the acute toxicity limit is 860 mg/l (USEPA, 1986). None of the samples exceeded the chronic aquatic life criterion for chloride or the acute criteria. However, the mean and the median for site LR 19 exceeded the 50mg/L chloride level determined by the Maryland Biological Stressor Identification Process (MDE, 2009) to be detrimental to aquatic life. In addition, site LR 18 was just below this threshold for its mean and median scores. Site LR 03 exceeded this threshold of 50mg/L for two samples with measurements of 71.17mg/L and 68.65mg/L. Site LR 02 did not exceed 50 mg/L for any samples. Baltimore City data has shown an increasing trend in chlorides and sodium in raw and treated potable water over the past three decades. While levels are below EPA "action levels", the 2005 Reservoir Watershed Action Strategy recommends the establishment of sodium and chloride reduction goals for all three reservoirs. (http://www.baltometro.org/RWP/RWPActionStrategy2005.pdf)

Nutrient data (i.e. nitrate/nitrite, TKN, TN and TP) were rated based on the rating system detailed in Table 3-13. Total nitrogen concentration data ratings are adapted from the Maryland Department of Natural Resources (2005a) using loading coefficients reported by Frink (1991). Total phosphorus ratings were developed by evaluating non-tidal phosphorus data from the Chesapeake Bay Program (USGS, 1999).

Table 3-14: Baseflow Site Nutrient RatingsTable 3-14provides a summary of the nutrient ratings for each sampling site. It should be noted that some detection limits exist on the low end, and samples below detection limits were scored by default at two times the low end detection limit. These default scores may impact ratings. For example, the default score for Total Phosphorus prior to 2009 is 0.01, and after 2009 it is 0.025 based on the limitations of sampling equipment. With these limitations, a site will score moderately elevated for Total Phosphorus prior to 2009 if the equipment cannot detect a measurement for Total Phosphorus, and after 2009 a site will score elevated if the Total Phosphorus is not detectable based on the limitations of the sampling equipment.

There are no water quality standards for nutrients in Maryland but for purposes of this analysis, the nutrient ratings used are provided in Table 3-13. Individual site rankings based on mean scores and the nutrient rating criteria are provided in Table 3-14. On average, total nitrogen is moderately elevated for site LR 18, and elevated for site LR 19, LR 03, and LR 02. On average, total phosphorus is elevated for sites LR 19, LR 18 and LR 02, and total phosphorus is high for site LR 03. On average, nitrate/nitrite is elevated for site LR 18, and nitrate/nitrite is high for LR 19, LR 03 and LR 02.

Table 3-13: Ratings by Mean Nutrient Concentrations

Rating	Total Nitrogen (mg/l)	Nitrate/Nitrite (mg/l)	Total Phosphorus (mg/l)
Low	<1.0	<0.65	<0.01

Rating	Total Nitrogen (mg/l)	Nitrate/Nitrite (mg/l)	Total Phosphorus (mg/l)
Moderately elevated	1.0 – <2.0	0.65 – <1.0	0.01 – <0.02
Elevated	2.0 – <3.0	1.0 – <2.0	0.02 – <0.03
High	3.0 – <4.0	2.0 – <4.0	0.03 – <0.04
Very High	>4.0	>4.0	>0.04

Table 3-14: Baseflow Site Nutrient Ratings

Rating	Total Nitrogen (mg/l)	Nitrate/Nitrite (mg/l)	Total Phosphorus (mg/l)
LR 19	Elevated	High	Elevated
LR 18	Moderately Elevated	Elevated	Elevated
LR 03	Elevated	High	High
LR 02	Elevated	High	Elevated

Table 3-15: Summary of Trend Monitoring Data for Area R

Parameter (mg/l)		Site
		LR 19
Chloride	No. Samples	12
	Min.	49.22
	Max.	73.56
	Mean	58.47
	St. Dev.	8.09
	Median	56.47
Nitrate/Nitrite	No. Samples	12
	Min.	1.70
	Max.	3.34
	Mean	2.24
	St. Dev.	2.22
	Median	0.42
Total Kjeldahl Nitrogen	No. Samples	19
	Min.	0.10
	Max.	0.37
	Mean	0.20
	St. Dev.	0.10
	Median	0.22
Total Nitrogen	No. Samples	12
	Min.	2.07
	Max.	3.56
	Mean	2.42
	St. Dev.	0.40
	Median	2.34
Total Phosphorus	No. Samples	20

Parameter (mg/l)		Site
		LR 19
	Min.	0.03
	Max.	0.03
	Mean	0.03
	St. Dev.	0.00
	Median	0.03
Temperature (°C)	No. Samples	19
	Min.	2.70
	Max.	23.50
	Mean	14.65
	St. Dev.	6.42
	Median	16.20

As noted above, Chloride is important because it is linked to chronic toxicity in urban streams and the Loch Raven Reservoir watershed is 303(d) listed for biological impairment. None of the samples for the trend monitoring site exceeded the chronic aquatic life criterion for chloride or the acute criteria. However, all samples except the minimum sample exceeded the 50mg/L chloride level determined by the Maryland Biological Stressor Identification Process (MDE, 2009) to be detrimental to aquatic life.

3.4.2 Biological Data

This section combines biological monitoring data from four different surveys. The collection methods for fish and macroinvertebrate sampling are fairly similar at each site but the station selection, sampling period and replication vary between sources. Baltimore County Department of Environmental Protection and Sustainability (EPS) employ a Random Point Monitoring Program to evaluate the benthic macroinvertebrate community. Maryland Department of Natural Resources (MD DNR) Fisheries and EPS used a targeted fish sampling strategy to evaluate the fish community in the Area R watersheds during 2011. The Maryland Biological Stream Survey (MBSS) uses a statewide stratified random sampling strategy for both fish and benthic macroinvertebrate data.

In order to provide a succinct overview of conditions within the Area R watershed, the results of all these studies have been combined and listed chronologically by subwatershed and year in the following tables and figures. All the raw data and methods are available in the source documents (MD DNR 1999).

Baltimore County Biological Monitoring Programs

In December 2011, the Baltimore County EPS published a biological assessment of Area R, referenced as the Northeast Loch Raven Watershed. This report was written in support of the

Small Watershed Action Plan (SWAP) for the Area R watershed. The report describes both the benthic macroinvertebrate and fish communities. The full report is found in Appendix L.

Fish Community Data

The fish community data were collected during August and September 2011 using a targeted fish sampling strategy, by biologists from EPS and the MD DNR Fisheries Service using the MBSS protocols. A primary goal of the fish sampling was to assess the status of naturally reproducing trout populations, especially native brook trout. Native brook trout are extremely sensitive to environmental disturbance such as elevated temperatures, and their presence indicates good water quality. Results of the fish data analysis include a Fish Index of Biological Integrity (FIBI) score based on the fish community characteristics at a sampling site. Qualitative ratings of stream biological integrity are based on FIBI scores and range from good (4.0 – 5.0) denoting minimally impacted conditions to very poor (1.0 – 1.9) indicating severe degradation. MD DNR Fisheries Service provided an additional site from 2008 in the Dulaney Valley branch subwatershed that included brown trout data, but FIBI analysis was not completed for this site.

Benthic Macroinvertebrate Data

The benthic macroinvertebrate data were compiled from an annual sampling program managed by EPS. EPS employs a Random Point Monitoring Program to evaluate the benthic macroinvertebrate community. Benthic macroinvertebrates are organisms without a backbone that live on the bottom of streams and can be seen with the naked eye. They are an important part of stream ecosystems as they are a source of food for other aquatic life such as fish. The presence, condition, numbers, and types of benthic macroinvertebrates also convey information about a water body’s quality. Similar to the fish data, results of the data include a Benthic Index of Biological Integrity (BIBI) score based on the benthic community characteristics at a sampling site.

Maryland Biological Stream Survey

Biological monitoring data are also available from the Maryland Biological Stream Survey (MBSS). MBSS is a random design stream sampling program intended to provide unbiased estimates of stream conditions with known precision at various spatial scales. Goals of the program are to assess the current condition of ecological resources in Maryland's streams and rivers; identify the impacts of acidic deposition, climate change, and other stressors on ecological resources in Maryland's streams and rivers; provide an inventory of biodiversity in Maryland's streams; assess the efficacy of stream restoration and conservation efforts to stream ecological resources; continue to build a long-term database and document changes over time in Maryland's stream ecological condition and biodiversity status and communicate results to the scientific community, the public, and policy makers. Figure 3-2 and Table 3-16 present the combined MBSS and EPS data for fish data. Figure 3-3 and Table 3-17 present the combined MBSS and EPS data for benthic data.

Figure 3-2: Location of Fish Sampling Sites

Figure 3-3: Location of Benthic Macroinvertebrate Sampling Sites.

Table 3-16: Fish Index of Biological Integrity

Station ID	Year	FIBI Score	Narrative Ranking	Data Source
Greene Branch				
BA-P-057-209-96	1996	2.67	Poor	MBSS
LOCH-209-S-2000	2000	3.67	Fair	MBSS
LR-SYN-1	2011	3.00	Fair	EPS
LR-SYN-6	2011	1.33	Very Poor	EPS
LR-SYN-6B	2011	1.67	Very Poor	EPS
LR-SYN-20	2011	2.67	Poor	EPS
Royston Run				
LR-SYN-17	2011	2.33	Poor	EPS
Overshot Run				
LR-SYN-2	2011	3.00	Fair	EPS
LR-SYN-2B	2011	4.00	Good	EPS
LR-SYN-5	2011	3.00	Fair	EPS
Fitzhugh Run				
LR-SYN-3	2011	2.33	Poor	EPS
LR-SYN-13	2011	2.33	Poor	EPS
Dulaney Valley Branch				
LR-SYN-8	2011	2.00	Poor	EPS
LR-SYN-8B	2011	2.33	Poor	EPS

Table 3-17: Benthic Index of Biological Integrity

Station ID	Year	BIBI score	Narrative ranking	Data source
Greene Branch				
BA-P-057-209-96	1996	3.00	Fair	MBSS
LOCH-209-S-2000	2000	4.33	Good	MBSS
304187	2004	4.67	Good	EPS
304190	2004	4.33	Good	EPS
310079	2010	2.67	Poor	EPS
310088	2010	4.33	Good	EPS
310107	2010	4.67	Good	EPS
Overshot Run				
306149	2006	4.33	Good	EPS
306163	2006	5.00	Good	EPS
308064	2008	4.67	Good	EPS
310073	2010	4.33	Good	EPS
310074	2010	4.00	Good	EPS
Fitzhugh Run				
308044	2008	3.33	Fair	EPS

Station ID	Year	BIBI score	Narrative ranking	Data source
308095	2008	4.33	Good	EPS
Dulaney Valley Branch				
306211	2006	3.33	Fair	EPS
308107	2008	3.33	Fair	EPS
308144	2008	4.00	Good	EPS
310018	2010	4.00	Good	EPS
310055	2010	4.00	Good	EPS

The results of the various sampling programs support the general conclusions presented in the December 2011, the Baltimore County EPS biological assessment for Area R. The full report is found in Appendix L.

Overall, the benthic and fish data show agreement in the condition of streams in Area R. Streams in the northeastern portion of the Loch Raven Reservoir watershed generally support healthy communities of fish and benthic macroinvertebrates. Many organisms that perform essential functions, such as processing of terrestrial organic matter, are present. Four streams in this area support moderate to high-density brown trout populations. Although brown trout have replaced the native brook trout, in itself an indicator of degraded stream condition, brown trout still require cold, relatively clear flows and stable habitat to prosper. Interestingly, stations with better habitat condition were located in the downstream portions of their streams, on land protected by Baltimore City Reservoir property. This phenomenon also occurs in streams of the Prettyboy Reservoir Watershed. The condition of biological communities in this portion of Loch Raven Reservoir is consistent with the light residential development present in the stream headwaters.

The following discussion also comes from the December 2011 EPS report.

Brook trout

No brook trout were collected during the survey.

Brown trout

Wild brown trout were collected at eight stations, distributed among Fitzhugh Run, Greene Branch, and Overshot Run. There are two year-classes of fish in Fitzhugh Run. Both Greene Branch and Overshot Run have four year-classes of fish. MD DNR collected wild brown trout from Dulaney Valley Branch in 2008. Of the 93 individuals found, 89 were young-of-year and 4 were adults.

Non-trout Fish Community

Fifteen non-trout fish species were collected from Loch Raven Reservoir streams. They were a combination of catfish, darters, minnows, sunfish, and suckers. All species are either

cool- or warm-water fish. Warm-water fish tended to be collected at stations near the stream mouth (LR-Syn- 1, 2B, 3, 8, 8B, 13, 17). Of the 16 species collected (including brown trout), 12 species are native to this region of Maryland. Bluegill, brown trout, green sunfish, and largemouth bass are non-native.

3.4.3 Illicit Discharge and Elimination Data

An illicit discharge is a discharge into a municipal separate storm sewer, which is not composed entirely of storm water (e.g. discharge of wastewater or gray water). Baltimore County is responsible for establishing an illicit discharge detection and elimination (IDDE) program to ensure that any potential illicit discharges are either permitted by MDE or eliminated under its MS4 permit. Baltimore County tracks illicit discharges through a program of routine storm drain outfall screening. A routine outfall screening consists of:

(1) A quantitative analysis of the effluent. This includes measuring the effluent flow rate, temperature and pH, and field-testing with the LaMotte NPDES test kit (parts per million tests for copper, chlorine, ammonia and phenol).

(2) A visual inspection of the effluent, the outfall structure and the receiving channel, noting such conditions as water color, odor, vegetative condition, sedimentation, erosion, structural damage, etc.

In Baltimore County, there are approximately 3,500 total outfalls. There are two types of outfalls: major and minor. Major outfalls are ≥36” in diameter and minor outfalls are <36”. There are 660 major outfalls in our database and 589 have been prioritized. The minor outfalls are still at the beginning of being prioritized, 292 have been completed so far. There are a greater number of them (2,836), so they will be dealt with in phases.

Outfalls are chosen by their priority. The prioritization system works as follows: Outfalls that have not yet been screened three times have not been prioritized. Outfalls that have been screened three times are assigned one of three priority ratings. Outfalls with major problems that require immediate correction and/or close monitoring, or outfalls with recurrent problems will be assigned a *Priority 1 (Critical)* rating. Outfalls with moderate to minor problems that have the potential to become severe are assigned a *Priority 2 (High)* rating. Outfalls with minor or no problems that do not require close monitoring are given a Priority 3 *(Low)* rating. Outfalls categorized as “Low Priority” are on a ten-year screening cycle, “High Priority” outfalls are screened once each year, and “Critical” outfalls are screened four times each year. This system allows for a more streamlined approach in selecting outfalls to screen, and provides a more efficient use of manpower. Outfall priority may be changed if it improves or degrades. Minor outfalls will be prioritized after one screening. If a severe problem is found, an investigation begins immediately.

There are two major outfalls and 91 minor outfalls in Area R. Table 3-18 shows the distribution of storm drain outfalls by subwatershed.

Table 3-18: Number of Storm Drain Outfalls by Subwatershed

	Greene Branch	Overshot Run	Fitzhugh Run	Royston Run	Dulaney Valley Branch	Jenkins Run	Direct Drainage	Total # of Outfalls
Major Outfalls (≥36")	1	0	0	0	0	0	1	2
Minor Outfalls (<36")	37	12	0	4	27	3	8	91
Total	38	12	0	4	27	3	9	93

Table 3-19 provides the outfall prioritization results for Area R. The sampling and prioritization of minor outfalls has only begun recently in areas with a higher degree of urbanization targeted. One of the major outfalls is priority 2 (moderate to minor pollution problems) and the other is not prioritized. All of the minor outfalls are categorized as "0" since none have been sampled.

Table 3-19: Storm Drain Outfall Prioritization Results

	Greene Branch	Overshot Run	Fitzhugh Run	Royston Run	Dulaney Valley Branch	Jenkins Run	Direct Drainage	Total # of Outfalls
Priority 0 (not prioritized)	37	12	0	4	27	3	9	92
Priority 1 (critical)	0	0	0	0	0	0	0	0
Priority 2 (high)	1	0	0	0	0	0	0	1
Priority 3 (low)	0	0	0	0	0	0	0	0
Total	38	12	0	4	27	3	9	93

3.5 Stream Corridor Assessments

Stream corridor assessments (SCAs) were conducted for a subset of stream reaches in Area R, all within the Dulaney Valley Branch subwatershed. The stream segments surveyed in this study were intended to cover parts of the watershed that had not been assessed during the preparation of Baltimore County's 1997 Water Quality Management Plan for Loch Raven Watershed (Tetra Tech, 1997). A summary of highlights from the 1997 watershed study is discussed later in section 3.5.5.

The current survey focused on first through fourth order stream reaches in the Dulaney Valley Branch subwatershed. Most of these stream reaches were not surveyed during the 1997 study. The stream survey method was based on Maryland DNR's SCA Survey Protocols. The SCA protocols were developed as a tool for environmental managers to quickly identify environmental problems within a watershed's stream network (Yetman, 2001). It is a rapid field survey rather than a detailed scientific assessment. It is intended to help target the need for more

detailed monitoring, management, and conservation efforts on the watershed and subwatershed scale.

The SCA survey is designed to be flexible and can be modified to suit the needs of the individual project. The modifications to the Area R SCA survey included the deletion of the accessibility and correctability ratings as well as the representative site forms. A channel condition evaluation was also included for erosion sites inventoried during the SCA surveys, which is based on concepts presented in Simon and Hupp (1986) on channel evolution models. The protocols and results of the SCA for Area R are described in the following sections.

3.5.1 Assessment Protocol

The SCA method is used to quickly assess physical conditions and identify common environmental problems in a stream corridor. Two-person field crews walked the wadeable streams within each of the selected subwatersheds and identified the following environmental problems:

- Channelized or Altered Stream Sections (CA)
- Unusual Conditions – Comments (UC-C)
- Erosion Sites (ES)
- Fish Migration Barriers (FB)
- Pipe Outfalls/Exposed Pipe (PO/ EP)
- Inadequate Stream Buffers (IB)
- Trash Dumping Sites (TD)
- In or Near Stream Construction (IC)

The field survey teams walked along the selected stream corridors noting the location of problems on either field maps or a hand held Global Positioning System (GPS). At least one photograph was taken at each site to document the conditions observed. After returning from the field, all data was entered into a Geographic Information System (GIS). Each site was assigned a unique identification (ID) number including a county map grid identification number. Figure 3-4 shows the county grid boundaries within Area R, the stream surveyed in 1997, and the streams surveyed in the 2012 SCA.

Figure 3-4: Grid Identification System and Stream Surveys

All problem sites were scored by the field survey team on a scale of one to five for severity. The scores are intended to help prioritize potential restoration opportunities where a score of five denotes a minor problem, or one that is easy to fix, and a score of one would be the worst observed in a particular problem category. The criterion for scoring problem severity is dependent on the problem type and is described in detail in the SCA manual (Yetman, 2001). The severity rating is a measure of how bad a problem site is compared to other problems in the same category. The most severe problems are those with a direct and wide impact on stream resources.

For stream reaches with erosion sites, Channel Condition was evaluated based on existing geomorphic characteristics of the stream channel and principles on channel evolution models presented by Simon and Hupp (1986). There are four evolution descriptions for Channel Condition: Stage I – Incision, Stage II – Widening, Stage III – Deposition, and Stage IV - Recovery and Reconstruction (Figure 3-5).

The numbering sequence for the four categories follows an abbreviated version of Simon and Hupp's (1986) progression of change in channel evolution after some type of physical disturbance. For Stage I – Incision, the channel is downcutting which liberates sediment. Storm flow cannot access the floodplain where erosive energy could be dissipated. The channel cross section becomes "U" shaped and woody vegetation is left high on the unstable banks. For Stage II – Widening, there are widespread bank failures as the banks are undercut by high storm flows which can no longer access the floodplain. The channel tries to adjust to the new confined flow regime. Significant sediment loads are generated; *the* most significant erosion hazard occurs during this phase. Bank armoring is generally ineffective at this stage. For Stage III –Deposition, the enlarged channel dimensions can now accommodate the higher stormwater volumes and begins to develop an entrenched low flow channel from the deposition of liberated sediment. Vegetation begins to appear near the water line. For Stage IV – Recovery and Reconstruction, a new entrenched bankfull floodplain may be established. Woody vegetation and stable stream habitat begin to appear and dynamic stability is re-established.

The data from the evaluation of channel condition were used in conjunction with SCA ratings for erosion, and local geology/land use in order to prioritize unstable stream segments for further investigation and/or restoration. All the SCA survey data are shown as tables in Appendix F.

3.5.2 Summary of Sites Investigated

The SCA targeted streams in the Dulaney Valley Branch subwatershed. As indicated in Table 3-20, the SCA evaluated 14.0 stream miles in the assigned subwatershed. The stream lengths and locations evaluated in the SCA survey were provided in the form of a GIS geo-database from Baltimore County. The GIS layer was compiled by Sanborn Mapping Company using stereophotogrammetry from 2005 orthophotography for stream lines. This method of delineating streams can create an over estimate of total stream mileage when compared to field

observations. The method is also known to delineate a number of ephemeral and intermittent stream channels that do not conform under SCA protocols. The variability in mapping protocols can also lead to some differences in mileage estimates between report documents developed in the Loch Raven Reservoir watershed in the past.

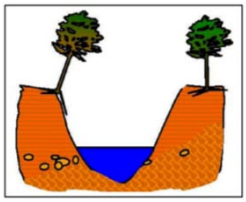
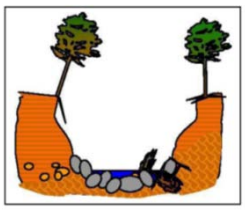
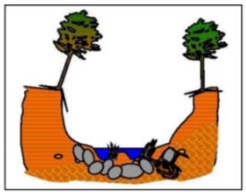
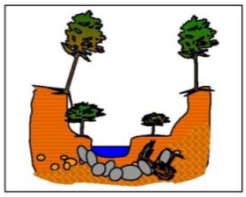
Stage I Incision • Downcutting liberates sediment • Loss of perched bankfull floodplains • "U" shaped channel • Woody vegetation high on bank with many "surfer" trees	
Stage II Channel Widening • Widespread bank failures as banks exceed critical height or were undercut by toe scour • Channel adjusts to new flow regime • Significant sediment loads generated; most significant erosion hazard in this phase • Bank armoring generally ineffective	
Stage III Deposition • Deposition begins from liberated sediment • Vegetation establishes near water line	
Stage IV Recovery and Reconstruction • Bankfull floodplains may be reconstructed from liberated sediment • Woody vegetation establishes near water line • Stability re-established	

Figure 3-5: Four Stages of Channel Evolution

Table 3-20: Area R Miles of Stream Assessed

Area R Subwatersheds	2012 SCA Survey	1997 Stream Miles Surveyed	Total Stream Miles Surveyed	% Total Stream Miles Surveyed
Dulaney Valley Branch	14.0	1.3	15.3	80.1
Greene Branch	0.0	5.4	5.4	24.3
Overshot Run	0.0	3.3	3.3	36.7
Royston Run	0.0	0.2	0.2	6.9
Fitzhugh Run	0.0	0.7	0.7	7.1
Jenkins Run	0.0	0.0	0.0	0.0
Totals	14.0	10.9	24.9	38.0

3.5.3 SCA General Findings

Within the 14.0 miles of streams surveyed within the Area R watershed, 369 potential problems were identified. Table 3-21 summarizes the number of potential problems identified in each category for the streams assessed.

Table 3-21: Area R SCA Survey Results – Number of Potential Problems

Subwatershed	Channel Alterations	Erosion Site	Exposed Pipes	Fish Barriers	Inadequate Buffers	In or Near Stream construction	Pipe Outfalls	Trash Dumping	Unusual Conditions	Totals
Dulaney Valley Branch	14	203	10	34	44	1	49	3	11	369
% of Total	3.8	55.0	2.7	9.2	11.9	0.3	13.3	0.8	3.0	100.0

Erosion sites were the most frequent problem observed (203) followed by pipe outfalls (49), inadequate buffers (44), and fish barriers (34). All of the other potential problem types combined amounted to only 39 of the observations. Trash dumping and in or near stream construction sites were the least common potential problem. Comment sheets (not included above) are provided in Appendix F and were used to document observations made in the field that were not identified as a potential problem. A summary of the lengths of channel alterations, erosion and inadequate buffers are summarized in

Table 3-22 for the Dulaney Valley Branch subwatershed. A description of each potential problem category is provided in the proceeding sections.

Table 3-22: Area R SCA Survey Results – Length of Potential Problems

Subwatershed	Length of Channel Alteration (ft)	Length of Erosion (ft)	Length of Inadequate Buffer (ft)
Dulaney Valley Branch	2,143	15,131	26,078

3.5.3.1 Channel Alterations

Channel Alteration refers to stream sections where the banks or channel has been significantly modified from their naturally occurring structure or condition. This includes channelized stream sections where a stream channel has been dredged, widened, straightened, and/or covered with concrete. Channelized streams are typically intended to convey more water and to prevent flooding but often create adverse environmental impacts such as impairing habitat and increasing water temperature. Table 3-23summarizes the number and length of channel alteration sites in each subwatershed and their associated severity rating. Locations of channel alteration sites are shown on Figure 3-6. Appendix F provides tables of channel alterations site data ranked by severity for the Dulaney Valley Branch subwatershed.

Table 3-23: Area R SCA Survey Results – Channel Alterations

Subwatershed	Severity Rating Inventory						Length		% of Total Length Surveyed
	Very Severe	Severe	Moderate	Low Severity	Minor	Total	Feet	Miles	
Dulaney Valley Branch	0	0	3	5	6	14	2,143	0.4	2.9

A total of 14 channel alteration sites were documented during the Area R survey for a total length of 2,143 feet or 2.9% of the stream length surveyed. The total length of channel alterations is relatively small considering historic agricultural land use of the region and residential development in the upper portion of the Dulaney Valley Branch subwatershed. This could be due to the amount of time that has passed since active ditching for agriculture has occurred. Many of the older, altered stream segments appear to have reached a new hydrologic and sediment transport equilibrium over time. Three out of the fourteen sites ranked moderate in severity. Of the eleven remaining sites inventoried for channel alterations, five ranked with a low severity and six ranked as minor. The channel alteration sections identified in the Dulaney Valley Branch subwatershed consist of relatively short stream lengths and would not represent major opportunity for water quality improvements. Many channel alterations are expensive and challenging to correct. Channel alterations were not identified as a significant issue impacting water quality or stream health in the Dulaney Valley subwatershed based on the results of the SCA surveys.

Figure 3-6: Dulaney Valley Branch Subwatershed, Channel Alteration

Figure 3-7 illustrates moderate channel alterations identified in the Dulaney Valley Branch subwatershed. The figure on the left, site CA-053A1-89, is not associated with a road crossing, and the figure on the right, site CA-044A3-93, is associated with a road crossing.

Figure 3-7: Examples of Moderate Channel Alteration Sites

3.5.3.2 Unusual Conditions

The unusual conditions form was used to document the location of anything out of the ordinary or to provide additional comments on a specific problem. An unusual condition was ranked as very severe if the potential problem was considered to have a direct and wide-reaching impact on the stream's aquatic resources. A site was rated as minor if it was considered to have no significant impact on the streams aquatic resources. Table 3-24 summarizes the number of unusual conditions sites and their severity rating. Locations of unusual conditions sites are shown on Figure 3-8. Appendix F provides tables of unusual conditions site data ranked by severity for the Dulaney Valley Branch subwatershed.

Table 3-24: Area R SCA Survey Results – Unusual Conditions

Subwatershed	Severity Rating Inventory					
	Very Severe	Severe	Moderate	Low Severity	Minor	Total
Dulaney Valley Branch	2	1	3	1	4	11

The two unusual condition sites rated as very severe included concrete slabs in the channel and an undermined asphalt ditch. This undermined ditch may pose as a public safety concern due to the large scour hole found in close proximity to the adjacent roadway. The one

Figure 3-8: Dulaney Valley Branch Subwatershed, Unusual Conditions

severe rating is of a debris jam accumulating at a wooden bridge. There was one site with a low severity rating and four sites with minor ratings. Stabilization matting, rip-rap, extraction wells, and old pipes located in the channel describe the unusual conditions noted at sites ranked as low severity and minor.

Figure 3-9 shows the two very severe unusual condition sites. The figure on the left, site UC-053A1-99, shows a large concrete slab in the stream channel. The figure on the right, site UC-044B3-28, shows a degrading asphalt ditch with a large scour hole adjacent to the manhole that may be a public safety issue.

Figure 3-9: Examples of Very Severe Rated Unusual Conditions

3.5.3.3 Erosion Sites

Erosion can destabilize stream banks, impact habitat, and cause sediment pollution problems downstream. Significant erosion problems are a result of changes to stream hydrology or sediment supply, which is often attributed to land use changes in a watershed (e.g., urbanization, increased impervious cover). Since erosion is also a natural process, it was not the purpose of the SCA survey to identify every occurrence of erosion. Erosion was documented for unstable stream reaches with significant amounts of erosion along the stream's banks such as vertical stream banks and where vegetative roots along a reach were unable to hold soil onto the banks. The type of erosion, possible cause, adjacent land use, and whether there was a threat to infrastructure was noted for each erosion site. The locations of erosion sites are shown on Figure 3-10

Table 3-25summarizes the number of erosion sites identified in the Dulaney Valley Branch subwatershed and their severity rating. Appendix F provides tables of erosion site data ranked by severity for the Dulaney Valley Branch subwatershed.

Figure 3-10: Dulaney Valley Branch Subwatershed, Erosion Sites

Table 3-25: Area R SCA Survey Results – Erosion Sites

Subwatershed	Severity Rating Inventory						Length		% of Total Length Surveyed
	Very Severe	Severe	Moderate	Low Severity	Minor	Total	(ft)	(mi)	
Dulaney Valley Branch	4	9	42	98	50	203	15,131	2.9	20.5

A total of 203 erosion sites were documented and 94 percent were rated in the minor to moderate categories. Erosion was the most documented problem identified from the SCA surveys. The length of stream channel identified with erosion totaled 15,131 linear feet and corresponded to approximately 54,180 square feet of erosion when factoring bank height and stream length. Stream widening was the most common type of erosion, usually found at a meander bend and/or associated with steep slopes. Some of this type of erosion could be described as a natural process. Most of the severe and very severe erosion sites occurred in first order or headwater tributaries where the land use is dominated by residential subdivisions. All but one of the severe and very severe erosion sites displayed a Stage I - Incision channel condition. Streams in the incision stage have the most potential for prolonged degradation and may contribute large amounts of sediment downstream through the channel evolution process.

Figure 3-11 shows an example of a very severe and severe erosion site. The figure on the left is of site ES-053A2-26, a very severe erosion site. The figure on the right is of site ES-053B2-15, a severe erosion site. Both erosion sites are currently incising.

Figure 3-11: Examples of Very Severe (lef) and Severe (right) Erosion Sites

Table 3-26 summarizes the channel condition or evolutionary stage evaluated during identification of the erosion sites. In terms of length and frequency, Stage II- Channel Widening was the predominant channel condition in the Dulaney Valley Branch subwatershed and accounted for 63% (1.8 miles) of the surveyed stream miles. Stage 1- Incision ranked second in terms of length and frequency with 24% (0.69 miles) of the stream length assessed in this

condition. Stage III- Deposition accounted for 10% (0.29 miles) of the surveyed stream miles, while stage IV- Recovery and Reconstruction, consisted of only 3% (0.09 miles) of the surveyed miles. Although the Stage II sites were the most frequent occurring, the most severe erosion observed was associated with sites in the Stage I – Incision condition. A large majority of the Stage II erosion appeared to be due to channel geometry. The Stage I erosion appeared to be more attributable to land use changes in the subwatershed.

Table 3-26: Area R SCA Survey Results – Channel Condition

Subwatershed	Channel Condition (Stage)	Length (ft)	Length (mi)	Number of Reaches	Percent Stage Lengths	Percent Stage Reaches
Dulaney Valley Branch	I Incision	3,654	0.7	41	24	20
	II Widening	9,489	1.8	128	63	63
	III Deposition	1,516	0.3	27	10	13
	IV Recovery and Reconstruction	472	0.1	7	3	4
Total		15,131	2.9	203	--	--

3.5.3.4 Fish Migration Barriers

A fish migration barrier denotes anything in the stream that significantly interferes with the upstream movement of fish. Unimpeded upstream movement is important for various species that move up and downstream during different parts of their life cycle such as spawning. Fish barriers can reduce the fish population and diversity in stream sections. Fish barriers include manmade structures such as dams or road culverts and natural features such as waterfalls. Three main factors were considered in the field when identifying blockages: 1) the vertical drop was too high for fish to swim over (e.g. vertical drop greater than 6 inches); 2) the water depth was too shallow (e.g., water spread over a large area at channelized sections or road crossings); and 3) the water was moving too fast (e.g., steep culvert pipe discharging high velocity flow). The severity was rated based on the location of the barrier in the stream network and whether the blockage was total, partial, or temporary. A fish migration barrier was considered very severe when a structure completely blocked a large stream or river. A minor rating was assigned to temporary and/or natural fish barriers that blocks little in-stream habitat. Locations of fish migration barrier sites are shown on Figure 3-12. Table 3-27 summarizes the number of fish migration barrier sites identified in the Dulaney Valley Branch subwatershed and their severity rating. Appendix F provides tables of fish migration barrier site data ranked by severity for the Dulaney Valley Branch subwatershed.

Figure 3-12: Dulaney Valley Subwatershed, Fish Barriers

Table 3-27: Area R SCA Survey Results – Fish Migration Barriers

Subwatershed	Severity Rating Inventory					
	Very Severe	Severe	Moderate	Low Severity	Minor	Total
Dulaney Valley Branch	5	5	12	6	6	34

Fish migration barriers are relatively abundant in the Dulaney Valley Branch subwatershed. It should be noted that the criteria for this metric were originally designed to evaluate problems for anadromous fish which are relatively weak swimmers. Anadromous fish spend most of their life in the sea and return to freshwater to spawn. Area R is in the Piedmont physiographic region where most resident fish species live in freshwater their entire life and are adapted to moving around steep, fast moving stream systems. Therefore, ratings of moderate or lower may not have as significant of an impact on migration of local fish species, particularly trout. That being said, there were still five fish barrier sites that ranked very severe and five sites that ranked severe. Pipe crossings, natural falls, dams and road crossings were conditions that created very severe fish migration barriers in the subwatershed. Debris dams and natural falls were the cause of all fish migration barriers ranked severe and were the cause of a large majority of sites ranked moderate.

Figure 3-13 shows two severe fish migration barrier sites. On the left is site FB-044A3-33, which is a twelve inch drop caused by a pipe crossing. On the right is site FB-053B1-13, which shows a dam with an approximate 144-inch drop in water surface.

Figure 3-13: Examples of Very Severe Fish Migration Barriers

3.5.3.5 Pipe Outfalls and Exposed Pipes

Pipe outfalls included pipes or small manmade channels that discharge into the stream. Pipe outfalls are considered a potential problem since they can carry untreated runoff and pollutants such as oil, heavy metals, and nutrients to a stream system. Pipe outfalls can also create significant erosion problems in the receiving channel if adequate scour protection is not

incorporated for the discharge. All pipe outfalls were inventoried and assessed; a higher severity rating was given if discharge was present with indicators of pollution (e.g. color and odor). The pipe material type and size were also recorded. Table 3-28 summarizes the number of pipe outfalls associated in the Dulaney Valley Branch subwatershed and their severity rating. Appendix F provides a table of pipe outfalls data ranked by severity.

Table 3-28: Area R SCA Survey Results – Pipe Outfalls

Subwatershed	Severity Rating Inventory					
	Very Severe	Severe	Moderate	Low Severity	Minor	Total
Dulaney Valley Branch	5	6	7	13	18	49

There were 49 pipe outfalls observed in the Dulaney Valley Branch subwatershed. Five of the pipe outfalls were rated as very severe. Three of the five very severe pipe outfalls were located at the head of the stream and two pipe outfalls discharged from the streambanks. Six pipe outfalls were rated as severe; all of which were located at the head of the stream. An additional seven pipe outfalls were rated as moderate, six of which were located at the head of streams. There was no odor observed at any pipe outfalls and all observed discharges were clear.

Figure 3-14 shows examples of very severe pipe outfall sites. The figure on the left is site PO-044A3-31, and the figure on the right is of site PO-053A2-25. Both are stormwater outfalls located at the head of stream channel with surrounding residential development. Locations of pipe outfalls are shown on Figure 3-15 .

Figure 3-14: Examples of Very Severe Pipe Outfalls

Figure 3-15: Dulaney Valley Branch Subwatershed, Pipe Outfalls

Exposed pipes were also assessed, and included any pipes that were either in the stream or along the immediate banks that could be damaged by a high storm flow event. Exposed pipes are susceptible to being punctured by debris, which is a concern since liquids carried by the pipeline can leak into the stream causing water quality problems depending on the liquid type. Exposed pipes include manhole stacks, pipes exposed along the stream banks or under the stream bed, and pipes built over a stream but that are low enough to be affected during high storm flows. Table 3-29 summarizes the number of exposed pipes identified in the Dulaney Valley Branch subwatershed and their severity rating. Appendix F provides a table of exposed pipe data ranked by severity.

Table 3-29: Area R SCA Survey Results – Exposed Pipes

Subwatershed	Severity Rating Inventory					
	Very Severe	Severe	Moderate	Low Severity	Minor	Total
Dulaney Valley Branch	0	3	4	1	2	10

There were a total of ten exposed pipes in Area R. Three of the exposed pipes were ranked as severe and four were ranked as moderate. For these severe and moderate exposed pipe sites, four pipes were across the stream bottom and three pipes were along the streambank. For the three remaining sites, there was one pipe that ranked as low severity and two pipes that ranked as minor.

Figure 3-16 provides a view of two exposed pipe sites. The exposed pipe site on the left is EP-053A1-10, which was given a severe rating for the twenty foot section of smooth metal pipe exposed on the right bank. This site was also documented as an erosion site and an inadequate buffer site. The exposed pipe site on the right is EP-044B3-11, which was given a moderate rating for the eight-foot section of smooth metal pipe exposed along the streambed. Locations of exposed pipes identified in the subwatershed are shown on Figure 3-17.

Figure 3-16: Examples of Severe and Moderate Exposed Pipes

Figure 3-17: Dulaney Valley Branch Subwatershed, Exposed Pipes

3.5.3.6 Inadequate Stream Buffers

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. For the SCA, a stream buffer was considered inadequate if it was less than 50 feet wide from the edge of the stream. Inadequate stream buffers were the third most commonly observed problem within Area R. The field teams identified 44 inadequate buffer sites with a total length of 26,078 feet or 35.3% of the total stream miles surveyed.

Table 3-30summarizes the number of inadequate stream buffer sites, along with the severity ranking and the length of inadequate stream buffer observed. The table also presents the percentage of the total stream miles surveyed that were identified with inadequate forested buffer. Locations of inadequate stream buffers are shown on Figure 3-18. Appendix F provides tables of inadequate stream buffer data ranked by severity.

The field teams identified 44 inadequate buffer sites with a total length of 26,078 feet (35 percent) of the total stream miles surveyed. Only two of the 44 inadequate buffer sites ranked as severe and nine sites ranked as moderate. As indicated on Figure 3-18, the two severe inadequate buffer sites are located along the lower mainstem of Dulaney Valley Branch and the other primary tributary draining the northern portion of the subwatershed. Seventy five percent of the inadequate buffer sites ranked as minor or low severity. Figure 3-19 shows two examples of severe inadequate buffer sites. The figure on the left is of site IB-053A1-03 along the mainstem of Dulaney Valley Branch. The site is associated with former pasture and fallow fields that comprises approximately 3,800 linear feet of inadequate buffer along both sides of the stream (the longest length of inadequate buffer within the Dulaney Valley Branch subwatershed). However, the majority of this impacted buffer site is within a Baltimore County forest easement (i.e., greenway) that has recently been planted with small trees. The figure on the right is of site, IB-053A1-106, which consists of pasture and fallow areas with approximately 3,450 linear feet of inadequate buffer along both sides of the stream.

Table 3-30: Area R SCA Survey Results – Inadequate Stream Buffers

Subwatershed	Severity Rating Inventory						Length		% of Total Length Surveyed
	Very Severe	Severe	Moderate	Low Severity	Minor	Total	(ft)	(mi)	
Dulaney Valley Branch	0	2	9	24	9	44	20,078	4.9	35.3

Figure 3-18: Dulaney Valley Subwatershed, Inadequate Buffers

Figure 3-19: Examples of Severe Inadequate Stream Buffers

3.5.3.7 In or Near Stream Construction and Trash Dumping

In or near stream construction is used to identify major earth disturbance activities within or near the stream corridor. Earth disturbance may lead to increased sedimentation of streams. Sites were ranked based on potential or evidence of sedimentation. Factors taken into consideration for determining the severity of the earth disturbance were the size of the earth disturbance, the proximity to the stream, use of appropriate erosion and sediment controls, and evidence that sediment is washing in or accumulating in the stream as a result of the earth disturbance.

There was only one near stream construction site located within the Dulaney Valley Branch subwatershed (Table 3-31). Figure 3- 21 shows the location of the near stream construction site, which is located at the headwater area of an intermittent channel. The site did not appear to be directly impacting the stream, but field observations showed evidence of sedimentation in the channel downstream. The site was given a moderate severity rating. It was not determined if any erosion or sediment control practices were being used at this construction site. Figure 3- 21 shows a photo of the near stream construction site (IC-044A3-81).

Table 3-31: Area R SCA Survey Results – In or Near Stream Construction

Subwatershed	Severity Rating Inventory					
	Very Severe	Severe	Moderate	Low Severity	Minor	Total
Dulaney Valley Branch	0	0	1	0	0	1

Figure 3-20: Dulaney Valley Branch Subwatershed, In or Near Stream Construction and Trash Dumping

Figure 3- 21: A Moderate Near Stream Construction Site

Trash dumping is used to identify locations where large amounts of trash or debris are being dumped in the stream corridor or to note where trash tends to accumulate. Severity of trash dumping was dependent upon the amount of trash present, the type of trash present, and the safety and accessibility for volunteer cleanup.

Table 3-32 summarizes the number of trash dumping sites identified in the Dulaney Valley Branch subwatershed and their severity rating. Figure 3-20 shows the locations of the trash dumping sites. Appendix F provides a table of trash dumping data ranked by severity.

Table 3-32: Area R SCA Survey Results – Trash Dumping

Subwatershed	Severity Rating Inventory					
	Very Severe	Severe	Moderate	Low Severity	Minor	Total
Dulaney Valley Branch	0	0	1	0	1	2

There were two trash dumping sites found in the Dulaney Valley Branch subwatershed. Both trash dumping sites are located on private land, had residential type trash, and were confined to a single area for each site. One trash dumping site was given low severity rating. Direct access to this site by vehicle may not be possible but the amount of trash could likely be carried out by hand. The other trash dumping site was given a moderate ranking. This site can be accessed from the field located to the east of the site and removed in approximately two to three loads in a pick-up truck.

Figure 3-22 shows an example of the minor and moderate rated trash dumping sites. The left figure is of the minor ranked site TD-044B3-13 and the right figure is of moderate ranked site TD-044A3-91.

Figure 3-22: Examples of Minor and Moderate Trash Dumping Sites

3.5.4 Summary of Stream Corridor Assessments

This section highlights the most significant observations of erosion, unstable channel conditions and inadequate buffer areas identified during the 2012 field surveys. Although this summary calls attention to particular erosion issues and areas with inadequate riparian buffer observed in 2012, the entire stream assessment data set should be considered when watershed management implementation activities are being prioritized for the Dulaney Valley Branch subwatershed. All of the individual findings have been discussed in the text above and complete SCA data tables are available in Appendix F.

While streams in the Dulaney Valley Branch subwatershed are in relatively good condition, compared to more urbanized watersheds, there is a small collection of areas where erosion and unstable channel conditions are concentrated. A majority of these areas are located in headwater or first order tributaries. Approximately 36 percent of the total channel erosion length surveyed in 2012 is concentrated in eight stream segments, referred to as 'areas' A to H, within Dulaney Valley Branch subwatershed (Figure 3-23). Table 3-33 shows the 5,381 linear feet of significant erosion areas. These eight erosion areas also compose 21,624 square feet of potential erosion identified when factoring bank height of the stream channel. This correlates to 40 percent of all the erosion sites identified in the Dulaney Valley Branch subwatershed when factoring bank height.

A summary of the 2012 these significant field survey findings for area A to H are described below. The most concentrated length of unstable eroded stream channels occurs on two first order tributaries (Areas A and B) on the eastern side of the Dulaney Valley Branch subwatershed. Figure 3-23 shows the erosion sites identified in Areas A and B that consists of non-contiguous erosion sites that varied from low severity up to very severe, and totaled approximately 2,703 linear feet of stream. Area A includes the second order tributary above the crossing at Windemere Parkway to the confluence of the Area B tributary.

Figure 3-23: Dulaney Valley Branch Subwatershed, Significant Erosion Sites

Table 3-33: Significant Erosion Sites

Map Site ID	Site #	Channel Condition	Cause	Street Connection	Avg. Exposed Bank Height (ft)	Severity	Erosion Length (ft)	Erosion Area (sf)
A	053A1-85ES	Stage II Widening	Land use change	Windemere Pkwy.	3	Low Severity	124	372
A	053A1-104ES	Stage II Widening	Land use change	Windemere Pkwy.	4	Low Severity	35	140
A	053A2-23ES	Stage I Incision	Land use change	Glen Alpine Rd.	1	Low Severity	32	32
A	053A2-21ES	Stage I Incision	Land use change	Glen Alpine Rd.	3	Low Severity	179	537
A	053A1-97ES	Stage II Widening	Land use change	Windemere Pkwy.	1	Moderate	589	589
A	053A1-94ES	Stage II Widening	Land use change	Windemere Pkwy.	3	Moderate	293	879
A	053A1-90ES	Stage II Widening	Other	Windemere Pkwy	2	Moderate	102	204
A	053A1-86ES	Stage I Incision	Land use change	Windemere Pkwy.	1	Severe	145	145
A	053A2-20ES	Stage I Incision	Land use change	Glen Alpine Rd.	5	Severe	58	290
A	053A2-26ES	Stage I Incision	Land use change	Glen Alpine Rd.	7	Very Severe	57	399
B	053A1-113ES	Stage I Incision	Land use change	Glen Alpine Rd.	3	Low Severity	105	315
B	053A1-119ES	Stage I Incision	Land use change	Glen Alpine Rd.	2	Low Severity	165	330
B	053B1-04ES	Stage II Widening	Land use change	Collingwood Rd.	3	Low Severity	8	24
B	053B1-05ES	Stage III Deposition	Land use change	Collingwood Rd.	4	Low Severity	94	376
B	053B1-02ES	Stage I Incision	Land use change	Collingwood Rd.	2	Low Severity	97	194
B	053A1-101ES	Stage II Widening	Land use change	Windemere Pkwy	5	Moderate	82	410
B	053B1-06ES	Stage I Incision	Land use change	Collingwood Rd.	3	Moderate	68	204
B	053A1-114ES	Stage I Incision	Land use change	Glen Alpine Rd.	6	Severe	470	2820
C	053B1-22ES	Stage II Widening	Land use change	Langtry Dr.	8	Severe	421	3368
D	053B2-14ES	Stage I Incision	Pipe outfall	Manor View Rd.	4	Moderate	19	76
D	053B2-18ES	Stage I Incision	Other	Manor View Rd.	3	Moderate	262	786
D	053B2-15ES	Stage I Incision	Pipe outfall	Manor View Rd.	5	Severe	215	1075
E	053A2-46ES	II Widening	Land use change	Deer Bit Ct.	3	Moderate	827	2480

Map Site ID	Site #	Channel Condition	Cause	Street Connection	Avg. Exposed Bank Height (ft)	Severity	Erosion Length (ft)	Erosion Area (sf)
E	053A2-66ES	Stage II Widening	Land use change	Deer Bit Ct.	5	Moderate	417	2085
E	053A2-70ES	Stage I Incision	Other	Deer Bit Ct.	8	Severe	158	1267
F	053A1-09ES	Stage I Incision	Other	Dulaney Valley Rd.	5	Severe	38	190
G	044A3-28ES	Stage I Incision	Other	Holly Berry Ct.	3	Very Severe	41	123
G	044A3-29ES	Stage I Incision	Pipe outfall	Holly Berry Ct.	8	Very Severe	117	936
H	053A1-138ES	Stage I Incision	Land use change	Ravenhurst Circle	6	Very Severe	163	978
						Total Erosion	5,381	21,624

- Area C (053B1-22ES) is associated with a first order tributary just upstream of the crossing at Langtry Drive. This site represents 421 linear feet of channel erosion but may represent a greater threat to sedimentation problems due to bank heights that averaged eight feet.

- Area D is also associated with a first order tributary that was identified with three erosion sites, two sites that ranked moderate and one that ranked severe. This stream channel includes approximately 500 linear feet of erosion. The site can be accessed from Manorview Road and further evaluated for potential restoration and TMDL credit.

- Area E is associated with three stream reaches that represent approximately 1,400 linear feet of erosion. These reaches also correspond to approximately 5,882 square feet of potential erosion when factoring bank height.

- Area F is the only significant erosion site along the mainstem of Dulaney Valley Branch was 053A1-09ES, located directly upstream of Dulaney Valley Road. This site is actively eroding around a meander bend, where a gas pipe has become exposed within the right bank. The length of erosion is approximately 38 feet, and the length of exposed pipe amounts to 20 feet. The site is easily accessible from Dulaney Valley Road or the property adjacent to the channel. This site also corresponds to an inadequate buffer area discussed below.

- Areas G and H correspond with two first order tributaries that each represent approximately 160 linear feet of erosion. These areas were listed for further evaluation due to high bank heights, the existing channel condition and any opportunities to incorporate SWM BMPs.

In general, the Dulaney Valley Branch subwatershed could be described as relatively stable with some fairly obvious problem areas. This is according to the 2012 field surveys and the expected progression of change in channel evolution after some type of physical disturbance

according to Simon and Hupp (1986). The data from the channel condition assessment is used in conjunction with SCA ratings that include erosion and inadequate buffers. Further, the channel condition assessment incorporates local geology and land use in order to prioritize unstable stream segments for additional investigation, restoration, and/or preservation. This information may be useful to geomorphologists and stream restoration professionals when they are prioritizing potential stream restoration projects.

Approximately 90 percent of the significant erosion sites that ranked severe or very severe had an incising channel condition (Stage I Channel Evolution). Of the significant erosion sites that ranked moderate, 33 percent had an incising channel condition (Stage I Channel Evolution), and 67 percent had a widening channel condition (Stage II Channel Evolution). Additional sites that ranked low severity for erosion were highlighted when their proximity to more severe erosion sites created an overall study area. Significant reductions in downstream sedimentation could be achieved by focusing resources on restoring streams in Stage I Channel Evolution and early Stage II Channel Evolution. The protection of headwater stream systems also reflects one of the goals developed from the action strategy highlighted in the 1997 Water Quality Management Plan for Loch Raven Watershed (Tetra Tech, 1997). The longest significant inadequate buffer reach was identified along the mainstem of Dulaney Valley Branch just upstream of Dulaney Valley Road for approximately 3,850 linear feet. A majority of this impacted buffer site is within a Baltimore County forest easement (i.e., greenway) that has recently been planted with small trees, both sides of the stream. Another significant inadequate buffer site is associated with the unnamed (primary) tributary that drains north to south on the eastern side of the subwatershed. This tributary is associated with site 053A1-106IB, upstream and downstream of the crossing at Long Green Road. This opportunity amounts to a total length of 3,453 linear feet of buffer enhancement on both sides of the stream. The remaining significant inadequate buffer sites were located alongside significant erosion sites discussed above in the summary. Table 3-34 summarizes the list of significant inadequate buffer sites. Figure 3-24 shows the locations of the inadequate buffer sites.

Table 3-34: Significant Inadequate Buffer Sites

Map Site ID	Site #	Buffer Inadequate on	Street Connection	Severity	Inadequate Buffer Length (ft)
53A1	053A1-03IB	Both	Dulaney Valley Rd	Severe	3,854
53A1	053A1-106IB	Both	Long Green Rd	Severe	3,453
53A1	053A1-88IB	Right	Windemere Pkwy	Moderate	1,073
53A1	053A1-120IB	Both	Fair Meadow Rd	Moderate	679
53A1	053A1-103IB	Right	Windemere Pkwy	Low Severity	323
53A1	053A1-112IB	Right	Glen Alpine Rd	Low Severity	748
44B3	044B3-30IB	Right	Langtry Dr.	Low Severity	1,220

Map Site ID	Site #	Buffer Inadequate on	Street Connection	Severity	Inadequate Buffer Length (ft)
53B1	053B1-21IB	Both	Langtry Dr.	Low Severity	322
53A1	053A1-137IB	Both	Ravenhurst Cir.	Low Severity	579
44A3	044A3-30IB	Left	Holly Berry Ct.	Minor	102
53A1	053A1-87IB	Left	Windemere Pkwy.	Minor	108
Total Inadequate Buffer					12,461

Figure 3-24: Dulaney Valley Branch Subwatershed, Significant Inadequate Buffer Sites

3.5.5 Summary of Previous Stream Assessments in Area R

Past watershed management reports, including the 1997 Water Quality Management Plan for Loch Raven Watershed (Tetra Tech, 1997) and the Gunpowder River Watershed Study (1999), have previously completed watershed characterizations employing alternative methodologies. The scale of assessment for the Dulaney Valley Branch subwatershed is much finer then these larger watershed assessments and the scale differences in combination with the differing data collection methods make it difficult to prioritize stream reaches for restoration. Despite the difficulty in prioritizing data or stream reaches, the findings of both reports reinforce management approaches including the creation or enhancement of riparian buffers and restoration of headwater stream systems in developing watersheds or watersheds without appropriate stormwater management.

1999 Gunpowder River Watershed Study

This report included 408 square miles of the Gunpowder River basin that included the Loch Raven Reservoir, Prettyboy Reservoir, Little Gunpowder Falls and the Lower Gunpowder Falls watersheds. The purpose of the study was to develop a comprehensive understanding of the current and potential water related impacts in the Gunpowder River basin. The study incorporated a suite of water quality monitoring that included collection of chemical, biological and hydrologic data. Hydrology data were derived from installed water level sensors and an analysis of baseflow and storm event characteristics associated with the monitoring stations. Landuse and geology was also analyzed for the subwatersheds where monitoring was conducted. Monitoring was conducted on four sites within the Loch Raven Reservoir watershed that are associated with subwatersheds located in Area R. The four subwatersheds include Jenkins Run, Fitzhugh Run, Dulaney Valley Branch, and Overshot Run.

The Jenkins Run site is located downstream of Dulaney Valley Road. Jenkins Run was identified as being incised below Dulaney Valley Road. The study also indicated that the Jenkins Run subwatershed could benefit from creation or enhancement of riparian buffers and further investigation of SWM opportunities. The Fitzhugh Run monitoring site was heavily forested with no evidence of eroded stream banks. The study did indicate that the Fitzhugh Run subwatershed would benefit from creation or enhancement of riparian buffer in the upper portions of the subwatershed and further investigation of SWM opportunities. The Dulaney Valley Branch monitoring site is located downstream of Dulaney Valley Road in the BGE powerline right of way. The channel in the vicinity of the monitoring site was documented as being relatively stable, but the subwatershed could benefit from creation or enhancement of riparian buffers and further investigation of SWM opportunities. The Overshot Run site is located below Jarrettsville Pike but the report did not reveal if there were any problems to be addressed in the subwatershed.

1997 Water Quality Management Plan for Loch Raven Watershed

The 1997 Loch Raven stream assessments initially focused on second and third order streams, although significant impairments of first order streams were also observed. A variety of stream survey methods were employed throughout the 1997 project. The stream stability indicators include those described by Pfankuch (1975). Information on a set of riparian indicators was also collected during the field survey including: vegetation type, buffer width and buffer density. The traditional Level I Rosgen approach (1994) was enhanced to include the use of in-field assessments rather than relying on estimates from topographic maps. In addition, a simplified pebble count procedure was used. The analysis provided information on unstable channels (Rosgen F and G stream type classifications). In some regions with a long growing season, relatively stable F channels can be found where streambanks are covered with extensive vegetation (Rosgen, 1996).

Approximately 10.9 miles of streams were assessed in the Area R subwatersheds during the 1997 Loch Raven watershed study. Greene Branch and Overshot Run are two of the subwatersheds in Area R that were assessed. More than five miles were surveyed in Greene Branch and more than three miles were surveyed in Overshot Run. For both subwatersheds, less than two percent of the assessed reaches ranked poor or very poor for channel instability based on methods described by Pfankuck (1975). In the Greene Branch subwatershed, seventeen out of twenty-one reaches (81 percent) were classified as F channels. In the Overshot Run subwatershed, five out of nineteen reaches (26 percent) were classified as F channels and one reach was classified as a G channel. If the assessed reaches are regarded as a representative sample, overall stream stability in Area R can be inferred from Figure 3-3 in the 1997 Loch Raven report.

Detailed stream assessments were conducted in eleven areas within the 1997 Loch Raven watershed. Two of these case study areas are located in Area R subwatersheds. Case study area 7 is located in the Dulaney Valley Branch subwatershed and is associated with portions of the significant erosion sites identified as Area E (Figure 3-23). Refer to Figure S7-1 in the 1997 Loch Raven report for more detailed locations of the reaches associated with case study area 7. This case study area represented 1,600 linear feet of potential stream restoration and the highest ranked reaches for stream restoration in Area R. Case study area 8 is located in the Fitzhugh Run subwatershed just southeast of the intersection of Jarrettsville Pike and Blenheim Road. Refer to Figure S8-1 in the 1997 Loch Raven report for more detailed locations of the reaches associated with case study area 7. This case study area represented 2,140 linear feet of potential stream restoration and ranked the third highest for stream restoration in Area R. As indicated above, the stream assessments initially focused on second and third order streams. However, during the field assessments it was observed that many of the first order streams within the case study areas should be considered in the overall development of watershed implementation activities.

CHAPTER 4.0
Uplands Assessment

4.1 Introduction

Upland areas in the watershed were assessed to locate potential pollution sources that could influence water quality and to identify opportunities for restoration projects. This assessment was conducted according to the Unified Subwatershed and Site Reconnaissance (USSR) Manual developed by CWP (CWP, 2004). This manual provides detailed guidance for watershed groups, municipal staff and consultants to quickly identify major sources of stormwater pollution and to assess restoration potential for source controls, pervious area management and improved municipal maintenance (e.g., education, retrofits, street sweeping, open space management, etc.).

This chapter outlines the four major components of the USSR:

Neighborhood Source Assessment (NSA)
Hotspot Site Investigation (HSI)
Institutional Site Investigation (ISI)
Pervious Area Assessment (PAA)

Each of these components is described in detail in the following sections. Site locations use the following naming convention: 'XYZ-R-123' where 'XYZ' is the type of assessment (NSA, HSI, or ISI), 'R' designates the Study Area R and '123' is the number assigned to each field site investigated. The neighborhoods were numbered sequentially as they were delineated, such as "NSA_R_18", which indicates the 18th NSA for SWAP Area R. The HSI, ISI and PAA sites are numbered by subwatershed; each subwatershed is assigned 100, 200, 300, etc. (generally in order from top to bottom, left to right) and the sites are then numbered sequentially as they were encountered. The numbering scheme for the Area R subwatersheds is as follows:

100 – Greene Branch
200 – Royston Run
300 – Overshot Run
400 – Fitzhugh Run
500 – Jenkins Run
600 – Dulaney Valley Branch

4.2 Neighborhood Source Assessment

4.2.1 Assessment Protocol

Prior to conducting NSAs in the field, neighborhoods were delineated in the office using GIS data, including tax parcels and aerial photographs. Neighborhoods were delineated based on groups of homes with similar characteristics such as lot size and age of development. These neighborhoods were then verified in the field. Adjustments to neighborhood boundaries were made as necessary in the field, either through grouping or dividing neighborhoods. For example, a neighborhood may be further divided if there were significant differences in the type of land cover where one part of the neighborhood was heavily forested, and another part of the neighborhood was dominated by turfgrass. If NSA boundaries were modified in the field, an additional letter was added at the end of the NSA naming convention.

The field team drove through every street in each defined neighborhood to identify potential pollution sources and restoration opportunities. General information was collected in each neighborhood for yards and lawns; driveways, sidewalks, and curbs; rooftop runoff; and common areas. These are each described briefly below. Stream buffer encroachment in neighborhoods is covered with the Stream Corridor Assessments in Chapter 3 (section 3.6.3.1.6 Inadequate Stream Buffers).

Yards and Lawns

In suburban residential areas, lawns typically represent a large portion of the pervious cover and can be a major source of pollutants such as pesticides and nutrients. Potential pollution sources evaluated by field teams under this category include grass cover and management status (i.e. fertilization and irrigation methods), bare soils, swimming pools and trash in yards. Existing tree cover and landscaping in each neighborhood was also noted to evaluate the potential to expand these areas to intercept additional stormwater runoff.

Driveways, Parking Lots, Sidewalks and Curbs

The presence of driveways, sidewalks and curbs was noted for each neighborhood assessed. Information was collected for potential or existing pollution sources from these areas such as stained or dirty driveways, lawn clippings or leaves on sidewalks, pet waste, trash and/or debris along curbs and long term car parking (i.e. unused cars can potentially leak oil and other pollutants).

Rooftops

Rooftops that are directly connected to other impervious surfaces through downspouts can contribute pollutants directly to stream systems. Disconnecting rooftops through downspout retrofits can reduce this potential source of pollution. In each neighborhood field teams estimated the percentage of downspouts discharging to impervious surfaces and evaluated the potential for implementing downspout retrofits.

Common Areas

Common areas within neighborhoods and in public parks are a good place to evaluate community behaviors such as pet waste disposal, trash dumping, storm drain marking, and buffer management. If present, stormwater management ponds are generally located in common areas (see section 4.2.3). Field teams noted the condition of common areas, the activities occurring there that could be a potential source of pollution, and opportunities for tree plantings.

Upon completion of the Neighborhood Source Assessments, specific actions were identified based on the overall assessment. The plan guides homeowners, community associations, watershed associations, and the local government toward specific actions where they are most needed. Potential actions generally include:

Downspout disconnection
Rain gardens
Rain barrels
Fertilizer reduction/education
BayScaping
Storm drain marking
Street tree planting
Trash management
Multi-family parking lot or alley retrofit

Once all of the above neighborhood information was compiled, the final step of the NSA was to rate the overall neighborhood pollution severity and restoration potential. The severity of pollution generated by a neighborhood is denoted by the Pollution Severity Index (PSI). There are up to 14 potential pollution sources rated. Neighborhoods are given PSI ratings of severe (7 or more sources), high (4 to 6), moderate (2 to 3), or low (0 to 1).The neighborhood's potential for restoration projects is also rated with the Restoration Opportunity Index (ROI) in a similar fashion, with nine potential opportunities. These are assigned a rating of high (5 or more), moderate (3 to 4), or low (0 to 2).

4.2.2 Summary of Sites Investigated

A total of 30 neighborhoods were assessed in Area R, as shown on Figure 4-1. The number of neighborhoods assessed in each subwatershed is shown on Table 4-1. Adjustments to the neighborhood boundaries provided by the EPS were made in the field to include: splitting up NSA_R_27 into NSA R_27A and NSA_R_27B due to their distinct characteristics, and joining NSA_R_17 and NSA_R_20 to NSA_R_17_20 given the similarities in development style, layout and age. Several neighborhoods cross subwatershed boundaries; in cases where there is a substantial area in more than one subwatershed it is counted in each subwatershed in which it falls. This resulted in a total of 39 unique neighborhoods by subwatershed.

Table 4-1: Neighborhoods Surveyed per Subwatershed

Subwatershed	# of NSAs	Acres
Greene Branch	12	1057.0
Royston Run	2	268.6
Overshot Run	8	492.3
Fitzhugh Run	3	88.5
Jenkins Run	1	40.3
Dulaney Valley Branch	13	980.4
Total*	39	2927.1

* Neighborhoods that cross subwatershed boundaries are counted more than once

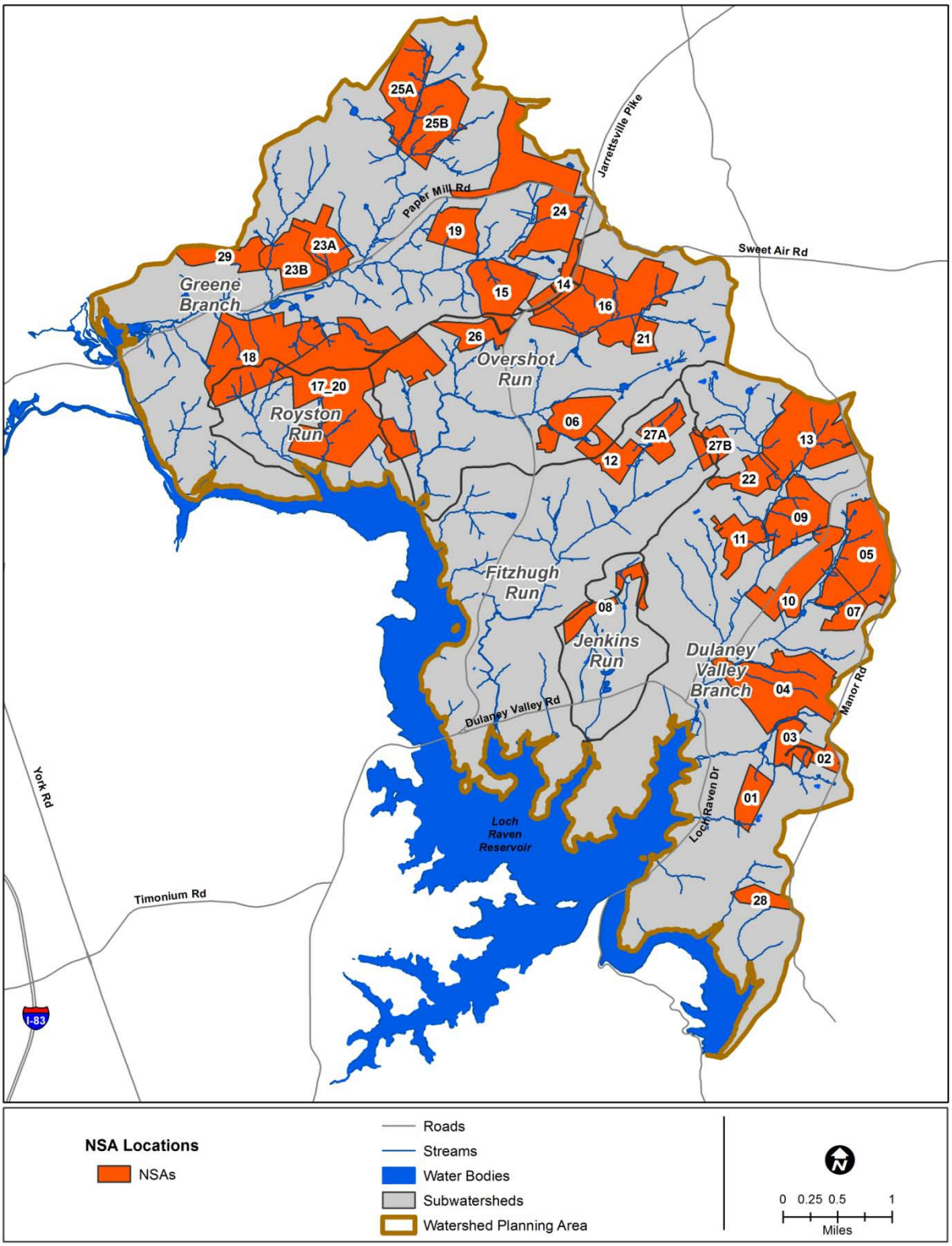


Figure 4-1: Neighborhood Source Assessment (NSA) Locations in Loch Raven East*

**Note that NSA_R_27 was divided into two separate neighborhoods, NSA_R_27A and NSA_R_27B. NSA-R_27B could not be accessed because it was a gated community and was therefore not assessed or included in the remainder of the NSA characterization presented in this chapter. Only NSA_R_27A is presented in subsequent figures.*

Of the 30 neighborhoods in Area R, none were rated as having a severe PSI. One was rated high, one rated low and the other 28 neighborhoods received moderate PSI ratings. One neighborhood received a high ROI rating, 21 were rated moderate, and eight had low ROI ratings. Neighborhoods should be prioritized to first address areas with both high PSI and high ROI ratings, followed by other neighborhoods. There was only one neighborhood that received a high PSI rating and a moderate ROI rating. The majority of neighborhoods received moderate PSI and moderate ROI ratings. The distribution of the NSA ratings is shown on Figure 4-3.

4.2.3 General Findings

The following sections describe the actions for Area R based on the NSA results. A description of the methods and criteria used to evaluate the potential for each action are provided, in addition to figures that show the neighborhoods in which each action is recommended. Due to the low level of development in Area R, actions such as street tree planting, street sweeping, and trash management identified for other Small Watershed Action Plans were not relevant. Street trees were not appropriate for Area R given the lack of sidewalks and limited right of way beyond the edge of pavement. More effective methods of adding canopy cover such as BayScaping and increasing lot canopy are suggested. Area R also had very few problems with trash or litter in the public right-of-way, so street sweeping and trash management weren't recommended. Appendix G includes a summary of NSA data collected and the actions needed for each individual neighborhood. Figure 4-2 illustrates typical neighborhood conditions for Area R.

Figure 4-2: Typical Large Lot Residential Development in Loch Raven East

Fertilizer Reduction/Education

Lawn maintenance activities often involve fertilization, pest-management, and watering. Lawns with a dense, uniform grass cover and green color are indicative of high lawn maintenance activities. The result is often polluted stormwater runoff that drains to local streams. The lawn care assessment was conducted in the summer.

Neighborhoods where 20 percent or more of the homes employ high lawn maintenance practices are generally identified for a fertilizer reduction/education program. Table 4-2 summarizes the 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. Table 4-2 also lists the percentage of total subwatershed area that would be addressed by this practice. The area treated in each neighborhood is based on the amount of lawn area. First, the lot area is found by taking the total acreage in each assessed neighborhood and subtracting out the acres of impervious roadway and buildings. This number is then multiplied by two factors estimated during the NSA assessment; the average percentage of grass cover on each lot and the percentage of high maintenance lawns in the neighborhood area.

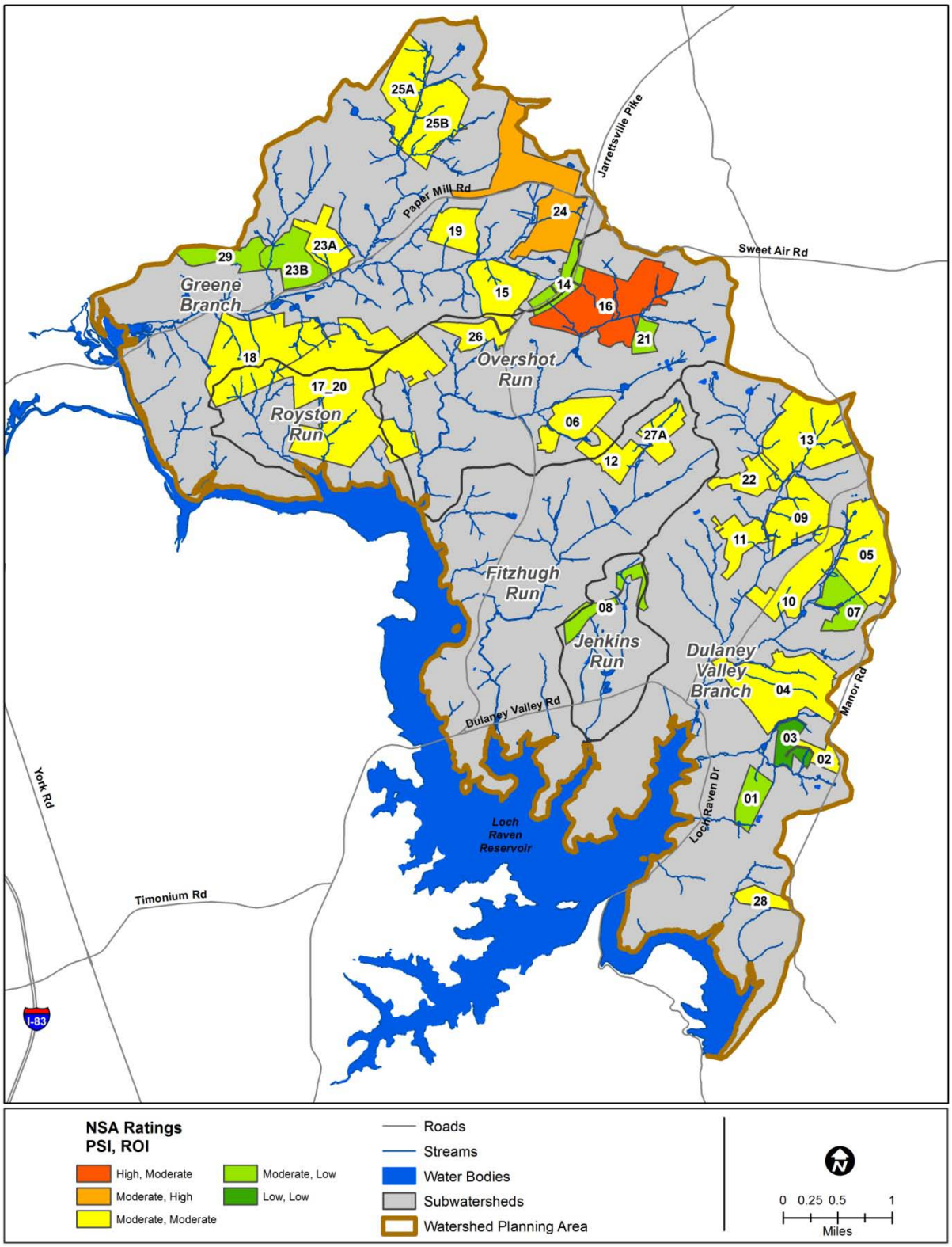


Figure 4-3: NSA Pollution Severity and Restoration Opportunity Indexes

Table 4-2: Acres of Lawn Addressed by Fertilizer Reduction

Subwatershed	# of Neighborhoods Identified for Fertilizer Reduction	Acres of Lawn Addressed	% of Subwatershed Area Addressed
Greene Branch	10	240.7	7
Royston Run	2	36.7	7
Overshot Run	5	58.7	0
Fitzhugh Run	2	9.9	1
Jenkins Run	1	1.5	0
Dulaney Valley Branch	6	183.1	5
Total	26	530.5	5*

* Percent of entire Watershed Area R

Figure 4-4 shows the locations of neighborhoods identified for fertilizer reduction/ education. Of the 30 neighborhoods assessed, 18 had high percentages of high maintenance lawns, and were identified for fertilizer reduction/education. As shown on Figure 4-4: Percentage of High Maintenance Lawns in Neighborhoods, implementation of fertilizer reduction/education will only address 5 percent of the total area. There are many neighborhoods that have a high percentage of grass cover classified as medium maintenance lawns. These neighborhoods may also prove to be a valuable target for fertilizer reduction/education.

BayScaping

BayScaping refers to the use of plants native to the Chesapeake Bay watershed for landscaping. Plants used in BayScaping are native to the region and therefore require less irrigation, fertilizers, and pesticides to maintain as compared to non-native or exotic plants. This means less stormwater pollution and lawn maintenance requirements.

BayScaping was identified for implementation in neighborhoods where the lots were at least ¼ acre in size, where 10 percent or less of the lots were already landscaped, and where there was sufficient open grass area available to implement BayScaping. Twenty three of the 30 neighborhoods met these criteria. Table 4-3 includes a summary of neighborhoods identified for BayScaping in each subwatershed and the total acres of land addressed. It also includes the percentage of total subwatershed area addressed. Area to be treated is based on the existing landscaped percentage of the lot, estimated during the NSA assessment. Lot area is found by taking the total acreage in each assessed neighborhood and subtracting out the acres of impervious roadway. This area is multiplied by the difference, in percent, between the target of 10 percent and the existing landscaped percentage. Figure 4-5 illustrates the location of the neighborhoods identified for BayScaping.

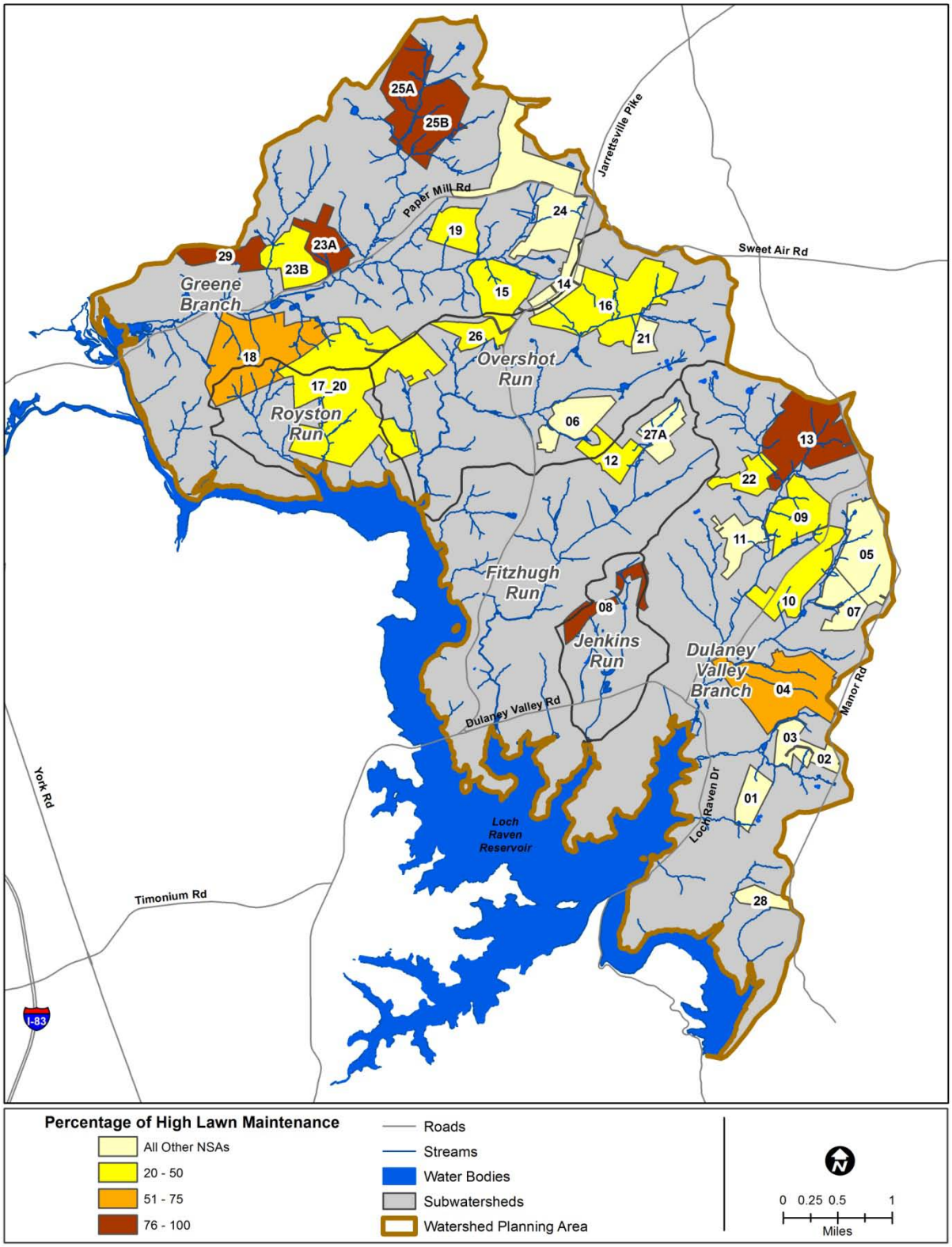


Figure 4-4: Percentage of High Maintenance Lawns in Neighborhoods

Table 4-3: Acres of Land Addressed by BayScaping

Subwatershed	# of Neighborhoods Identified for BayScaping	Acres of Land Addressed	% of Subwatershed Area Addressed
Greene Branch	11	33.0	1
Royston Run	2	13.1	2
Overshot Run	7	10.3	1
Fitzhugh Run	3	4.3	0
Jenkins Run	1	1.9	0
Dulaney Valley Branch	8	32.5	1
Total	32	95.1	1*

* Percent of entire Watershed Area R

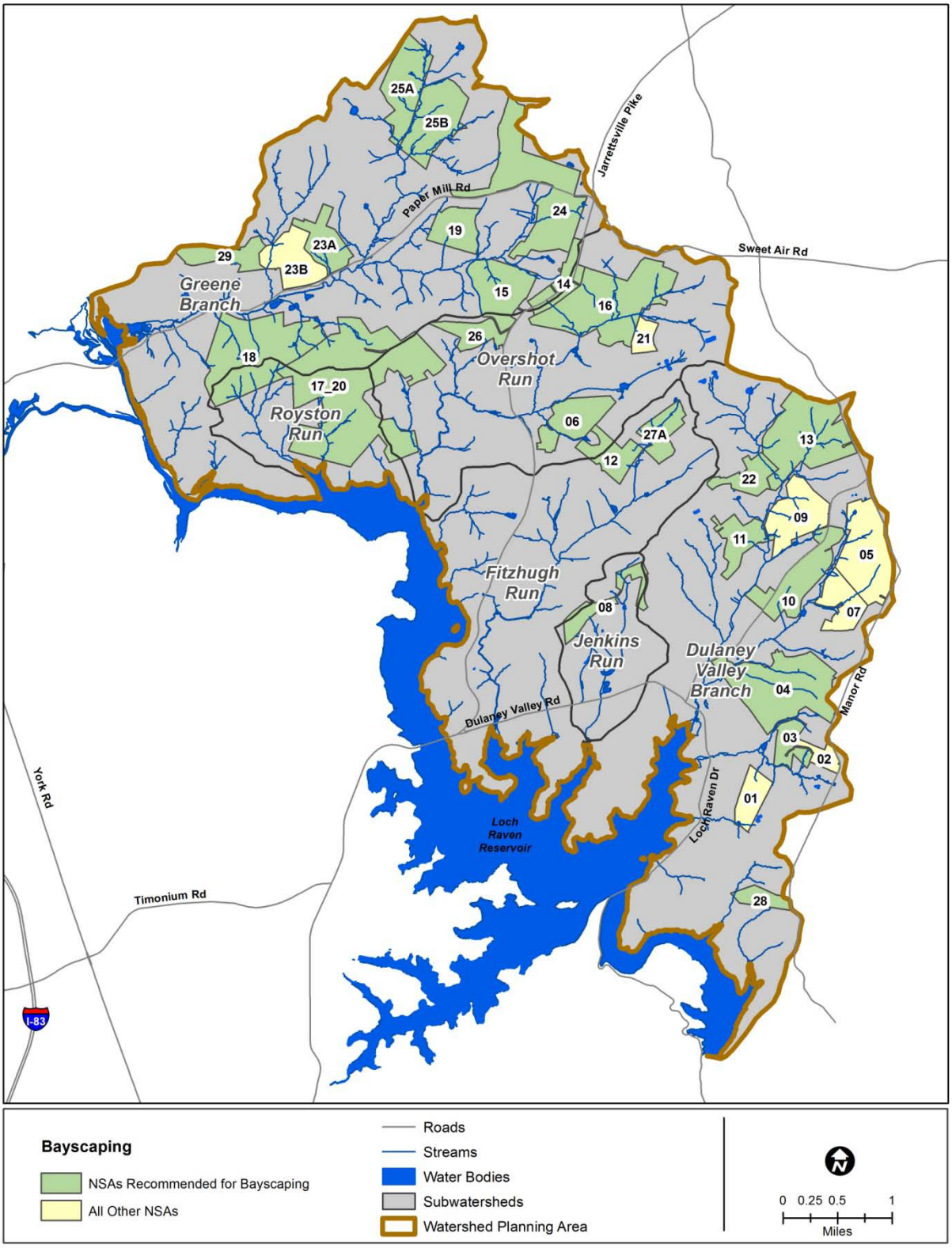


Figure 4-5: Neighborhoods Identified for BayScaping

Storm Drain Marking

Most of the neighborhoods in Area R have roads with curb and gutter systems that include storm drain inlets that convey stormwater runoff quickly and directly to the stream system and ultimately to the Chesapeake Bay. Only one of the neighborhoods assessed had approximately 20% of its inlets marked as an awareness indicator that the inlets drain untreated stormwater to Loch Raven Reservoir and the Chesapeake Bay. Storm drain marking indicates that the inlets drain to the Chesapeake Bay; this is 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 curb and gutter systems with inlets appropriate for marking. As shown in Table 4-4, a majority of neighborhoods are recommended for storm drain marking. They are shown in Figure 4-6. Area treated was calculated using the total area of each recommended neighborhood: streets, public and privately-owned lots, and common areas. The calculation of inlets to be marked was made by overlaying storm drain mapping with the NSA neighborhoods. All inlets draining to an outfall within a designated neighborhood were assumed to be candidates for marking.

Table 4-4: Acres of Land Addressed by Storm Drain Marking

Subwatershed	# of Neighborhoods Identified for Storm Drain Marking	Acres of Land Addressed	% of Sub-watershed Area Addressed	Approx # of Inlets Addressed	Inlet Drainage Area from Minor and Major Outfall Shapefiles	% of Sub-watershed Inlets Addressed
Greene Branch	7	741.7	21.4	51	119.3	52.6
Royston Run	2	268.6	48.1	15	33.9	68.2
Overshot Run	5	409.2	22.9	14	15.1	48.3
Fitzhugh Run	3	88.5	5.0	0	0	0
Jenkins Run	1	40.3	10.0	8	9.3	100.0
Dulaney Valley Branch	12	810.4	22.6	33	87.5	40.2
Total	30	2358.7	20.4	121	265.1	50.8*

* Percent of entire Watershed Area R

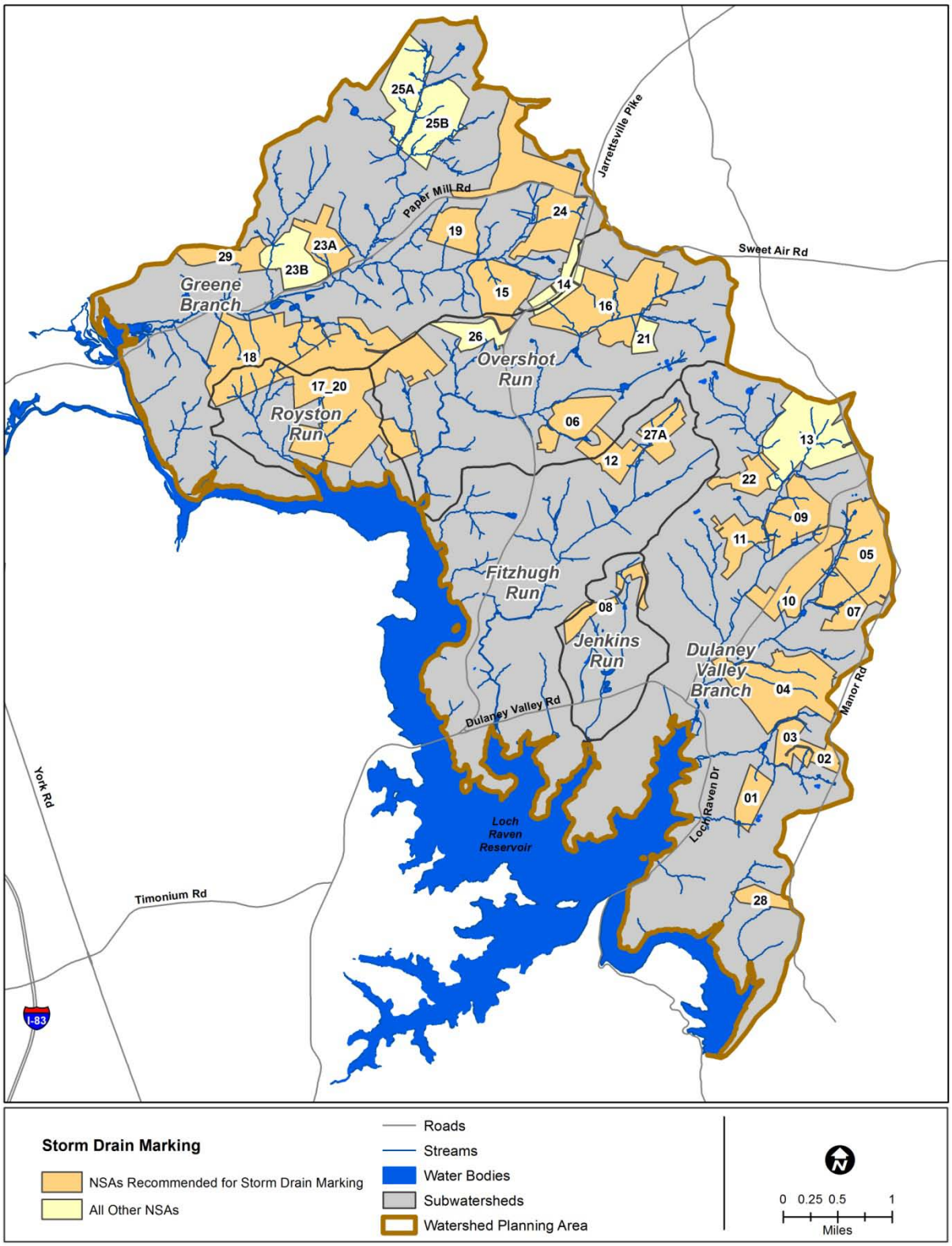


Figure 4-6: Neighborhoods Identified for Storm Drain Marking

Lot Canopy Improvement

Increasing the canopy cover in a watershed is an effective way of reducing runoff and peak flows, promoting infiltration to ground water, providing filtration for water quality, moderating the effect of summer heat spikes on stream temperature, and supplying food in the way of leaf litter for organisms at the base of the stream food web. Reforestation works with BayScaping and rain gardens to reduce the amount of lawn area and provide more terrestrial habitat in developed areas.

Outreach efforts to encourage canopy improvements were identified in neighborhoods where existing canopy coverage was less than 40 percent of the lot. Thirteen of the 30 assessed neighborhoods met these criteria as shown in Figure 4-7. Table 4-5 includes a summary of neighborhoods identified for canopy improvement in each subwatershed and the total acres of land addressed. It also includes the percentage of total subwatershed area addressed through implementation of canopy improvements. The area treated is based on the existing canopy cover of the lot, estimated during the NSA assessment. Lot area is found by taking the total acreage in each assessed neighborhood and subtracting out the acres of impervious roadway. This area is multiplied by the difference, in percent, between the target of 40 percent and the existing percentage of canopy cover.

Nine of the 30 neighborhoods were recommended for better stream buffer management due to encroachment and include: NSA_R_04, NSA_R_05, NSA_R_06, NSA_R_09, NSA_R_16, NSA_R_21, NSA_R_24, NSA_R_25B, and NSA_R_26. These stream buffers can be enhanced through reforestation, thereby increasing the lot canopy.

Table 4-5: Acres of Land Addressed by Lot Canopy Improvement

Subwatershed	# of Neighborhoods Identified for Canopy Improvement	Acres of Land Addressed	% of Subwatershed Area Addressed
Greene Branch	4	73.2	2.1
Royston Run	0	0	0
Overshot Run	4	24.5	1.4
Fitzhugh Run	1	8.7	0.5
Jenkins Run	0	0	0
Dulaney Valley Branch	6	118.1	3.3
Total	15	224.5	1.9*

* Percent of entire Watershed Area R

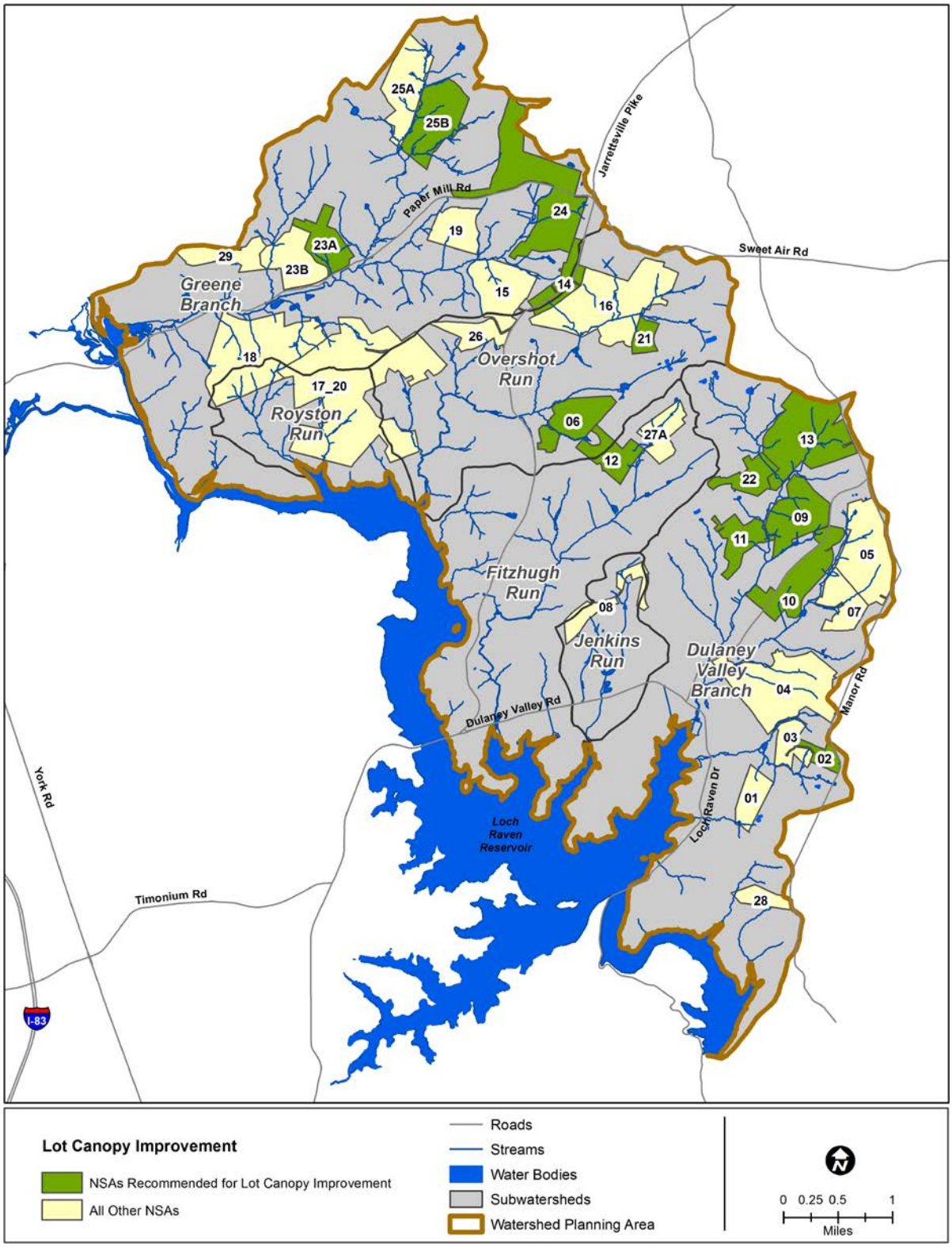


Figure 4-7: Illustrates the Location of the Neighborhoods Identified for Lot Canopy Improvements

Stormwater Retrofits

Potential sites for upland stormwater retrofits are identified in several locations. Stormwater retrofits provide stormwater management in developed areas that do not currently have stormwater management. Many neighborhoods contained cul-de-sacs that are potential sites for bioretention retrofits, including NSA_R_04, NSA_R_17_20, NSA_R_19, NSA_R_27A, and NSA_R_29. In addition, a regenerative stormwater conveyance system is suggested to repair a headcut and replace an existing outfall practice in NSA_R_23A.

Figure 4-8: Potential Cul-de-sac Retrofit Opportunity in NSA_R_17_20 and Regenerative Stormwater Conveyance Proposed at an Outfall in NSA_R_23A

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 2004). These generally include commercial, industrial, municipal, or transport-related operations. 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. Operations characteristic of commercial hotspots include waste or wash water generation, outdoor material storage, fuel handling, or vehicle repair. Common commercial hotspots include auto repair shops, car dealers, car washes, parking facilities, gas stations, marinas, 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 National Pollution Discharge Elimination System (NPDES) industrial discharge permits. Like industrial operations, many municipal hotspots are subject to NPDES stormwater permits. Many are regulated and include uses such as airports, ports, highway construction, and trucking centers.

The purpose of the HSI 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 the hotspots in Loch Raven East.

4.3.1 Assessment Protocol

Because there are few operations in Loch Raven East that qualify as stormwater hotspots, it was possible to identify all the sites in the office through a desktop assessment. The HSIs were focused on unregulated hotspots since regulated hotspots are previously known pollutant sources. Regulated stormwater hotspots are already subject to NPDES permit regulations.

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. The HSI provides 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 visited each potential hotspot to determine water quality impacts and restoration opportunities. These six categories were used to standardize the HSI process and be able to prioritize potential restoration efforts. These categories 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.

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 they 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. The field team 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 that 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/in poor condition, and/or overflowing were noted as potential pollution sources. Dumpsters located near storm drain inlets or 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. For each hotspot, the condition of the building itself was

evaluated. Similarly, parking lots that were stained, dirty, breaking up, and/or impervious were recorded as potential pollution sources.

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 pollution sources of nutrients, fertilizer, and pesticides. The field team also determined whether landscaped areas drained directly to storm drains or if organics such as leaves and grass accumulated on impervious surfaces.

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 potential. Storm drains with considerable amounts of sediment, organics, and/or trash was identified as potential pollution sources.

For each operation on the HSI field form, there is an observed pollution source box that is checked when there is clear evidence of pollution problems at a site. One example would be trash spilling over the edges of the dumpster and directly into a local stream while the trash was being compacted. If applicable, one or more of the potential follow-up actions listed below were identified, based on field observations of a hotspot site.

- Refer for immediate enforcement
- Follow-up on-site inspection
- Test for illicit discharge
- Future education effort
- On-site non-residential retrofit

The overall pollution prevention potential for each hotspot site is assessed based on observed sources of pollution and the potential of the site to generate pollutants that would likely enter the storm drain network. There are up to 26 potential pollution sources rated in the assessment. Sites are classified into four hotspot severity categories:

- Not a Hotspot – no observed pollutant; less than 5 sources noted
- Potential– no observed pollution; five to ten sources noted
- Confirmed– pollution observed; 10 to 15 sources noted
- Severe– multiple polluting activities directly observed, more than 15 sources noted

4.3.2 Summary of Sites Investigated and General Findings

There were eight hotspot candidates investigated in Area R, as shown in Table 4-6. All except for one of the commercial establishments (i.e. restaurants and retail businesses) were investigated primarily for opportunities to improve waste management, parking areas, downspouts, landscaping or stormwater management. Only one municipal site was investigated – the Baltimore County Public Safety Building. The majority of sites were rated as potential

hotpots. One site was designated a confirmed hotspot and two others were not designated as hotspots. Improvement on the majority of sites can be achieved through education efforts targeting outdoor material storage and waste management. **Error! Reference source not found.** provides photos of the hotspots and Figure 4-10 shows the locations of the sites investigated in Area R.

Table 4-6: Summary of Hotspot Sites Investigated in Area R.

Site ID	Type	Subwatershed	HSI Status
HSI_R_101	Commercial	Greene Branch	Potential Hot Spot
HSI_R_102	Municipal	Greene Branch	Potential Hot Spot
HSI_R_103	Commercial	Greene Branch	Potential Hot Spot
HSI_R_104	Commercial	Greene Branch	Confirmed Hot Spot
HSI_R_105	Commercial	Greene Branch	Not a Hot Spot
HSI_R_301	Commercial	Overshot Run	Potential Hot Spot
HSI_R_302	Commercial	Overshot Run	Potential Hot Spot
HSI_R_601	Commercial	Dulaney Valley Branch	Not a Hot Spot

Figure 4- 9: Sand Used to Absorb Grease Leaking from Steel Drums at HSI_R_104 (top left), Erosion and Sediment Control Needed at HSI_R_103 (top right), Outdoor Material Storage at HSI_R_102 (bottom left), Outdoor Material Storage at HSI_R_302 (bottom right)

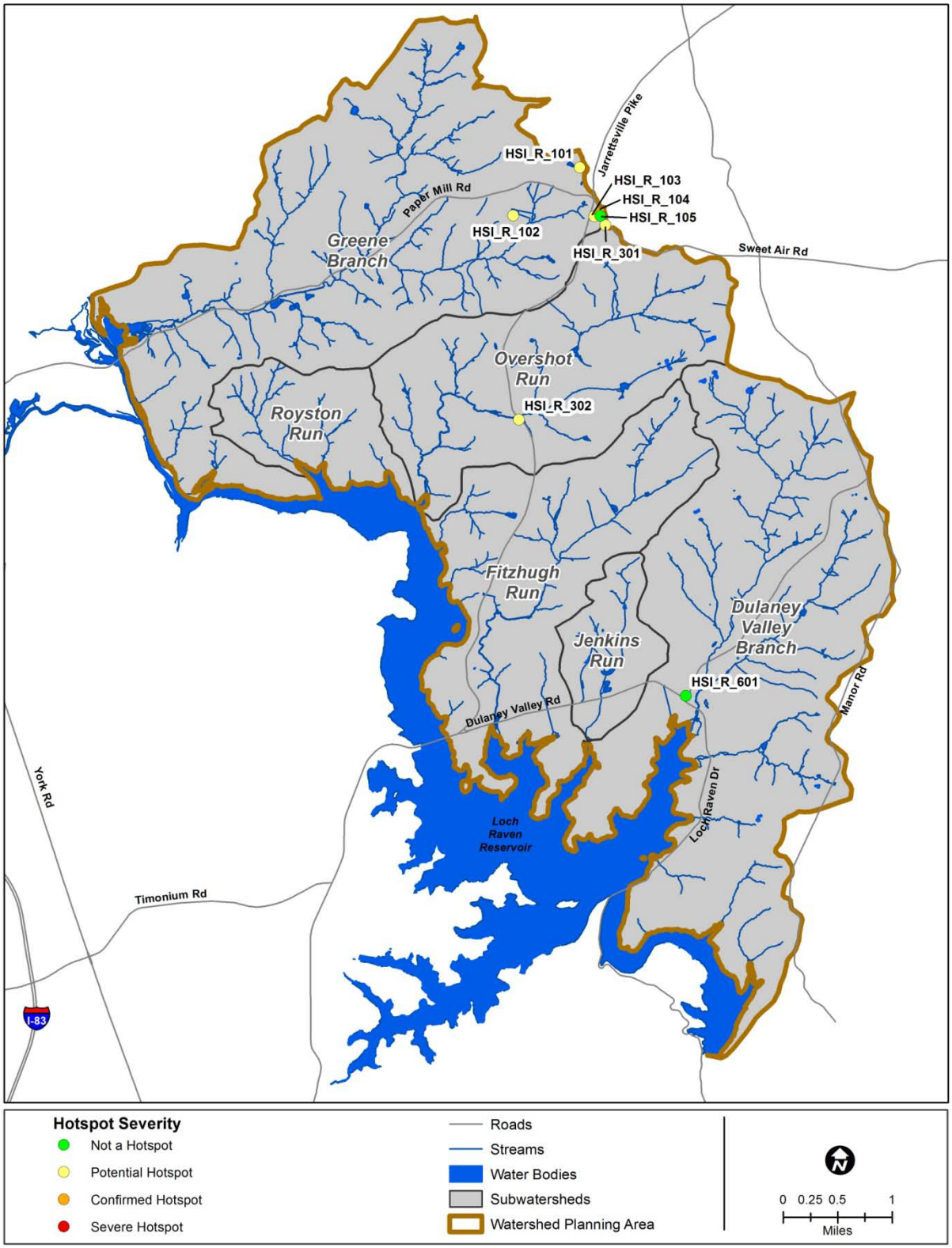


Figure 4-10: Locations of Hotspot Site Investigations (HSIs) in Area R

4.4 Institutional Site Investigations (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 earlier SWAP projects, 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 institutional sites surveyed within Loch Raven East as part of this study included faith-based facilities, golf courses, public schools and a park. The following subsections describe the methods used to identify and evaluate pollution sources and restoration potential at institutional facilities.

4.4.1 Assessment Protocol

Institutional properties were identified in the office prior to conducting the field assessment using GIS tax parcel information, land use data, aerial photographs, and an ADC map. In the field, sites were visited to collect necessary data and take photographs. The ISI field form includes many of the pollution source categories used on the HSI form that include an assessment of vehicle operations, outdoor materials, waste management, turf/landscaping areas, and stormwater infrastructure. Some of the restoration opportunities and actions from the NSAs are also incorporated into the ISI. The focus of ISIs is to identify potential restoration opportunities, educate the community, and provide water quality benefits. The information collected for each of the pollution sources and restoration categories is briefly described below.

Tree Planting

Potential tree planting locations at an institution were marked on aerial photographs while at the property. The total number of trees that could be planted at the site was estimated based on 40 foot spacing between trees or 200 trees/acre. More accurate numbers were determined during the post-fieldwork desktop analysis after restoration opportunities were 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/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.

Waste Management

Every institution generates waste as a result of daily operations but unlike hotspots, it is typically just garbage. 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/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

Most institutions do not have vehicle operations but a few may have buses on-site. 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 source of metals, oil and grease, and hydrocarbons.

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 (i.e. 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 (i.e. leaves, grass) accumulated on impervious surfaces. Evidence of buffer encroachment and whether the buffer was 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.

After evaluating the categories discussed above, if appropriate one or more of the follow-up actions listed below were identified based on initial field observations:

- Storm drain marking
- Tree planting
- Downspout disconnection
- Stormwater retrofit
- Education
- Impervious cover removal
- Stream buffer improvement
- Trash management
- Invasive species removal

- Follow-up on-site inspection

4.4.2 Summary of Sites Investigated and General Findings

There were 10 institutional sites assessed in Area R; four churches, three golf courses, two elementary schools, and one park. Information about these sites and identified actions for each one are summarized in Table 4-7. Figure 4-11 shows institutional sites in Area R and Figure 4-12 shows the locations of these sites.

Figure 4-11: Opportunity for Tree Planting at ISI_R_302 (top left), Bioretention Stormwater Retrofit at Parking Lot of ISI_R_303 (top right), Stream Buffer Improvement at ISI_R_501 (bottom left), and Rain Barrels to Capture Rooftop Runoff at ISI_R_701 (bottom right)

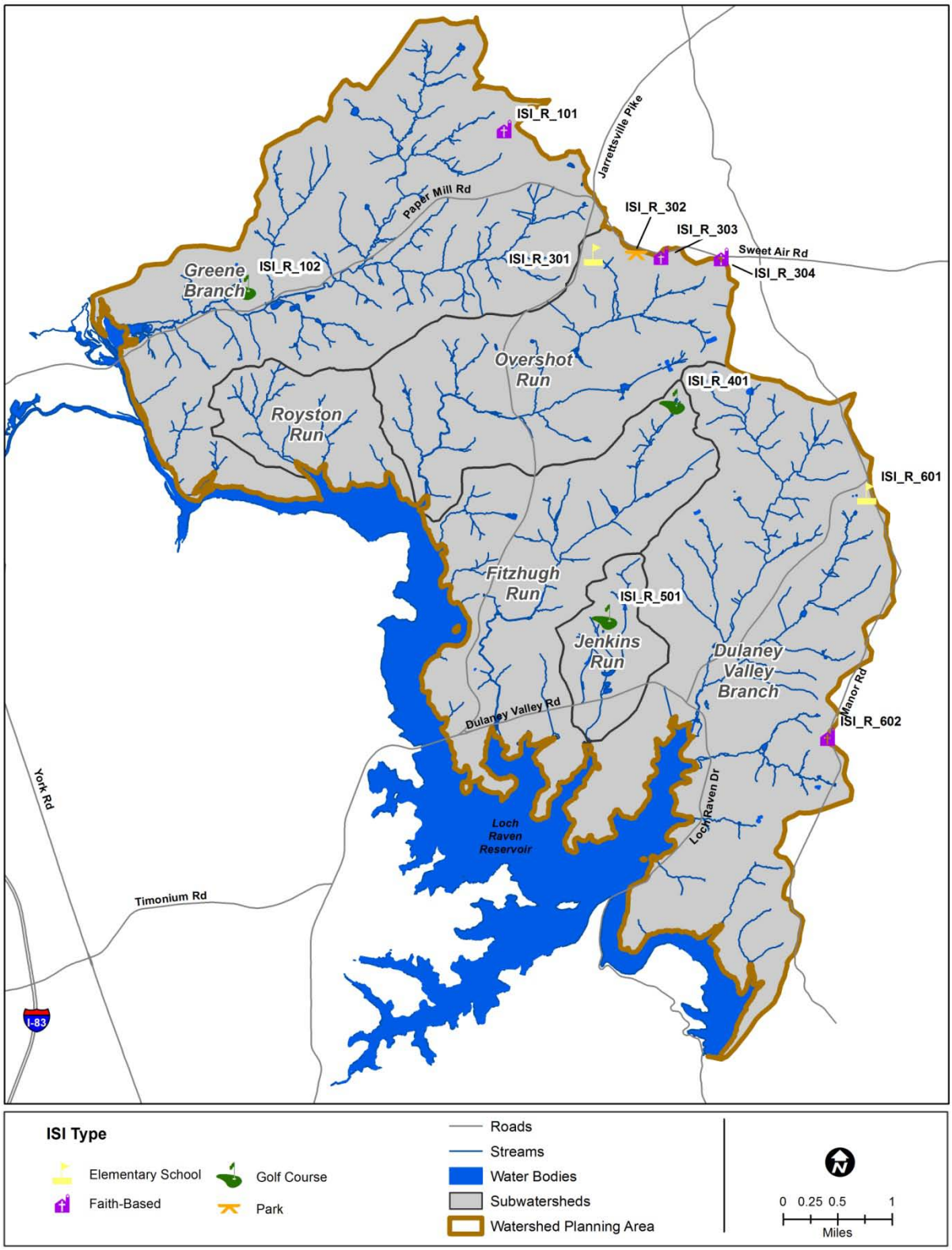


Figure 4- 12: Institutional Site Investigation (ISI) Locations in Area R

Table 4-7: Types of Institutions Assessed by Subwatershed and Identified Actions

Site ID	Type	Sub-watershed	Identified Actions					
			Tree Planting	Stormwater Retrofit	Downspout Discon.	Trash Mgmt.	Stormdrain Marking	Stream Buffer Improv.
ISI_R_101	Faith-Based	Greene Branch	0	Y	N	N	N	N
ISI_R_102	Golf Course	Greene Branch	0	Y	N	N	N	Y
ISI_R_301	Elementary School	Overshot Run	0	N	N	N	N	N
ISI_R_302	Park	Overshot Run	260	N	N	N	Y	N
ISI_R_303	Faith-Based	Overshot Run	0	Y	N	N	Y	N
ISI_R_304	Faith-Based	Overshot Run	0	N	N	N	N	N
ISI_R_401	Golf Course	Fitzhugh Run	0	Y	N	N	N	N
ISI_R_501	Golf Course	Jenkins Run	0	Y	N	N	N	Y
ISI_R_601	Elementary School	Dulaney Valley Branch	200	N	Y	N	N	N
ISI_R_602	Faith-Based	Dulaney Valley Branch	0	N	Y	N	Y	N

Tree Planting

It was estimated that a total of 460 trees were identified to be planted in Area R at two sites, including an elementary school in Dulaney Valley Branch and a park in Overshot Run. These numbers are planning level estimates only and would need to be refined through a follow-up site investigation prior to planting. Tree planting at the park is recommended for a large currently mowed field that does not appear to have a specific use, however, this needs to be confirmed.

Downspout Disconnection

Downspout disconnection was identified for a school and a church in Dulaney Valley Branch. Specifically, the downspouts at the church are recommended for rain barrels because they discharge to a confined space with landscaping in an area between the buildings. The downspouts at the school are most likely connected to the storm drain system and are recommended for simple disconnection.

Stormwater Retrofit

Stormwater retrofits are recommended for a church and a golf course in Dulaney Valley Branch and include converting the golf course ponds to extended detention wet ponds and installing swales and a rain garden at the church. A church in Overshot Run is recommended for

either a bioretention parking lot retrofit or regenerative stormwater conveyance at an outfall. Golf courses in Fitzhugh Run and Jenkins Run are recommended for regenerative stormwater conveyance and additional stormwater treatment practices.

Trash Management

No institutional sites were identified for trash management.

Stormdrain Marking

Three sites were identified for stormdrain marking – a church and park in Overshot Run and a church in Dulaney Valley Branch.

Stream Buffer Improvement

Golf courses in Greene Branch and Jenkins Run were both identified for stream buffer improvements due to encroachment.

4.5 Pervious Area Assessment (PAA)

PAAs were conducted to identify and evaluate sites within the Loch Raven East watershed with potential for reforestation or re-vegetation. The following subsections describe the methods used to identify and evaluate restoration potential of pervious areas.

4.5.1 Assessment Protocol

Sections of open land throughout the watershed were identified in the office by EPS staff. Although there are numerous open field areas in Loch Raven East, only public land or land owned by institutions was assessed for tree planting opportunities at this time. 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_R_101", where 'R' denotes the Loch Raven East watershed and the number corresponds to a specific subwatershed. As previously described, subwatersheds were assigned the following numbers for the purposes of HSIs, ISIs, and PAAs: Greene Branch – 100s, Royston Run – 200s, Overshot Run – 300s, Fitzhugh Run – 400s, Jenkins Run – 500s, and Dulaney Valley Branch – 600s. Pervious areas were numbered sequentially in the order they were surveyed within a particular subwatershed. For example, PAAs in Dulaney Valley Branch would be identified as 601, 602, etc.

A new method of assessment was developed and piloted on this SWAP area. It is a desktop method utilizing Geographic Information Systems (GIS). Open pervious areas were identified by looking at the current aerial photography (2011). The parameters considered in the assessment are briefly described below.

Stream Buffer

This attribute in the GIS database was indicated if a stream with no forest buffer is located on the site and received a high score for reforestation potential. Also indicated is whether there is a stream on or adjacent to the property with an inadequate forest buffer (<100') and the potential to expand it. It is widely accepted that streams in our region should be buffered with forest cover, or natural vegetation, for at least 100 feet on either side to protect the stream environment and downstream conditions.

Length of Stream

An approximate linear distance of stream to be buffered with reforestation is recorded. The greater the distance of stream in need of forest cover protection, the higher the priority the PAA for tree planting.

Proximity to Forest Interior

For purposes of this assessment, forest interior is defined as forested area which is at least 500 feet from any forest edge. Many forest dwelling plants and animals benefit by a continuous forest condition. It protects the ecosystem from invasive plant and animal species, which thrive in edge habitats and disturbed conditions. Invasive species compete with native species and have been documented in many cases to decimate native populations. Sites that have the potential to increase forest interior acreage are a higher priority than those that do not.

Exterior Forest Gap

An exterior forest gap is an unforested area located along the edge of a forest patch, but partially surrounded by the forest. Only exterior forest gaps with edges less than 500' apart were included. Similar to forest interior, it is beneficial to close forest gaps to increase the amount of contiguous forest, and decrease the amount of edge area. Forest edges are subject to colonization pressure from invasive plants, especially vines which can damage trees and encroach on the forest environment. Non-native animals are also more prevalent in areas with greater forest edge, such as the brown-headed cowbird that lays its eggs in other bird's nests.

Planting Area

The size of the potential planting area is of importance. The more land available for reforestation, the greater the environmental benefit. Although smaller planting sites are also valuable, and may present opportunities for community-based projects.

Ownership

Restoration projects are typically easier to accomplish on publicly owned land for a variety of reasons. Projects on private land are not out of the question, but require additional steps, often making them more time consuming and costly.

4.5.2 Summary of Sites Assessed and General Findings

A total of five pervious areas were assessed within the Loch Raven East watershed totaling 282 acres of potential tree plantings. The following PAAs were conducted according to subwatershed: one in Greene Branch, one in Overshot Run, one in Fitzhugh Run, and two in Dulaney Valley Branch. There were no PAAs assessed in Royston Run or Jenkins Run. Two sites are on church properties (9 acres total), and the others are owned by the county or the state (273 acres). Potential planting sites ranged from 2 to 176 acres. Figure 4- 13 shows the location and size of PAAs within the watershed.

A summary of PAA results including size of potential tree planting, presence of stream buffer, length of stream that can be planted, potential to expand forest interior acreage, presence of exterior forest gap, ownership, and restoration score is provided in Table 4-8.

Table 4-8: PAA Results

PAA	Size (ac)	Stream Buffer Present	Length of Stream for Planting (linear ft)	Expand Forest Interior	Exterior Forest Gap	Public or Private	Restoration Score	SW Retrofit Potential
PAA_R_101	7	yes	23	yes	yes	public	70	yes
PAA_R_301	7	no	n/a	no	no	private	20	yes
PAA_R_401	176	yes	>3800	yes	yes	public	100	no
PAA_R_601	90	no	n/a	no	no	public	40	no
PAA_R_602	2	no	n/a	no	no	private	10	yes

Baltimore County, Department of Public Works – Public Safety and Training Academy (PAA_R_101)

Located in the Greene Branch subwatershed, the academy is surrounded by forest on three sides. The site is in use as a training facility, including training in the use of heavy equipment. This type of training requires a fair amount of space, however there appears to be approximately seven acres not in use. This area is either mowed grass or in meadow. The site may have special considerations and will require further investigation, as it was formerly used as a Nike missile silo. In addition to tree planting, the site has potential for a stormwater retrofit near the gate.

St. John's Evangelical Lutheran Church – Sweet Air Road (PAA_R_301)

The church property in the Overshot Run subwatershed includes two fallow fields behind the church complex, totaling approximately seven acres. There is no stream on the property, but a stream is located about 700 feet away. The fields are surrounded by narrow bands of forest. Little forest is present on adjacent properties. There appears to be an opportunity for a stormwater retrofit where the southern-most parking lot drains into a swale.

Maryland Department of Natural Resources - Gunpowder State Park (PAA_R_401)

In Fitzhugh Run, six parcels in close proximity were combined into a single PAA along Jarrettsville Pike. The pervious area totals 176 acres. Numerous stream reaches are present on these properties, providing a great opportunity for stream buffer planting. The PAA borders city-owned reservoir watershed land, and is very close to the Loch Raven Reservoir. Portions of the PAA are connected to forested areas with forest interior. There are a few places that meet the definition of exterior forest gap. This PAA is high priority for reforestation because of its size, presence of unforested streams and exterior forest gaps, and proximity to forest interior. It received the maximum score for priority. The State currently has agricultural leases on these fields.

Baltimore County Parcels – Dulaney Valley Road (PAA_R_601)

Along the watershed divide between Dulaney Valley Branch and Jenkins Run, there are three parcels owned by Baltimore County. These open fields are located on either side of Peerce's Plantation. There is potential to reforest 90 acres on this site. No streams are present on the site, but the PAA is less than 900 feet from the reservoir. Dulaney Valley Road divides the site from a forest patch containing interior forest area. A 4-5 acre utility right-of-way bisects the PAA.

St. John's Evangelical Church – Manor Road (PAA_R_602)

The smallest of the PAA sites is this church in the Dulaney Valley Branch subwatershed that has approximately two acres of turf that could be planted with trees. Since it does not have a stream on the site and it is not close to forest interior, it scored low for priority. There is potential for a stormwater retrofit next to the parking lot.

Prioritization of Tree Plantings on Pervious Areas

A Restoration Score was derived by a point system of parameters. The maximum score is 100 (greatest restoration benefit), and the minimum is 5. Restoration scores for Area R PAAs range from 10 to 100. The highest scores go to large, public lands with streams, and the lowest scores go to small, private lands. To comply with the Chesapeake Bay TMDL, Baltimore County must plant trees in stream buffer areas to decrease nutrient and sediment transport to the waterways, so the sites with streams are of greatest importance. Decreasing forest fragmentation is also paramount in protecting the populations of native species, including neo-tropical migrating birds. See Table 4-9 for prioritization results.

Table 4-9: PAA Restoration Priority

PAA Number	Restoration Score	Priority
PAA_R_401	100	High
PAA_R_101	70	High
PAA_R_601	40	Medium
PAA_R_301	20	Low
PAA_R_602	10	Low

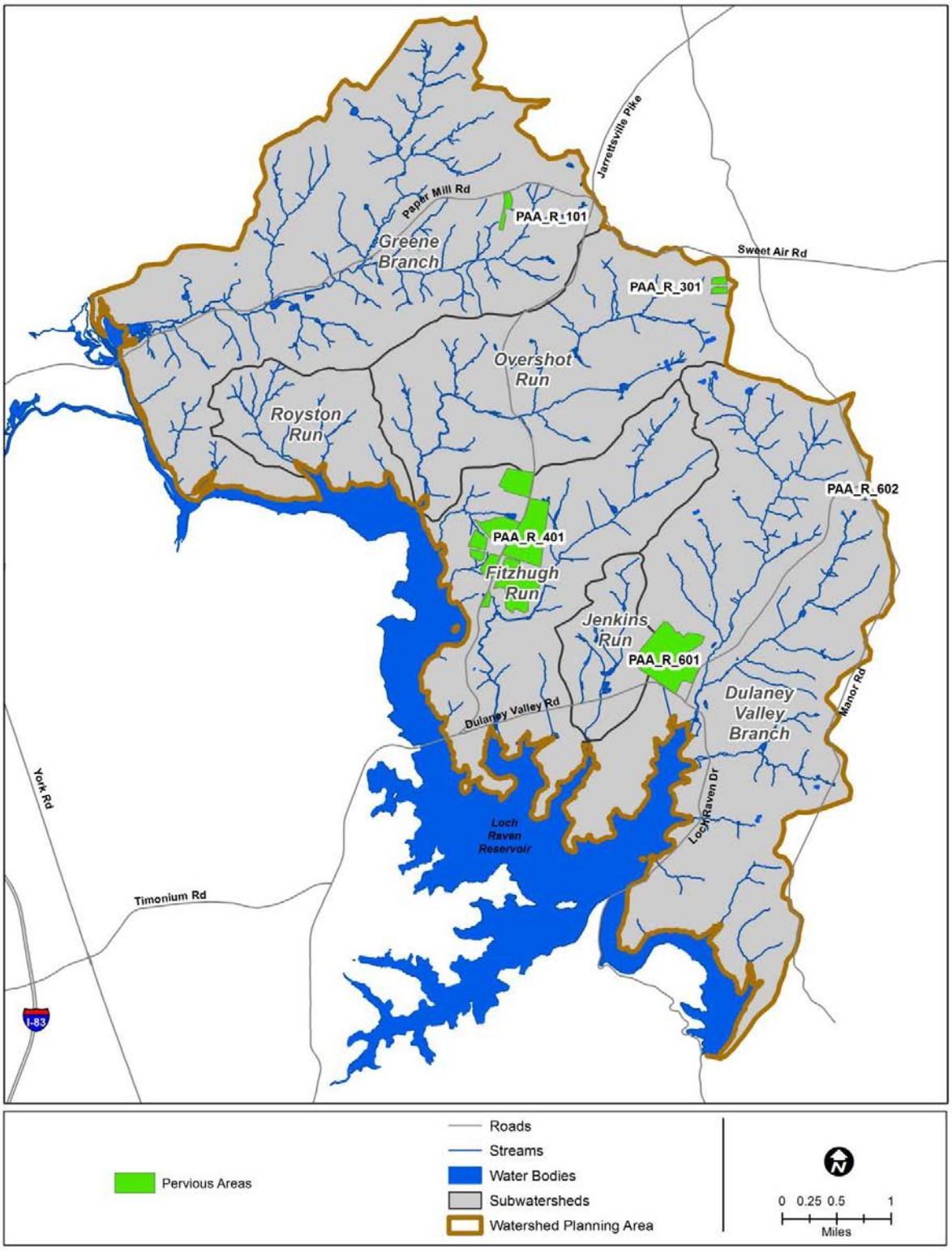


Figure 4- 13: Pervious Area Assessment (PAA) Locations in Area R

CHAPTER 5.0
Restoration and Preservation Options

5.1 Introduction

This chapter presents an overview of the best management practices (BMPs) potentially suitable for the Loch Raven East watershed. There is a significant difference in land cover and runoff characteristics between residential and agricultural areas, and the difference extends to stormwater BMPs as well. For that reason, potential treatment approaches for the Loch Raven East watershed are discussed based on those that apply to developed areas and those applicable to agricultural lands. In addition, citizen awareness activities, volunteer restoration programs, and land preservation options are discussed.

5.2 Best Management Practices for Developed Areas

5.2.1 County Restoration Programs

5.2.1.1 Stormwater Management Upgrades

Stormwater Management Conversion

Older stormwater management facilities were typically designed only for flood control and have little to no pollutant removal capacity. However, these facilities can generally be altered to capture and retain stormwater runoff to provide water quality benefits. Consideration must be given to the pond's storage capacity and overflow outlets to ensure the structure is capable of handling large storm events. Conversion to an extended detention facility typically requires adjustments to the facility's outlet structure. This will result in water quality benefits by allowing sediments and pollutants to settle out, in addition to controlling the amount of runoff entering receiving waters. Wetland vegetation can be planted in and around an extended detention pond for additional environmental benefits. Dry detention ponds have the greatest potential for conversion to extended detention BMPs.

Stormwater Retrofits

Retrofitting involves the implementation of stormwater management controls in developed areas where previous practices did not exist. Stormwater retrofits improve water quality by capturing, slowing and treating runoff before it reaches receiving water bodies. Retrofits are targeted towards specific objectives, depending on BMP type; objectives may include water quality, soil stabilization, and runoff flow control. Several considerations must be taken into account to select appropriate stormwater treatment measures such as ecological benefit, available land area, cost, and community acceptance. There are factors which limit the effectiveness of stormwater retrofitting, such as insufficient land area in an appropriate portion of the subwatershed (i.e., must intercept a significant amount of runoff). Small-scale BMPs such as

bioretention for parking lot/alley retrofits can be effective if space is limited. See Section 5.5 for more information about these and other citizen-led BMPs.

5.2.1.2 Stream Corridor Restoration

Stream corridor restoration practices are used to enhance the ecological function, stability, and riparian habitat of degraded stream corridors. These types of practices typically involve a comprehensive approach using earth-moving equipment to address wide-spread channel degradation. Stream corridor restoration practices are often combined with stormwater management upgrades and riparian enhancement practices to meet watershed restoration objectives. Primary practices considered for Loch Raven East watershed stream corridors include stream restoration, buffer restoration, and wetland restoration.

Stream Restoration

Stream restoration projects are implemented to restore physical, biological, and/or ecological function to a natural watercourse which has become degraded. Degradation of a stream often occurs due to changes in the watershed, such as an increase in impervious surface and/or vegetation removal; and alterations made to the channel itself, such as straightening, lining with concrete or gabions, and/or culvert installation for road crossings.

The goal of stream restoration is to return a degraded channel to a stable state in which it does not significantly erode or fill with sediment, can convey runoff for a range of storm events and has improved ecological function.

A sound restoration project should utilize native materials such as rock, wood, and vegetation to imitate a natural, self-sustaining and ecologically functional stream system. The design approach of a stream restoration project requires an extensive quantity of field collected data and scientifically defensible calculations to determine the appropriate size, shape, and planform of the degraded channel. The design should take into account existing and possible future land use within the watershed. Hydrology and stormwater management practices upstream of a restoration site will dictate the velocity and volume of runoff that will reach a site. In addition, the sediment supply of the upstream channel is also an important consideration during the design of a stream restoration.

Implementation of a stream restoration project usually involves grading of the earth to reconfigure the shape and planform of the degraded channel and/or using structural controls where required for optimal hydrological and ecological function. Stream restoration utilizes a number of techniques to stabilize eroded stream banks, prevent stream bed degradation, recreate habitat, and protect adjacent infrastructure such as utilities, roads and structures. Bank stabilization improves water quality by attenuating the erosion of soils and adhered pollutants, in addition to reducing the likelihood of sewer line breaks. Appropriate placement of bed features and the use of grading and/or structures dissipates energy, creates a variety of aquatic habitats, and oxygenates the water.

Buffer Restoration

Riparian buffers are vegetated areas along rivers, streams and shorelines which help stabilize banks and prevent erosion; filter pollutants such as sediment and nutrients; provide wildlife habitat; and aid in regulating stream water temperatures. Several portions of the Loch Raven East watershed stream system have inadequate riparian buffers as a result of human activities.

This restoration strategy enhances or reforests areas adjacent to streams with a variety native trees, shrubs and herbaceous plantings. Plants are selected based on the growing conditions at each site and the plant's requirements. Implementation of targeted educational programs can teach private and institutional property owners that having vegetation along the stream can help preserve their property, as well as about what plants are appropriate for their site and the water quality benefits of riparian buffers. The inclusion of stream buffer signs is one way to remind residents of the importance of this essential vegetation.

Wetland Creation

Wetlands are highly valuable lands in terms of their ability to both improve water quality by filtering and slowing runoff, and as critical habitat for many species. A wetland is an area of land that has a specific soil type that remains wet or covered with water, and native vegetation that is adapted to these conditions. Swamps, marshes, and bogs are all types of wetland. Unfortunately, many wetlands were drained and converted to land useable for agriculture or development before their importance was realized. One strategy entails the reintroduction of wetlands in settings where they have been lost in the past but favorable conditions still exist. Unfortunately, due to the very specific parameters required, it can be difficult to create and sustain new wetlands. Preservation of the few remaining wetlands and limiting changes to hydrology in the landscape adjacent to existing wetlands are key strategies for watershed protection.

5.2.1.3 Reforestation

The Community Reforestation Program (CRP) was established by Baltimore County's Department of Environmental Protection and Sustainability (EPS) to provide a dedicated workforce for planting, monitoring, and maintaining forest mitigation projects. The program is funded through fees-in-lieu of mitigation for forests removed as a result of public and private land development, as required by the implementation of the county's Forest Conservation Act and Chesapeake Bay Critical Area Regulations. The CRP is the only full-time county-wide reforestation mitigation program among Maryland's counties.

The CRP includes a four-person reforestation crew that carries out year-round reforestation operations. The crew is based at a one-acre site in eastern Baltimore County that is provided by the Department of Recreation and Parks. This home base houses a growing out nursery for 13,000 tree seedlings; equipment and machinery needed for planting, monitoring, and maintaining the reforestation projects; and office space for the reforestation team. Occasionally, the CRP will undertake special grant-funded projects to improve water quality and groundwater recharge, as well as wildlife habitat. The most recent example is the expansion of forest buffers and the reforestation of fields on private rural properties.

In addition to mitigatory reforestation, the newly named Sustainability and Forest Management program in EPS is working to increase tree canopy in support of the county's Tree Canopy Goals announced in spring 2013, and to increase total tree cover by about 1,500 acres by 2025 as part of the county's Chesapeake Bay Watershed Implementation Plan (WIP). County revenues from the state-mandated stormwater remediation fees will be used mostly for contractor-installed reforestation projects. Planting in urban areas will include street trees; county facilities; and managed urban lands such as apartments, condominiums, businesses, and private institutions. Trees will also be planted by homeowners who purchase potted saplings through the county's Big Trees sales. EPS will also track citizen planting projects on county lands under the Policy & Guidelines for Community Tree Planting Projects. Contractor-installed planting in rural areas will include large-lot rural residential subdivisions, properties with conservation easements, and other properties where landowners want to increase tree cover.

5.2.2 County Management Programs

Municipal management programs can directly support watershed restoration efforts through services, monitoring and development review. Street sweeping, inlet cleaning, and trash and recycling collection are services that help protect water quality. The Illicit Discharge Detection and Elimination Program monitors stormwater outfalls to identify any potential contamination. The land development review process imposes a rigorous review of impacts to natural resources. This section describes these municipal programs.

5.2.2.1 Street Sweeping

Baltimore County has an active street sweeping program to remove debris, dirt and pollutants from the roads before they enter the storm drain system. Effective street sweeping usually involves using a vacuum assisted sweeper, and a schedule that takes into account factors such as trash pickup days and seasonal changes, such as leaf litter in the fall and more frequent lawn care activities by residents in spring and summer.

5.2.2.2 Inlet Cleaning

The Baltimore County storm drain system consists of approximately 1,760 miles of storm drain pipe, 72,096 inlets, and 8,640 outfalls. To keep the entire system clean of trash, debris, and sediment, the Department of Public Works maintains three storm drain cleaning vehicles. Each vehicle has a two man crew and operates each day, cleaning the storm drains and pipes. Removing the material from the storm drain system reduces street flooding, a potential safety hazard, and aids in the detection of illicit connections.

5.2.2.3 Illicit Discharge Detection and Elimination Program

The county's illicit connection program ensures that all discharges to and from the municipal separate storm sewer system that are not stormwater are either permitted by the Maryland Department of the Environment (MDE) or eliminated. The County is required to screen a minimum of 150 storm drain outfalls annually for the purposes of detecting and removing these unpermitted discharges. The illicit connection program is responsible for performing outfall screenings, reporting screening data, and coordinating remedial actions. The illicit connection program also investigates illicit connection complaints from other agencies,

citizens or volunteers in the Stream Watch Program. Stream Watch allows citizens to adopt a stream, which includes tracking the health of that stream and reporting problems or potential problems they observe.

Routine outfall screenings for detection of illicit connections complements screenings and follow-up triggered by citizen reports of problems they observe. The routine outfall screenings catch the chronic problems that may be missed by the public, such as chlorine leaks from the municipal water supply. Citizens provide additional surveillance at a level beyond that of the monitoring staff. A majority of the time citizens call while they are actually observing a problem and often can provide immediate local information that increases the chance of eliminating illicit connections. The illicit connections program also recently began taking data on potential retrofit opportunities at the outfalls that are investigated.

5.2.2.4 Land Development Review

New development and redevelopment projects undergo a rigorous review for impacts to natural resources. Regulations are in place for the protection of stream buffers, forests, tidal shorelines, groundwater, and stormwater runoff. In addition, on-site inspections take place during the construction process for erosion and sediment control. Tidal shoreline protection must be inspected before a development project is released for occupancy. Stormwater facilities must be confirmed to be functional one year after construction before “close-out” can occur and security bonds returned to the developer. After construction is complete, stream buffers and forest conservation areas are inspected on a random basis for compliance. The following are the current regulatory programs applicable to the development and redevelopment plan review process and follow-up inspections.

Riparian Forest Buffers

Baltimore County enacted the Regulations for the Protection of Water Quality, Streams, Wetlands and Floodplains in 1991. These regulations require development designs to include a 75 or 100-foot stream buffer and include provisions for expansion of the riparian buffer for steep slopes, wetlands, and floodplains. Development plans must minimize stream and buffer road crossings; have stormwater management facilities and outfalls outside of the riparian buffer; and place utilities outside the buffer to the extent possible. In cases where fish passage is an issue, stream crossings should be either open bottom bridges or provide for low flow fish passage. These regulations are intended to maintain the integrity of the riparian buffer.

Forest Conservation

The main purpose of the Maryland Forest Conservation Act, enacted in 1991, is to minimize the loss of Maryland's forest resources during land development by making the identification and protection of forests and other sensitive areas an integral part of the site planning process. EPS oversees local implementation of these regulations during the development review process and conducts inspections during the construction and post-construction closeout process. Of primary interest are areas adjacent to streams or wetlands; those on steep or erodible soils; or those within or adjacent to large contiguous blocks of forest or wildlife corridors. Identification of priority areas is completed prior to design of the

development plan. Any construction activity or development proposal for an area that is 40,000 square feet (approximately one acre) or greater is subject to the Forest Conservation Act and requires a Forest Conservation Plan prepared by a licensed forester, licensed landscape architect, or other qualified professional.

Chesapeake Bay Critical Area

The Chesapeake Bay Critical Area law and criteria were designed to foster more sensitive land use and development activity along the tidal shorelines and to ensure the implementation of appropriate long-term conservation measures to protect important habitats. The law identified the "Critical Area" as all land within 1,000 feet of the mean high water line of tidal waters or the landward edge of tidal wetlands. The Critical Area Act, passed in 1984, was significant and far-reaching, and marked the first time that the state and local governments jointly addressed the impacts of land development on habitat and aquatic resources. (There is no Critical Area in Loch Raven East.)

Groundwater Management

The Groundwater Management section of EPS is charged with the responsibility of managing and protecting the groundwater resources of Baltimore County. It handles issues related to drinking water wells, septic systems, and removal of residential underground storage tanks. These systems are regulated during the development review process and property title transfers to protect residents and groundwater resources.

Stormwater Management

Stormwater management in the State of Maryland has evolved over time, with the initial emphasis on quantity control in the mid to late 1980s, to quantity and quality control in the 1990s, to the more recent emphasis on channel protection (one-year storm management) and diffusing stormwater over the site (Low Impact Development [LID]). The control of erosive flows through stormwater management augments the riparian forest buffer in the protection of natural resources.

Erosion and Sediment Control

Baltimore County has authority delegated from the Maryland Department of the Environment to enforce the State Erosion and Sediment Control Program. The main function of this program is to monitor best management practices (BMPs) for sediment from new development and redevelopment during the construction phase. These practices prevent sediment and other pollutant inputs into the storm drain system and stream network. The sediment control BMPs are specified in the sediment and erosion control plan for each development site. Sediment control plans are required for any construction activity disturbing an area greater than 5,000 square feet. Standard Plans are used in lieu of Sediment and Erosion Control Plans approved by the Baltimore County Soil Conservation District for residential construction activities that disturb less than 30,000 square feet and for all other construction activities that disturb less than 20,000 square feet.

5.2.2.5 Trash and Recycling

Single Stream Recycling

All recyclables (e.g., plastics, glass, metals, paper, and cardboard) are collected co-mingled at the curbside or in the alley for all single-family homes. The majority of multifamily complexes (apartments, condominiums) also have single stream recycling collection each week. Under this program, recycling rates increased as a result of a greater number of accepted materials, convenience of placing everything in the same container, and weekly pickup. Recycling saves energy, helps protect natural resources, reduces air and water pollution, extends the life of the Eastern Sanitary Landfill, and saves the county money.

Household Hazardous Waste Collection

In response to numerous requests from citizens and elected officials concerned with disposal of hazardous wastes from their own homes, Baltimore County citizens can drop off household hazardous waste materials for recycling or proper disposal at a permanent processing facility located at the Eastern Sanitary Landfill Solid Waste Management Facility. Materials dropped off for processing include unwanted household chemicals, such as paints, flammable cleaning solvents, automotive fluids, pesticides, pool chemicals, acids, mercury thermometers, gasoline, corrosive material, etc. In addition, EPS holds two one-day collection events annually, in the spring and fall, at different locations around Baltimore County.

5.3 Best Management Practices for Agricultural Areas

There are a large number of agricultural practices that are used by farmers to reduce soil loss, trap nutrients, and minimize the amounts of nutrients and pesticides used on the land. For many of these agricultural BMPs, the Chesapeake Bay Program has assigned specific reduction efficiencies for nitrogen, phosphorus, and sediment to each practice. The following description of agricultural BMPs is derived from MDE (2010).

5.3.1 Farm Conservation Plans

A Soil Conservation and Water Quality Plan (SCWQP) is a comprehensive plan that addresses natural resource management on agricultural lands and describes BMPs which will be used to control erosion and sediment loss and manage runoff. SCWQPs include management practices such as crop rotations and structural practices such as grassed waterways and water troughs. At the request of a farmer, a Soil Conservation District (SCD), Maryland Department of Agriculture (MDA) or USDA professional provides assistance to determine the group of practices needed to address specific runoff concerns on the farm. The practices are designed to control erosion within acceptable levels and to be compatible with management and cropping systems. A SCWQP can be used for up to ten years without revision if substantial changes in the farm’s operation or management do not occur. Nutrient reduction is only one of many benefits derived from SCWQPs. Also included in a SCWQP are recommendations concerning forestry management; wildlife habitat and plantings; and other natural resource management practices. SCWQPs are required on agricultural land in the critical area. These plans must be approved by

SCD and updated every five years; enforcement authority lies with MDE. Plans are also required on agricultural land under preservation easement, such as Coastal Rural Legacy, and enforcement of these plans are by the holder of the easement. BMPs that could be included in a SCWQP that applies to Loch Raven East are discussed below.

Streamside Buffers

Streamside forest buffers are wooded areas along rivers and streams that help filter nutrients, sediments and other pollutants from runoff, as well as remove nutrients from groundwater and slow erosion. In addition to their ability to improve water quality, their value lies in enhancing terrestrial and aquatic habitat. Forest buffers an important BMP for natural resources managers.

Streamside grass buffers are strips of grass or other non-woody vegetation maintained between the edge of fields and streams, rivers or tidal waters. These grass strips help filter nutrients, sediment and other pollutants from runoff, as well as remove nutrients from groundwater.

Tree Planting

The tree planting BMP includes any tree planting on agricultural lands, except those used to establish riparian forest buffers. This program targets lands that are highly erodible or identified as critical resource areas. Tree planting on previously cleared land is also called afforestation because it involves growing trees and converting the land use from agricultural to forest over time.

Cover Crops

Cover crops are small grains such as wheat, barley, or rye that are planted in the fall after the harvest of corn, soybeans or vegetables to absorb unused nutrients that may remain in the soil. During the winter, these nutrients, particularly nitrate, are subject to leaching to groundwater. In addition, the plants and roots of cover crops help anchor the soil to decrease erosion and reduce phosphorus loss, and add organic matter to soil. By timing the springtime cover crop burn or plowdown, the trapped nitrogen can be released and used by the following crop.

Conservation Tillage

Conservation tillage involves planting and growing crops with minimal disturbance of the surface soil. Conservation tillage requires two components: a minimum 30% residue coverage at the time of planting and a non-inversion tillage method. No-till farming is a form of conservation tillage in which the crop is seeded directly into vegetative cover or crop residue, with little disturbance of the surface soil. Minimum tillage farming involves some disturbance of the soil, but uses tillage equipment that leaves much of the vegetation cover or crop residue on the surface. The overall benefit is the reduction of surface soil erosion.

Continuous No-Till

Continuous no-till (CNT) conservation is a crop planting and management practice in which soil disturbance by plows, disk or other tillage equipment is eliminated. CNT involves no-till methods on all crops in a multi-crop, multi-year rotation. When an acre is reported under CNT, it is not eligible for additional reductions from the implementation of cover crops and nutrient management application reductions because these benefits are accounted for in the CNT.

Stream Protection with Fencing

Stream protection with fencing is the installation of fencing along streams to exclude livestock. The fenced areas may be planted with trees or grass, but are typically not wide enough to provide the full benefits of buffers. Stream fencing should be implemented so as to substantially limit livestock access to streams; however, it can allow for the use of limited hardened crossing areas, where necessary, to accommodate access to additional pastures or for livestock watering. By preventing or limiting access of livestock to streams, erosion from hooves and bacterial contamination is curtailed.

Off-Stream Watering

Off-stream watering provides livestock an alternative drinking water source away from streams. By providing an off-stream watering source, livestock will reduce the time they spend near and in streams and stream banks. This will reduce animal waste deposition and move heavy traffic areas near streams to more upland locations. This practice works in conjunction with the practice of stream protection with fencing.

Animal Waste Management

Animal waste management systems are practices designed for proper handling, storage, and utilization of wastes generated from animal operations. They include a means of collecting, scraping or washing wastes and contaminated runoff into appropriate waste storage structures.

Runoff Control Systems

Runoff on agricultural lands may be controlled or intercepted in several ways. Gutters, downspouts and other water conveyance devices prevent roof runoff water from causing severe erosion or mixing with animal waste and transporting pollutants to waterways. Roof runoff systems improve water quality, reduce soil erosion, increase infiltration, and protect buildings and other structures. Diversions may be used to direct runoff flows away from a feedlot or to collect and direct water to a pond. Diversions reduce soil erosion, filter runoff improving water quality, and provide cover for wildlife. Grassed waterways use natural drainage to prevent gullies from forming and control soil erosion. Stormwater runoff flows over the grass rather than tearing soil away and forming a gully. Vegetation may act as a filter, absorbing some of the pesticides and nutrients in runoff water, and provides cover for wildlife.

5.3.2 Nutrient Management Plans

Nutrient management plans (NMPs) are comprehensive plans required by MDA that describe the optimum use of nutrient inputs for crop yield to minimize loss of excess nutrients to the environment. A NMP details the type, rate, timing, and placement of nutrients for each crop.

Soil, plant tissue, manure and/or sludge tests are used to assure optimal application rates. Plans are prepared either by University of Maryland Extension or by certified private consultants. Though some of these plans are written to cover a three year period, most are revised every year so that they incorporate management, fertility and technology changes.

5.4 Citizen Awareness Activities

Residents and businesses can engage in behaviors and activities that can negatively influence water quality, including over-fertilizing lawns, using excessive amounts of pesticides, poor housekeeping practices (such as inappropriate disposal of paints, household cleaners or automotive fluids), and dumping into storm drains. Alternatively, positive behaviors such as tree planting, disconnecting downspouts, and picking up pet waste can help improve water quality. Whether a pollution prevention program is designed to discourage negative behaviors or encourage positive ones, targeted education is needed to deliver messages that promote changes in behavior. Local watershed organizations and other civic groups, such as the Master Gardeners, are in a position to influence these changes using pollution prevention education and outreach to teach citizens how to properly care for the watershed.

5.4.1 Stormwater Runoff

A survey regarding people's knowledge about stormwater was conducted in 2007 by the Herring Run Watershed Association and the Jones Falls Watershed Association (both organizations are now part of Blue Water Baltimore) in conjunction with OpinionWorks. It concluded that even citizens who want to reduce the negative impacts of stormwater runoff do not realize their role in controlling runoff. By slowing and reducing the amount of stormwater runoff, more water can infiltrate into the ground and lessen damaging stormwater surges into streams. Annually, Baltimore County holds a one-day truckload sale of rain barrels for citizens to purchase. There is more detail on this and other ways that homeowners can help reduce stormwater runoff in section 5.5.

5.4.2 Pet Waste/Bacteria Awareness

Pet waste is one of the contributors of bacteria to streams and can cause health problems in humans. A pet waste station is a sign reminding pet owners of the importance of proper disposal of pet waste and it usually includes a supply of bags for pet waste cleanup. Often it is located next to an existing trashcan or it includes one. Pet waste stations can help neighborhoods to reduce bacteria flowing into their local streams and help to keep their neighborhood park or school site clean. Citizens can participate by monitoring the supply of bags to make sure they are continually available. In collaboration with other county agencies, EPS is developing an awareness campaign for better pet waste management.

5.4.3 Fertilizer Reduction

A well-manicured and responsibly maintained lawn can be an asset to the watershed. Too often however, over fertilization and irresponsible pest management result in pollutant-charged runoff to local streams. Significant reductions of total nitrogen to stormwater can be achieved

through careful fertilizer management. Homeowners should be reminded to follow the fertilizer application instructions so that it is applied in the correct amount, during the right season, and under the right conditions so that the fertilizer does not wash away in a rainstorm. Citizens can be more cognizant about fertilizer placement so that it doesn't land on driveways and sidewalks where it may wash directly into the street and storm drain system. The County also promotes eco-friendly lawn care, including the use of mulching lawn mowers that reduce the need for fertilizer and decrease the amount of material handled by the yard material collection program.

5.4.4 Trash and Recycling

Compost Bins

Baltimore County holds a one-day compost bin sale for residents to purchase bins for composting yard waste in their backyards. By composting leaves and weeds in backyard bins, the amount of material handled by the municipal yard material collection is reduced. Use of compost is an environmentally friendly way of improving soil and avoids the application of manufactured chemical fertilizer. This event is held in conjunction with the annual rain barrel sale.

Stewardship Projects

EPS provides assistance in planning and advertising local stewardship projects such as Project Clean Stream, an annual stream cleanup hosted by the Alliance for the Chesapeake Bay.

Reuse Directory

The Reuse Directory is a listing of reuse organizations for Baltimore County residents and businesses that is available online and in print. In it are all of the places that you can take unwanted items for reuse, including construction materials, appliances, office supplies, clothing, household items, automobiles, food, medical equipment, and more. By donating reusable items, you will: help other people and organizations, reduce disposal costs, reduce air and water pollution, and conserve space in the landfill. The directory is published by the Baltimore County Bureau of Solid Waste Management

http://resources.baltimorecountymd.gov/Documents/Public_Works/solidwastemanagement/reuse130927web.pdf

The Re-Source Newsletter

The Re-Source Newsletter is an online resource that is published quarterly and provides information and updates about Baltimore County's solid waste reduction, reuse, recycling, and refuse disposal programs.

http://www.baltimorecountymd.gov/Agencies/publicworks/recycling/newsletter/index.html

5.4.5 Environmental Awareness and Education

Outreach and education programs are intended to communicate to the public how to reduce the potential for pollutants to reach waterways. These programs are designed to change

pollutant-causing behaviors by providing information on how certain habits and actions affect water quality and to recommend new behaviors that can reduce impacts. There are also a number of activities that can reduce runoff or improve water quality that don't involve pollution prevention, such as landscaping improvements, which could be the target of an outreach program.

A pollution prevention program can be designed to discourage negative behaviors and/or encourage positive behaviors. Either way, the goal is to deliver a tailored message through targeted education to promote behavior changes. Local watershed organizations such as the Gunpowder Valley Conservancy can help influence these changes using pollution prevention education and outreach to teach citizens how to properly care for the watershed. The upland assessments described in Chapter 4 identified pollution prevention or source control education programs which could be effective in the Loch Raven East watershed.

Community-based facilities present good opportunities for educating the public about water quality issues and opportunities for improving the health of the watershed. This can be accomplished by implementing water quality BMPs such as rain gardens and bioretention areas at these sites. In addition to environmental education, these BMPs have water quality and aesthetic benefits for property users. Tree plantings present great opportunities for community involvement and education, as do water quality sampling and monitoring of stormwater management.

5.5 Volunteer Restoration Programs

There are several restoration activities that citizens in the watershed can engage in to help restore and protect the watershed. These activities are described in the following sections and include downspout disconnection, BayScaping, tree canopy improvement, fertilizer reduction/education, planting open space trees, and participating in a citizen stream watch program.

5.5.1 Downspout Disconnection

In addition to road runoff, rooftops can sometimes contribute stormwater directly into streams. Many downspouts are connected directly to the storm drain system through underground pipes, while others are funneled toward driveways and sidewalks, which then are connected to the street. By redirecting downspouts to a pervious area, this runoff is allowed to infiltrate the ground in areas such as gardens and lawns.

Downspout disconnection refers to several practices that capture or treat rooftop runoff from individual downspouts through either a simple disconnection that allows the runoff to spread across the lawn or yard where it filters or infiltrates into the ground, a rain barrel that captures the runoff for re-use in watering gardens, or a rain garden that infiltrates the runoff. Several of the neighborhoods assessed in the Loch Raven East watershed were recommended for downspout disconnection because they are draining to impervious surfaces such as driveways, sidewalks, or the curb and gutter system.

Simple downspout disconnection can be achieved, where appropriate, if the downspouts are relocated to drain onto pervious areas (i.e. lawn). This will allow rooftop runoff to be filtered by vegetation, and soak into the ground. This decreases flow to local streams during storm events, reducing erosion and pollutant loads to streams.

The use of rain barrels for the collection and reuse of the runoff is a highly sustainable practice, and is effective when there is limited space on the property and other disconnection practices are not possible. Downspouts are directed into rain barrels, where rooftop water is captured and stored for later use to water the yard or garden, or simply to be released onto a pervious area on a dry day.

Finally, some of the residential lots in the watershed have sufficient room for rain gardens, which are the most desirable option in terms of water quality. Rain gardens capture runoff from impervious surfaces such as roofs, roads, patios and driveways. They are planted with native perennials and shrubs that are compatible with wet soils. A downhill area that naturally collects rain water is an ideal location for a rain garden. The garden temporarily holds runoff, allowing it to gradually percolate into the ground, thus replenishing groundwater and reducing floods. Garden plants naturally filter pollutants and improve the water quality.

5.5.2 BayScaping

Numerous water quality benefits are achieved from converting turf into landscaping and through increasing the area of urban tree canopy. A BayScape is a designed feature that uses 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 waterbodies. 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. The removal of exotic, invasive plant species also benefits native plant and animal communities.

5.5.3 Tree Canopy Improvement

Programs to promote tree planting in residential yards and commercial open space can increase the tree canopy; increase evapotranspiration and interception; slow runoff; and allow greater infiltration of stormwater into the ground due to tree roots reducing soil compaction. Trees also reduce erosion by holding soil and by reducing the impact of rain to bare ground. These types of programs also provide an opportunity to involve volunteers from 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.

Big Trees Sale – Baltimore County has its own native tree nursery for county reforestation projects. Twice a year, in the spring and fall, trees from the nursery are made available to the public to encourage planting of native trees, especially oaks, which have exceptional water quality, air quality, and wildlife benefits. Trees are sold at one-day sale events.

The State of Maryland's TREE-MENDOUS program provides high-quality, native trees and shrubs, available at reasonable prices, for plantings on public lands. The trees may be planted in places such as community open spaces, schools, government facilities, and rights-of-way. They may not be planted at private residences.

5.5.4 Fertilizer Reduction/Education

Proper lawn and turf care practices can reduce excess nitrogen, phosphorus, insecticides and herbicides from getting into local streams. Education on soil testing, fertilizer application and pesticide use is intended to reduce the amount of these materials applied to the land.

5.5.5 Stream Watch Program

The Stream Watch Program is intended to develop citizen stewardship through participation of citizen volunteers who actively assume the responsibility of caring for segments of the stream network by observing changes in the system, providing stream clean-ups, and participating in planting activities. The Stream Watch Program also includes identification of potential restoration projects for possible inclusion in the Waterway Capital Improvement Program and provides a valuable addition to the county's Illicit Connection Program through reports of potential illicit discharges by Stream Watch participants.

5.5.6 Open Space Trees

Pervious areas and natural area remnants provide important natural groundwater recharge functions within a subwatershed, and should be optimized to promote natural infiltration. These areas also present an opportunity for reforestation in the watershed. Reforestation is the best way of improving the infiltration, recharge function, and pollutant reduction capability of the site. However other techniques such as soil aeration, amendments, and establishing native plantings or meadows also function better than turf grass in this regard. Ideal sites for planting have little evidence of soil compaction, invasive plants, or trash/dumping, and can be reforested with minimal site preparation.

5.6 Institutional Initiatives

There are several restoration activities that institutions in the watershed such as churches and schools can engage in to help restore and protect the watershed. These activities are described in the following sections.

5.6.1 Parking Lot Retrofits

Often large parking surfaces are included in commercial and institutional development projects for events that occur very infrequently. If reducing the impervious cover is not an option, then filtering practices can provide a substantial benefit when applied over large areas. Onsite commercial and institutional retrofit practices often include the use of sand filters, bioretention, and grass swales adjacent to parking lots. Larger redevelopment projects often include underground storage or filtering systems. Several research groups are exploring

innovative parking surfaces to develop a surface that is both durable and porous. These surfaces are another option for providing better filtration of runoff, while still allowing for the same number of parking spaces.

5.6.2 Open Space Planting

An increasing number of faith-based institutions are showing interest in adopting conservation landscaping practices. This often begins with removal of unused turf areas at these institutions. These areas are then replaced by an assortment of more sustainable and environmentally-friendly practices. Options include: planting trees, restoring wildlife habitat, introducing no-mow zones, and creating meadows, all of which also improve the quality and quantity of stormwater runoff. Trees planted near buildings provide wind protection and shade which can reduce energy use leading to lower heating and cooling costs. When lawn area is eliminated less mowing is required, reducing fossil fuel consumption and associated air pollution.

5.7 Land Preservation

Land preservation complements the implementation of BMPs by insuring that land use is stabilized over time. Unlike park land, land preservation maintains certain restrictions on the land's use in perpetuity. The restrictions range from limits on development to specific resource protection, such as forest, stream buffer or prime land protection.

These preservation areas may be large, multi-parcel blocks or small, individual parcels. Land preservation in Baltimore County complements the long-term multifaceted efforts to limit sprawl and protect rural resources, water supplies and rural economies. The limitations on the property vary depending on the principle of the easement program, and as specifically limited by the Deed of Conservation Easement. For example, the Maryland Environmental Trust easements provide for a broad array of environmental protection restrictions. The Agricultural Protection programs focus on protection of prime and productive soils, while still permitting resource extraction. Rural Legacy blends these two objectives.

For purposes of watershed management, an understanding of existing protected lands can provide a starting point in prioritizing potential protection and restoration activities. In many cases, protected lands may provide a better opportunity for restoration projects simply because the risk of the land being converted to development is removed, thus the investment involved in the implementation of the practice is secure. A summary of current conservation easements is provided in Chapter 2.

Descriptions of the land preservation programs in effect in the Loch Raven East watershed follow.

5.7.1 Maryland and County Rural Legacy Program

Baltimore County participates in the State's Rural Legacy Program which was developed in 1997 to protect large, continuous tracts of valuable cultural and natural resource lands through state grants made to local land trusts (DNR 2007). Baltimore County has five Rural Legacy

Areas that aim to protect large blocks of farmland, forest, wetlands, and other environmental resources that seek to protect the Chesapeake Bay both directly and indirectly. Protection is afforded through the purchase of development rights and the placement of a perpetual Conservation Easement on the property. The easements, totaling over 10,000 acres, are held by the private land trust, state or county, or a combination. In all cases, the land trust and the governmental co-holder of the easement is responsible for monitoring the property to assure compliance with the easement. Only the northwestern corner of Loch Raven East lies within a Rural Legacy Program boundary.

5.7.2 Maryland Environmental Trust 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 18,500 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.

5.7.3 Maryland Agricultural Land Preservation Foundation

Created in 1979, this program has been dedicated to preserving farmland and fostering commercial agriculture. With joint funding by the county and the state, over 22,000 acres of farmland have been preserved in Baltimore County. To qualify for this program, a farm must be a minimum of 50 acres or located adjacent to a preserved property. Applications to sell development rights may be made annually by July 1st following enrollment in an Agricultural District. Landowners receive cash payments for participating in the easement program.

5.7.4 Baltimore County Agricultural Land Preservation Program

Created in 1994 to preserve working family farms, this Baltimore County program has used innovative and collaborative funding mechanisms for land preservation. Landowners have protected over 5,600 acres through this program. To participate, a farm must be 50 acres in size or located adjacent to a preserved property.

5.8 Public Lands/Open Space

Lands in the SWAP area, owned by Baltimore County, Baltimore City, and the State of Maryland, meet various public needs as described.

5.8.1 Baltimore County Department of Recreation and Parks

Sweet Air Park

This 30 acre park in Phoenix, is home to the Jacksonville Recreation Center and the Jacksonville Senior Center. Amenities include a community center, pavilions, picnic areas, athletic fields, restrooms, and a walking trail. The recreation center is operated by the Carroll Manor Recreation Council. http://www.carrollmanor.org/

5.8.2 Loch Raven Fishing Center

Located on Dulaney Valley Road in Timonium, this facility is operated by the Baltimore County Department of Recreation and Parks in cooperation with the Baltimore City Bureau of Water Supply. It offers fishing, daily boat rentals, and seasonal launch and docking permits. The center is open daily from April to Labor Day, and limited days from Labor Day through November.
http://www.baltimorecountymd.gov/Agencies/recreation/countyparks/fishingcenter/index.html

5.8.3 Gunpowder Falls State Park Land

In the Maryland State Park system, a section of the Gunpowder Falls State Park lies within Area R. This 160-acre park area is not open to the public. There are agricultural leases on a number of fields. Portions of the land have been reforested.

5.8.4 Loch Raven Reservoir Protected Land

In addition to owning the reservoir and operating the municipal water supply, Baltimore City Department of Public Work, Bureau of Water and Wastewater also owns and manages 8,000 acres of protected land surrounding the reservoir. This natural land area helps to ensure a clean and safe water supply, and provides wildlife habitat.
http://publicworks.baltimorecity.gov/Bureaus/WaterWastewater/Water/ReservoirNaturalResources.aspx

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Appendix F

Loch Raven East
Stream Corridor Assessment
Survey Tables

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Dulaney Valley Branch Subwatershed SCA Survey Sites:
Channel Alterations

Map	Site	Date Assessed	Type	Bottom Width	Perennial Flow	Sediment Deposition	Vegetation	Road Crossing	Channelized Length Above Road Crossing (ft)	Channelized Length Below Road Crossing (ft)	Length (ft)	Length (mi)	Severity
044A3	044A3-93CA	26-Jul-12	Rip-rap	5	Y	Y	N	Below		30	28.49	0.0054	Moderate
053A1	053A1-74CA	26-Jul-12	Rip-rap	10	Y	Y	Y	Both	85	70	55.38	0.0105	Moderate
053A1	053A1-89CA	27-Jul-12	Rip-rap	6	Y	Y	Y	No			144.11	0.0273	Moderate
053A2	053A2-18CA	27-Jul-12	Rip-rap	8	Y	Y	Y	Below		1000	1124.71	0.2130	Low Severity
053B1	053B1-28CA	03-Aug-12	Concrete	6	Y	N	N	Above	170		117.41	0.0222	Low Severity
053B1	053B1-30CA	03-Aug-12	Concrete	9	Y	N	N	Below		100	75.81	0.0144	Low Severity
053A2	053A2-38CA	07-Aug-12	Concrete	8	Y	Y	N	No			28.00	0.0053	Low Severity
053B2	053B2-21CA	21-Aug-12	Gabion	8	Y	N	Y	No			78.86	0.0149	Low Severity
053A1	053A1-06CA	17-Jul-12	Rip-rap	11	Y	Y	Y	Above	100		6.96	0.0013	Minor

Dulaney Valley Branch Subwatershed SCA Survey Sites:
(Channel Alterations continued from page 3)

Map	Site	Date Assessed	Type	Bottom Width	Perennial Flow	Sediment Deposition	Vegetation	Road Crossing	Channelized Length Above Road Crossing (ft)	Channelized Length Below Road Crossing (ft)	Length (ft)	Length (mi)	Severity
044A3	044A3-07CA	19-Jul-12	Rip-rap	10	Y	Y	Y	No			147.39	0.0279	Minor
044A3	044A3-08CA	19-Jul-12	Rip-rap	13	Y	Y	Y	No			78.23	0.0148	Minor
044A3	044A3-24CA	19-Jul-12	Rip-rap	15	Y	Y	Y	No			162.91	0.0309	Minor
044A3	044A3-27CA	19-Jul-12	Rip-rap	3	N	Y	Y	No			31.63	0.0060	Minor
044A3	044A3-32CA	19-Jul-12	Rip-rap	10	Y	Y	Y	No			63.55	0.0120	Minor

Dulaney Valley Branch Subwatershed SCA Survey Sites:
Unusual Conditions

Map	Site	Date Assessed	Type	Description	Notes	Potential Cause	Severity
044B3	044B3-28UC	03-Aug-12	Unusual Condition	Other	degrading asphalt v ditch	undermining	Very Severe
053A1	053A1-99UC	27-Jul-12	Unusual Condition	Other	concrete slabs in channel	channel instability	Very Severe
053A1	053A1-45UC	24-Jul-12	Unusual Condition	Other	debris jam at wooden bridge crossing	flooding	Severe
053A1	053A1-38UC	19-Jul-12	Unusual Condition	Other	erosion and concrete failure at bridge	overland flow	Moderate
053A2	053A2-22UC	27-Jul-12	Unusual Condition	Other	stone dam built by property owner	man made	Moderate
053B1	053B1-25UC	03-Aug-12	Unusual Condition	Other	old bridge crossing	unknown	Moderate
053A1	053A1-12UC	17-Jul-12	Unusual Condition	Other	stabilization fabric lb	erosion	Low Severity
044A3	044A3-22UC	19-Jul-12	Unusual Condition	Other	extraction well	water withdrawal	Minor
044A3	044A3-67UC	26-Jul-12	Unusual Condition	Other	riprap and stabilization fabric along lb	utility line	Minor
053A1	053A1-17UC	17-Jul-12	Unusual Condition	Other	stabilization fabric lb	erosion prevention	Minor
053A2	053A2-41UC	07-Aug-12	Unusual Condition	Other	remnants of concrete pipe	unknown	Minor

Dulaney Valley Branch Subwatershed SCA Survey Sites:
Comments

Map	Site	Date Assessed	Type	Description	Notes	Potential Cause	Severity
044A2	044A2-08C	03-Aug-12	Comment	NA	st right fork	NA	NA
044A2	044A2-10C	03-Aug-12	Comment	NA	end right fork	NA	NA
044A2	044A2-07C	03-Aug-12	Comment	NA	end lb trib	NA	NA
044A2	044A2-06C	03-Aug-12	Comment	NA	st lb trib	NA	NA
044A3	044A3-74C	26-Jul-12	Comment	NA	trash ds of pond	NA	NA
044A3	044A3-95C	21-Aug-12	Comment	NA	st lb trib	NA	NA
044A3	044A3-98C	21-Aug-12	Comment	NA	end reach	NA	NA
044B3	044B3-20C	31-Jul-12	Comment	NA	st rb trib	NA	NA
044B3	044B3-23C	31-Jul-12	Comment	NA	st rb trib	NA	NA
044B3	044B3-25C	31-Jul-12	Comment	NA	stone structure in channel	NA	NA
044B3	044B3-21C	31-Jul-12	Comment	NA	end rb trib	NA	NA
044B3	044B3-37C	03-Aug-12	Comment	NA	end left trib	NA	NA

Dulaney Valley Branch Subwatershed SCA Survey Sites:
(Comments continued from page 6)

Map	Site	Date Assessed	Type	Description	Notes	Potential Cause	Severity
044B3	044B3-33C	03-Aug-12	Comment	NA	end lb trib	NA	NA
044B3	044B3-35C	03-Aug-12	Comment	NA	st left fork	NA	NA
044B3	044B3-32C	03-Aug-12	Comment	NA	st lb trib	NA	NA
044B3	044B3-38C	03-Aug-12	Comment	NA	end right trib	NA	NA
044B3	044B3-48C	03-Aug-12	Comment	NA	end lb trib 2	NA	NA
044B3	044B3-47C	03-Aug-12	Comment	NA	st lb trib 2	NA	NA
044B3	044B3-46C	03-Aug-12	Comment	NA	st lb trib	NA	NA
044B3	044B3-44C	03-Aug-12	Comment	NA	st right fork	NA	NA
044B3	044B3-42C	03-Aug-12	Comment	NA	end right trib	NA	NA
044B3	044B3-40C	03-Aug-12	Comment	NA	st right trib	NA	NA
044B3	044B3-39C	03-Aug-12	Comment	NA	confluence	NA	NA
044B3	044B3-55C	21-Aug-12	Comment	NA	end reach	NA	NA

Dulaney Valley Branch Subwatershed SCA Survey Sites:
(Comments continued from page 7)

Map	Site	Date Assessed	Type	Description	Notes	Potential Cause	Severity
044B3	044B3-53C	21-Aug-12	Comment	NA	begin reach	NA	NA
044B3	044B3-52C	21-Aug-12	Comment	NA	no defined channel us of confluence	NA	NA
053A1	053A1-59C	26-Jul-12	Comment	NA	concrete on bank	NA	NA
053A1	053A1-131C	31-Jul-12	Comment	NA	lb entering ditch with headcut	NA	NA
053A1	053A1-122C	31-Jul-12	Comment	NA	intermittent channel	NA	NA
053A1	053A1-121C	31-Jul-12	Comment	NA	end of flow	NA	NA
053A1	053A1-136C	07-Aug-12	Comment	NA	st trib	NA	NA
053A2	053A2-43C	07-Aug-12	Comment	NA	end of rb trib	NA	NA
053A2	053A2-44C	07-Aug-12	Comment	NA	st channel us from pond	NA	NA
053A2	053A2-48C	07-Aug-12	Comment	NA	st lb trib	NA	NA
053A2	053A2-49C	07-Aug-12	Comment	NA	end lb trib	NA	NA
053A2	053A2-34C	07-Aug-12	Comment	NA	end of trib	NA	NA

Dulaney Valley Branch Subwatershed SCA Survey Sites:
(Comments continued from page 8)

Map	Site	Date Assessed	Type	Description	Notes	Potential Cause	Severity
053A2	053A2-33C	07-Aug-12	Comment	NA	st of trib	NA	NA
053A2	053A2-50C	07-Aug-12	Comment	NA	rb outfall channel eroding	NA	NA
053A2	053A2-39C	07-Aug-12	Comment	NA	st rb trib	NA	NA
053A2	053A2-27C	07-Aug-12	Comment	NA	st left branch	NA	NA
053A2	053A2-28C	07-Aug-12	Comment	NA	st right branch	NA	NA
053A2	053A2-29C	07-Aug-12	Comment	NA	end braided channel	NA	NA
053A2	053A2-54C	21-Aug-12	Comment	NA	st lb trib	NA	NA
053A2	053A2-63C	21-Aug-12	Comment	NA	headcut on lb	NA	NA
053A2	053A2-69C	21-Aug-12	Comment	NA	st lb trib	NA	NA
053A2	053A2-71C	21-Aug-12	Comment	NA	end of reach	NA	NA
053B1	053B1-20C	31-Jul-12	Comment	NA	st lb trib	NA	NA
053B1	053B1-19C	31-Jul-12	Comment	NA	end lb trib	NA	NA

Dulaney Valley Branch Subwatershed SCA Survey Sites:
(Comments continued from page 9)

Map	Site	Date Assessed	Type	Description	Notes	Potential Cause	Severity
053B1	053B1-18C	31-Jul-12	Comment	NA	old stone bridge abutment	NA	NA
053B1	053B1-33C	03-Aug-12	Comment	NA	st lb trib	NA	NA
053B2	053B2-08C	07-Aug-12	Comment	NA	end left branch	NA	NA
053B2	053B2-05C	07-Aug-12	Comment	NA	confluence	NA	NA
053B2	053B2-11C	07-Aug-12	Comment	NA	end right branch	NA	NA
053B2	053A2-51C	07-Aug-12	Comment	NA	confluence	NA	NA
053B2	053C2-12C	07-Aug-12	Comment	NA	end of right fork	NA	NA
053B2	053B2-16C	21-Aug-12	Comment	NA	st lb trib	NA	NA

Dulaney Valley Branch Subwatershed SCA Survey Sites:
Erosion Sites

Map	Site	Date Assessed	Channel Condition	Cause	Average Exposed Bank Height (ft)	Land Use (Left)	Land Use (Right)	Threat to Infrastructure	Length (ft)	Length (mi)	Severity
044A3	044A3-28ES	19-Jul-12	Stage I Incision	Other	3	Forest	Forest	N	41.21	0.0078	Very Severe
044A3	044A3-29ES	19-Jul-12	Stage I Incision	Pipe outfall	8	Lawn	Forest	N	116.50	0.0221	Very Severe
053A2	053A2-26ES	27-Jul-12	Stage I Incision	Land use change	7	Forest	Forest	N	57.27	0.0108	Very Severe
053A1	053A1-138ES	07-Aug-12	Stage I Incision	Land use change	6	Lawn	Lawn	N	162.96	0.0309	Very Severe
053A1	053A1-09ES	17-Jul-12	Stage I Incision	Other	5	Other	Other	N	38.07	0.0072	Severe
044B3	044B3-01ES	20-Jul-12	Stage I Incision	Bend at steep slope	4	Forest	Lawn	N	34.06	0.0065	Severe
053A2	053A2-70ES	21-Aug-12	Stage I Incision	Other	8	Forest	Forest	N	158.43	0.0300	Severe
044B3	044B3-15ES	24-Jul-12	Stage I Incision	Other	5	Forest	Forest	N	74.72	0.0142	Severe
053A1	053A1-86ES	27-Jul-12	Stage I Incision	Land use change	1	Lawn	Forest	N	145.24	0.0275	Severe
053A2	053A2-20ES	27-Jul-12	Stage I Incision	Land use change	5	Forest	Lawn	N	58.46	0.0111	Severe
053A1	053A1-114ES	31-Jul-12	Stage I Incision	Land use change	6	Lawn	Lawn	N	469.95	0.0890	Severe
053B1	053B1-22ES	03-Aug-12	Stage II Widening	Land use change	8	Pasture	Pasture	N	421.01	0.0797	Severe
053B2	053B2-15ES	21-Aug-12	Stage I Incision	Pipe outfall	5	Forest	Forest	N	214.95	0.0407	Severe
053A2	053A2-03ES	17-Jul-12	Stage II Widening	Land use change	4	Forest	Forest	N	147.92	0.0280	Moderate
053A2	053A2-06ES	17-Jul-12	Stage III Deposition	Other	3	Other	Forest	N	113.24	0.0214	Moderate
053A2	053A2-09ES	17-Jul-12	Stage II Widening	Other	6	Forest	Other	N	109.29	0.0207	Moderate
044A3	044A3-48ES	20-Jul-12	Stage I Incision	Other	3	Forest	Forest	N	18.36	0.0035	Moderate
044A3	044A3-54ES	20-Jul-12	Stage II Widening	Bend at steep slope	6	Forest	Forest	N	28.72	0.0054	Moderate
044A3	044A3-55ES	20-Jul-12	Stage II Widening	Bend at steep slope	6	Forest	Forest	N	26.74	0.0051	Moderate

Dulaney Valley Branch Subwatershed SCA Survey Sites:
(Erosion Sites continued from page 11)

Map	Site	Date Assessed	Channel Condition	Cause	Average Exposed Bank Height (ft)	Land Use (Left)	Land Use (Right)	Threat to Infrastructure	Length (ft)	Length (mi)	Severity
044A3	044A3-57ES	20-Jul-12	Stage II Widening	Bend at steep slope	6	Forest	Forest	N	38.80	0.0073	Moderate
044B3	044B3-06ES	20-Jul-12	Stage II Widening	Pipe outfall	3	Forest	Forest	N	25.32	0.0048	Moderate
044A3	044A3-59ES	24-Jul-12	Stage II Widening	Bend at steep slope	5	Forest	Forest	N	23.36	0.0044	Moderate
044B3	044B3-12ES	24-Jul-12	Stage II Widening	Bend at steep slope	5	Forest	Forest	N	44.03	0.0083	Moderate
053A1	053A1-44ES	24-Jul-12	Stage II Widening	Other	2	Pasture	Pasture	N	31.25	0.0059	Moderate
053A1	053A1-49ES	24-Jul-12	Stage II Widening	Land use change	4	Pasture	Pasture	N	46.32	0.0088	Moderate
044A3	044A3-73ES	26-Jul-12	Stage II Widening	Land use change	5	Forest	Forest	N	3.03	0.0006	Moderate
044A3	044A3-80ES	26-Jul-12	Stage II Widening	Other	3	Forest	Forest	N	89.77	0.0170	Moderate
053A1	053A1-65ES	26-Jul-12	Stage III Deposition	Bend at steep slope	6	Lawn	Forest	N	32.56	0.0062	Moderate
053A1	053A1-97ES	27-Jul-12	Stage II Widening	Land use change	1	Lawn	Lawn	N	589.48	0.1116	Moderate
053A1	053A1-94ES	27-Jul-12	Stage II Widening	Land use change	3	Lawn	Lawn	N	292.69	0.0554	Moderate
053A1	053A1-90ES	27-Jul-12	Stage II Widening	Other	2	Lawn	Lawn	N	101.77	0.0193	Moderate
053A1	053A1-101ES	27-Jul-12	Stage II Widening	Land use change	5	Forest	Forest	N	82.25	0.0156	Moderate
053A2	053A2-13ES	27-Jul-12	Stage II Widening	Other	4	Forest	Forest	N	28.50	0.0054	Moderate
053A2	053A2-14ES	27-Jul-12	Stage II Widening	Other	5	Forest	Forest	N	33.58	0.0064	Moderate
053A2	053A2-16ES	27-Jul-12	Stage II Widening	Other	5	Forest	Forest	N	152.90	0.0290	Moderate
053A1	053A1-123ES	31-Jul-12	Stage I Incision	Land use change	3	Lawn	Forest	N	65.85	0.0125	Moderate
053A1	053A1-127ES	31-Jul-12	Stage II Widening	Land use change	4	Pasture	Pasture	N	30.04	0.0057	Moderate
053A1	053A1-130ES	31-Jul-12	Stage II Widening	Bend at steep slope	6	Pasture	Pasture	N	39.44	0.0075	Moderate

Dulaney Valley Branch Subwatershed SCA Survey Sites:
(Erosion Sites continued from page 12)

Map	Site	Date Assessed	Channel Condition	Cause	Average Exposed Bank Height (ft)	Land Use (Left)	Land Use (Right)	Threat to Infrastructure	Length (ft)	Length (mi)	Severity
053A1	053A1-134ES	31-Jul-12	Stage II Widening	Land use change	5	Pasture	Pasture	N	44.43	0.0084	Moderate
053A1	053A1-135ES	31-Jul-12	Stage II Widening	Land use change	4	Pasture	Pasture	N	47.48	0.0090	Moderate
053B1	053B1-06ES	31-Jul-12	Stage I Incision	Land use change	3	Forest	Forest	N	67.88	0.0129	Moderate
053B1	053B1-07ES	31-Jul-12	Stage I Incision	Land use change	2	Forest	Lawn	N	94.11	0.0178	Moderate
053B1	053B1-08ES	31-Jul-12	Stage II Widening	Land use change	3	Lawn	Lawn	N	237.84	0.0450	Moderate
053B1	053B1-17ES	31-Jul-12	Stage II Widening	Bend at steep slope	5	Forest	Forest	N	140.44	0.0266	Moderate
044B3	044B3-36ES	03-Aug-12	Stage II Widening	Land use change	5	Forest	Forest	N	76.60	0.0145	Moderate
044B3	044B3-49ES	03-Aug-12	Stage I Incision	Land use change	2	Forest	Forest	N	30.96	0.0059	Moderate
053B1	053B1-27ES	03-Aug-12	Stage II Widening	Land use change	4	Forest	Lawn	N	237.78	0.0450	Moderate
053A2	053A2-46ES	07-Aug-12	Stage II Widening	Land use change	3	Lawn	Forest	N	826.52	0.1565	Moderate
053B2	053B2-04ES	07-Aug-12	Stage II Widening	Land use change	5	Forest	Forest	N	155.25	0.0294	Moderate
044A3	044A3-96ES	21-Aug-12	Stage II Widening	Land use change	6	Pasture	Forest	N	152.14	0.0288	Moderate
044B3	044B3-54ES	21-Aug-12	Stage I Incision	Other	2	Forest	Forest	N	31.38	0.0059	Moderate
053A2	053A2-59ES	21-Aug-12	Stage II Widening	Pipe outfall	5	Lawn	Forest	N	125.22	0.0237	Moderate
053A2	053A2-66ES	21-Aug-12	Stage II Widening	Land use change	5	Forest	Forest	N	417.09	0.0790	Moderate
053B2	053B2-14ES	21-Aug-12	Stage I Incision	Pipe outfall	4	Lawn	Forest	N	19.19	0.0036	Moderate
053B2	053B2-18ES	21-Aug-12	Stage I Incision	Other	3	Forest	Forest	N	262.15	0.0497	Moderate
053A1	053A1-02ES	17-Jul-12	Stage I Incision	Other	1	Forest	Forest	N	66.45	0.0126	Low Severity
053A1	053A1-08ES	17-Jul-12	Stage III Deposition	Land use change	3	Forest	Other	N	42.58	0.0081	Low Severity

Dulaney Valley Branch Subwatershed SCA Survey Sites:
(Erosion Sites continued from page 13)

Map	Site	Date Assessed	Channel Condition	Cause	Average Exposed Bank Height (ft)	Land Use (Left)	Land Use (Right)	Threat to Infrastructure	Length (ft)	Length (mi)	Severity
053A1	053A1-20ES	17-Jul-12	Stage II Widening	Other	4	Other	Other	N	18.92	0.0036	Low Severity
053A1	053A1-23ES	17-Jul-12	Stage II Widening	Other	2	Other	Other	N	45.62	0.0086	Low Severity
053A2	053A2-04ES	17-Jul-12	Stage III Deposition	Bend at steep slope	4	Forest	Forest	N	59.59	0.0113	Low Severity
053A2	053A2-07ES	17-Jul-12	Stage III Deposition	Other	3	Other	Forest	N	49.78	0.0094	Low Severity
044A3	044A3-01ES	19-Jul-12	Stage I Incision	Other	3	Pasture	Pasture	N	31.81	0.0060	Low Severity
044A3	044A3-10ES	19-Jul-12	Stage I Incision	Other	8	Forest	Pasture	N	63.17	0.0120	Low Severity
044A3	044A3-13ES	19-Jul-12	Stage I Incision	Pipe outfall	2	Pasture	Pasture	N	27.07	0.0051	Low Severity
044A3	044A3-14ES	19-Jul-12	Stage I Incision	Pipe outfall	2	Pasture	Pasture	N	10.31	0.0020	Low Severity
044A3	044A3-17ES	19-Jul-12	Stage II Widening	Bend at steep slope	2	Forest	Forest	N	21.58	0.0041	Low Severity
044A3	044A3-20ES	19-Jul-12	Stage I Incision	Bend at steep slope	2	Forest	Forest	N	17.46	0.0033	Low Severity
044A3	044A3-21ES	19-Jul-12	Stage II Widening	Bend at steep slope	3	Forest	Forest	N	14.61	0.0028	Low Severity
044A3	044A3-25ES	19-Jul-12	Stage II Widening	Other	4	Forest	Forest	N	94.73	0.0179	Low Severity
044A3	044A3-02ES	19-Jul-12	Stage II Widening	Other	4	Pasture	Pasture	N	71.53	0.0135	Low Severity
053A1	053A1-39ES	19-Jul-12	Stage III Deposition	Other	3	Pasture	Pasture	N	28.16	0.0053	Low Severity
053A1	053A1-41ES	19-Jul-12	Stage II Widening	Pipe outfall	3	Pasture	Pasture	N	36.35	0.0069	Low Severity
044A3	044A3-35ES	20-Jul-12	Stage II Widening	Bend at steep slope	3	Forest	Lawn	N	31.56	0.0060	Low Severity
044A3	044A3-37ES	20-Jul-12	Stage II Widening	Bend at steep slope	2	Forest	Lawn	N	44.27	0.0084	Low Severity
044A3	044A3-38ES	20-Jul-12	Stage II Widening	Bend at steep slope	3	Forest	Lawn	N	32.96	0.0062	Low Severity
044A3	044A3-41ES	20-Jul-12	Stage II Widening	Bend at steep slope	3	Forest	Forest	N	17.84	0.0034	Low Severity

Dulaney Valley Branch Subwatershed SCA Survey Sites:
(Erosion Sites continued from page 14)

Map	Site	Date Assessed	Channel Condition	Cause	Average Exposed Bank Height (ft)	Land Use (Left)	Land Use (Right)	Threat to Infrastructure	Length (ft)	Length (mi)	Severity
044A3	044A3-42ES	20-Jul-12	Stage II Widening	Bend at steep slope	4	Forest	Forest	N	22.07	0.0042	Low Severity
044A3	044A3-44ES	20-Jul-12	Stage II Widening	Other	2	Forest	Forest	N	17.72	0.0034	Low Severity
044A3	044A3-45ES	20-Jul-12	Stage II Widening	Bend at steep slope	4	Forest	Forest	N	37.03	0.0070	Low Severity
044A3	044A3-47ES	20-Jul-12	Stage II Widening	Bend at steep slope	3	Forest	Forest	N	4.12	0.0008	Low Severity
044A3	044A3-49ES	20-Jul-12	Stage II Widening	Bend at steep slope	4	Forest	Forest	N	21.88	0.0041	Low Severity
044A3	044A3-50ES	20-Jul-12	Stage II Widening	Land use change	3	Forest	Forest	N	73.53	0.0139	Low Severity
044A3	044A3-51ES	20-Jul-12	Stage II Widening	Land use change	2	Forest	Forest	N	89.30	0.0169	Low Severity
044A3	044A3-52ES	20-Jul-12	Stage II Widening	Land use change	4	Forest	Forest	N	29.00	0.0055	Low Severity
044A3	044A3-53ES	20-Jul-12	Stage II Widening	Land use change	2	Forest	Forest	N	64.31	0.0122	Low Severity
044B3	044B3-04ES	20-Jul-12	Stage II Widening	Other	2	Forest	Forest	N	20.85	0.0039	Low Severity
044B3	044B3-08ES	20-Jul-12	Stage II Widening	Other	3	Forest	Forest	N	11.28	0.0021	Low Severity
044A2	044A2-01ES	24-Jul-12	Stage II Widening	Land use change	3	Forest	Forest	N	33.12	0.0063	Low Severity
044A2	044A2-03ES	24-Jul-12	Stage II Widening	Other	3	Forest	Forest	N	11.34	0.0021	Low Severity
044A2	044A2-04ES	24-Jul-12	Stage II Widening	Other	3	Forest	Forest	N	33.95	0.0064	Low Severity
044B3	044B3-19ES	24-Jul-12	Stage II Widening	Other	4	Forest	Forest	N	22.50	0.0043	Low Severity
053A1	053A1-42ES	24-Jul-12	Stage II Widening	Other	2	Pasture	Pasture	N	21.67	0.0041	Low Severity
053A1	053A1-46ES	24-Jul-12	Stage II Widening	Bend at steep slope	2	Pasture	Pasture	N	42.88	0.0081	Low Severity
053A1	053A1-47ES	24-Jul-12	Stage II Widening	Land use change	3	Pasture	Pasture	N	24.51	0.0046	Low Severity
053A1	053A1-48ES	24-Jul-12	Stage II Widening	Land use change	2	Pasture	Pasture	N	27.80	0.0053	Low Severity

Dulaney Valley Branch Subwatershed SCA Survey Sites:
(Erosion Sites continued from page 15)

Map	Site	Date Assessed	Channel Condition	Cause	Average Exposed Bank Height (ft)	Land Use (Left)	Land Use (Right)	Threat to Infrastructure	Length (ft)	Length (mi)	Severity
044A3	044A3-61ES	26-Jul-12	Stage III Deposition	Bend at steep slope	4	Forest	Forest	N	27.65	0.0052	Low Severity
044A3	044A3-66ES	26-Jul-12	Stage III Deposition	Pipe outfall	3	Other	Forest	N	35.94	0.0068	Low Severity
044A3	044A3-69ES	26-Jul-12	Stage I Incision	Other	2	Forest	Forest	N	27.21	0.0052	Low Severity
044A3	044A3-70ES	26-Jul-12	Stage II Widening	Other	3	Forest	Forest	N	11.19	0.0021	Low Severity
044A3	044A3-71ES	26-Jul-12	Stage II Widening	Other	4	Forest	Forest	N	13.98	0.0026	Low Severity
044A3	044A3-72ES	26-Jul-12	Stage I Incision	Other	3	Forest	Forest	N	4.93	0.0009	Low Severity
044A3	044A3-75ES	26-Jul-12	Stage II Widening	Bend at steep slope	3	Forest	Forest	N	35.60	0.0067	Low Severity
044A3	044A3-76ES	26-Jul-12	Stage II Widening	Bend at steep slope	2	Forest	Forest	N	19.70	0.0037	Low Severity
044A3	044A3-84ES	26-Jul-12	Stage III Deposition	Bend at steep slope	4	Forest	Forest	N	96.76	0.0183	Low Severity
044A3	044A3-85ES	26-Jul-12	Stage II Widening	Bend at steep slope	4	Forest	Forest	N	25.68	0.0049	Low Severity
044A3	044A3-89ES	26-Jul-12	Stage III Deposition	Other	3	Other	Forest	N	31.97	0.0061	Low Severity
053A1	053A1-53ES	26-Jul-12	Stage II Widening	Other	4	Pasture	Pasture	N	43.02	0.0081	Low Severity
053A1	053A1-54ES	26-Jul-12	Stage III Deposition	Bend at steep slope	3	Pasture	Pasture	N	55.52	0.0105	Low Severity
053A1	053A1-55ES	26-Jul-12	Stage II Widening	Land use change	3	Pasture	Pasture	N	58.66	0.0111	Low Severity
053A1	053A1-60ES	26-Jul-12	Stage II Widening	Other	2	Pasture	Pasture	N	32.15	0.0061	Low Severity
053A1	053A1-64ES	26-Jul-12	Stage II Widening	Other	2	Lawn	Forest	N	23.70	0.0045	Low Severity
053A1	053A1-66ES	26-Jul-12	Stage III Deposition	Other	3	Forest	Forest	N	42.49	0.0080	Low Severity
053A1	053A1-68ES	26-Jul-12	Stage II Widening	Other	1	Forest	Forest	N	68.91	0.0131	Low Severity
053A1	053A1-69ES	26-Jul-12	Stage II Widening	Other	2	Forest	Forest	N	58.37	0.0111	Low Severity

Dulaney Valley Branch Subwatershed SCA Survey Sites:
(Erosion Sites continued from page 16)

Map	Site	Date Assessed	Channel Condition	Cause	Average Exposed Bank Height (ft)	Land Use (Left)	Land Use (Right)	Threat to Infrastructure	Length (ft)	Length (mi)	Severity
053A1	053A1-75ES	26-Jul-12	Stage III Deposition	Below road crossing	2	Lawn	Forest	N	217.14	0.0411	Low Severity
053A1	053A1-76ES	26-Jul-12	Stage III Deposition	Below road crossing	2	Lawn	Forest	N	29.06	0.0055	Low Severity
053A1	053A1-78ES	26-Jul-12	Stage I Incision	Land use change	3	Other	Pasture	N	289.21	0.0548	Low Severity
053A1	053A1-56ES	26-Jul-12	Stage II Widening	Other	1	Other	Other	N	79.06	0.0150	Low Severity
053A1	053A1-80ES	27-Jul-12	Stage II Widening	Land use change	4	Other	Other	N	35.58	0.0067	Low Severity
053A1	053A1-81ES	27-Jul-12	Stage II Widening	Land use change	2	Other	Other	N	70.73	0.0134	Low Severity
053A1	053A1-85ES	27-Jul-12	Stage II Widening	Land use change	3	Lawn	Lawn	N	124.38	0.0236	Low Severity
053A1	053A1-104ES	27-Jul-12	Stage II Widening	Land use change	4	Pasture	Forest	N	34.53	0.0065	Low Severity
053A1	053A1-107ES	27-Jul-12	Stage II Widening	Land use change	4	Pasture	Pasture	N	29.39	0.0056	Low Severity
053A1	053A1-108ES	27-Jul-12	Stage II Widening	Land use change	6	Pasture	Pasture	N	70.04	0.0133	Low Severity
053A1	053A1-109ES	27-Jul-12	Stage II Widening	Land use change	3	Pasture	Pasture	N	100.79	0.0191	Low Severity
053A1	053A1-110ES	27-Jul-12	Stage III Deposition	Land use change	6	Pasture	Pasture	N	4.39	0.0008	Low Severity
053A1	053A1-111ES	27-Jul-12	Stage II Widening	Below road crossing	3	Pasture	Pasture	N	23.88	0.0045	Low Severity
053A2	053A2-12ES	27-Jul-12	Stage II Widening	Other	2	Forest	Forest	N	34.88	0.0066	Low Severity
053A2	053A2-23ES	27-Jul-12	Stage I Incision	Land use change	1	Forest	Lawn	N	32.27	0.0061	Low Severity
053A2	053A2-21ES	27-Jul-12	Stage I Incision	Land use change	3	Forest	Lawn	N	178.78	0.0339	Low Severity
044B3	044B3-22ES	31-Jul-12	Stage II Widening	Land use change	3	Forest	Forest	N	115.99	0.0220	Low Severity
044B3	044B3-24ES	31-Jul-12	Stage II Widening	Land use change	4	Forest	Forest	N	112.46	0.0213	Low Severity
053A1	053A1-113ES	31-Jul-12	Stage I Incision	Land use change	3	Forest	Lawn	N	105.10	0.0199	Low Severity

Dulaney Valley Branch Subwatershed SCA Survey Sites:
(Erosion Sites continued from page 17)

Map	Site	Date Assessed	Channel Condition	Cause	Average Exposed Bank Height (ft)	Land Use (Left)	Land Use (Right)	Threat to Infrastructure	Length (ft)	Length (mi)	Severity
053A1	053A1-119ES	31-Jul-12	Stage I Incision	Land use change	2	Lawn	Pasture	N	164.84	0.0312	Low Severity
053A1	053A1-126ES	31-Jul-12	Stage II Widening	Land use change	3	Pasture	Pasture	N	15.95	0.0030	Low Severity
053A1	053A1-128ES	31-Jul-12	Stage II Widening	Land use change	2	Pasture	Pasture	N	145.36	0.0275	Low Severity
053A1	053A1-129ES	31-Jul-12	Stage II Widening	Land use change	2	Pasture	Pasture	N	7.19	0.0014	Low Severity
053A1	053A1-132ES	31-Jul-12	Stage II Widening	Land use change	2	Pasture	Pasture	N	96.80	0.0183	Low Severity
053A1	053A1-133ES	31-Jul-12	Stage II Widening	Land use change	3	Pasture	Pasture	N	58.27	0.0110	Low Severity
053B1	053B1-04ES	31-Jul-12	Stage II Widening	Land use change	3	Forest	Forest	N	8.28	0.0016	Low Severity
053B1	053B1-05ES	31-Jul-12	Stage III Deposition	Land use change	4	Forest	Forest	N	94.24	0.0178	Low Severity
053B1	053B1-14ES	31-Jul-12	Stage II Widening	Land use change	3	Forest	Pasture	N	129.85	0.0246	Low Severity
053B1	053B1-15ES	31-Jul-12	Stage II Widening	Land use change	2	Forest	Forest	N	26.73	0.0051	Low Severity
053B1	053B1-02ES	31-Jul-12	Stage I Incision	Land use change	2	Forest	Lawn	N	96.84	0.0183	Low Severity
044B3	044B3-34ES	03-Aug-12	Stage II Widening	Land use change	3	Multiflora	Forest	N	165.84	0.0314	Low Severity
044B3	044B3-45ES	03-Aug-12	Stage II Widening	Land use change	8	Forest	Forest	N	43.01	0.0081	Low Severity
053B1	053B1-26ES	03-Aug-12	Stage I Incision	Other	3	Forest	Forest	N	23.37	0.0044	Low Severity
053A2	053A2-31ES	07-Aug-12	Stage II Widening	Land use change	3	Forest	Forest	N	39.83	0.0075	Low Severity
053A2	053A2-32ES	07-Aug-12	Stage III Deposition	Bend at steep slope	4	Forest	Forest	N	44.96	0.0085	Low Severity
053B2	053B2-01ES	07-Aug-12	Stage II Widening	Bend at steep slope	4	Forest	Forest	N	81.83	0.0155	Low Severity
053A2	053A2-53ES	21-Aug-12	Stage II Widening	Other	5	Forest	Other	N	143.47	0.0272	Low Severity
053A2	053A2-62ES	21-Aug-12	Stage II Widening	Land use change	4	Lawn	Forest	N	113.04	0.0214	Low Severity

Dulaney Valley Branch Subwatershed SCA Survey Sites:
(Erosion Sites continued from page 18)

Map	Site	Date Assessed	Channel Condition	Cause	Average Exposed Bank Height (ft)	Land Use (Left)	Land Use (Right)	Threat to Infrastructure	Length (ft)	Length (mi)	Severity
053A2	053A2-68ES	21-Aug-12	Stage II Widening	Land use change	4	Forest	Forest	N	34.18	0.0065	Low Severity
053A1	053A1-01ES	17-Jul-12	Stage III Deposition	Other	4	Forest	Forest	N	122.40	0.0232	Minor
053A1	053A1-05ES	17-Jul-12	Stage IV Recovery and Reconstruction	Other	2	Other	Other	N	23.96	0.0045	Minor
053A1	053A1-07ES	17-Jul-12	Stage I Incision	Other	1	Forest	Other	N	19.34	0.0037	Minor
053A1	053A1-11ES	17-Jul-12	Stage I Incision	Land use change	3	Forest	Other	N	104.19	0.0197	Minor
053A1	053A1-13ES	17-Jul-12	Stage II Widening	Other	3	Other	Other	N	26.63	0.0050	Minor
053A1	053A1-14ES	17-Jul-12	Stage II Widening	Other	3	Other	Other	N	12.65	0.0024	Minor
053A1	053A1-15ES	17-Jul-12	Stage II Widening	Other	1	Other	Other	N	20.66	0.0039	Minor
053A1	053A1-16ES	17-Jul-12	Stage II Widening	Other	4	Forest	Other	N	28.54	0.0054	Minor
053A1	053A1-18ES	17-Jul-12	Stage I Incision	Other	3	Other	Other	N	113.01	0.0214	Minor
053A1	053A1-19ES	17-Jul-12	Stage I Incision	Other	2	Other	Other	N	19.65	0.0037	Minor
053A1	053A1-21ES	17-Jul-12	Stage II Widening	Other	2	Other	Other	N	56.63	0.0107	Minor
053A1	053A1-22ES	17-Jul-12	Stage II Widening	Other	2	Other	Other	N	30.38	0.0058	Minor
053A1	053A1-24ES	17-Jul-12	Stage III Deposition	Other	3	Other	Other	N	86.40	0.0164	Minor
053A1	053A1-25ES	17-Jul-12	Stage II Widening	Other	3	Other	Other	N	51.42	0.0097	Minor
053A2	053A2-01ES	17-Jul-12	Stage II Widening	Below road crossing	2	Forest	Forest	N	193.67	0.0367	Minor
053A2	053A2-05ES	17-Jul-12	Stage IV Recovery and Reconstruction	Other	2	Forest	Forest	N	80.12	0.0152	Minor
053A2	053A2-10ES	17-Jul-12	Stage III Deposition	Other	2	Forest	Forest	N	15.16	0.0029	Minor

Dulaney Valley Branch Subwatershed SCA Survey Sites:
(Erosion Sites continued from page 19)

Map	Site	Date Assessed	Channel Condition	Cause	Average Exposed Bank Height (ft)	Land Use (Left)	Land Use (Right)	Threat to Infrastructure	Length (ft)	Length (mi)	Severity
053A2	053A2-11ES	17-Jul-12	Stage III Deposition	Land use change	5	Shrubs and small trees	Forest	N	73.23	0.0139	Minor
044A3	044A3-03ES	19-Jul-12	Stage IV Recovery and Reconstruction	Land use change	7	Forest	Pasture	N	121.46	0.0230	Minor
044A3	044A3-05ES	19-Jul-12	Stage II Widening	Other	4	Forest	Pasture	N	33.00	0.0063	Minor
044A3	044A3-15ES	19-Jul-12	Stage IV Recovery and Reconstruction	Other	2	Pasture	Pasture	N	7.61	0.0014	Minor
044A3	044A3-26ES	19-Jul-12	Stage III Deposition	Other	4	Forest	Forest	N	36.71	0.0070	Minor
053A1	053A1-26ES	19-Jul-12	Stage IV Recovery and Reconstruction	Land use change	2	Pasture	Pasture	N	81.49	0.0154	Minor
053A1	053A1-27ES	19-Jul-12	Stage IV Recovery and Reconstruction	Land use change	2	Pasture	Pasture	N	48.75	0.0092	Minor
053A1	053A1-29ES	19-Jul-12	Stage I Incision	Land use change	2	Pasture	Pasture	N	72.45	0.0137	Minor
053A1	053A1-30ES	19-Jul-12	Stage I Incision	Land use change	1	Pasture	Forest	N	24.67	0.0047	Minor
053A1	053A1-31ES	19-Jul-12	Stage II Widening	Other	2	Pasture	Pasture	N	13.85	0.0026	Minor
053A1	053A1-32ES	19-Jul-12	Stage III Deposition	Other	2	Pasture	Pasture	N	33.23	0.0063	Minor
053A1	053A1-34ES	19-Jul-12	Stage II Widening	Other	1	Pasture	Pasture	N	15.80	0.0030	Minor
053A1	053A1-35ES	19-Jul-12	Stage II Widening	Other	2	Pasture	Pasture	N	12.22	0.0023	Minor
053A1	053A1-36ES	19-Jul-12	Stage IV Recovery and Reconstruction	Land use change	3	Pasture	Pasture	N	108.62	0.0206	Minor
053A1	053A1-37ES	19-Jul-12	Stage III Deposition	Other	3	Pasture	Pasture	N	23.64	0.0045	Minor
044A3	044A3-46ES	20-Jul-12	Stage II Widening	Bend at steep slope	1	Forest	Forest	N	16.72	0.0032	Minor

Dulaney Valley Branch Subwatershed SCA Survey Sites:
(Erosion Sites continued from page 20)

Map	Site	Date Assessed	Channel Condition	Cause	Average Exposed Bank Height (ft)	Land Use (Left)	Land Use (Right)	Threat to Infrastructure	Length (ft)	Length (mi)	Severity
044B3	044B3-05ES	20-Jul-12	Stage II Widening	Other	1	Forest	Forest	N	17.64	0.0033	Minor
044A2	044A2-02ES	24-Jul-12	Stage II Widening	Land use change	2	Forest	Forest	N	20.63	0.0039	Minor
044A3	044A3-60ES	24-Jul-12	Stage II Widening	Bend at steep slope	3	Forest	Forest	N	38.12	0.0072	Minor
044B3	044B3-09ES	24-Jul-12	Stage II Widening	Bend at steep slope	3	Forest	Forest	N	10.79	0.0020	Minor
044A3	044A3-65ES	26-Jul-12	Stage III Deposition	Other	3	Forest	Forest	N	9.18	0.0017	Minor
044A3	044A3-77ES	26-Jul-12	Stage II Widening	Bend at steep slope	3	Forest	Forest	N	10.35	0.0020	Minor
044A3	044A3-78ES	26-Jul-12	Stage II Widening	Bend at steep slope	2	Forest	Forest	N	39.49	0.0075	Minor
044A3	044A3-79ES	26-Jul-12	Stage II Widening	Bend at steep slope	3	Forest	Forest	N	16.88	0.0032	Minor
044A3	044A3-82ES	26-Jul-12	Stage II Widening	Bend at steep slope	2	Forest	Forest	N	19.01	0.0036	Minor
044A3	044A3-83ES	26-Jul-12	Stage III Deposition	Bend at steep slope	2	Forest	Forest	N	21.63	0.0041	Minor
044A3	044A3-88ES	26-Jul-12	Stage II Widening	Other	2	Other	Forest	N	33.91	0.0064	Minor
044A3	044A3-94ES	26-Jul-12	Stage III Deposition	Other	1	Forest	Forest	N	88.58	0.0168	Minor
053A1	053A1-52ES	26-Jul-12	Stage II Widening	Other	2	Pasture	Pasture	N	14.20	0.0027	Minor
053A1	053A1-83ES	27-Jul-12	Stage II Widening	Land use change	3	Lawn	Lawn	N	267.94	0.0507	Minor
053A1	053A1-105ES	27-Jul-12	Stage II Widening	Land use change	2	Pasture	Pasture	N	33.74	0.0064	Minor
053B1	053B1-31ES	03-Aug-12	Stage II Widening	Land use change	3	Forest	Forest	N	147.25	0.0279	Minor
053A2	053A2-57ES	21-Aug-12	Stage II Widening	Other	2	Forest	Forest	N	88.29	0.0167	Minor

Dulaney Valley Branch Subwatershed SCA Survey Sites:
Fish Barriers

Map	Site	Date Assessed	Blockage Type	Barrier Type	Reason	Water Drop (in)	Water Depth (in)	Severity
044A3	044A3-33FB	20-Jul-12	Total	Pipe Crossing	Too high	12	1	Very Severe
044A3	044A3-58FB	24-Jul-12	Total	Natural Falls	Too high	240	4	Very Severe
053A1	053A1-73FB	26-Jul-12	Total	Road Crossing	Too high	8	1	Very Severe
053A1	053A1-117FB	31-Jul-12	Total	Road Crossing	Too high	24	1	Very Severe
053B1	053B1-13FB	31-Jul-12	Total	Dam	Too high	144	1	Very Severe
044A3	044A3-43FB	20-Jul-12	Total	Natural Falls	Too high	48	1	Severe
044A3	044A3-56FB	20-Jul-12	Total	Natural Falls	Too high	60	1	Severe
053A1	053A1-77FB	26-Jul-12	Temporary	Debris Dam	Too high	24	1	Severe
053A2	053A2-36FB	07-Aug-12	Partial	Debris Dam	Too high	24	2	Severe
053A2	053A2-47FB	07-Aug-12	Temporary	Debris Dam	Too high	24	1	Severe
044A3	044A3-18FB	19-Jul-12	Partial	Other	Too high	6	1	Moderate

Dulaney Valley Branch Subwatershed SCA Survey Sites:
(Fish Barriers continued from page 22)

Map	Site	Date Assessed	Blockage Type	Barrier Type	Reason	Water Drop (in)	Water Depth (in)	Severity
044A3	044A3-34FB	20-Jul-12	Total	Natural Falls	Too high	18	1	Moderate
044A3	044A3-39FB	20-Jul-12	Total	Natural Falls	Too high	29	1	Moderate
044A3	044A3-40FB	20-Jul-12	Total	Natural Falls	Too high	18	1	Moderate
044A3	044A3-63FB	26-Jul-12	Total	Debris Dam	Too high	24	1	Moderate
044A3	044A3-86FB	26-Jul-12	Temporary	Debris Dam	Too high	36	1	Moderate
044A3	044A3-90FB	26-Jul-12	Partial	Debris Dam	Too high	24	1	Moderate
053A1	053A1-57FB	26-Jul-12	Temporary	Debris Dam	Too high	6	3	Moderate
053A1	053A1-62FB	26-Jul-12	Partial	Other	Too high	24	1	Moderate
053A1	053A1-67FB	26-Jul-12	Temporary	Debris Dam	Too high	12	1	Moderate
053A1	053A1-92FB	27-Jul-12	Partial	Other	Too high	12	1	Moderate
053A2	053A2-35FB	07-Aug-12	Temporary	Debris Dam	Too high	18	2	Moderate

Dulaney Valley Branch Subwatershed SCA Survey Sites:
(Fish Barriers continued from page 23)

Map	Site	Date Assessed	Blockage Type	Barrier Type	Reason	Water Drop (in)	Water Depth (in)	Severity
053A1	053A1-51FB	26-Jul-12	Temporary	Debris Dam	Too shallow	6	1	Low Severity
053A1	053A1-61FB	26-Jul-12	Partial	Natural Falls	Too high	12	1	Low Severity
053A1	053A1-71FB	26-Jul-12	Temporary	Debris Dam	Too high	6	2	Low Severity
053A2	053A2-17FB	27-Jul-12	Temporary	Debris Dam	Too high	12	3	Low Severity
053A1	053A1-118FB	31-Jul-12	Temporary	Debris Dam	Too high	8	1	Low Severity
044A3	044A3-06FB	19-Jul-12	Partial	Other	Too high	6	2	Minor
044A3	044A3-12FB	19-Jul-12	Temporary	Debris Dam	Too shallow	12	1	Minor
044A3	044A3-19FB	19-Jul-12	Temporary	Other	Too high	4	1	Minor
053A1	053A1-28FB	19-Jul-12	Partial	Other	Too high	3	1	Minor
053A1	053A1-33FB	19-Jul-12	Temporary	Debris Dam	Too high	24	1	Minor
044A3	044A3-62FB	26-Jul-12	Partial	Natural Falls	Too high	12	2	Minor

Dulaney Valley Branch Subwatershed SCA Survey Sites:
Pipe Outfalls

Map	Site	Date Assessed	Type of Outfall	Type of Pipe	Location	Pipe Diameter (in)	Channel Width (ft)	Discharge	Color	Odor	Severity
044A3	044A3-31PO	19-Jul-12	Stormwater	Corrugated Pipe	Head of Stream	12	8	N	NA	NA	Very Severe
053A1	053A1-50PO	24-Jul-12	Other	Concrete Pipe	Head of Stream	48	20	Y	Clear	None	Very Severe
053A1	053A1-96PO	27-Jul-12	Other	Other	Left Bank	8	3	Y	Clear	None	Very Severe
053A2	053A2-25PO	27-Jul-12	Stormwater	Concrete Pipe	Right Bank	24	4	N	NA	NA	Very Severe
053B2	053B2-13PO	21-Aug-12	Stormwater	Concrete Pipe	Head of Stream	36	9	N	NA	NA	Very Severe
044B3	044B3-03PO	20-Jul-12	Stormwater	Corrugated Pipe	Head of Stream	24	2	N	NA	NA	Severe
053A2	053A2-24PO	27-Jul-12	Other	Concrete Pipe	Head of Stream	36	8	Y	Clear	None	Severe
044B3	044B3-27PO	31-Jul-12	Stormwater	Concrete Pipe	Head of Stream	Unknown	2	N	NA	NA	Severe
044B3	044B3-29PO	03-Aug-12	Stormwater	Concrete Pipe	Head of Stream	36	8	N	NA	NA	Severe
053A1	053A1-139PO	07-Aug-12	Stormwater	Concrete Pipe	Head of Stream	24	3	N	NA	NA	Severe
053A2	053A2-64PO	21-Aug-12	Other	Corrugated Pipe	Head of Stream	12	7	Y	Clear	None	Severe
044B3	044B3-14PO	24-Jul-12	Stormwater	Concrete Pipe	Head of Stream	36	3	N	NA	NA	Moderate
044A3	044A3-68PO	26-Jul-12	Other	Corrugated Pipe	Head of Stream	48	3	Y	Clear	None	Moderate
044A3	044A3-92PO	26-Jul-12	Other	Corrugated Pipe	Head of Stream	48	5	Y	Clear	None	Moderate
053A1	053A1-72PO	26-Jul-12	Other	Corrugated Pipe	Head of Stream	36	5	Y	Clear	None	Moderate

Dulaney Valley Branch Subwatershed SCA Survey Sites:
(Pipe Outfalls continued from page 25)

Map	Site	Date Assessed	Type of Outfall	Type of Pipe	Location	Pipe Diameter (in)	Channel Width (ft)	Discharge	Color	Odor	Severity
053A2	053A2-19PO	27-Jul-12	Stormwater	Concrete Pipe	Head of Stream	18	2	Y	Clear	None	Moderate
044B3	044B3-43PO	03-Aug-12	Other	Plastic	Right Bank	6	8	N	NA	NA	Moderate
053A2	053A2-61PO	21-Aug-12	Other	Concrete Pipe	Head of Stream	30	8	Y	Clear	None	Moderate
044B3	044B3-07PO	20-Jul-12	Stormwater	Corrugated Pipe	Head of Stream	12	1	N	NA	NA	Low Severity
053A1	053A1-91PO	27-Jul-12	Stormwater	Plastic	Right Bank	3	5	N	NA	NA	Low Severity
053A1	053A1-95PO	27-Jul-12	Stormwater	Plastic	Right Bank	4	5	N	NA	NA	Low Severity
053A2	053A2-19PO	27-Jul-12	Other	Concrete Pipe	Head of Stream	60	5	Y	Clear	None	Low Severity
053A1	053A1-116PO	31-Jul-12	Other	Concrete Pipe	Head of Stream	48	12	Y	Clear	None	Low Severity
053A1	053A1-124PO	31-Jul-12	Stormwater	Unknown	Head of Stream	Unknown	3	N	NA	NA	Low Severity
053B1	053B1-10PO	31-Jul-12	Stormwater	Plastic	Right Bank	4	12	N	NA	NA	Low Severity
053B1	053B1-11PO	31-Jul-12	Other	Concrete Pipe	Head of Stream	36	4	Y	Clear	None	Low Severity
053B1	053B1-12PO	31-Jul-12	Other	Concrete Pipe	Head of Stream	36	6	Y	Clear	None	Low Severity
053B1	053B1-01PO	31-Jul-12	Stormwater	Concrete	Head of Stream	24	10	N	NA	NA	Low Severity
053B1	053B1-23PO	03-Aug-12	Stormwater	Concrete Channel		6	1	N	NA	NA	Low Severity
053B1	053B1-34PO	03-Aug-12	Stormwater	Concrete Pipe	Head of Stream	36	3	N	NA	NA	Low Severity

Dulaney Valley Branch Subwatershed SCA Survey Sites:
(Pipe Outfalls continued from page 26)

Map	Site	Date Assessed	Type of Outfall	Type of Pipe	Location	Pipe Diameter (in)	Channel Width (ft)	Discharge	Color	Odor	Severity
053B2	053B2-07PO	07-Aug-12	Stormwater	Corrugated Pipe	Head of Stream	12	10	N	NA	NA	Low Severity
053A1	053A1-82PO	27-Jul-12	Stormwater	Other	Both sides	4	30	N	NA	NA	Minor
053A1	053A1-93PO	27-Jul-12	Other	Concrete Pipe	Head of Stream	36	8	N	NA	NA	Minor
053A1	053A1-98PO	27-Jul-12	Stormwater	Plastic	Right Bank	4	6	N	NA	NA	Minor
053A1	053A1-100PO	27-Jul-12	Stormwater	Plastic	Left Bank	4	1	N	NA	NA	Minor
053A1	053A1-102PO	27-Jul-12	Pumping Station	Other	Right Bank	0	7	N	NA	NA	Minor
053B1	053B1-16PO	31-Jul-12	Stormwater	Concrete Pipe	Left Bank	18	2	N	NA	NA	Minor
044B3	044B3-51PO	03-Aug-12	Other	Concrete Pipe	Head of Stream	24	6	N	NA	NA	Minor
053B1	053B1-24PO	03-Aug-12	Other	Concrete Pipe	Head of Stream	36	9	Y	Clear	None	Minor
053B1	053B1-29PO	03-Aug-12	Other	Corrugated Pipe	Head of Stream	84	9	Y	Clear	None	Minor
053B1	053B1-32PO	03-Aug-12	Stormwater	Concrete Pipe	Right Bank	18	1	N	NA	NA	Minor
053A2	053A2-30PO	07-Aug-12	Other	Concrete Pipe	Head of Stream		15	Y	Clear	None	Minor
053A2	053A2-37PO	07-Aug-12	Stormwater	Plastic	Right Bank	4	15	N	NA	NA	Minor
053A2	053A2-42PO	07-Aug-12	Other	Smooth Metal Pipe	Head of Stream	6	5	N	NA	NA	Minor
053B2	053B2-09PO	07-Aug-12	Stormwater	Concrete Pipe	Head of Stream	18	2	N	NA	NA	Minor

Dulaney Valley Branch Subwatershed SCA Survey Sites:
(Pipe Outfalls continued from page 27)

Map	Site	Date Assessed	Type of Outfall	Type of Pipe	Location	Pipe Diameter (in)	Channel Width (ft)	Discharge	Color	Odor	Severity
053A2	053A2-55PO	21-Aug-12	Other	Plastic	Right Bank	6	3	N	NA	NA	Minor
053A2	053A2-60PO	21-Aug-12	Stormwater	Plastic	Left Bank	4	6	N	NA	NA	Minor
053B2	053B2-20PO	21-Aug-12	Stormwater	Concrete Pipe	Head of Stream	36	4	N	NA	NA	Minor
053B2	053B2-22PO	21-Aug-12	Stormwater	Plastic	Right Bank	4	3	N	NA	NA	Minor

Dulaney Valley Branch Subwatershed-SCA Survey Sites:
Exposed Pipes

Map	Site	Date Assessed	Pipe Is	Type of Pipe	Pipe Diameter (in)	Length Exposed (ft)	Purpose of Pipe	Evidence of Discharge	Color	Odor	Severity
053A1	053A1-10EP	17-Jul-12	Exposed along stream	Smooth Metal	Unknown	20	Other	N	NA	NA	Severe
044A3	044A3-16EP	19-Jul-12	Exposed along stream	Plastic	24	6	Other	Y	Clear	None	Severe
053B1	053B1-03EP	31-Jul-12	Exposed across botto	Plastic	8	4	Unknown	N	NA	NA	Severe
044B3	044B3-10EP	24-Jul-12	Exposed across botto	Concrete	10	5	Unknown	N	NA	NA	Moderate
044B3	044B3-11EP	24-Jul-12	Exposed across botto	Smooth Metal	12	8	Unknown	N	NA	NA	Moderate
053A1	053A1-63EP	26-Jul-12	Exposed along stream	Concrete	24	15	Unknown	N	NA	NA	Moderate
053A2	053A2-56EP	21-Aug-12	Exposed across botto	Corrugated Metal	12	5	Stormwater	N	NA	NA	Moderate
044B3	044B3-26EP	31-Jul-12	Exposed across botto	Smooth Metal	1	5	Unknown	N	NA	NA	Low Severity
053A1	053A1-04EP	17-Jul-12	Exposed along stream	Smooth Metal	48	16	Unknown	N	NA	NA	Minor

Dulaney Valley Branch Subwatershed-SCA Survey Sites:
(Exposed Pipes continued from page 29)

Map	Site	Date Assessed	Pipe Is	Type of Pipe	Pipe Diameter (in)	Length Exposed (ft)	Purpose of Pipe	Evidence of Discharge	Color	Odor	Severity
053A1	053A1-84EP	27-Jul-12	Other	Plastic	3	1	Stormwater	N	NA	NA	Minor

Dulaney Valley Branch Subwatershed SCA Survey Sites:
Inadequate Buffers

Map	Site	Date Assessed	Buffer Inadequate On	Stream Unshaded On	Buffer Width Left (ft)	Buffer Length Left (ft)	Buffer Width Right (ft)	Buffer Length Right (ft)	Land Use (Left)	Land Use (Right)	Buffer Recently Established	Livestock Present	Type	Length (ft)	Length (mi)	Severity
053A1	053A1-03IB	17-Jul-12	Both	Both	10	3500	10	3500	Other	Other	Y	N		3853.70	0.730	Severe
053A1	053A1-106IB	27-Jul-12	Both	Neither	5	3000	15	3000	Pasture	Pasture	N	N		3453.08	0.654	Severe
044A3	044A3-04IB	19-Jul-12	Right	Both	100	NA	20	550	Pasture	Pasture	N	N		546.47	0.103	Moderate
053A1	053A1-40IB	19-Jul-12	Both	Both	0	400	0	400	Pasture	Pasture	N	N		405.89	0.077	Moderate
053A1	053A1-43IB	24-Jul-12	Both	Neither	10	1500	10	1500	Pasture	Pasture	N	N		1583.81	0.300	Moderate
053A1	053A1-70IB	26-Jul-12	Both	Neither	20	1000	20	1000	Pasture	Lawn	N	N		1386.07	0.263	Moderate
053A1	053A1-79IB	27-Jul-12	Both	Both	20	1000	20	1000	Lawn	Lawn	N	N		1155.59	0.219	Moderate
053A1	053A1-88IB	27-Jul-12	Right	Neither	50	NA	10	1000	Lawn	Lawn	N	N		1073.49	0.203	Moderate
053A1	053A1-120IB	31-Jul-12	Both	Neither	10	500	25	500	Lawn	Pasture	N	Y	Horses	679.06	0.129	Moderate
053A1	053A1-125IB	31-Jul-12	Both	Neither	10	1000	10	1000	Pasture	Pasture	N	N		1101.91	0.209	Moderate
053A2	053A2-65IB	21-Aug-12	Both	Both	0	70	0	70	Other	Other	N	N		136.57	0.026	Moderate
053A2	053A2-02IB	17-Jul-12	Right	Right	30	NA	25	60	Forest	Pasture	N	N		59.18	0.011	Low Severity
053A2	053A2-08IB	17-Jul-12	Left	Left	75	415	50	NA	Forest	Forest	N	N		418.73	0.079	Low Severity
044A3	044A3-09IB	19-Jul-12	Right	Neither	100	NA	20	360	Forest	Pasture	N	N		360.23	0.068	Low Severity
044A3	044A3-36IB	20-Jul-12	Right	Neither	100	NA	5	300	Forest	Lawn	N	N		275.82	0.052	Low Severity
044B3	044B3-02IB	20-Jul-12	Right	Neither	100	NA	15	100	Forest	Lawn	N	N		108.80	0.021	Low Severity

Dulaney Valley Branch Subwatershed SCA Survey Sites:
(Inadequate Buffers continued from page 31)

Map	Site	Date Assessed	Buffer Inadequate On	Stream Unshaded On	Buffer Width Left (ft)	Buffer Length Left (ft)	Buffer Width Right (ft)	Buffer Length Right (ft)	Land Use (Left)	Land Use (Right)	Buffer Recently Established	Livestock Present	Type	Length (ft)	Length (mi)	Severity
044A2	044A2-05IB	24-Jul-12	Right	Neither	100	NA	0	90	Forest	Forest	N	N		90.77	0.017	Low Severity
044B2	044B2-01IB	24-Jul-12	Right	Neither	100	NA	10	700	Forest	Pasture	N	N		694.88	0.132	Low Severity
053A1	053A1-103IB	27-Jul-12	Right	Neither	75	NA	10	300	Forest	Pasture	N	N		323.44	0.061	Low Severity
053A1	053A1-112IB	31-Jul-12	Right	Neither	100	NA	30	700	Forest	Lawn	N	N		747.85	0.142	Low Severity
053B1	053B1-09IB	31-Jul-12	Both	Neither	10	400	10	400	Lawn	Lawn	N	N		442.93	0.084	Low Severity
044A2	044A2-09IB	03-Aug-12	Left	Neither	30	570	100	NA	Pasture	Forest	N	N		570.35	0.108	Low Severity
044B3	044B3-30IB	03-Aug-12	Right	Neither	100	NA	10	1000	Forest	Lawn	N	N		1219.71	0.231	Low Severity
044B3	044B3-41IB	03-Aug-12	Left	Neither	10	200	100	NA	Lawn	Forest	N	N		214.00	0.041	Low Severity
044B3	044B3-50IB	03-Aug-12	Left	Neither	15	250	100	NA	Multiflora	Forest	N	N		254.31	0.048	Low Severity
053B1	053B1-21IB	03-Aug-12	Both	Neither	10	300	30	300	Pasture	Lawn	N	N		321.53	0.061	Low Severity
053B1	053B1-35IB	03-Aug-12	Left	Neither	20	400	100	NA	Pasture	Forest	N	N		402.25	0.076	Low Severity
053A1	053A1-137IB	07-Aug-12	Both	Neither	30	580	10	580	Lawn	Lawn	N	N		578.75	0.110	Low Severity
053A2	053A2-40IB	07-Aug-12	Both	Both	0	50	0	50	Other	Other	N	N		45.79	0.009	Low Severity
053A2	053A2-45IB	07-Aug-12	Left	Neither	10	450	100	NA	Other	Multiflora	Y	N		445.15	0.084	Low Severity
053B2	053B2-10IB	07-Aug-12	Both	Both	0	130	0	130	Other	Lawn	N	N		130.11	0.025	Low Severity
044A3	044A3-97IB	21-Aug-12	Left	Neither	10	100	100	NA	Pasture	Forest	N	N		106.59	0.020	Low Severity
053A2	053A2-52IB	21-Aug-12	Right	Right	100	NA	0	200	Forest	Other	N	N		213.59	0.040	Low Severity

Dulaney Valley Branch Subwatershed SCA Survey Sites:
(Inadequate Buffers continued from page 32)

Map	Site	Date Assessed	Buffer Inadequate On	Stream Unshaded On	Buffer Width Left (ft)	Buffer Length Left (ft)	Buffer Width Right (ft)	Buffer Length Right (ft)	Land Use (Left)	Land Use (Right)	Buffer Recently Established	Livestock Present	Type	Length (ft)	Length (mi)	Severity
053A2	053A2-58IB	21-Aug-12	Left	Neither	0	500	100	NA	Lawn	Forest	N	N		500.29	0.095	Low Severity
053B2	053B2-19IB	21-Aug-12	Both	Both	10	500	10	500	Lawn	Lawn	N	N		492.48	0.093	Low Severity
044A3	044A3-11IB	19-Jul-12	Both	Neither	100	150	30	150	Forest	Pasture	N	N		147.23	0.028	Minor
044A3	044A3-23IB	19-Jul-12	Left	Neither	100	100	100	NA	Lawn	Lawn	N	N		105.28	0.020	Minor
044A3	044A3-30IB	19-Jul-12	Left	Neither	10	100	100	NA	Lawn	Forest	N	N		102.17	0.019	Minor
044A3	044A3-87IB	26-Jul-12	Left	Neither	30	250	100	NA	Lawn	Lawn	N	N		262.68	0.050	Minor
053A1	053A1-87IB	27-Jul-12	Left	Neither	0	100	100	NA	Lawn	Forest	N	N		108.18	0.020	Minor
053A2	053A2-15IB	27-Jul-12	Both	Neither	50	450	50	450	Lawn	Forest	N	N		455.66	0.086	Minor
053B2	053B2-03IB	07-Aug-12	Right	Neither	100	NA	10	300	Forest	Lawn	N	N		311.68	0.059	Minor
053B2	053B2-06IB	07-Aug-12	Both	Neither	20	90	10	90	Other	Lawn	N	N		91.56	0.017	Minor
053A2	053A2-67IB	21-Aug-12	Left	Neither	10	100	100	NA	Other	Forest	N	N		100.42	0.019	Minor

Dulaney Valley Branch Subwatershed SCA Survey Sites:
In or Near Stream Construction

Map	Site	Date Assessed	Type of Activity	Sediment Control	If Inadequate Why	Below Site Sediment	Length Affected (ft)	Construction Company Name	Severity
044A3	044A3-IC81	26-Jul-12	Other	Unknown		Y			Moderate

Dulaney Valley Branch Subwatershed SCA Survey Sites:
Trash Dumping

Map	Site	Date Assessed	Type of Trash	Amount Pick up Trash Loads	Other Measure	Trash Confined To	Site For Volunteers	Land Ownership	Name if Public	Severity
044A3	044A3-91TD	26-Jul-12	Residential	1		Single Site	Y	Private		Moderate
044B3	044B3-13TD	24-Jul-12	Residential	1		Single Site	Y	Unknown		Minor

Appendix G

Summary of Upland Assessments

Neighborhood Source Area (NSA) Data

NSA ID	Subwatershed	Neighborhood_Name	PSI	ROI	NSA Acres	Imperv Acres	% Imperv
NSA_R_01	Dulaney Valley Branch	Lakeside	Moderate	Low	43.5	4.6	11%
NSA_R_02	Dulaney Valley Branch	Manorview Road	Moderate	Moderate	20.6	2.1	10%
NSA_R_03	Dulaney Valley Branch	Woodcrest Lane	Low	Low	38.1	1.5	4%
NSA_R_04	Dulaney Valley Branch	Windmere / Manor Hill	Moderate	Moderate	195.9	19.2	10%
NSA_R_05	Dulaney Valley Branch	Dulaney Hills	Moderate	Moderate	136.6	10.1	7%
NSA_R_06	Overshot Run	Sunnybrook	Moderate	Moderate	74.5	11.5	15%
NSA_R_07	Dulaney Valley Branch	Ravenhurst	Moderate	Low	57.9	5.7	10%
NSA_R_08	Jenkins Run; Dulaney Valley Branch; Fitzhugh Run	Eagles Nest	Moderate	Low	48.7	5.5	11%
NSA_R_09	Dulaney Valley Branch	Holly Knoll Estates	Moderate	Moderate	92.9	8.3	9%
NSA_R_10	Dulaney Valley Branch	Dulaney Valley Rd	Moderate	Moderate	102.4	10.4	10%
NSA_R_11	Dulaney Valley Branch	Valley View	Moderate	Moderate	53.4	6.2	12%
NSA_R_12	Fitzhugh Run; Overshot Run	Blenheim Manor	Moderate	Moderate	53.5	5.8	11%
NSA_R_13	Dulaney Valley Branch	Kimberly	Moderate	Moderate	188.2	8.9	5%
NSA_R_14	Greene Branch; Overshot Run	Jarrettsville Pike	Moderate	Low	47.8	6.1	13%
NSA_R_15	Greene Branch; Overshot Run	Cambria Manor and Merrymans Mill	Moderate	Moderate	96.4	8.0	8%
NSA_R_16	Overshot Run	Hillendale Heights	High	Moderate	210.3	12.5	6%
NSA_R_17_20	Royston Run; Greene Branch; Overshot Run	Summer Hill / Cambria	Moderate	Moderate	418.4	43.0	10%
NSA_R_18	Greene Branch; Royston Run	Greenlands of Hunt Valley	Moderate	Moderate	220.9	15.1	7%
NSA_R_19	Greene Branch	Old York Manor	Moderate	Moderate	56.8	5.4	10%
NSA_R_21	Overshot Run	Blenheim Forest	Moderate	Low	22.5	2.6	11%
NSA_R_22	Dulaney Valley Branch	Valley North	Moderate	Moderate	44.6	3.5	8%
NSA_R_23A	Greene Branch	Misty Hollow	Moderate	Moderate	60.2	4.0	7%

NSA ID	Subwatershed	Neighborhood_Name	PSI	ROI	NSA Acres	Imperv Acres	% Imperv
NSA_R_23B	Greene Branch	Fairwood of Hunt Valley	Moderate	Low	78.0	4.1	5%
NSA_R_24	Greene Branch	Jackson Ridge and Ascot Estates	Moderate	High	214.7	20.7	10%
NSA_R_25A	Greene Branch	Brookfield	Moderate	Moderate	98.9	3.3	3%
NSA_R_25B	Greene Branch	Stockton Road	Moderate	Moderate	109.1	6.9	6%
NSA_R_26	Overshot Run	Sunnybrook Woods	Moderate	Moderate	42.1	5.8	14%
NSA_R_27A	Fitzhugh Run	Woodmont	Low	Moderate	48.9	3.1	6%
NSA_R_27B	Fitzhugh Run; Dulaney Valley Branch	Blenheim Farms			33.7	2.0	6%
NSA_R_28	Dulaney Valley Branch	Halifax Heights	Moderate	Moderate	27.5	2.0	7%
NSA_R_29	Greene Branch	Highlands of Hunt Valley	Moderate	Low	65.0	4.7	7%

NSA Recommendations

NSA ID	Downspout Redirect	Rain Barrel	Rain Garden	Stencil	BayScape	Lot Canopy	Fertilizer Reduction	Pct Lawns High	Pet Waste	Buffer Impact
NSA_R_01			x	x				10		
NSA_R_02			x	x		x		0		
NSA_R_03				x	x			0		
NSA_R_04		x		x	x		x	70		x
NSA_R_05				x				0		x
NSA_R_06				x	x	x		10		x
NSA_R_07			x	x				10		
NSA_R_08				x	x		x	80		
NSA_R_09	x	x	x	x		x	x	50		x
NSA_R_10			x	x	x	x	x	30		
NSA_R_11			x	x	x	x		0		
NSA_R_12			x	x	x	x	x	40		
NSA_R_13			x		x	x	x	90		
NSA_R_14			x		x	x		0		
NSA_R_15			x	x	x		x	30		
NSA_R_16			x	x	x		x	25		x
NSA_R_17_20			x	x	x		x	30		
NSA_R_18			x	x	x		x	60		
NSA_R_19			x	x	x		x	50		
NSA_R_21						x		0		x
NSA_R_22			x	x	x	x	x	40		
NSA_R_23A			x	x	x	x	x	100		
NSA_R_23B							x	30		
NSA_R_24			x	x	x	x		15		x
NSA_R_25A			x		x		x	90		
NSA_R_25B			x		x	x	x	90		x
NSA_R_26			x		x		x	20		x
NSA_R_27A			x	x	x			0		
NSA_R_27B										
NSA_R_28			x	x	x			0		
NSA_R_29				x	x		x	80		

Hotspot Investigation (HIS) Data

		Category		
HSI ID	Description	Commercial or Industrial	Transport Related	Other
HSI_R_101	Retail	x		
HSI_R_102	Training Facility		x	Baltimore County Public Safety Building; potential hazardous materials onsite
HSI_R_103	Retail Garden Center	x		Index Rating is for Parking Area not Gutters
HSI_R_104	Retail/ Restaurant	x		
HSI_R_105	Fast Food Restaurant	x		
HSI_R_301	Retail	x		
HSI_R_302	Pool Supplies and Maintenance	x		
HSI_R_601	Restaurant	x		

	Hotspot Status			
HSI ID	Not a Hotspot	Potential	Confirmed	Severe
HSI_R_101		x		
HSI_R_102		x		
HSI_R_103		x		
HSI_R_104			x	
HSI_R_105	x			
HSI_R_301		x		
HSI_R_302		x		
HSI_R_601	x			

	Pollution Sources					
HSI ID	Vehicle Operations	Outdoor Materials	Waste Mgmt	Physical Plant	Turf / Land-scaping	Storm Water
HSI_R_101		x	x	x	x	x
HSI_R_102	x	x	x	x		
HSI_R_103		x	x	x	x	x
HSI_R_104			x	x		
HSI_R_105			x	x		x
HSI_R_301		x	x	x	x	x
HSI_R_302		x	x		x	
HSI_R_601			x	x	x	

Institutional Site Investigation (ISI) Data

ISI ID	Subwatershed	Name	Type	Ownership	Nutrient Mgmt Plan Required	Tree Planting	Stormwater Retrofit	Downspout Disconnection	Stormdrain Marking	Stream Buffer Improvement	Comments
ISI_R_101	Greene Branch	Jacksonville Church of God	Faith-Based	Private		0	x				Swales at edges
ISI_R_102	Greene Branch	Hunt Valley Inn Golf Course	Golf Course	Private	x	0	x			x	Convert to Extended Detention Wet Pond
ISI_R_301	Overshot Run	Jacksonville Elementary School	Elementary School	Public		0					
ISI_R_302	Overshot Run	Sweet Air Park		Public		260	x		x		Retrofit swales
ISI_R_303	Overshot Run	Chestnut Grove Presbyterian Church	Faith-Based	Private		0	x		x		Retrofit low point to bio cell
ISI_R_304	Overshot Run	St. John's Evangelical Lutheran Church	Faith-Based	Private		0					
ISI_R_401	Overshot Run/Fitzhugh	Hillendale Country Club	Golf Course	Private	x	0	x				Redirect stormwater discharge to treatment practices
ISI_R_501	Jenkins Run	Towson Golf and Country Club	Golf Course	Private	x	0	x			x	
ISI_R_601	Dulaney Valley Branch	St. John's Lutheran School	Elementary School	Private		200	x	x			
ISI_R_602	Loch Raven Reservoir	Vestry of Trinity Church, Long Green	Faith-Based	Private		0		x	x		

Pervious Area Assessment (PAA) Data

PAA ID	Subwatershed	Ownership	Area (Acres)	SW Retrofit Potential	Comments
PAA_R_101	Greene Branch	public	7	yes	Retrofit site near gate
PAA_R_301	Overshot Run	private	7	yes	Potential rain garden/bioretention where southernmost parking lot drains into a swale
PAA_R_401	Fitzhugh Run	public	176	no	
PAA_R_601	Dulaney Valley Branch and Jenkins Run	public	90	no	
PAA_R_602	Dulaney Valley Branch	private	2	yes	Potential site at existing sidewalk area next to parking lot

Appendix H

Synoptic Survey
Area R Small Watershed Action Plan
Conducted in August 2011 and April 2012

Baltimore County
Department of Environmental Protection and Sustainability
Watershed Management and Monitoring Section
November 2012

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Introduction

A synoptic survey for water quality was conducted during April 2012 in the Greene Branch, Loch Raven Direct Drainages, Royston Run, Overshot Run, Fitzhugh Run, Dulaney Valley Branch, and Jenkins Run watersheds (Area R) as part of the Small Watershed Action Plan (SWAP). Water samples were analyzed from twenty sites throughout the watershed for dissolved nutrients, total suspended sediment, chloride, bacteria, hardness, sulfates and metals.

The synoptic sampling was scheduled for spring to coincide with the period of maximum nitrogen concentrations in the free flowing fresh water streams. The major proportion of the nitrogen compounds are carried dissolved in the ground water rather than in surface runoff. The higher nitrogen concentrations in the late winter and early spring reflect the higher proportion of nitrogen rich shallow ground water present in the base flow at this time of year. Nitrogen concentrations are reduced in summer as the proportion of shallow ground water is reduced through plant uptake, and replaced by deeper ground water that may have lower nitrate concentrations, or has been denitrified through interaction with anoxic conditions in the soils below the streambed. Point sources can also contribute to in-stream nitrate concentrations.

Ranges used for interpretation of total nitrogen concentrations (Table 1) were derived from Frink (1991) and are used in the Baltimore County National Pollution Discharge Elimination System (NPDES) annual report (2011). The low end values are based on estimated nutrient exports from forested watersheds, and the high end values are based on estimated nutrient exports from intensively agricultural watersheds. As an additional benchmark, the Chesapeake Bay Program uses 1 mg/L total nitrogen as a threshold for indicating anthropogenic impact.

Table 1. Total Nitrogen Ranges and Rating

Rating	Total Nitrogen (mg/L)
Low	<1.0
Moderately Elevated	1.0- <2.0
Elevated	2.0- <3.0
High	3.0- <4.0
Very High	>4.0

Methods

Synoptic water chemistry samples were collected in spring throughout the watershed on April 17 and 18, 2012. Baseflow sampling is conducted with a minimum of 72 hours after rainfall events. Grab samples of whole water (1000 ml) were collected just below the water surface at mid-stream. The samples were stored on ice and delivered to the Baltimore County Department of Public Works laboratory the same day. Bacteria samples (100 mL) were collected in sterile sample containers containing sodium thiosulfate, stored on ice, and brought to the EPS lab for analysis. The samples were analyzed for E. coli using IDEXX methodology and equipment including Colilert-18 and Quanti-Tray/2000, and read after 18-24 hours of incubation.

Water temperature and pH were measured in the field with an Oakton pHtestr30 at all sites at the time of water quality collections. The drainage areas were determined from a digitized watershed map using Arcview software.

Concentrations for a site are based on the entire area upstream of the site, but are mapped showing just the area between sites in order to highlight variations within the subwatershed. The downstream sites therefore illustrate the cumulative impact from all upstream activities. Tables 2 and 3 describe water quality parameters and instrumentation used.

Table 2. Water Quality Parameters

Parameter	Code	Method	Reporting Limit	Holding Time
Total Suspended Solids	TSS	EPA 160.2	1 mg/L	7 days
Total Solids	TS	EPA 160.3	1 mg/L	7 days
Total Kjeldahl Nitrogen	TKN	EPA 351.3	0.2 mg/L	28 days
Nitrate/Nitrite Nitrogen	NO_2-NO_3	EPA 353.2	0.06 mg/L	28 days
Total Phosphorus	TP	EPA 365.3	0.05 mg/L	28 days
Orthophosphorus	OP	EPA 365.3	0.1 mg/L	48 hours
Biological Oxygen Demand	BOD	EPA 405.1	2 mg/L	48 hours
Chemical Oxygen Demand	COD	EPA 410.4	5 mg/L	28 days
Total Copper	Cu	EPA 200.7	0.001 mg/L	6 months
Total Lead	Pb	EPA 239.2	0.001 mg/L	6 months
Total Zinc	Zn	EPA 200.7	0.001 mg/L	6 months
Total Cadmium	Cd	EPA 213.2	0.001 mg/L	6 months

Table 4. Instrumentation

Instrument	Measure	Units	Range	Accuracy
Oakton Waterproof pH Testr30	pH	$-\log[H^+]$	-1.00 to 15.00	± 0.1
Oakton Waterproof pH Testr30	Temperature	°C	0 to 50 °C	±0.5 °C

Results

Sampling site locations are noted in Table 4. Water samples were analyzed for dissolved nutrients, total suspended sediment, chloride, bacteria, hardness, sulfates and metals. All data is presented in Table 6.

Total nitrogen concentrations (Figure 1) were found to be low (<1.0 mg/L) in two sites, moderately elevated (1.0-<2.0) at six sites, elevated (2.0- <3.0) at 11 sites and high (3.0- <4.0) at one site. No sites were found to be very high (>4.0 mg/L). Nitrogen results are shown in Table 5.

For consideration, estimates of annual total nitrogen concentrations from spring samples will result in inflated estimates, but the relative contributions of subwatersheds should remain reasonably stable. More accurate estimates need to include sampling during the growing season to account for potential lower concentrations. Storm flows can also significantly impact concentrations delivered to a watershed outlet.

Chloride concentrations were found to be low (<77.0 mg/L) in all 20 sites (Figure 2). No sites were found to be moderate (>77.0 – 153.0 mg/L), high (>153.0 – 230.0 mg/L) or very high (>230.0 mg/L). The Maryland Water Quality Criteria for chronic chloride is 230 mg/L and the acute level is 860 mg/L.

Bacteria results are given in Most Probable Number (MPN), an estimate based on the number of organisms present per sample. Single samples are analyzed based on a limit of 576 MPN for human contact in infrequently used full body contact recreational waters. E. coli counts were found to be low (0 - 192 MPN) at eleven sites, fair (193 - 384 MPN) at four sites, approaching bacteria standard (385 - 576 MPN) at three sites, and two sites exceeding the 576 MPN standard (Figure 3).

Total phosphorus was below the detection limit of 0.05 mg/L for almost all of the sites. One site, R-15, had a total phosphorus concentration of 0.18 mg/L and was also the only site to rank high for total nitrogen. No sites exceeded the water quality criteria limit of 250 mg/L sulfate. No sites exceeded the chronic or acute levels of dissolved copper, 0.013 mg/L and 0.009 mg/L. No sites exceeded the chronic or acute levels of dissolved zinc, 0.12 mg/L for both. No sites exceeded the expected hardness; normal levels in streams are 100-200 mg/L. Water temperatures were all under 23.9 Celsius and pH levels were between 6 and 9.

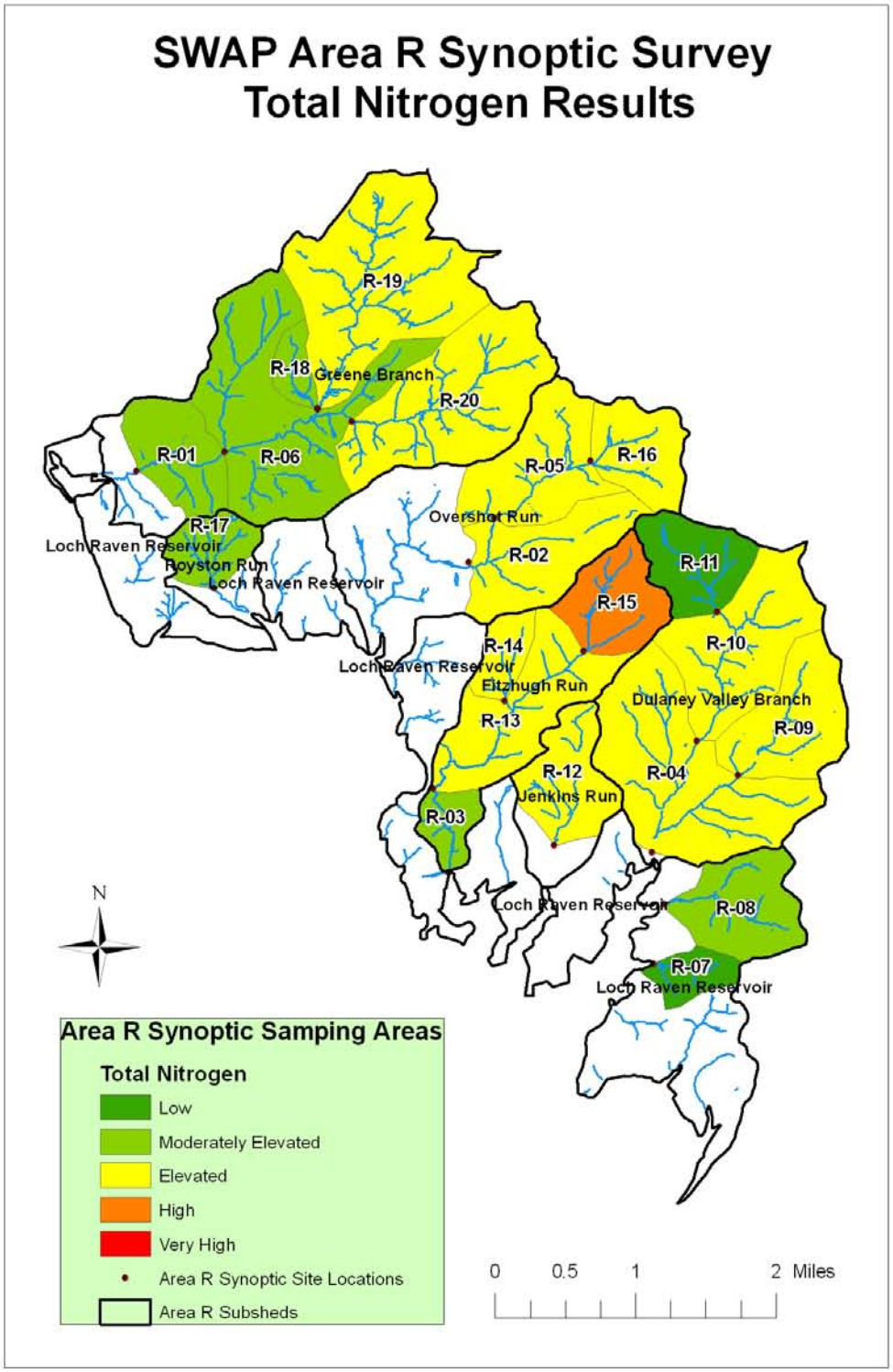

Figure 1. Total Nitrogen Results, SWAP Area R Synoptic Survey

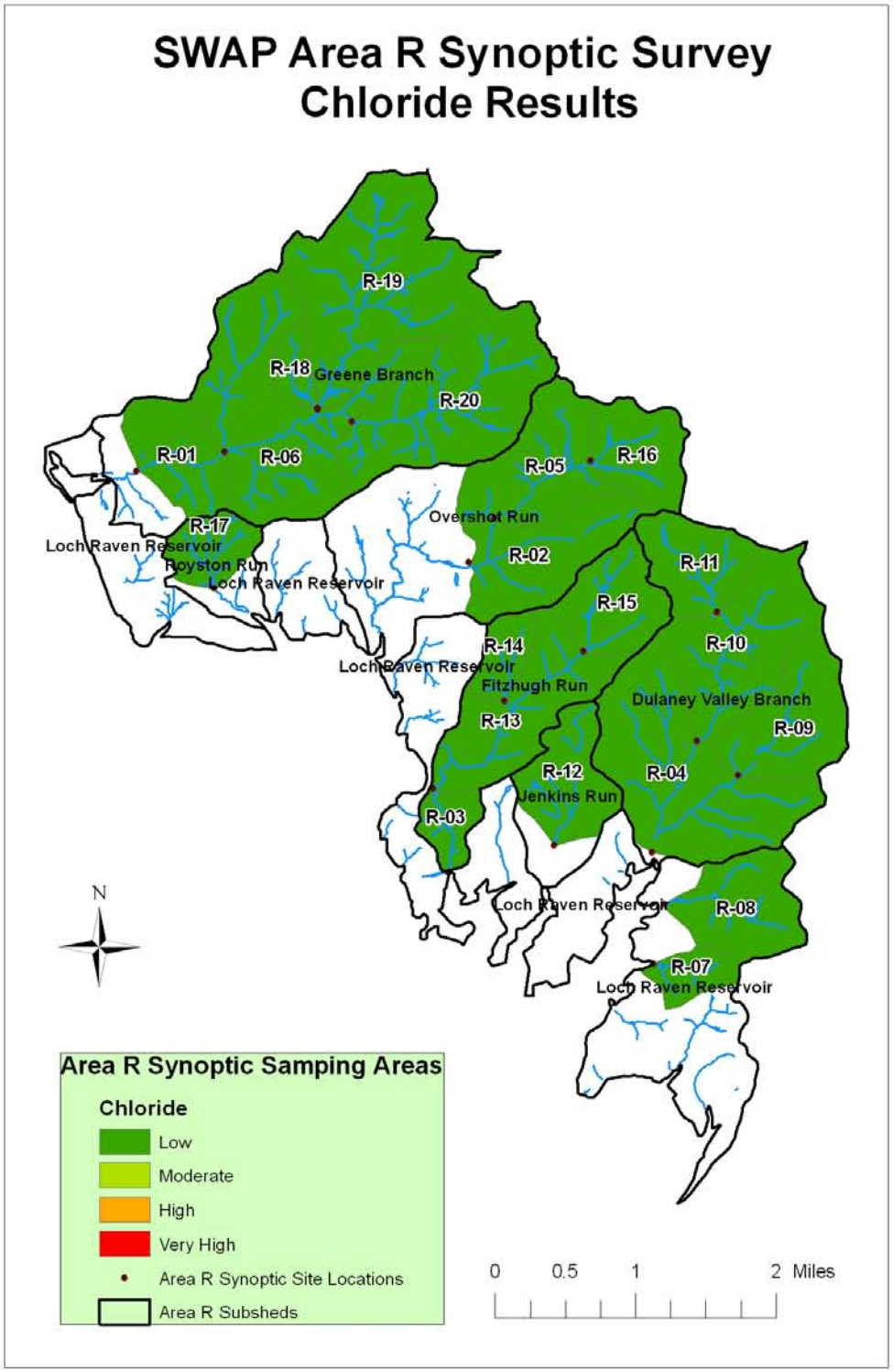

Figure 2. Chloride Results, SWAP Area R Synoptic Survey

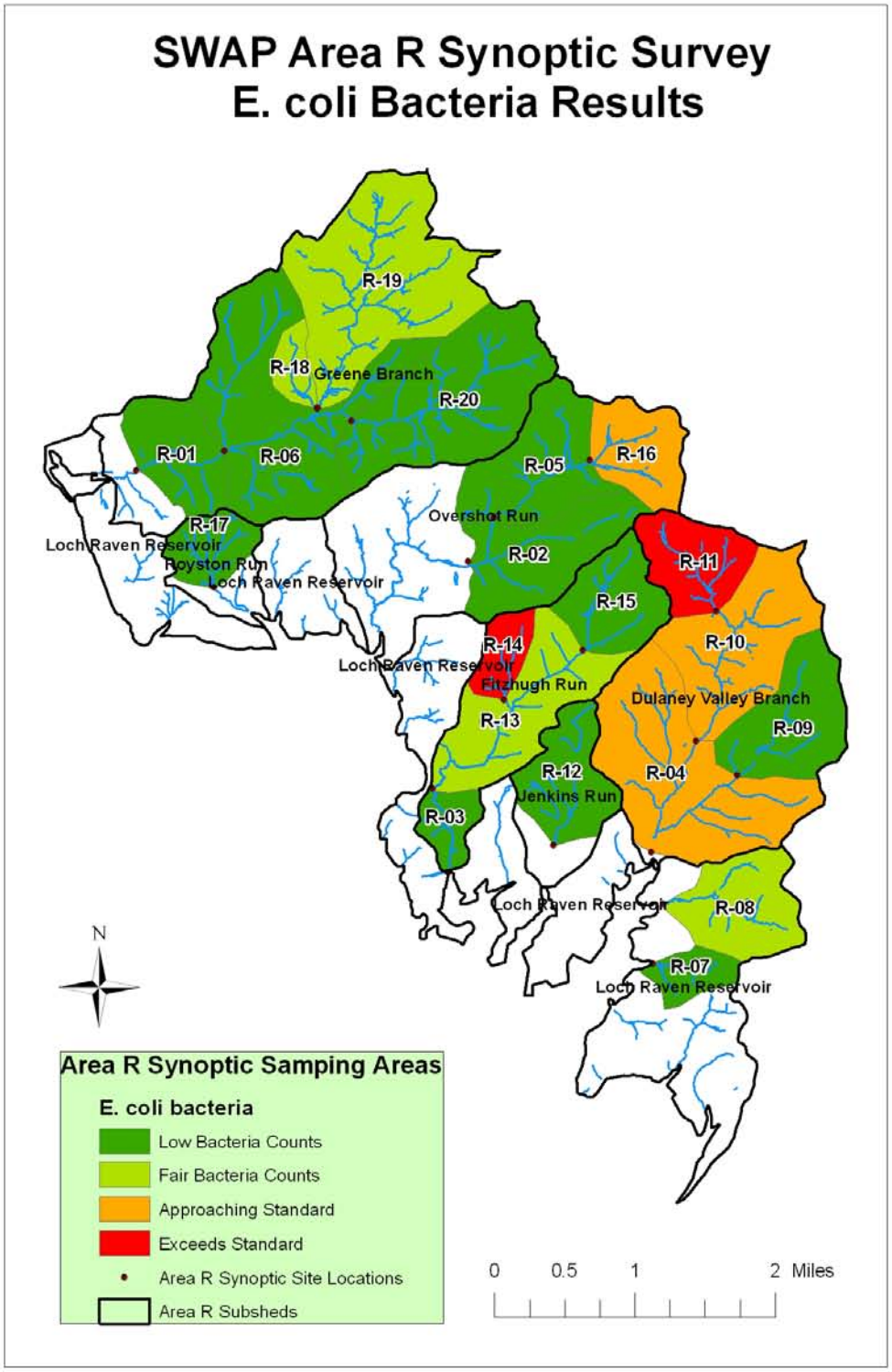

Figure 3. E. coli Bacteria Results, SWAP Area R Synoptic Survey

Table 4. Sampling Site Locations

Sample	LOCATION	Lat	Long
R – 01	Greene Branch – Downstream of Phoenix Road	39.50616	-76.61379
R – 02	Overshot Run – Upstream of Jarrettsville Pike	39.49664	-76.56962
R – 03	Fitzhugh Run – Downstream of Dulaney Valley Road	39.50700	-76.55337
R – 04	Dulaney Valley Branch – Upstream of Loch Raven Road	39.48740	-76.55441
R – 05	Overshot Run – Downstream of Richfield Lane	39.48232	-76.56492
R – 06	UT to Greene Branch – Downstream of Paper Mill Road	39.47318	-76.57455
R – 07	Direct Drainage – Downstream of Loch Raven Drive near Morgan Mill	39.46452	-76.57255
R – 08	Direct Drainage – Downstream of Loch Raven Drive	39.46729	-76.55841
R – 09	UT to Dulaney Valley Branch – Upstream of Long Green Road	39.49140	-76.53661
R – 10	Direct Drainage – Downstream of Long Green Road near Dance Mill	39.47799	-76.53943
R – 11	UT to Dulaney Valley Branch – at Redcoat Lane	39.47443	-76.53398
R – 12	Jenkins Run – Upstream of Dulaney Valley Road	39.46653	-76.54543
R – 13	Fitzhugh Run – Jarrettsville Pike	39.46123	-76.54387
R – 14	UT to Fitzhugh Run – Upstream of Windy Farms Court	39.45505	-76.54527
R – 15	Fitzhugh Run – Downstream of Blenheim Road	39.50117	-76.56611
R – 16	Overshot Run – Near Jackson Manor Court	39.49406	-76.60348
R – 17	Royston Run – Upstream of Merrymans Mill Road	39.50810	-76.60205
R – 18	UT to Greene Branch – Paper Mill Road near Misty Hollow Court	39.51251	-76.58965
R – 19	UT to Greene Branch – Paper Mill Road near Sunnybrook Road	39.51253	-76.58958
R – 20	Greene Branch – Downstream of Sunnybrook Road	39.51117	-76.58511

Note: UT = un-named tributary

Table 5. Dissolved Nitrogen Concentrations

Site	DATE	TKN mg/L	NO2+NO3 mg/L	TN mg/L
R – 01	04/18/12	0.10	1.75	1.85
R – 02	04/17/12	0.10	2.02	2.12
R – 03	04/18/12	0.10	1.84	1.94
R – 04	04/18/12	0.10	2.19	2.29
R – 05	04/18/12	0.20	2.12	2.32
R – 06	04/18/12	0.10	1.50	1.60
R – 07	04/18/12	0.10	0.53	0.63
R – 08	04/18/12	0.10	1.24	1.34
R – 09	04/18/12	0.35	2.18	2.53
R – 10	04/18/12	0.10	2.53	2.63
R – 11	04/18/12	0.27	2.04	2.31
R – 12	04/18/12	Dry	Dry	Dry
R – 13	04/18/12	0.10	2.15	2.25
R – 14	04/18/12	0.10	2.42	2.52
R – 15	04/18/12	1.26	2.59	3.85
R – 16	04/18/12	0.26	2.17	2.43
R – 17	04/18/12	0.10	0.91	1.01
R – 18	04/18/12	0.10	0.98	1.08
R – 19	04/18/12	0.10	2.12	2.22
R – 20	04/18/12	0.30	2.18	2.48

Table 6. Select Water Quality Parameter Results

Site	Date	Temp °C	pH	Chloride (mg/L)	TSS (mg/L)	SO4 (mg/L)	Copper (mg/L)	Zinc (mg/L)	Hardness	Date *E. coli* Sampling	*E. coli* MPN
R – 01	04/18/12	13.0	7.2	48.48	<1.0*	8.67	0.0005	0.0050	142.94	08/31/11	191.8
R – 02	04/17/12	17.2	6.9	56.60	<1.0*	7.00	0.0005	0.0030	88.98	08/31/11	184.2
R – 03	04/18/12	13.6	6.7	29.39	<1.0*	5.66	0.0005	0.0020	83.13	08/31/11	146.7
R – 04	04/18/12	14.1	7.8	42.47	<1.0*	5.57	0.0005	0.0010	162.68	08/31/11	547.5
R – 05	04/18/12	12.3	7.4	52.95	<1.0*	4.64	0.0005	0.0010	107.85	08/31/11	133.4
R – 06	04/18/12	12.5	7.3	31.16	2.0	11.40	0.0005	0.0020	11.08	08/31/11	76.3
R – 07	04/18/12	12.9	7.4	41.17	<1.0*	3.93	0.0005	0.0040	71.64	08/31/11	70.3
R – 08	04/18/12	13.9	7.6	41.63	<1.0*	4.48	0.0005	0.0005	100.30	08/31/11	290.9
R – 09	04/18/12	14.1	7.1	65.21	<1.0*	4.10	0.0005	0.0080	110.51	08/31/11	143.9
R – 10	04/18/12	13.5	7.1	36.37	<1.0*	5.02	0.0005	0.0080	92.94	08/31/11	435.2
R – 11	04/18/12	12.1	7.3	11.57	<1.0*	5.36	0.0005	0.0010	62.55	08/31/11	1986.3
R – 12	04/18/12	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	08/31/11	120.3
R – 13	04/18/12	12.4	7.3	29.26	<1.0*	5.64	0.0005	0.0010	78.78	08/31/11	307.6
R – 14	04/18/12	12.3	7.3	23.07	<1.0*	13.06	0.0005	0.0020	99.35	08/31/11	816.4
R – 15	04/18/12	12.2	7.2	58.60	<1.0*	3.63	0.0005	0.0170	110.43	08/31/11	178.2
R – 16	04/18/12	12.1	8.4	36.84	4.0	4.53	0.0005	0.0020	95.36	08/31/11	547.5
R – 17	04/18/12	13.6	7.1	31.84	<1.0*	11.89	0.0005	0.0020	100.25	08/31/11	178.5
R – 18	04/18/12	12.2	8.1	14.94	170.0	17.09	0.0005	0.0020	91.55	08/31/11	298.7
R – 19	04/18/12	12.4	7.4	24.23	<1.0*	7.19	0.0005	0.0010	92.20	08/31/11	201.4
R – 20	04/18/12	12.6	8.4	71.29	<1.0*	8.20	0.0005	0.0030	108.20	08/31/11	76.7

*1.0 mg/L is the detection limit for total suspended solids.

Discussion

Total nitrogen results for Direct Drainage are low and moderately elevated. Royston Run is moderately elevated. Greene Branch is moderately elevated and elevated. Overshot Run, Jenkins Run and Dulaney Valley Branch are elevated. Fitzhugh Run is elevated and high. The concern with nitrogen is not in the freshwater streams, lakes and reservoirs, but downstream in the Chesapeake Bay. The bay is vulnerable to eutrophication from over-enrichment of nitrogen, leading to dead zones. Reduction of total nitrogen is required in order to meet the Chesapeake Bay TMDL.

All the sites in Area R had low Chloride concentrations. Over the past several decades, there has been an increase in the chloride and sodium concentrations in the Loch Raven Reservoir, and other drinking water reservoirs. A high sodium concentration in drinking water (20 mg/l) is a human health risk for sodium-sensitive individuals. A high chloride concentration makes water treatment for the public drinking water supply more difficult, and more costly. It also gives the water a salty taste, if over 250 mg/l. The Maryland Department of Environment

(2009) has identified a chloride concentration of 50 mg/l as detrimental to freshwater aquatic communities. Baltimore County has been investigating alternative mechanisms for clearing roadways of snow and ice, but must maintain public safety.

The majority of the bacteria samples taken in Area R were well below the human health standard for single sample E. coli bacteria in infrequently used fully body contact recreational waters (576 MPN). One site in Overshot Run was approaching the standard, and one site in Fitzhugh Run exceeded the standard. The subwatershed showing the most potential for elevated E. coli was Dulaney Valley Branch, with two sites approaching the standard, and one site exceeding the standard. A single sample with elevated bacteria at a site does not necessarily indicate a persistent bacteria problem, however should be followed up with additional sampling. If additional sampling does show elevated bacteria levels, then upstream monitoring should be conducted to identify possible sources. Potential sources of E. coli bacteria contamination are livestock, failing septics, and wildlife.

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APPENDIX I

TMDL of Mercury for Loch Raven Reservoir

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

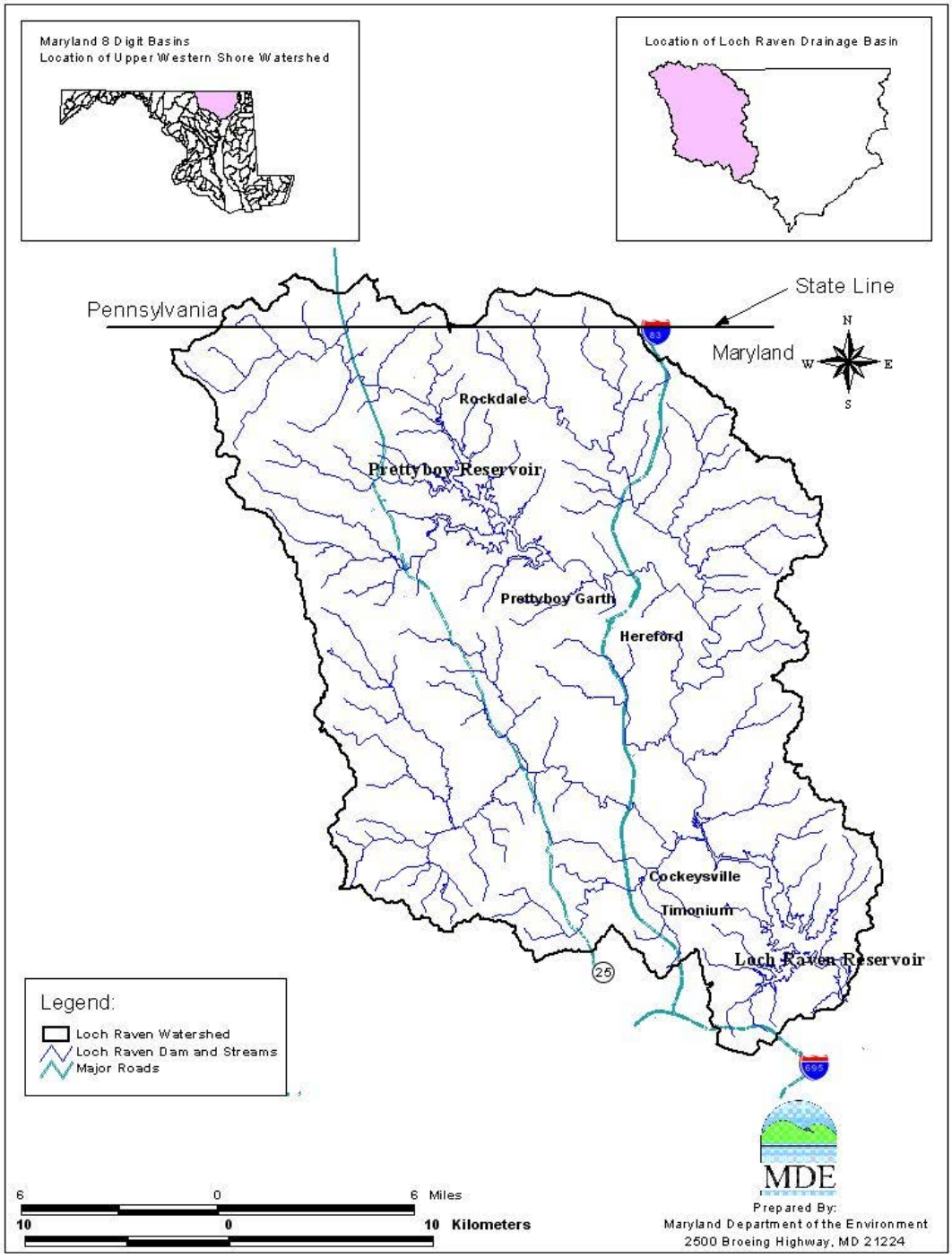

Figure 1: Location Map of Loch Raven Reservoir in Baltimore County, Maryland

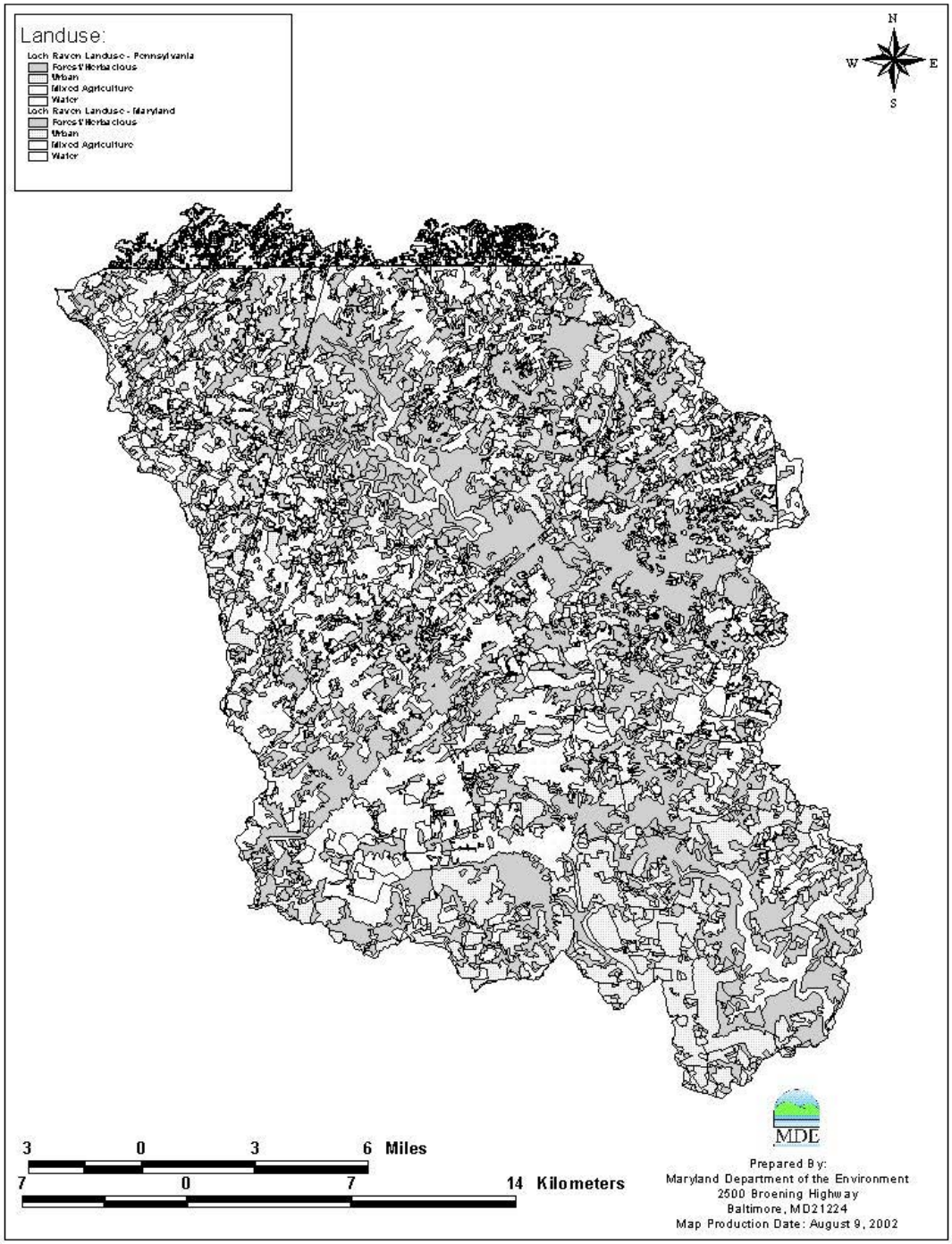

Figure 2: Predominant Land Use in the Loch Raven Reservoir Subwatershed

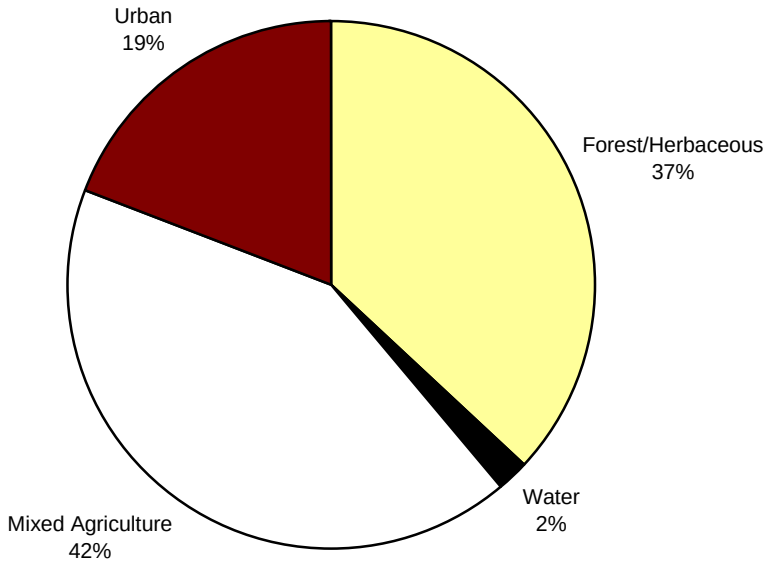

Figure 3: Land Use Distribution in the Loch Raven Reservoir Subwatershed

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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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).

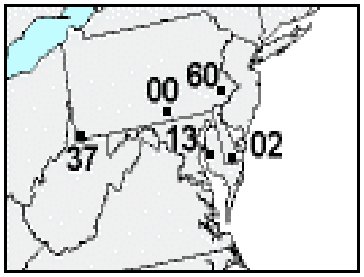

Figure A1: Mercury Deposition Network Monitoring Stations

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.

References

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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

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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.

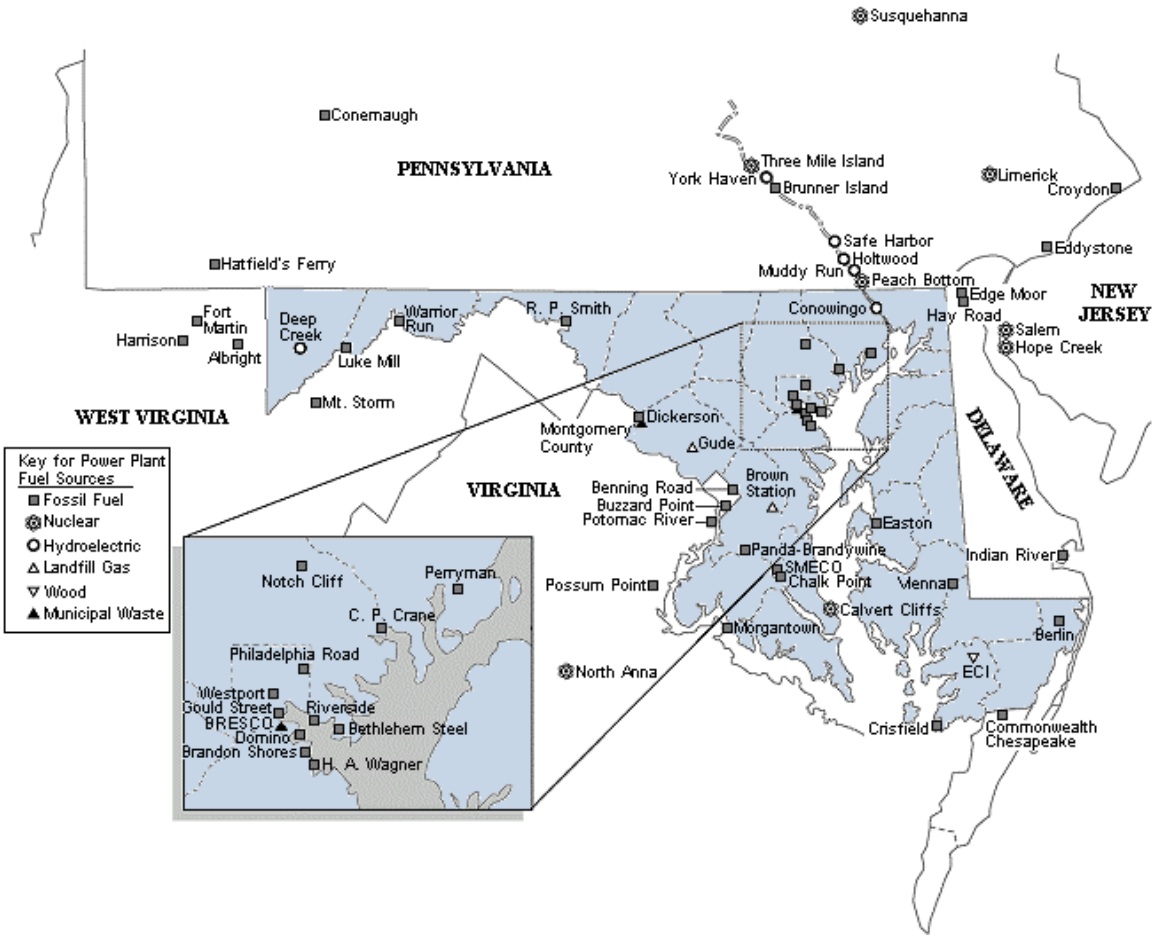


Figure D1: Power Plant Locations In and Around Maryland

** 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:

$$\frac{4.95}{3.61} = \frac{X}{2.27}$$

$$X = 3.11 \text{ ng/L total mercury}$$

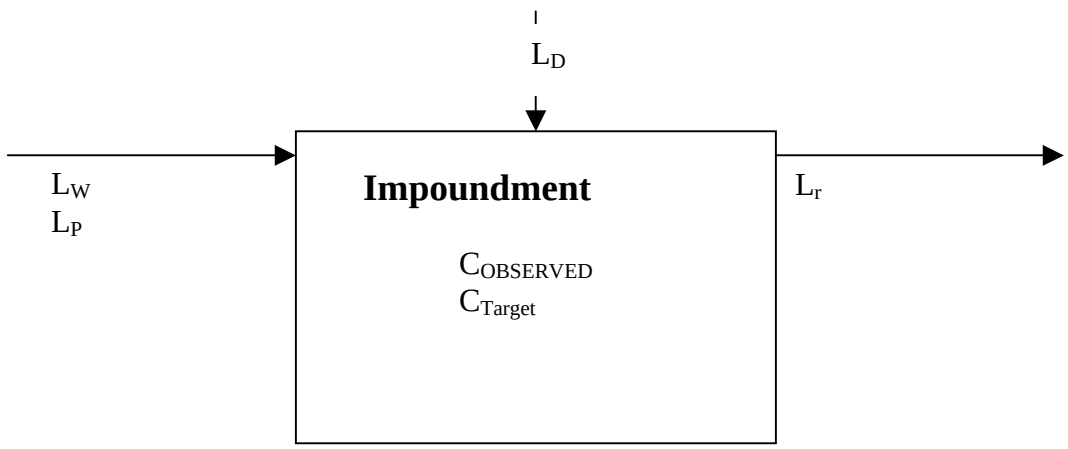
As explained, X – AAWCC equals the particulate fraction.

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

TMDL of Fecal Coliform Bacteria for Loch Raven Reservoir

Total Maximum Daily Loads of Fecal Bacteria for the Loch Raven Reservoir Basin in Baltimore, Carroll, and Harford Counties, Maryland

FINAL

DEPARTMENT OF THE ENVIRONMENT
1800 Washington Boulevard, Suite 540
Baltimore MD 21230-1718

Submitted to:

Water Protection Division
U.S. Environmental Protection Agency, Region III
1650 Arch Street
Philadelphia, PA 19103-2029

July 2009

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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

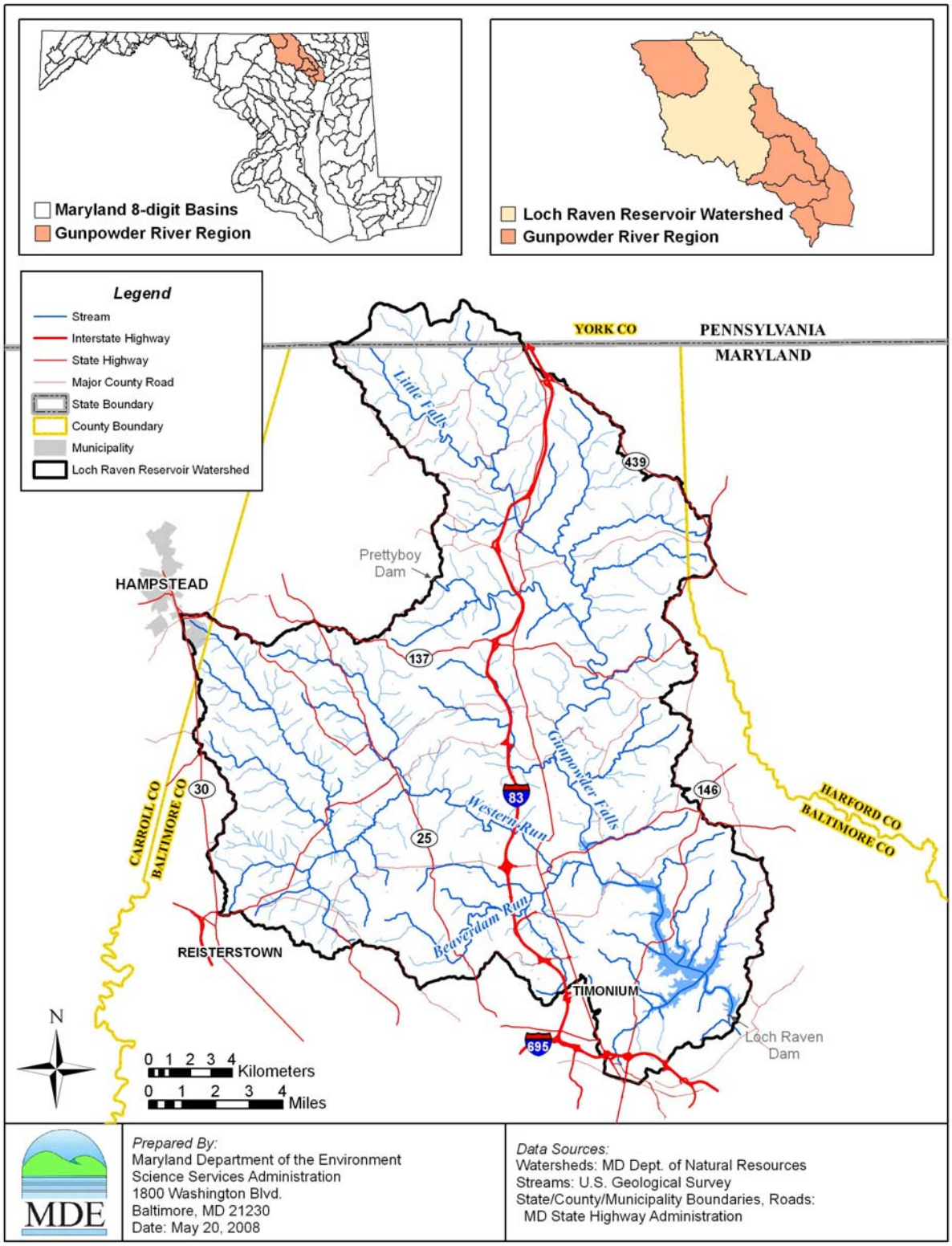

Figure 2.1.1: Location Map of the Loch Raven Reservoir Watershed

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

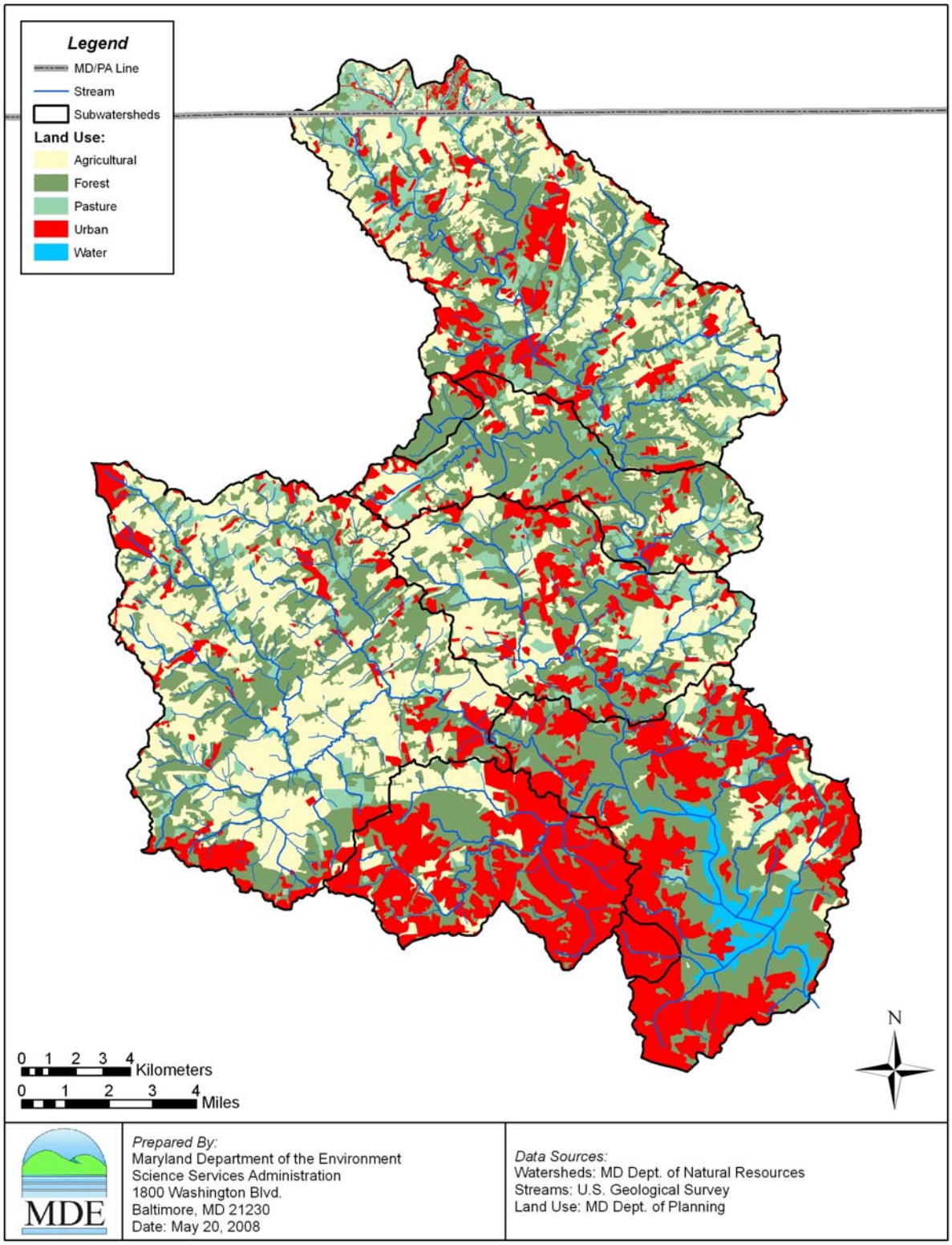

Figure 2.1.2: Land Use of the Loch Raven Reservoir Watershed

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**

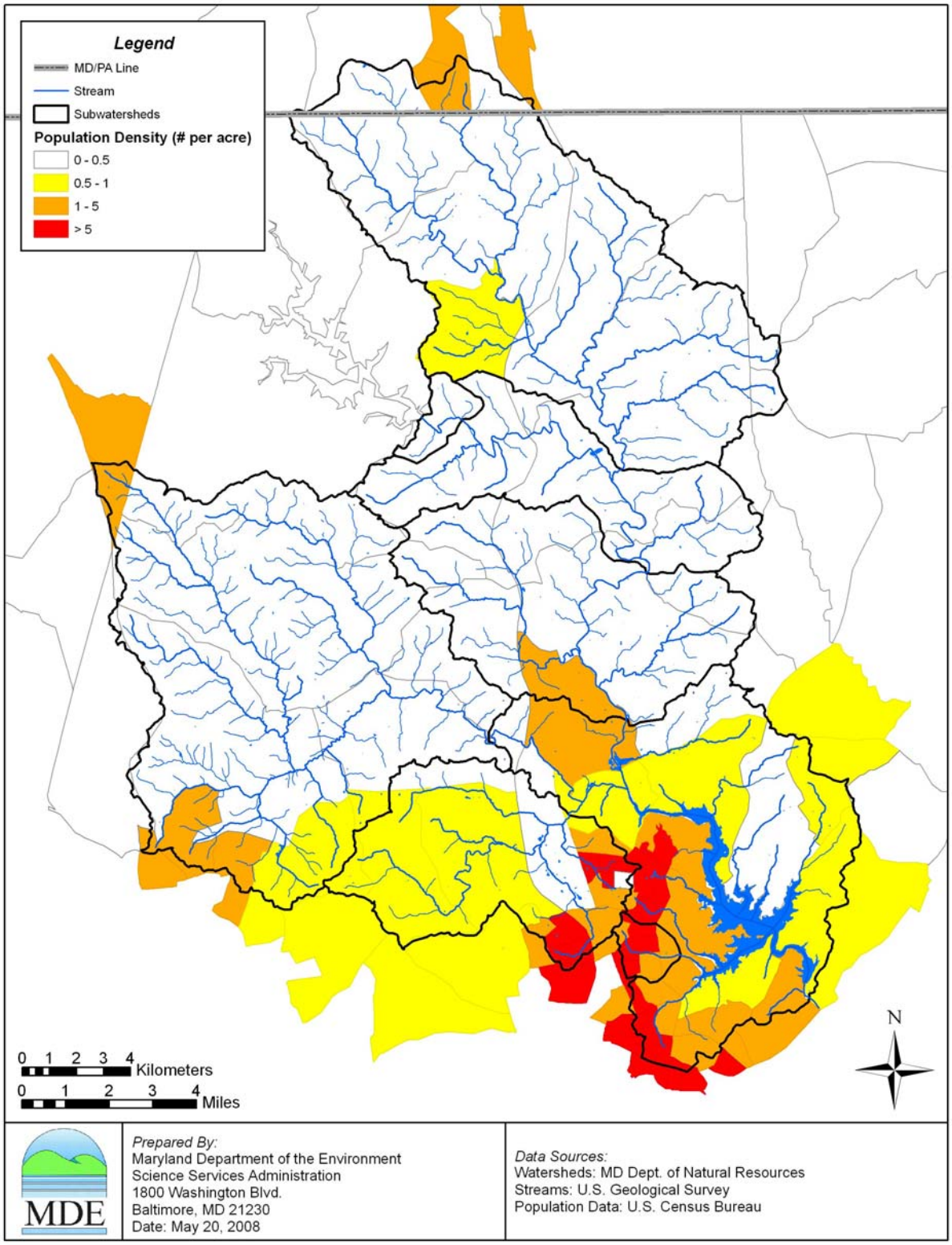

Figure 2.1.3: Population Density in the Loch Raven Reservoir Watershed

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

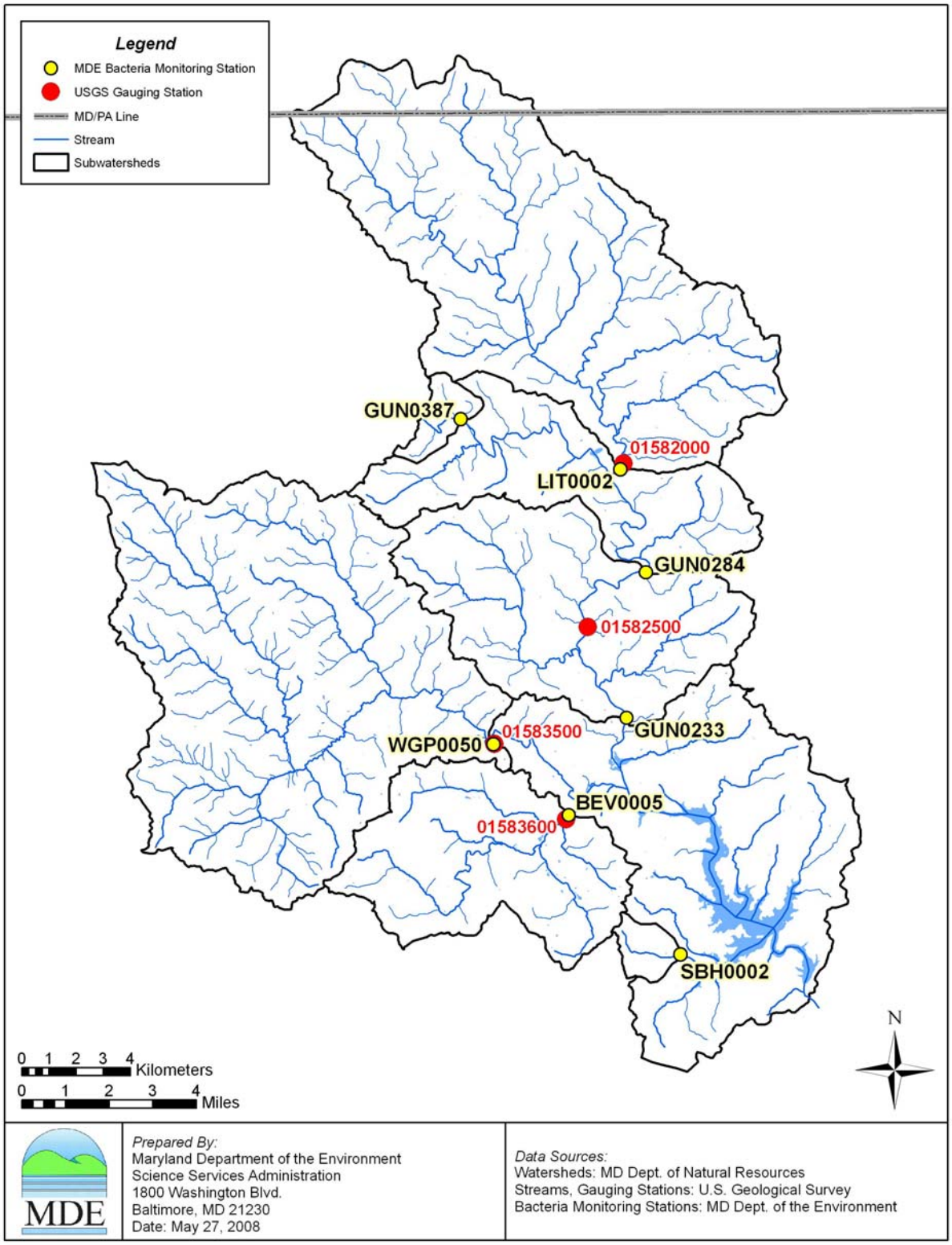

Figure 2.2.1: Monitoring Stations and Subwatersheds in the Loch Raven Reservoir Watershed

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**

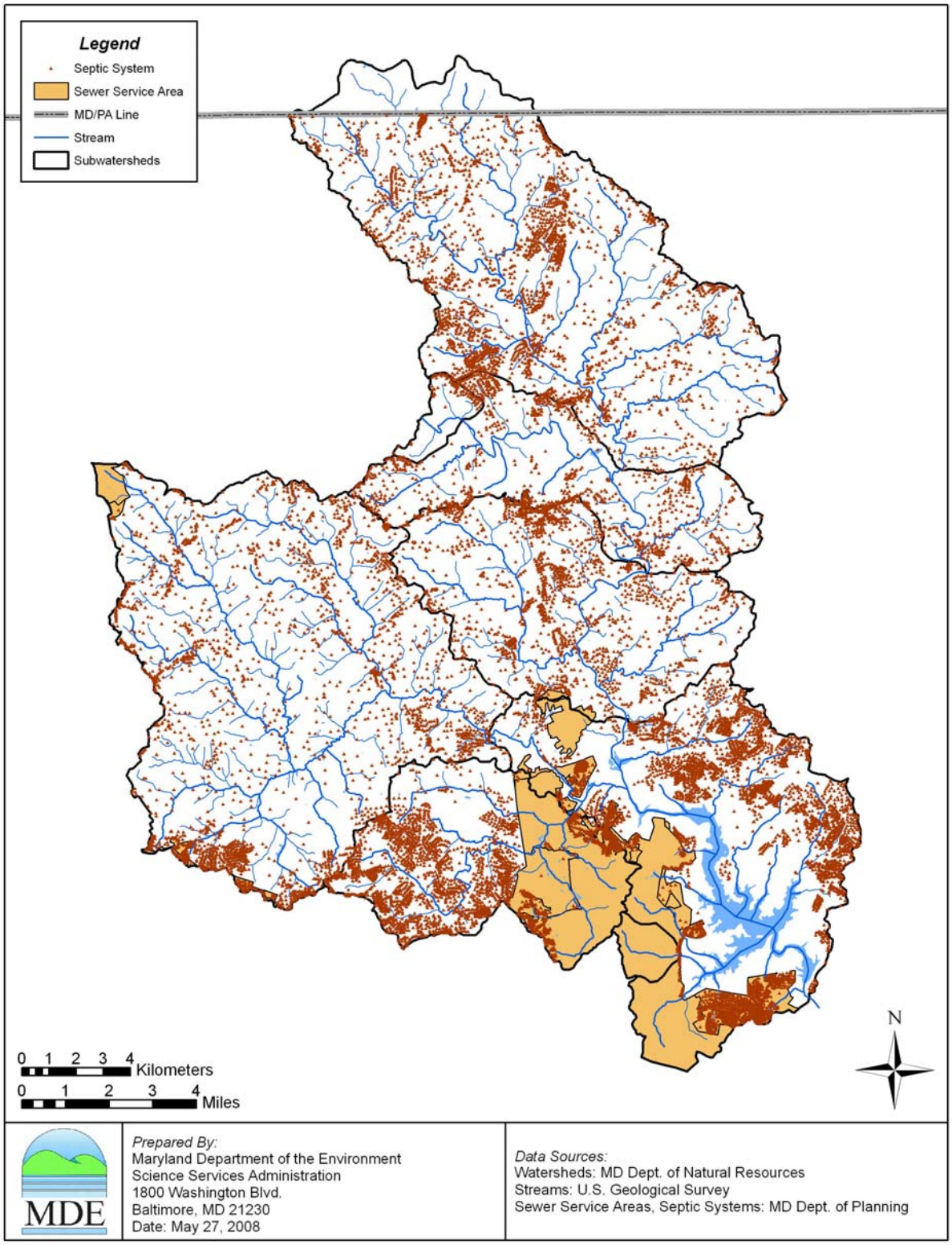

Figure 2.4.1: Sanitary Sewer Service Areas and Septic Locations in MD's Portion of the Loch Raven Reservoir Watershed

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.

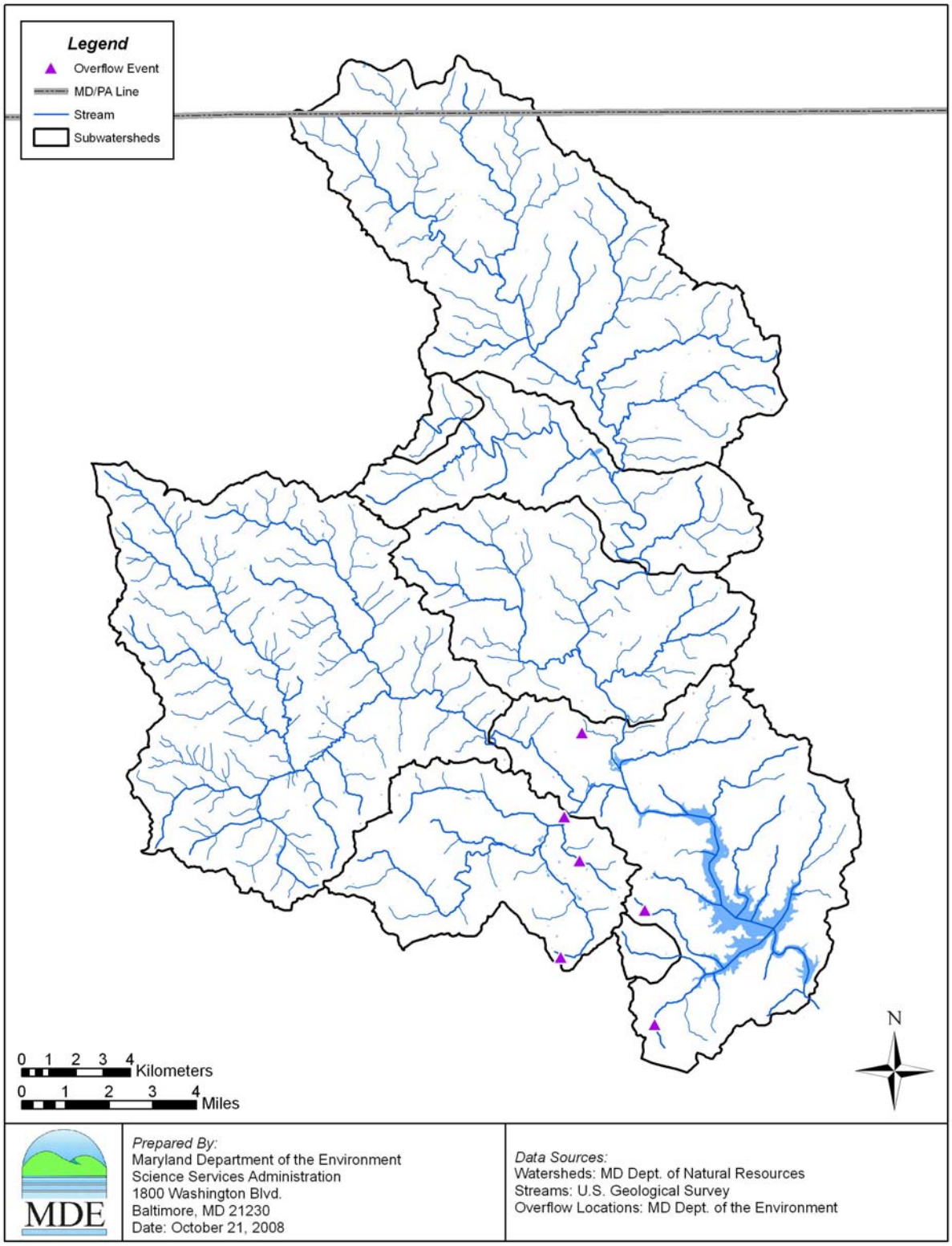

Figure 2.4.2: Sanitary Sewer Overflow Areas in the Loch Raven Reservoir Watershed

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

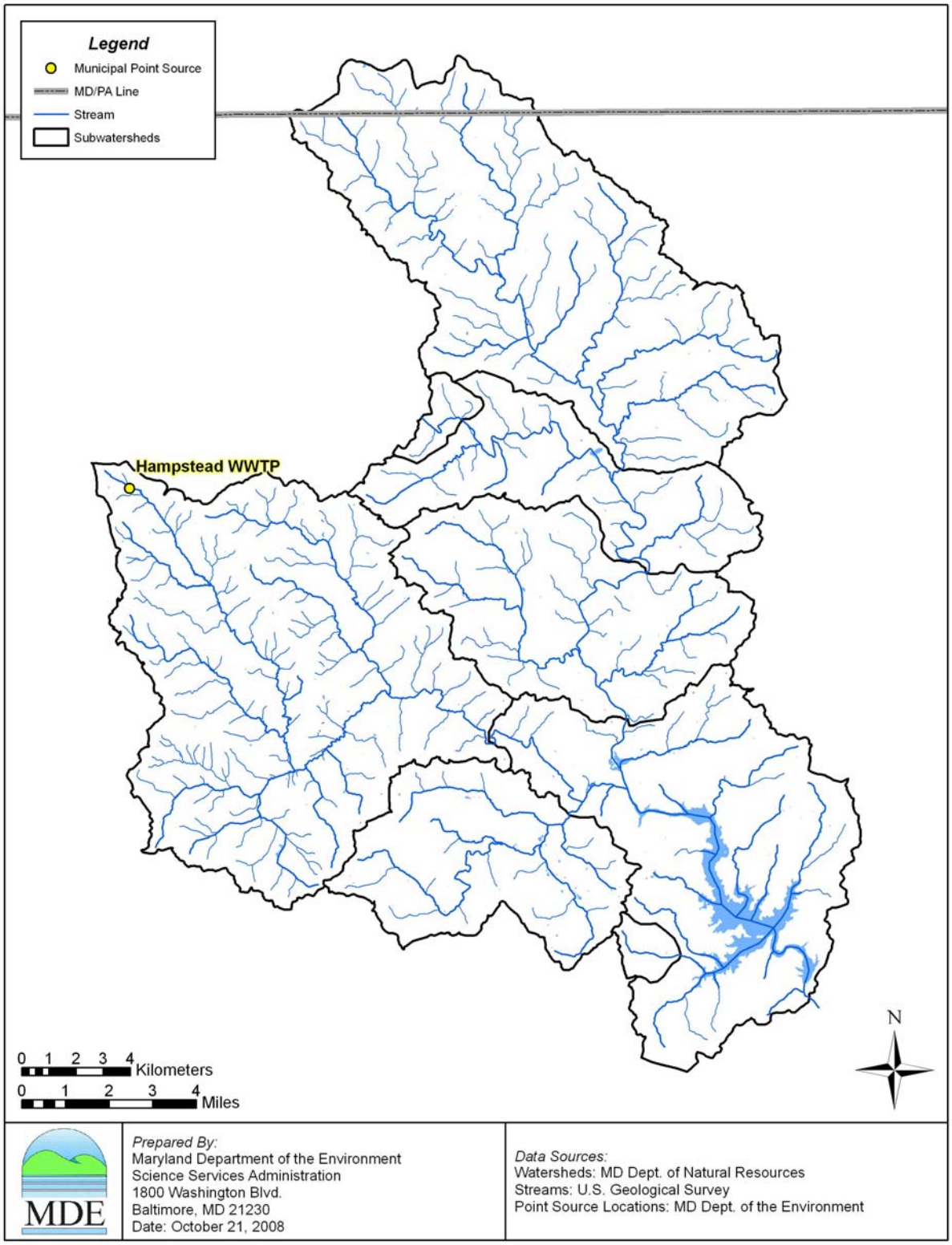

Figure 2.4.3: Permitted Point Sources Discharging Fecal Bacteria in the Loch Raven Reservoir Watershed

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.

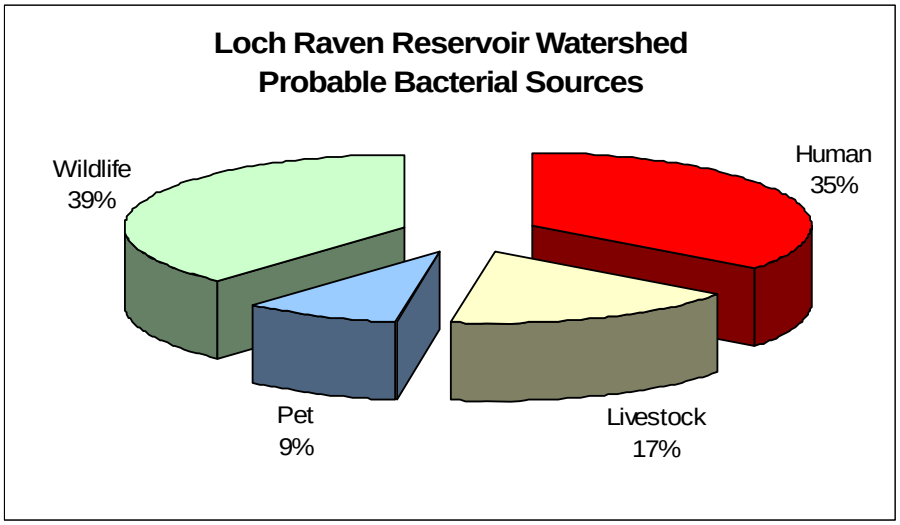

Figure 2.4.4: Loch Raven Reservoir Watershed Relative Contributions by Probable Sources of Fecal Bacteria Contamination

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.

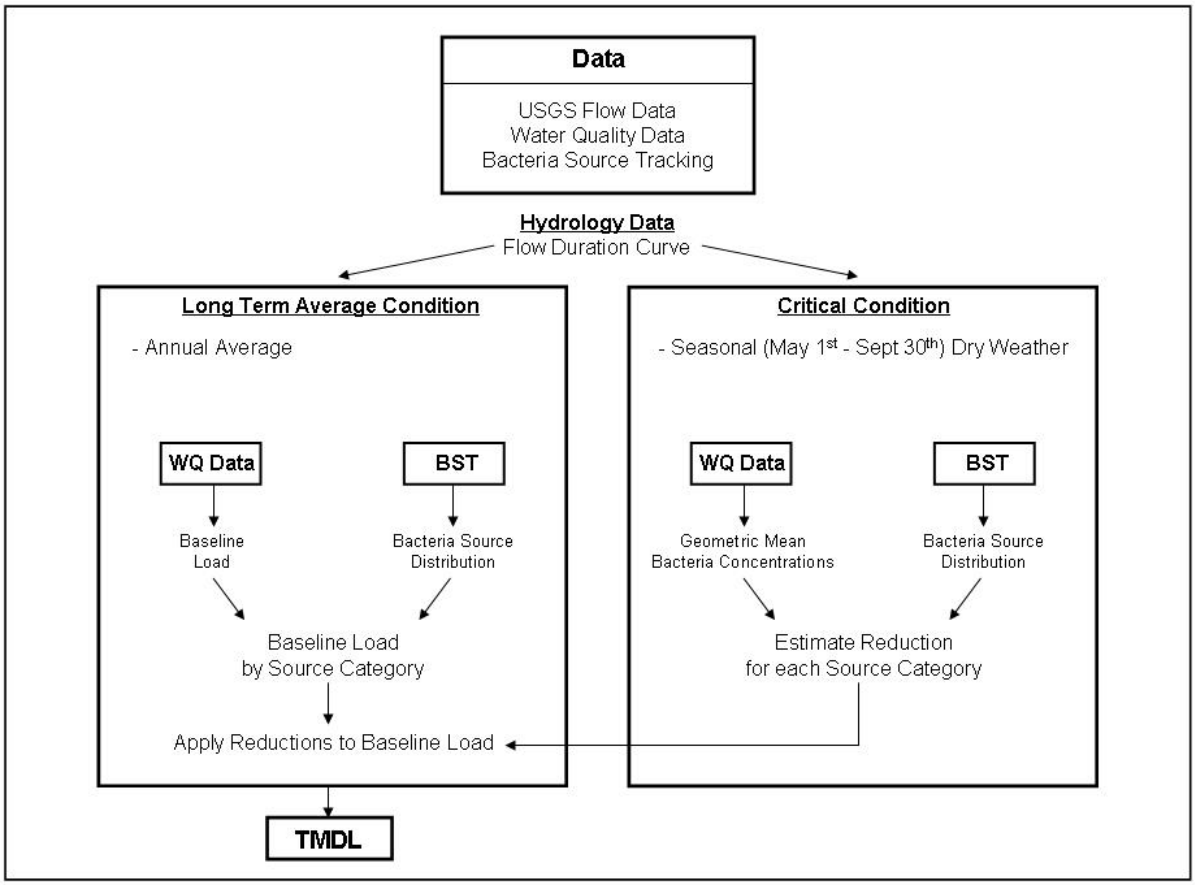

Figure 4.2.1: Diagram of the Non-tidal Bacteria TMDL Analysis Framework

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.

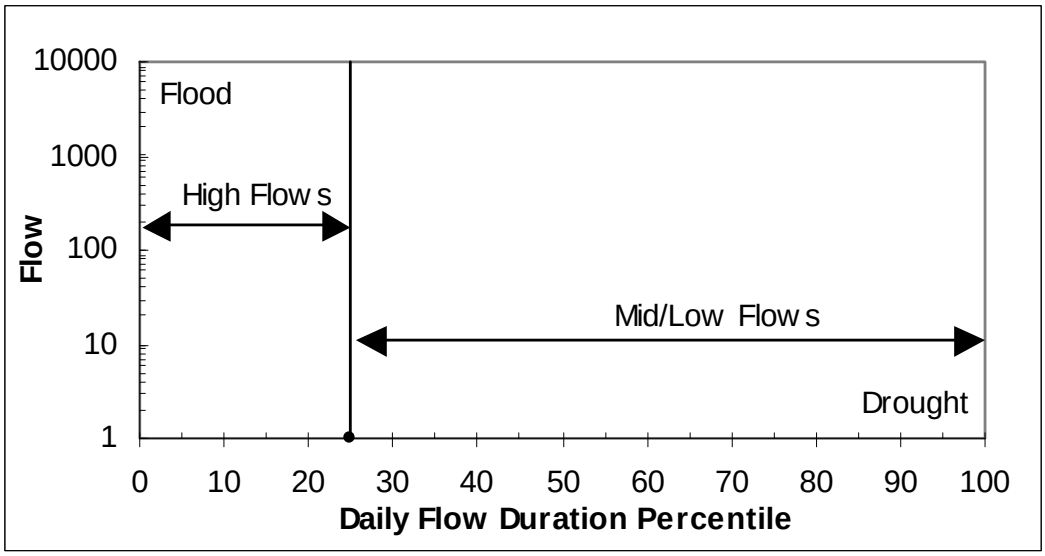

Figure 4.3.1: Conceptual Diagram of Flow Duration Zones

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

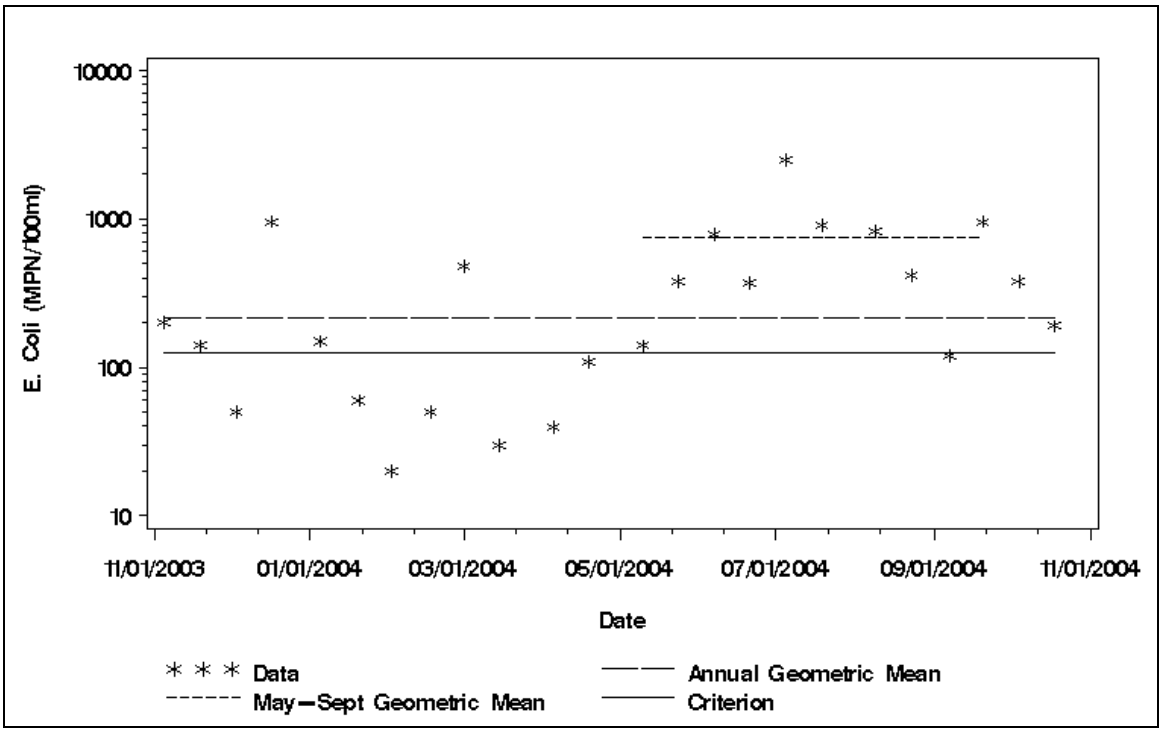

Figure A-1: *E. coli* Concentration vs. Time for MDE Monitoring Station BEV0005

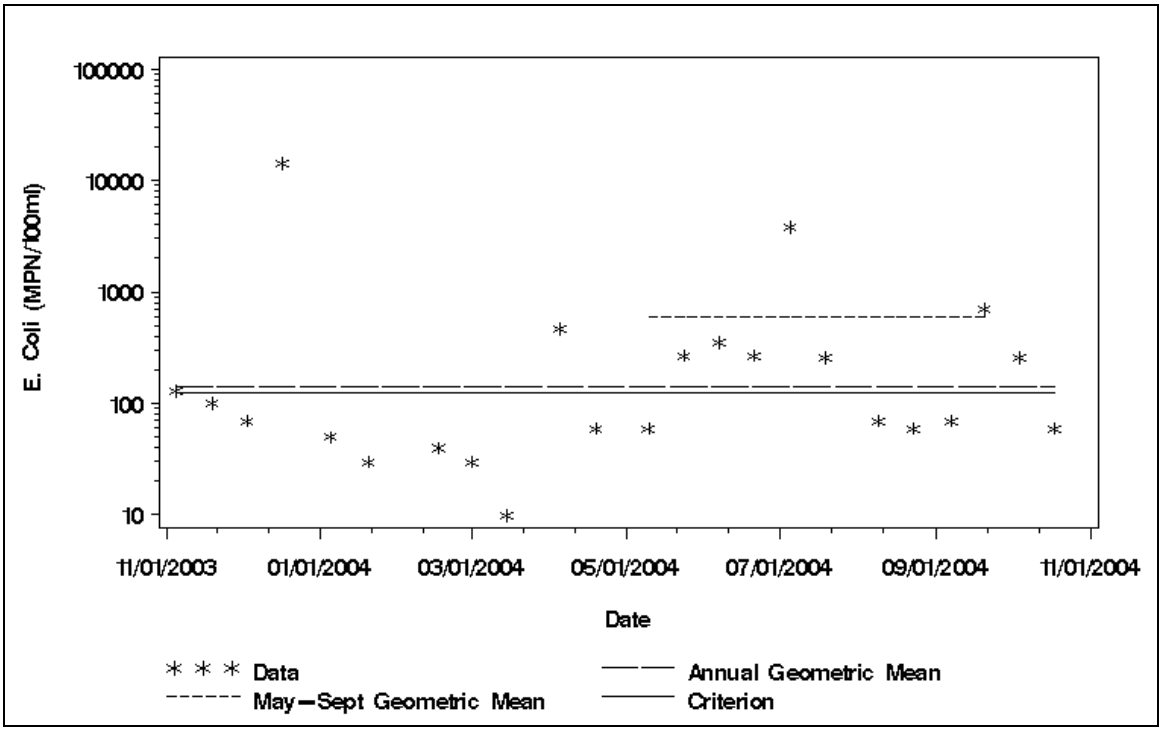

Figure A-2: *E. coli* Concentration vs. Time for MDE Monitoring Station GUN0233

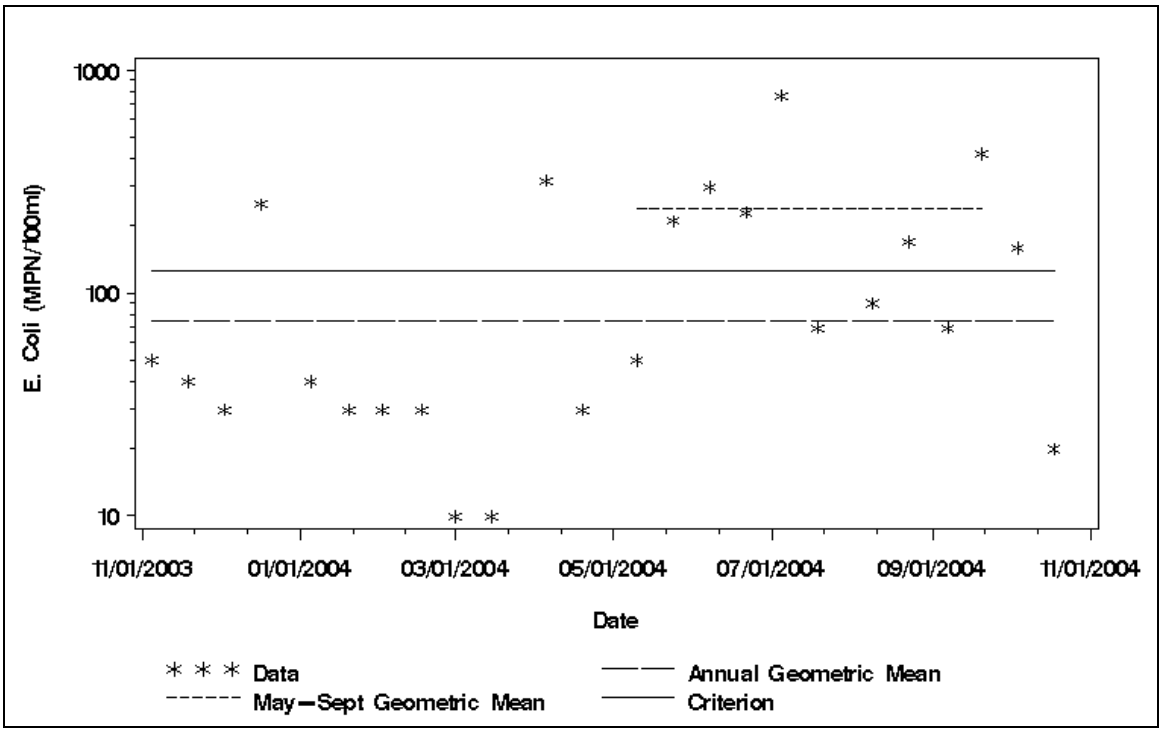

Figure A-3: *E. coli* Concentration vs. Time for MDE Monitoring Station GUN0284

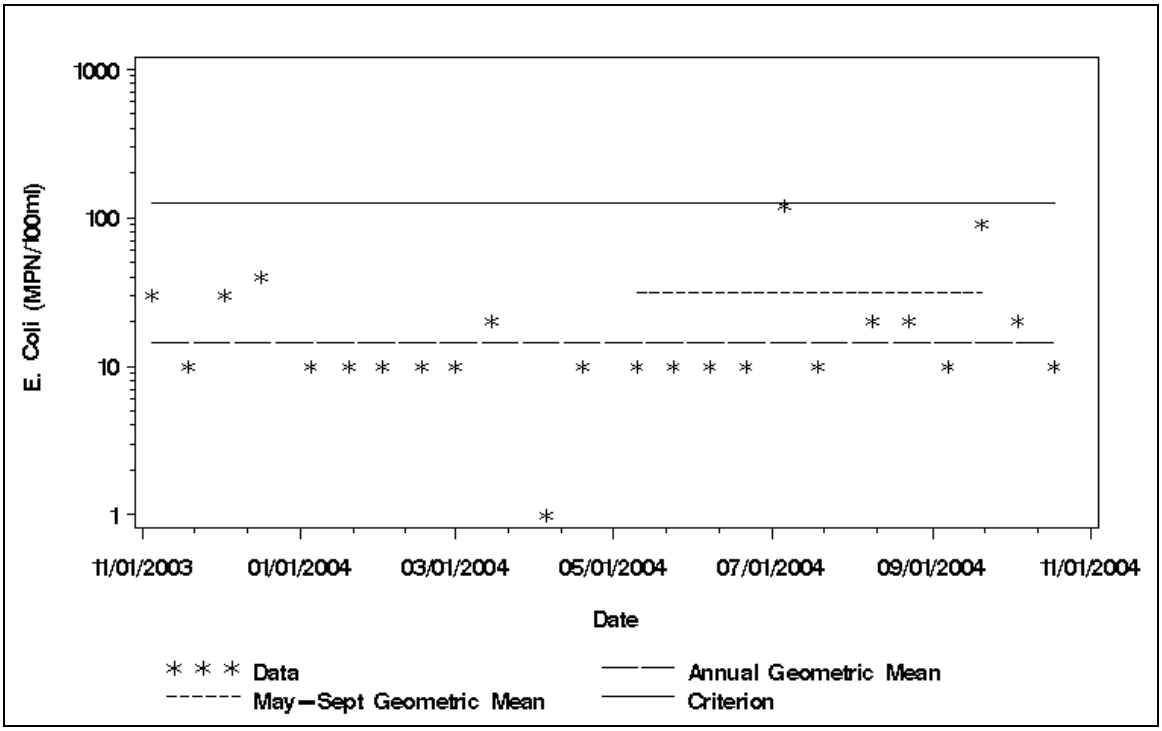

Figure A-4: *E. coli* Concentration vs. Time for MDE Monitoring Station GUN0387

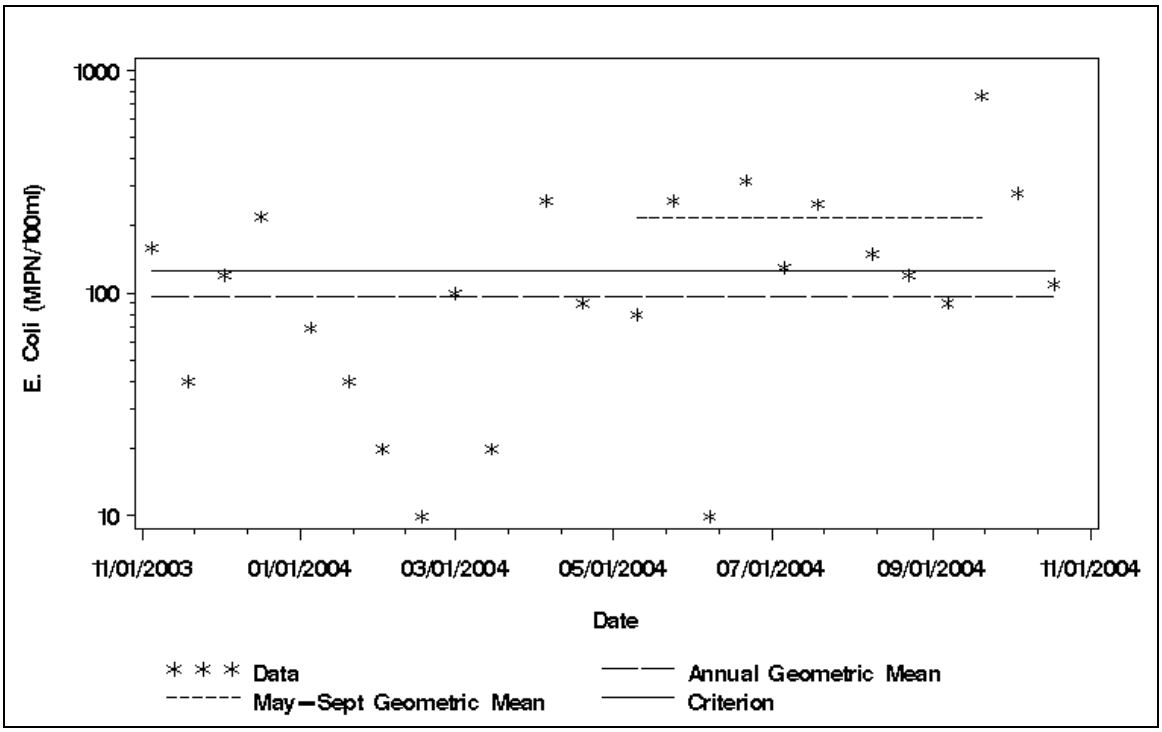

Figure A-5: *E. coli* Concentration vs. Time for MDE Monitoring Station LIT0002

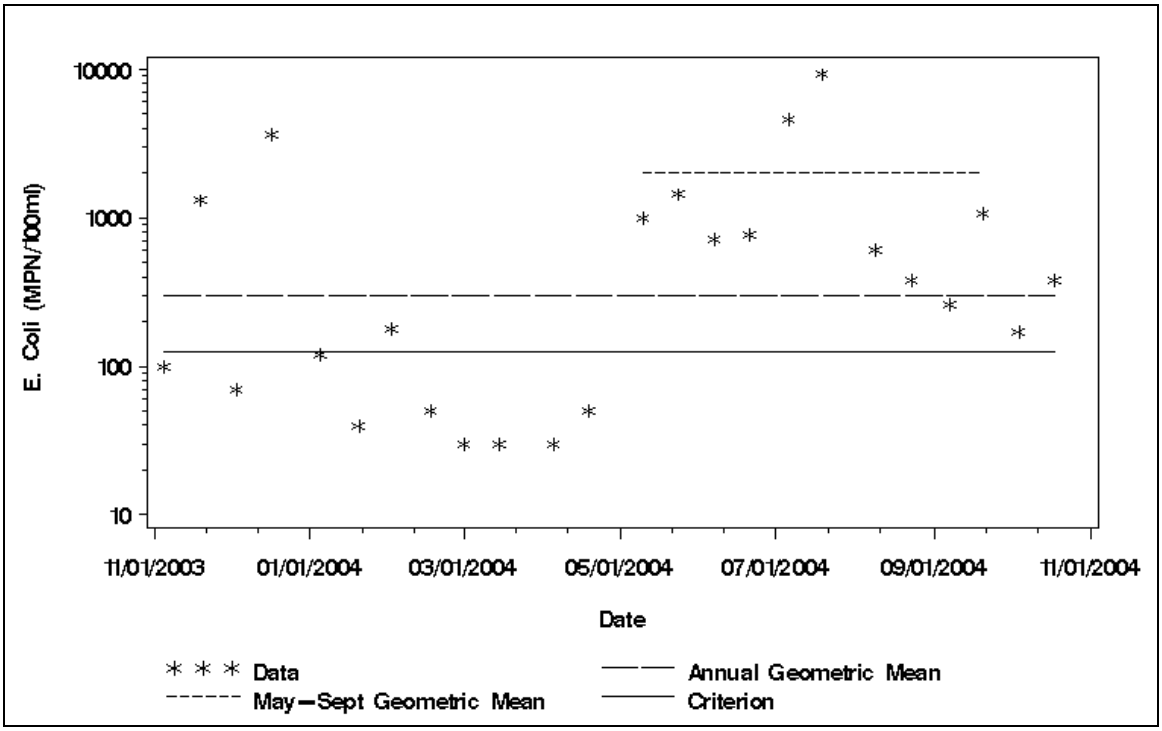

Figure A-6: *E. coli* Concentration vs. Time for MDE Monitoring Station SBH0002

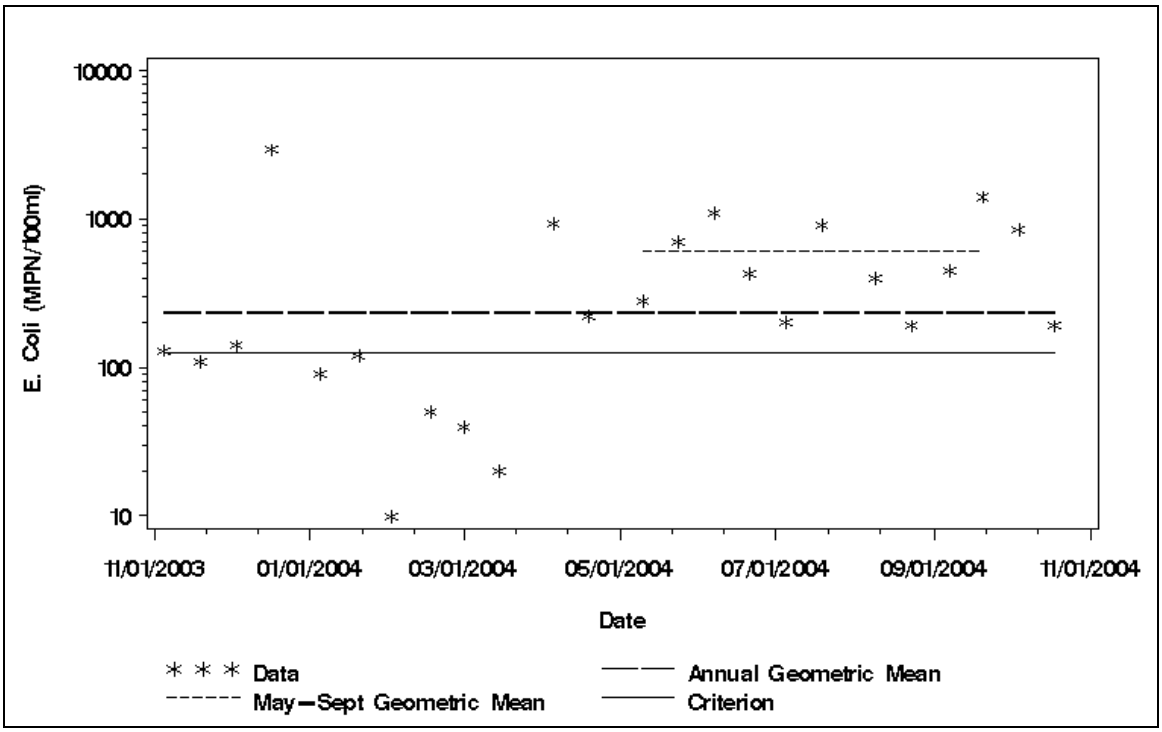

Figure A-7: *E. coli* Concentration vs. Time for MDE Monitoring Station WGP0050

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

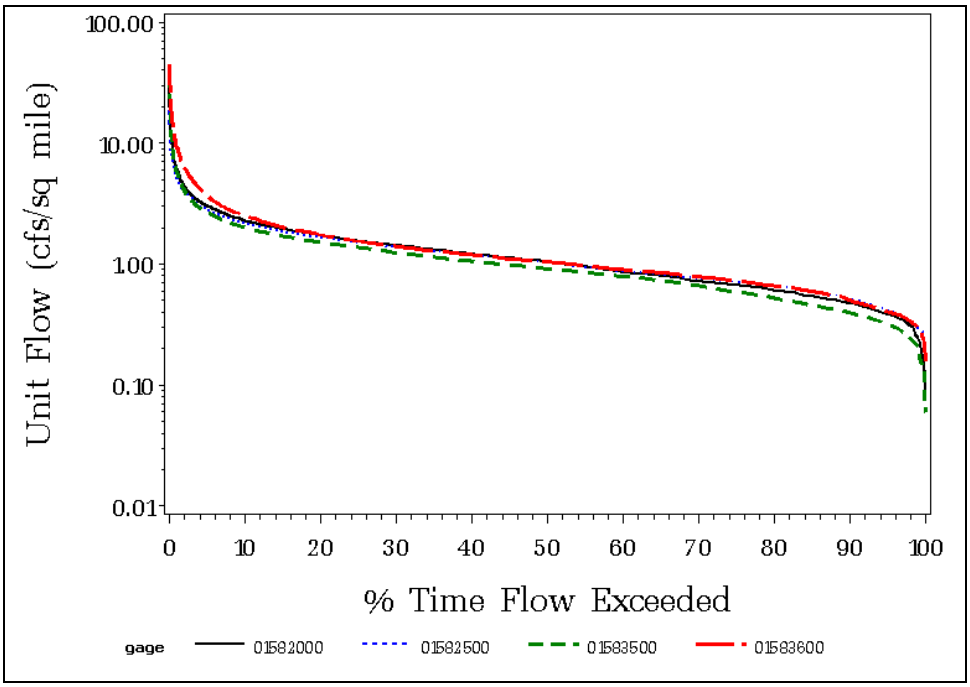

Figure B-1: Flow Duration Curve for Loch Raven Reservoir Watershed USGS Sites

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.

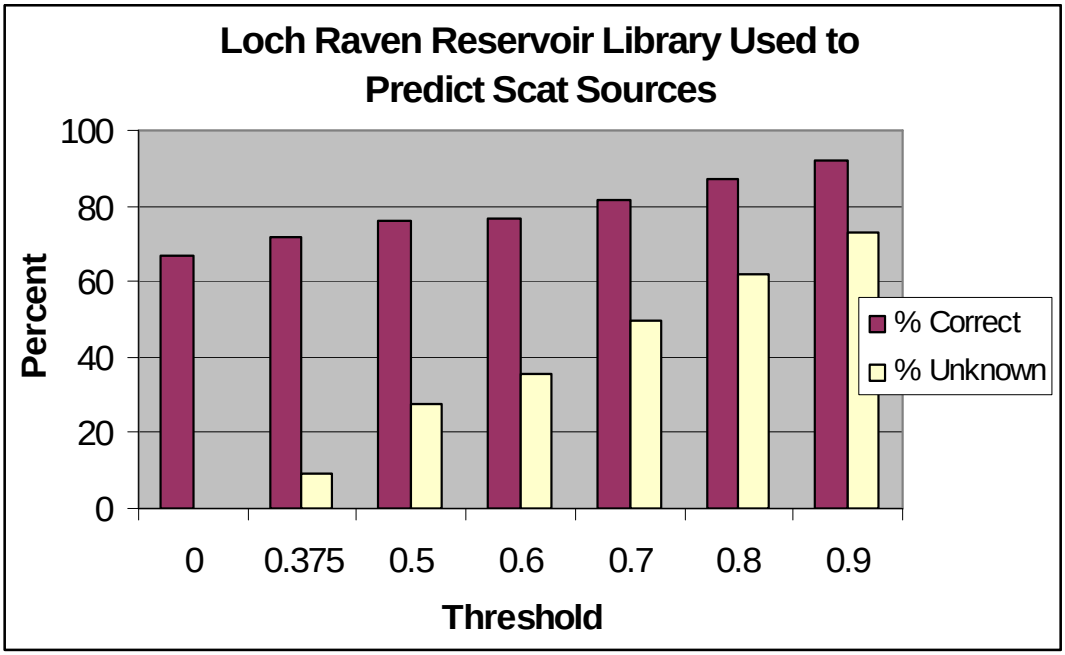


Table C-4: Actual species categories versus predicted categories, at 50% probability cutoff, with rates of correct classification (RCC) for each category.

	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%

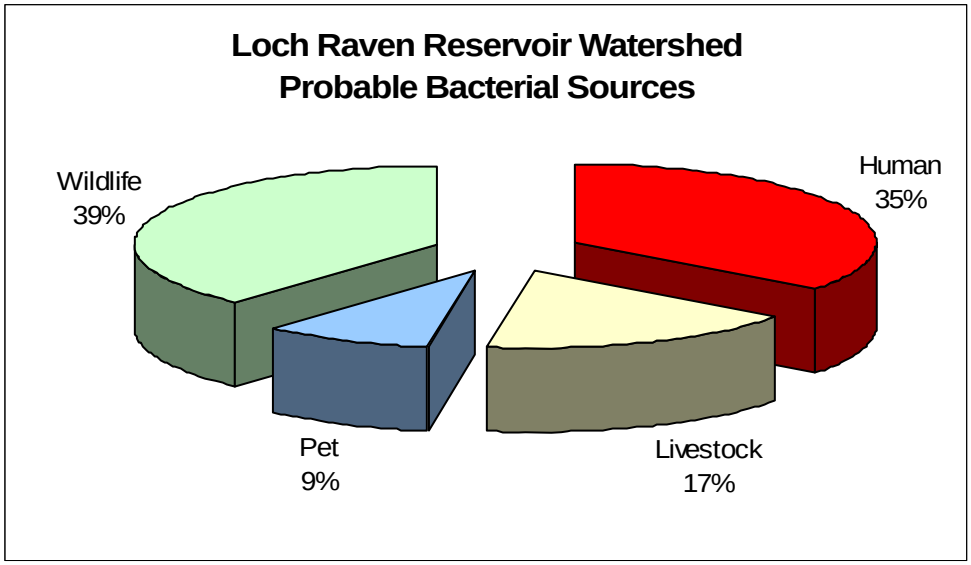
Table C-8 (continued): BST Analysis: Percent of Isolates per Station per Date.

		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 K

TMDL of Phosphorus and Sediments for Loch Raven Reservoir

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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Nutrients/Sediment TMDLs
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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.

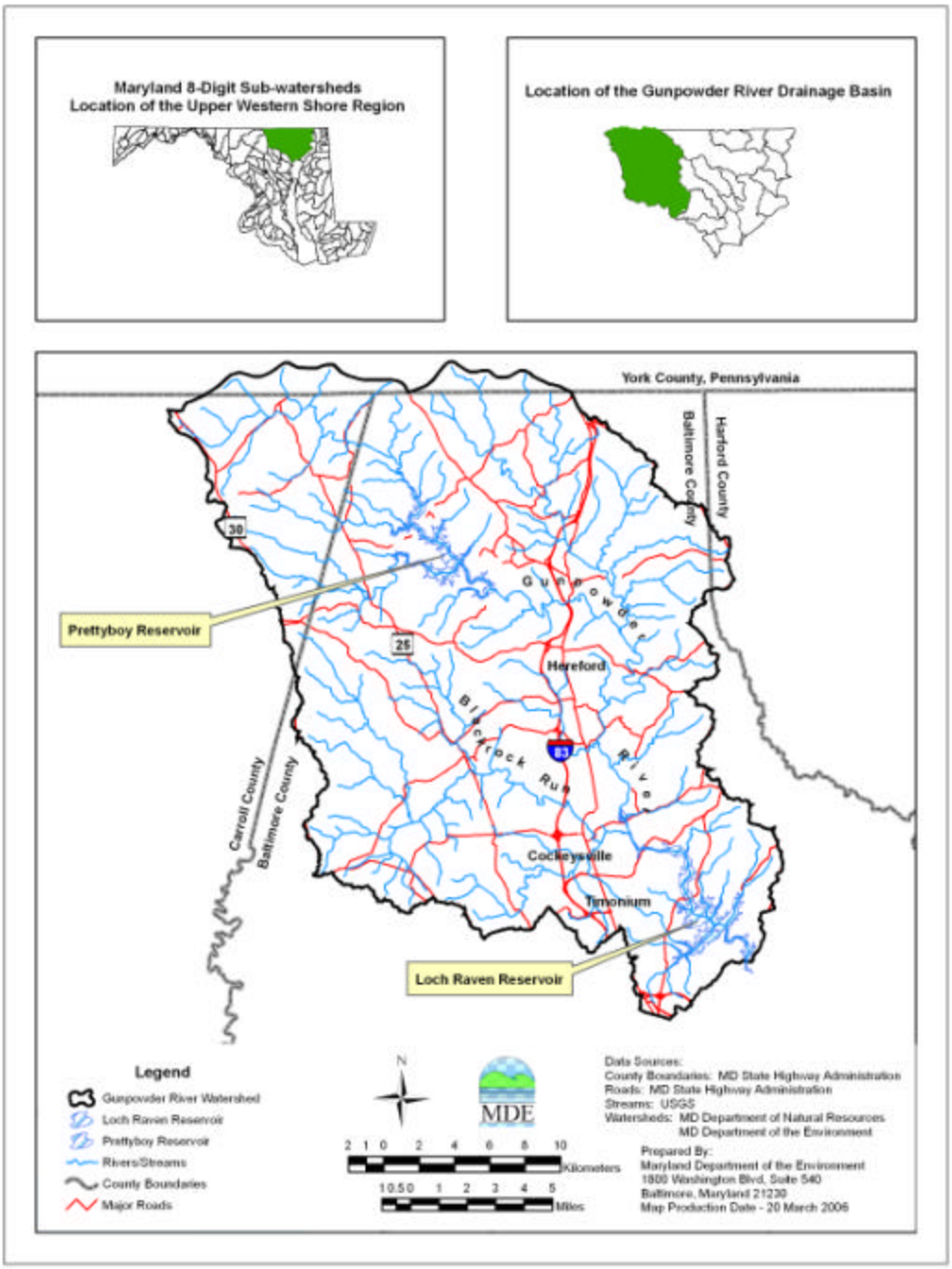

Figure 1: Location of Prettyboy and Loch Raven Reservoirs

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.

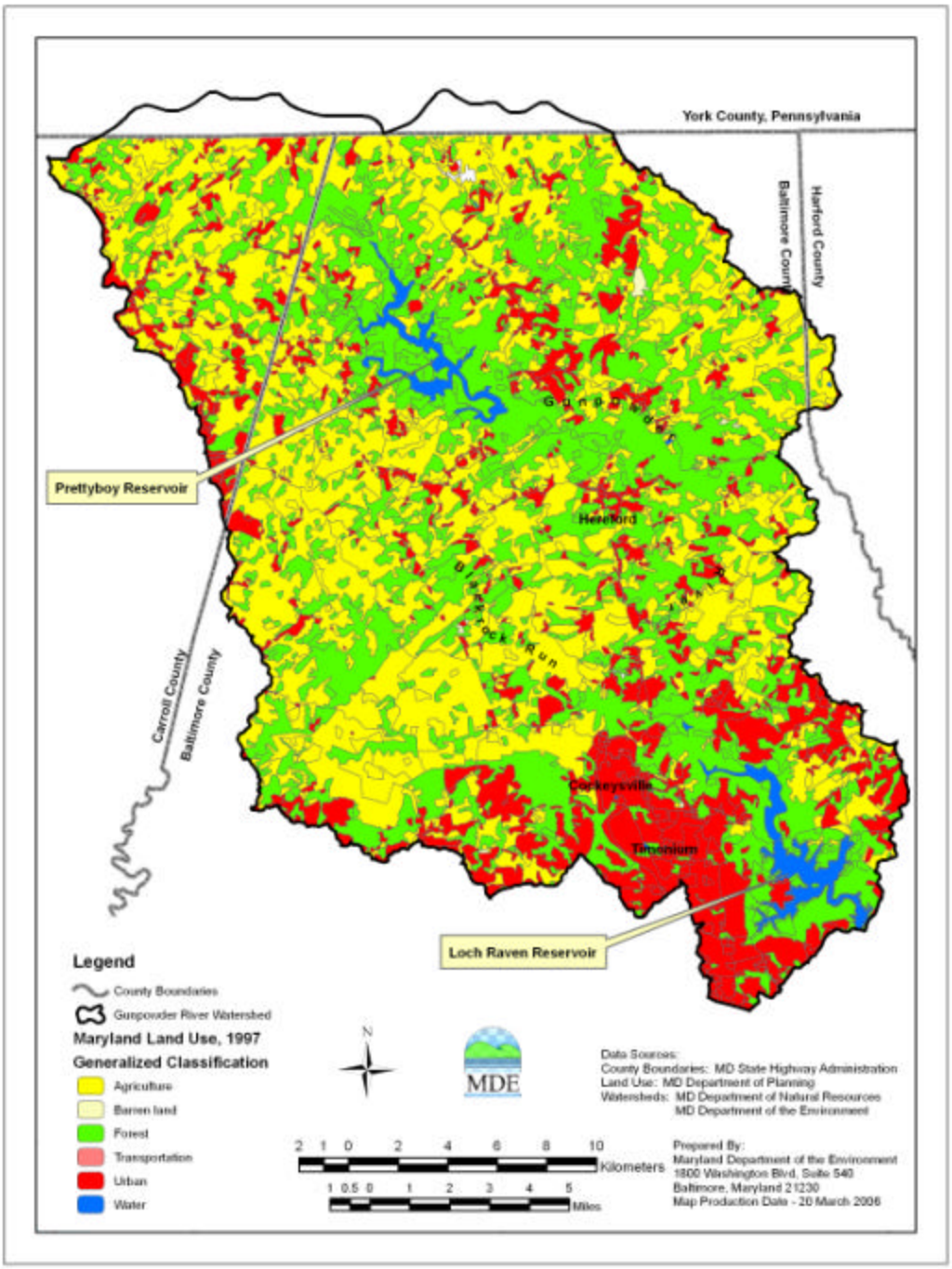

Figure 2: Land Use in Gunpowder Falls Watershed

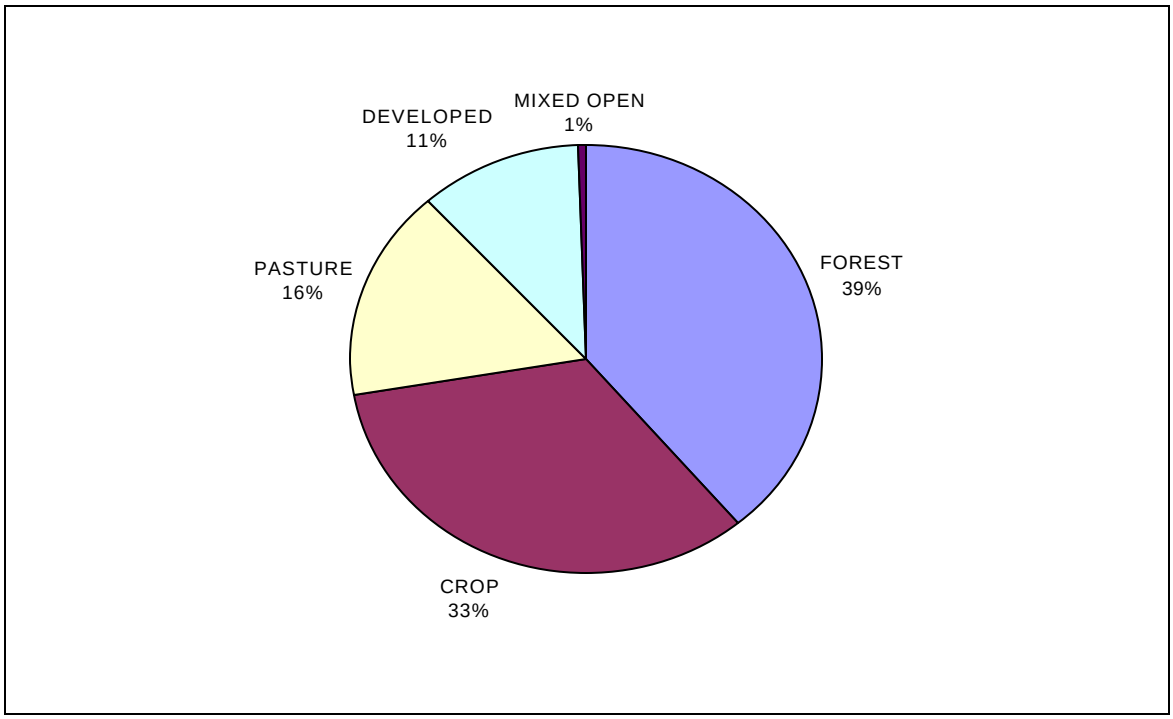

Figure 3: Proportion of Land Use in the Prettyboy Reservoir Watershed

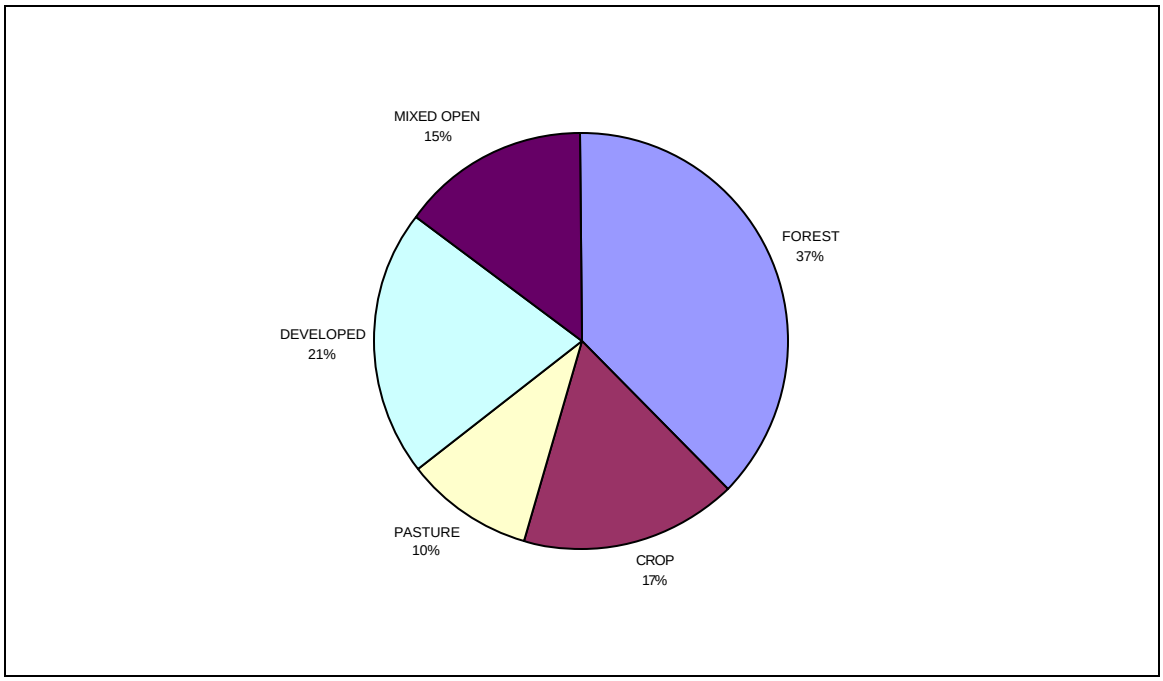

Figure 4: Proportion of Land Use in the Loch Raven Reservoir Watershed

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.

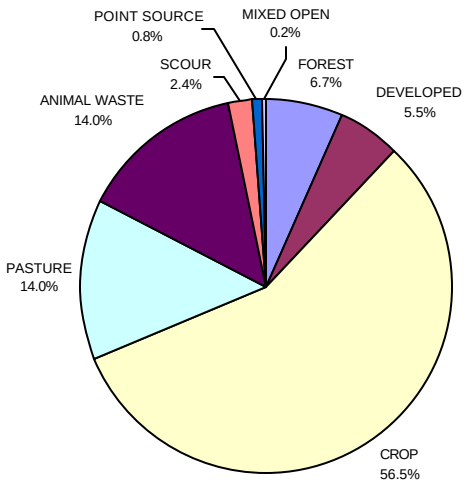

Figure 5: Percent Contribution of Sources to Total Phosphorus Loads to Prettyboy Reservoir

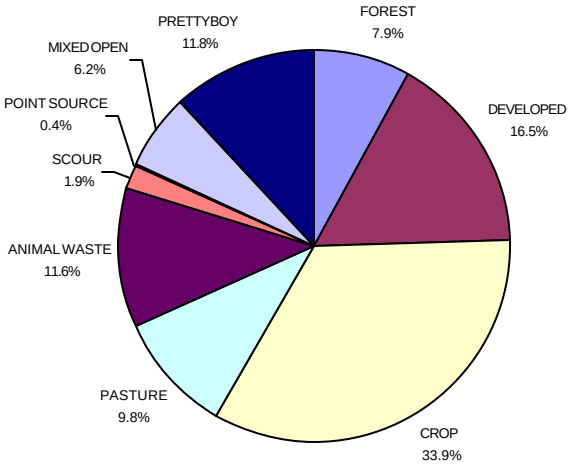

Figure 6: Percent Contribution of Sources to Total Phosphorus Loads to Loch Raven Reservoir

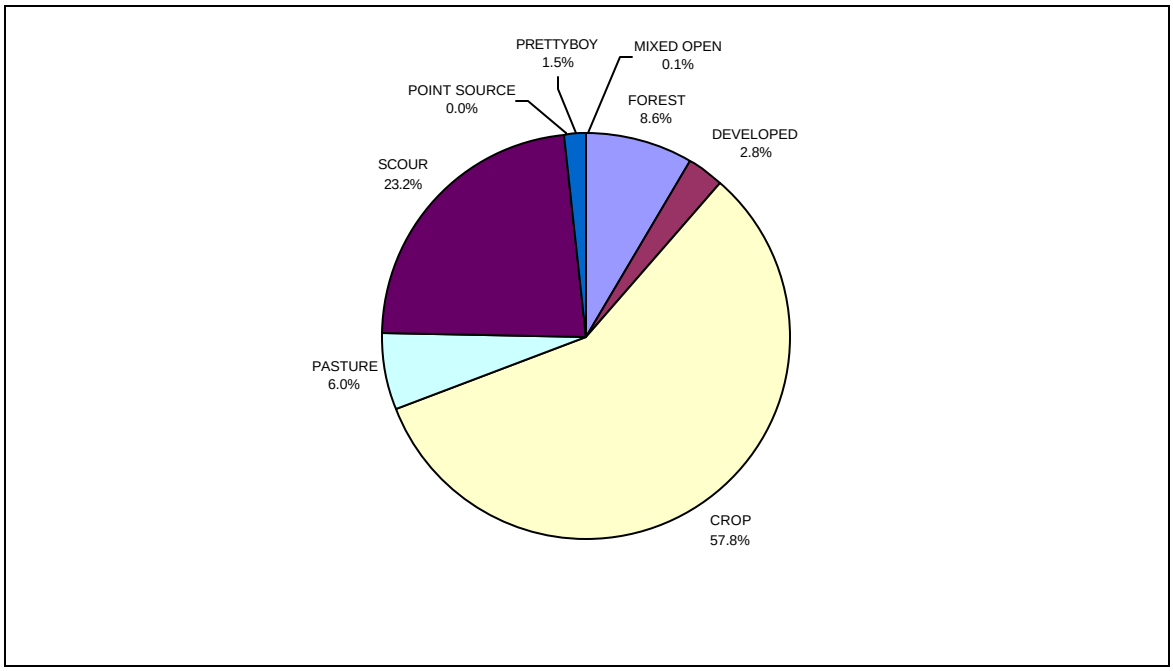

Figure 7: Percent Contribution of Sources to Sediment Loads to Loch Raven Reservoir

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)

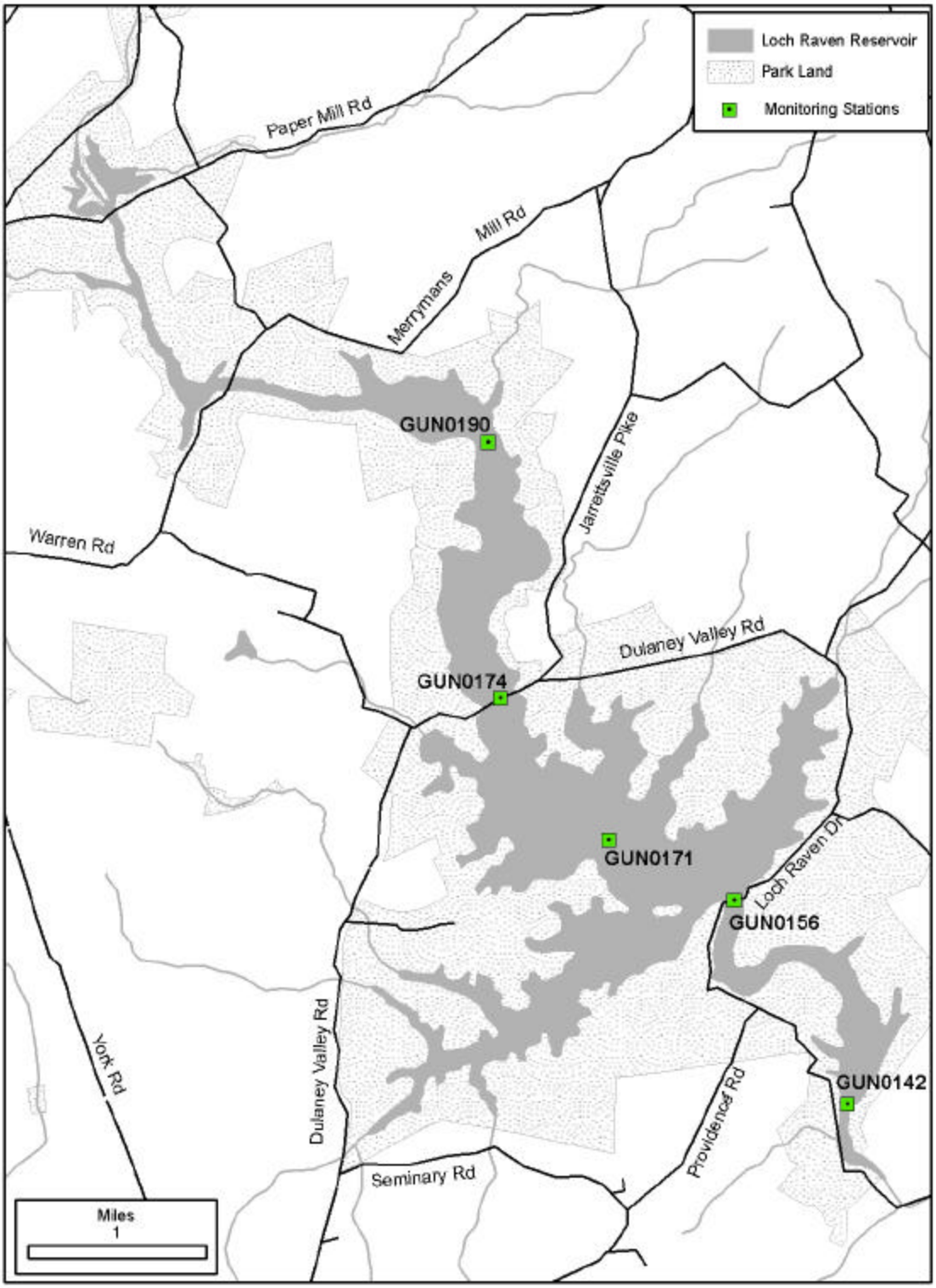

Figure 9: Sampling Locations in Loch Raven Reservoir (from DPW)

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.

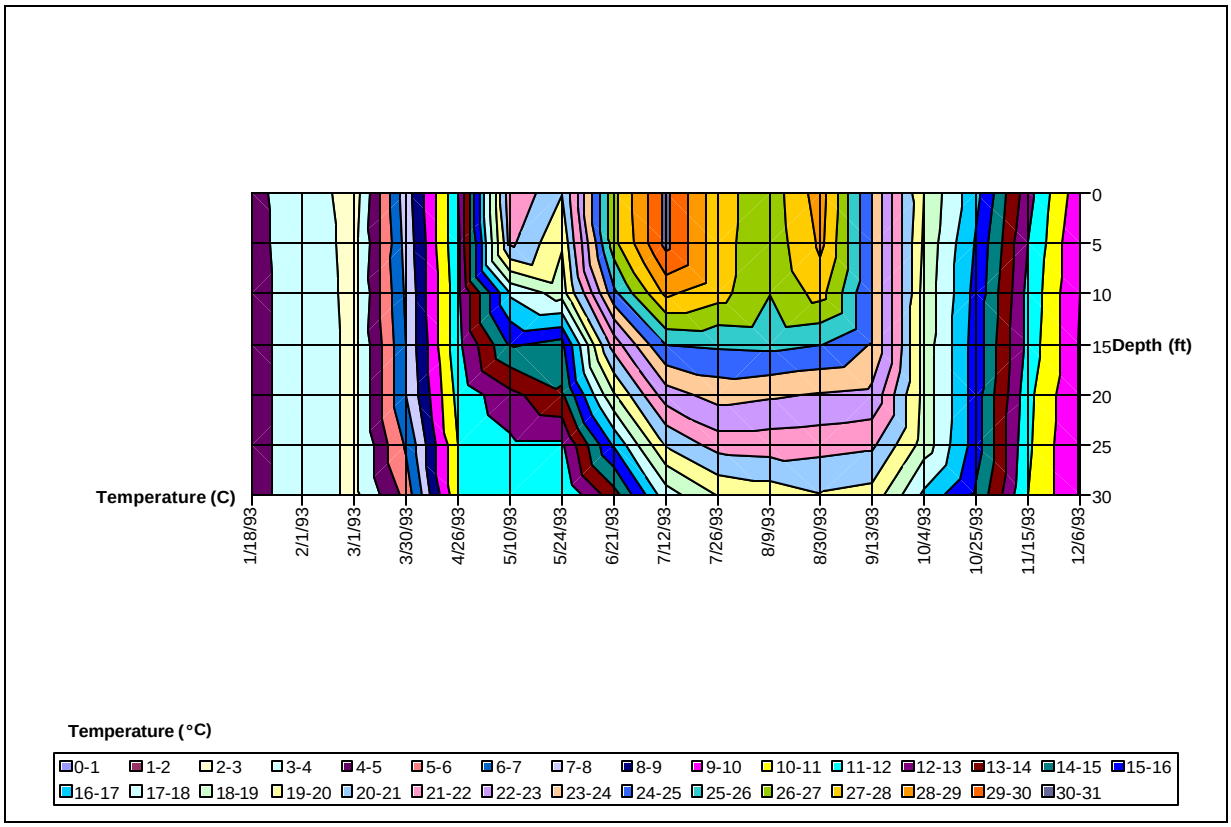

Figure 10: Isothermal Contours, Loch Raven Reservoir, Middle Stations, 1993

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.

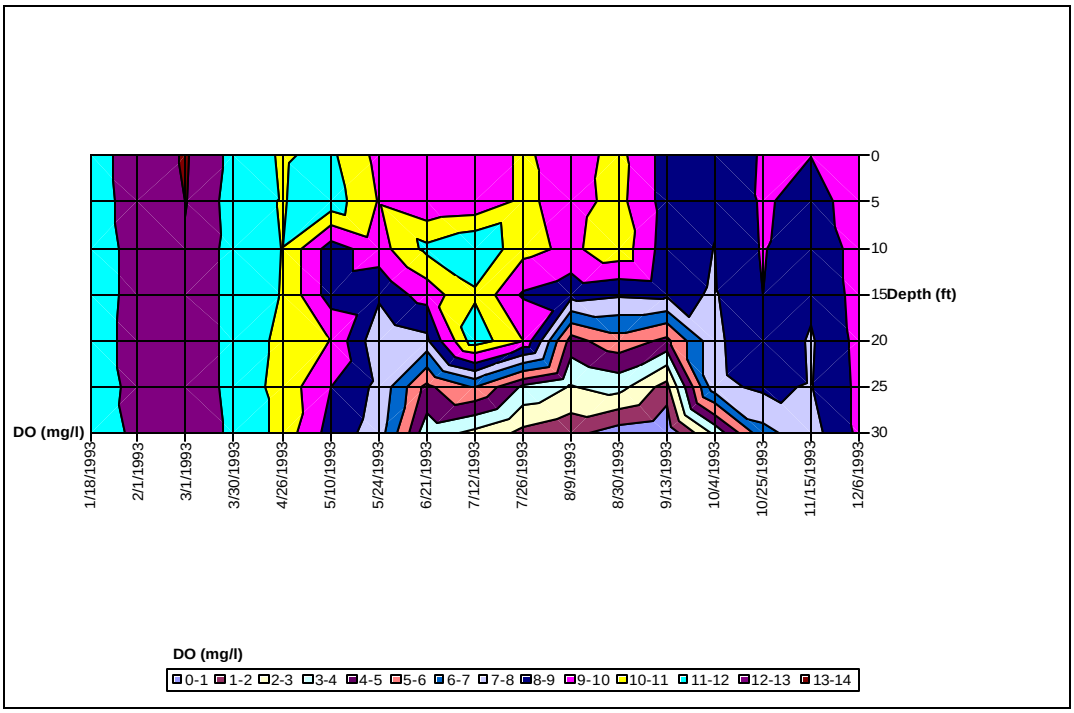

Figure 11: DO Contour, Loch Raven Reservoir, Middle Locations, 1993

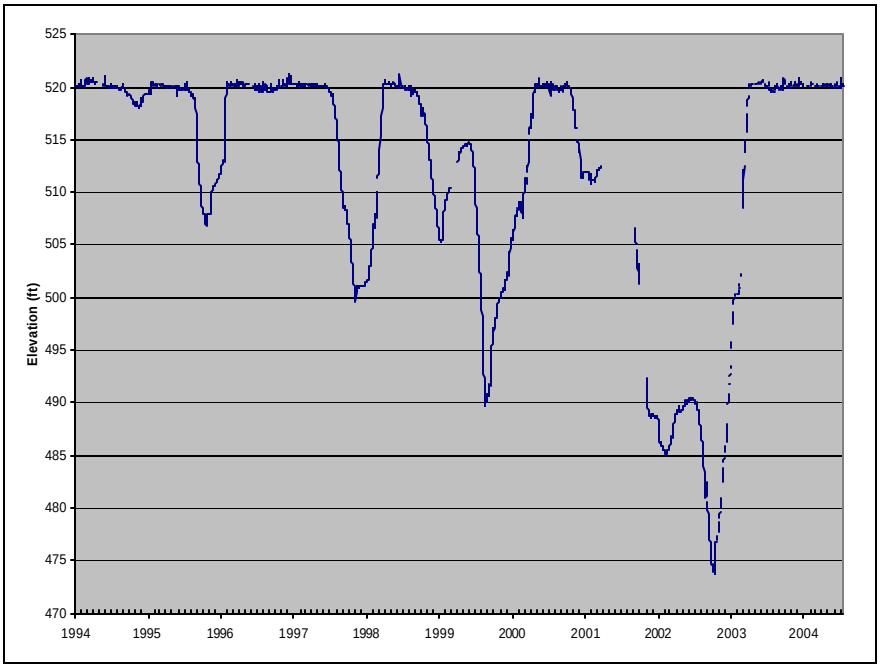

Figure 12: Surface Water Elevations in Prettyboy Reservoir, 1994-2004

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.

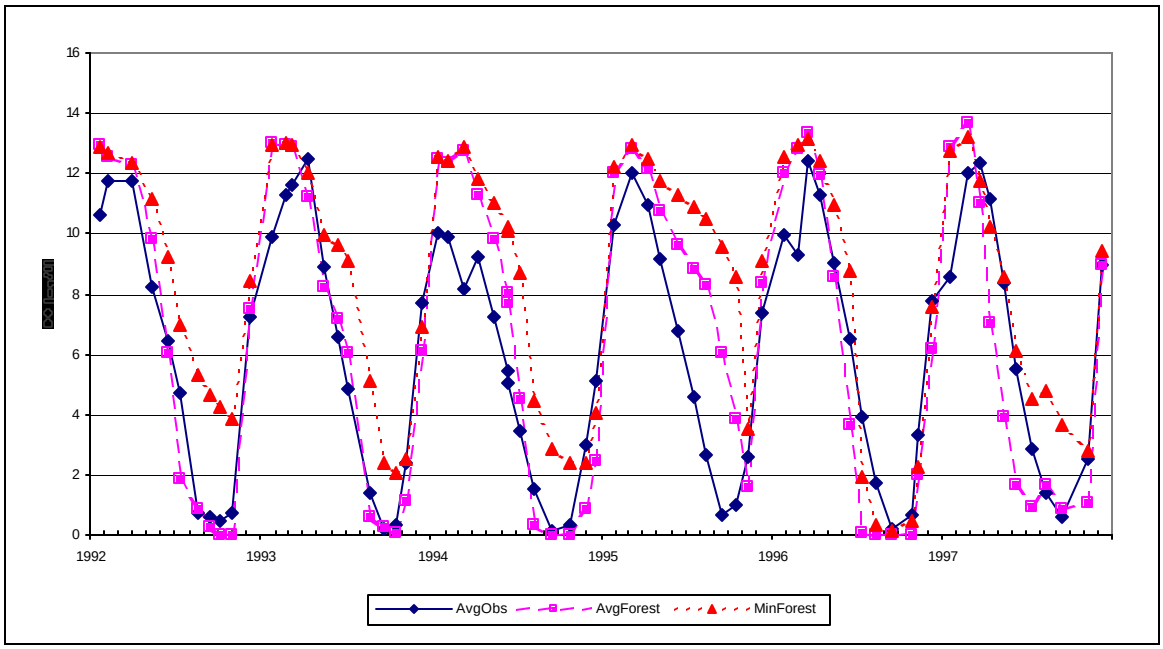

Figure 13: Observed and Simulated Average Bottom DO Concentrations, Lower Stations, All-Forest Scenario, Prettyboy Reservoir

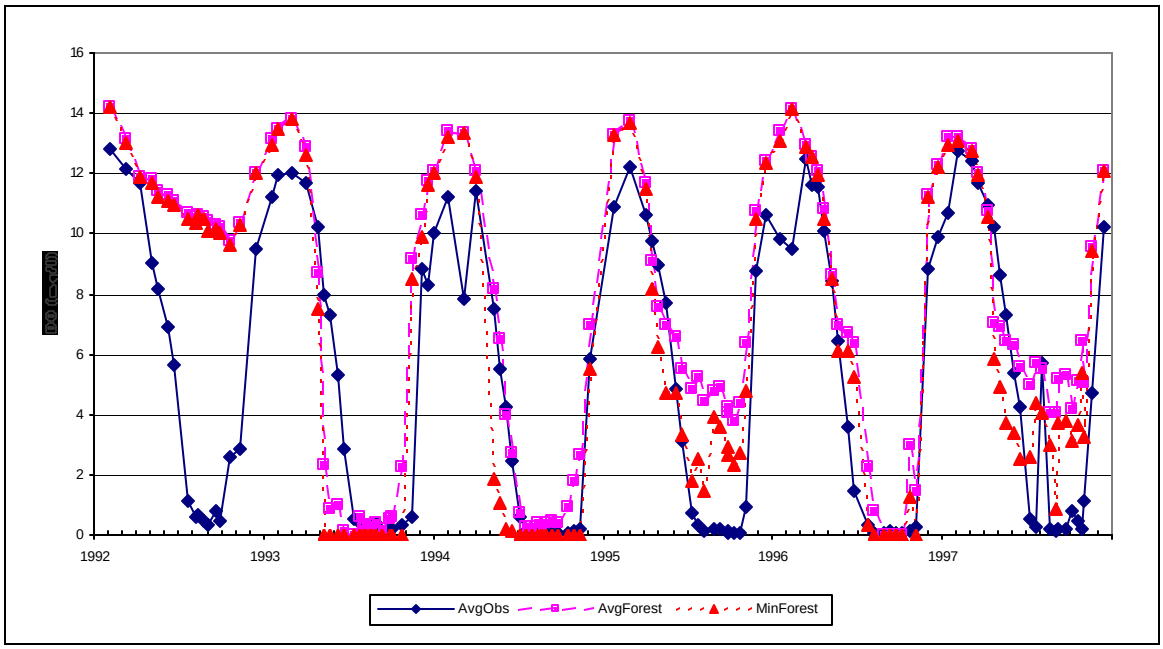

Figure 14: Observed and Simulated Average Bottom DO Concentrations, Lower Stations, All-Forest Scenario, Loch Raven Reservoir

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.

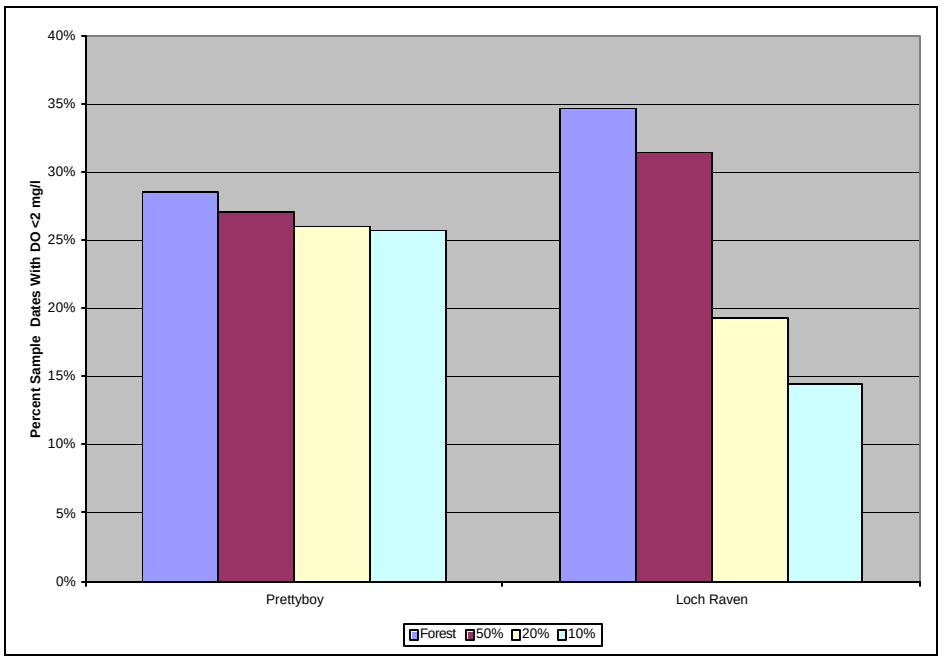

Figure 15: Percent of Sampling Dates on which DO < 2.0 mg/l as a function of proportion of All-Forest Scenario

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 L

Biological Assessment for Loch Raven East Watershed (Area R) Conducted in 2011

By Dennis Genito

Baltimore County
Department of Environmental Protection and Sustainability
Watershed Management and Monitoring Section
December 2011

Introduction

This report is in support of a Small Watershed Action Plan (SWAP), which is a watershed management function of the Baltimore County Department of Environmental Protection and Sustainability (EPS). The report describes the benthic macroinvertebrate and fish communities of streams draining the northeastern portion of Loch Raven Reservoir (Area R). The benthic data was compiled from an annual sampling program managed by EPS and the fish data was collected during August and September 2011, by biologists from EPS and the Maryland Department of Natural Resources Fisheries Service (MD DNR). A primary goal of the fish sampling was to assess the status of naturally reproducing trout populations, especially native brook trout. Brook trout are extremely sensitive to environmental disturbance, and their presence indicates good water quality. Fish will be discussed in the first section of the report, and benthic macroinvertebrates will be discussed in the second section. An integrated discussion of all biological data will follow Section 2.

Section 1 - Fish

Twelve stations were sampled in Area R. Maryland Biological Stream Survey (MBSS) protocols were followed. The specific goals of the sampling were (1) to assess the abundance and distribution of naturally reproducing brook and brown trout, (2) to document the abundance and distribution of the general fish community, and use that data to determine the biological health of the watershed, and (3) to assess physical habitat quality at all stations sampled for fish.

Methods

A combination of mapping, examination of existing data, field reconnaissance surveys, and cooperation of private landowners provided thirteen stations for fish sampling. Stations were also selected to correspond with a chemical synoptic survey. Stations are shown in Figure 1, and detailed station locations are provided in Table 1. MD DNR provided 2008 data for a station on Dulaney Valley Branch. Electrofishing was conducted between August 30 and September 30, 2011. A 75-m reach was sampled at each station, using the two-pass removal method with Smith-Root® LR12 backpack electrofishing units. All fish species were identified, counted, and weighed. Trout young-of-year and adults were counted and weighed separately. Non-trout fish species were weighed in aggregate. An MBSS Summer Index Period physical habitat assessment was completed at each station. The MBSS Fish Index of Biotic Integrity (FIBI) and Physical Habitat Index (PHI) were calculated for each station. Epifaunal substrate quality, instream habitat quality, and riffle quality are rated as “Optimal,” “Sub-optimal,” “Marginal,” and “Poor” in the field. For the purpose of discussion, number of pieces of instream wood, erosion extent and severity, and percent embeddedness were placed into the four condition categories as follows. The scoring range for percent shading and percent embeddedness (0-100%) was divided into quartiles. Shading greater than 75% was considered optimal, between 51-75% sub-optimal, 26-50% marginal, and 25% or less poor. Embeddedness of 25% or less was considered optimal, between 26-50% sub-

optimal, 51-75% marginal, and greater then 75% poor. Erosion extents for the left and right banks were averaged. Mean erosion extents less than 18.75 m were considered optimal, 18.76-37.5 sub-optimal, 37.6-56.25 marginal, and greater than 56.25 poor. Left and right bank erosion severities were also averaged. Mean erosion severity of 0 was optimal, 0-1 sub-optimal, 1-2 marginal, and 2-3 poor. Distance to the nearest road and number of pieces of instream wood were not converted to a condition scale because the range of scores was too narrow to make such a transformation meaningful.

Results

Brook trout

No brook trout were collected during the survey.

Brown trout

Wild brown trout were collected at eight stations, distributed among Fitzhugh Run, Greene Branch, and Overshot Run. Figure 2 shows the length-frequency distribution of brown trout in Fitzhugh Run, Greene Branch, and Overshot Run. These data show the number of year-classes of fish in each stream, and also how the different ages of fish are distributed along the length of the stream. There are two year-classes of fish in Fitzhugh Run. Both Greene Branch and Overshot Run have four year-classes of fish. MD DNR collected wild brown trout from Dulaney Valley Branch in 2008 (Table 2). Of the 93 individuals found, 89 were young-of-year and 4 were adults.

Non-trout Fish Community

Fifteen non-trout fish species were collected from Loch Raven Reservoir streams (Table 2). They were a combination of catfish, darters, minnows, sunfish, and suckers. All species are either cool- or warm-water fish. Warm-water fish tended to be collected at stations near the stream mouth (LR Syn 1, 2B, 3, 8, 8B, 13, 17). Of the 16 species collected (including brown trout), 12 species are native to this region of Maryland. Bluegill, brown trout, green sunfish, and largemouth bass are non-native.

Overshot Run was the only stream with a FIBI rating of Good (LR Syn 2B; Table 3). Three stations were rated Fair (LR Syn 1, 2, 5). All other stations were rated either Poor or Very Poor.

Stream Physical Habitat

Stream habitat was generally intact, as only one station was considered degraded (Table 3). Three stations received the highest rating of minimally degraded, while the rest were partially degraded. The 3 stations with the best habitat were located in the downstream portions of their sub-watersheds, close to Loch Raven Reservoir (LR Syn 2B, 3, and 8B). To isolate physical stressors to Area R streams, Figure 3 shows the percentage of sites in

each condition category for individual habitat parameters. Erosion extent and severity, riffle quality, and percent embeddedness had less than 50% of sites in the optimal range. Small percentages of sites had poor conditions for epifaunal substrate quality, erosion severity, riffle quality, and percent embeddedness. Shading was generally good, as 75% of sites were considered optimal. Seventy-five percent of sites were more than 50 m away from any road. Seventeen percent of sites had at least ten pieces of instream wood per 75 m, while 67% had at least five pieces.

Section 2 – Benthic Macroinvertebrates

Benthic macroinvertebrates are small, stream-dwelling organisms with no backbone that are visible to the naked eye. They are used as water quality indicators worldwide because of their ability to integrate water quality conditions over long time periods. As partial fulfillment of the requirements of the National Pollutant Discharge and Elimination System (NPDES) permit administered by EPS, a probabilistic benthic macroinvertebrate sampling program was initiated in 2003. Benthic macroinvertebrates are collected annually following MBSS methods and Benthic Index of Biotic Integrity (BIBI) scores are reported.

Methods

Potential sampling stations are randomly generated using a geographic information system (GIS). Where necessary, permission to enter private property is obtained. Eighty-seven stations are selected for sampling. Thirteen stations are re-sampled annually to monitor biological condition over time. These stations are referred to as "sentinel sites." A consultant collects the macroinvertebrate and habitat data, performs the macroinvertebrate identification, and provides the raw data to EPS. The raw data are converted to metrics, from which the BIBI is calculated. Each metric contributes unique information to the overall index value. A brief definition of each metric follows.

No. Taxa: the total number of different invertebrate taxa collected. Higher numbers indicate better water quality.

No. EPT Taxa: the total number of Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly) taxa collected. These three orders of aquatic invertebrates are considered to be the most sensitive to disturbances in stream environments. Higher numbers indicate better water quality.

No. Ephemeroptera Taxa: the number of Ephemeroptera (mayfly) taxa collected. Higher numbers indicate better water quality.

Percentage Intolerant Urban: the percentage of invertebrates considered intolerant to urbanization. Higher percentages indicate better water quality.

Percentage Chironomidae: the percentage of invertebrates composed of Chironomidae (midges). This family of two-winged flies is tolerant of a wide range of environmental stressors. Lower percentages indicate better water quality.

Percentage Clingers: the percentage of invertebrates adapted for life in flowing water. These organisms require hard, clean substrates. Higher percentages indicate better water quality.

Figure 4 shows the 17 stations isolated from the 2004-2010 benthic data.

Results

Benthic metric and BIBI values are shown in Table 4. Greater than 50% of all stations in all years had Good BIBIs (Figure 5). By sub-watershed, all stations over all years in Overshot Run had good biological condition. Eighty percent of Greene Branch stations, and 50% of Fitzhugh Run and Dulaney Valley Branch stations had Good BIBI values (Figure 6). Only one station (0310079, sampled in 2010) on Greene Branch had poor biological condition.

Stations with higher diversity (as measured by the total number of taxa collected) and higher numbers of mayfly, stonefly, and caddisfly taxa (EPT taxa) had higher BIBI scores (Figure 7). Likewise, stations with higher percentages of organisms considered intolerant to urban conditions had higher BIBI scores (Figure 7). Stations with benthic communities composed of higher percentages of pollution-tolerant Chironomidae had lower BIBI scores (Figure 8).

Discussion

Streams in the northeastern portion of the Loch Raven Reservoir watershed generally support healthy communities of fish and benthic macroinvertebrates. Many organisms that perform essential functions, such as processing of terrestrial organic matter, are present. Four streams in this area support moderate to high-density brown trout populations. Although brown trout have replaced the native brook trout, in itself an indicator of degraded stream condition, brown trout still require cold, relatively clear flows and stable habitat to prosper. Interestingly, stations with better habitat condition were located in the downstream portions of their streams, on land protected by Baltimore City Reservoir property. Stream habitat showed the effects of impervious cover, as erosion extent and severity, riffle quality, and percent embeddedness showed the most deviation from optimal conditions. Impervious land cover concentrates storm flow, causing erosion along floodplains and stream banks. Erosion results in greater substrate embeddedness and lowered riffle condition, as fine material surrounds the cobble and gravel used by benthic macroinvertebrates. It should be noted, however, that the natural topography of Area R streams contributes to the physical conditions observed in the field. Many of the surveyed streams flow through valleys with steep slopes, which naturally concentrate storm flow. The condition of biological communities in this portion of Loch Raven Reservoir is consistent with the light residential development present in the stream

headwaters.

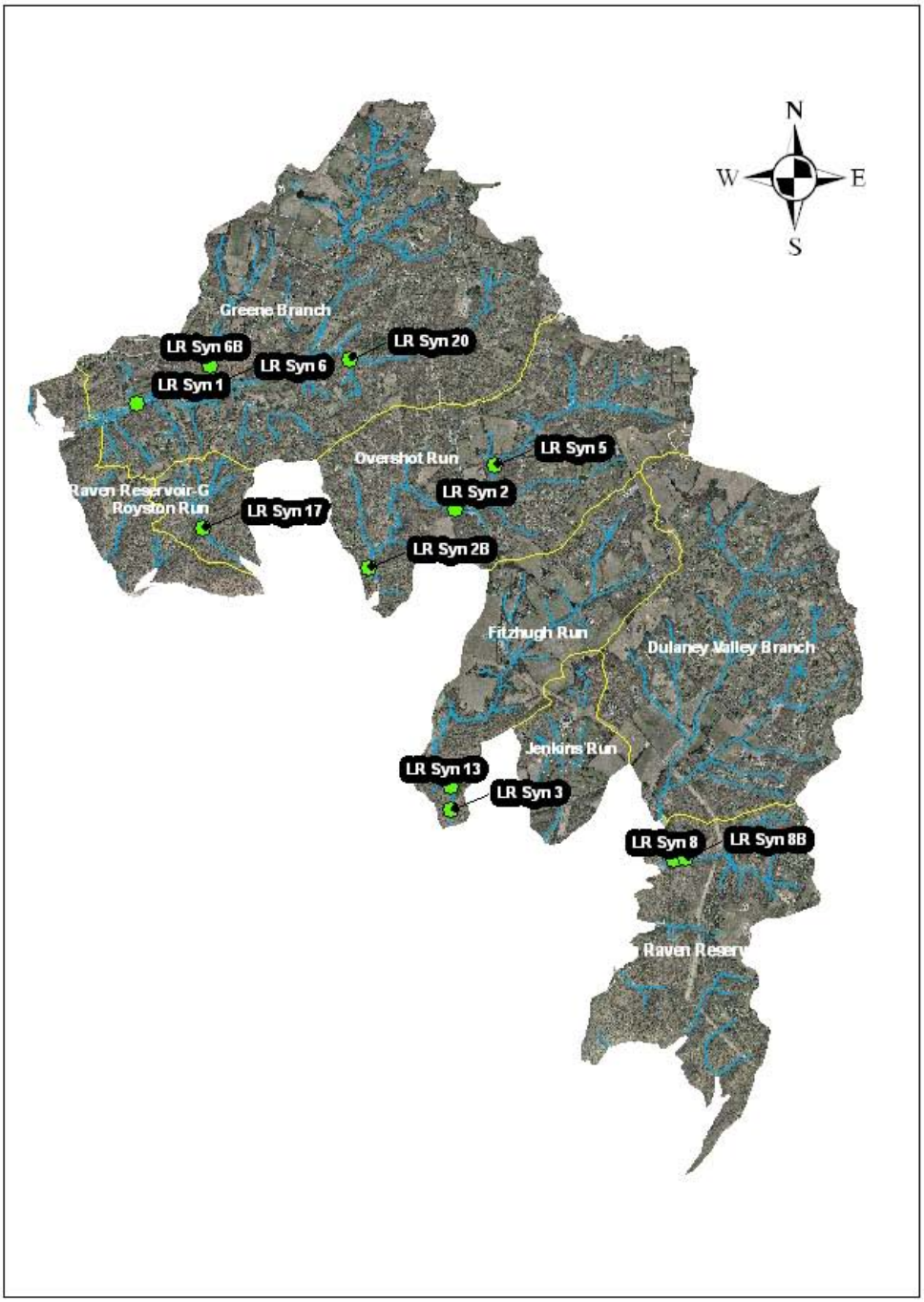
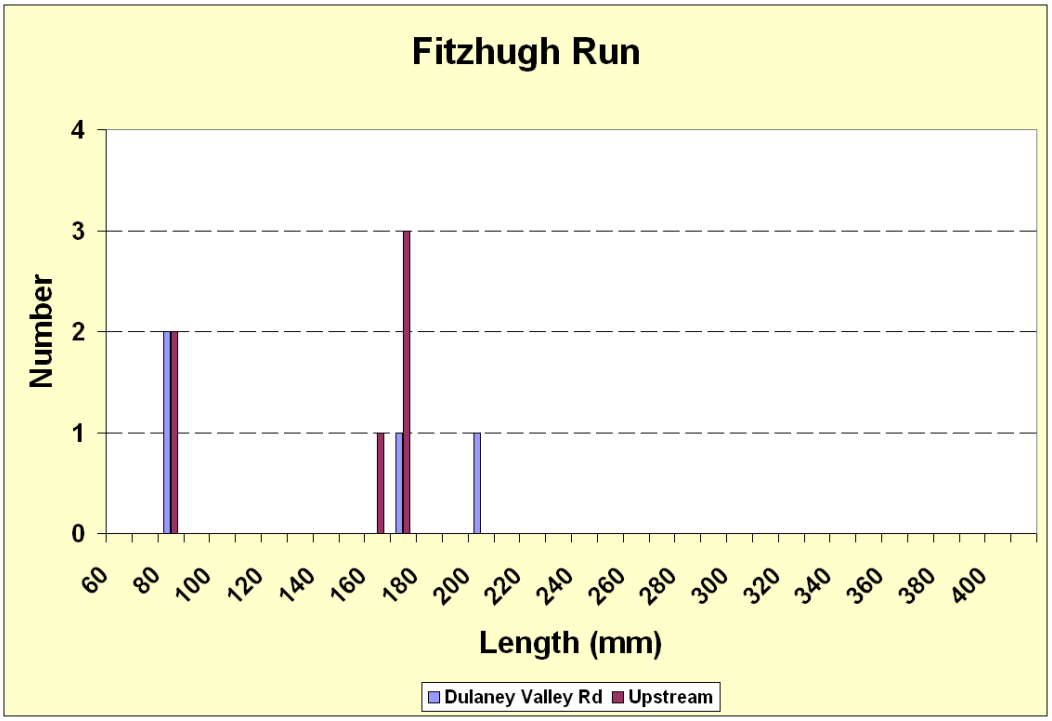
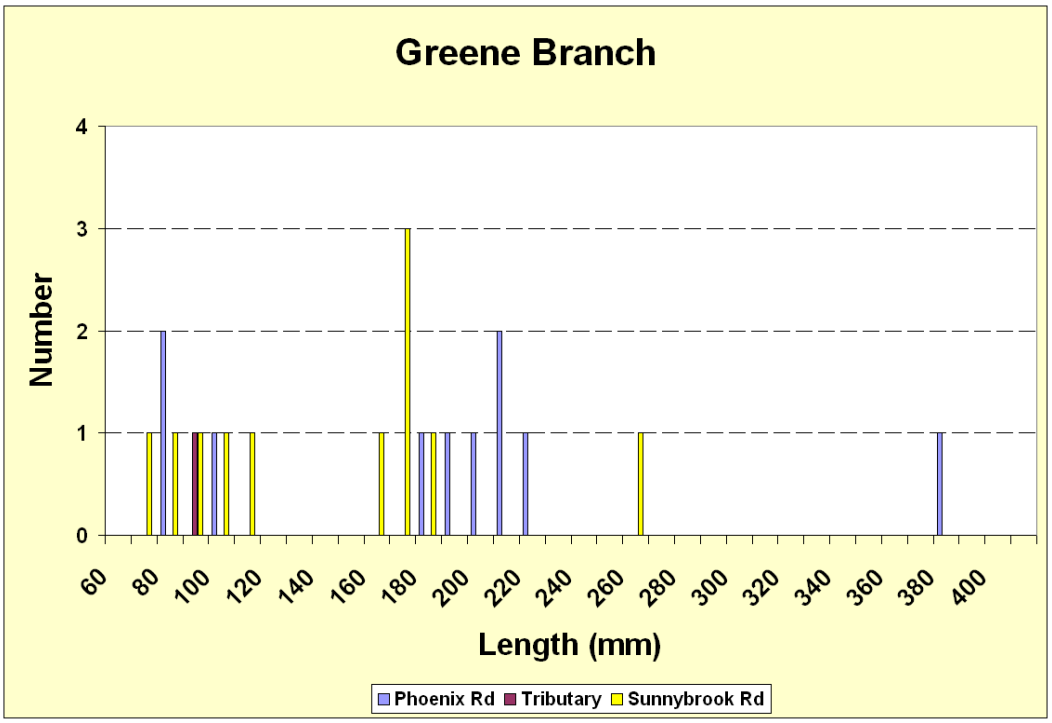


Figure 1. Area R fish sampling stations.

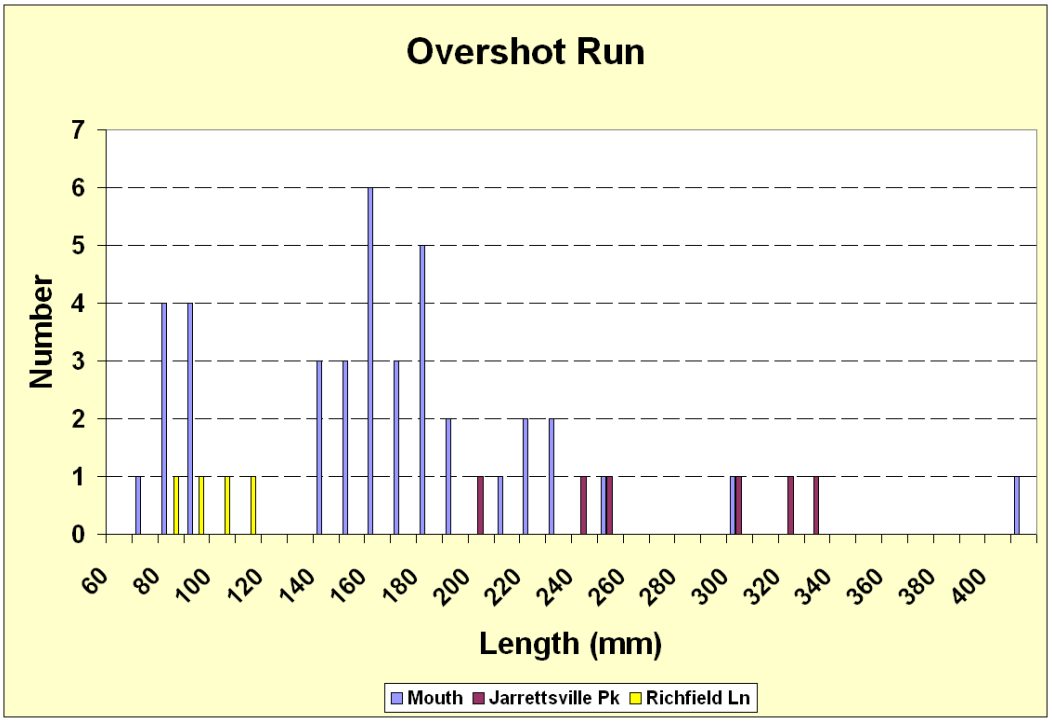


(a)



(b)

Figure 2. Length-frequency distributions for brown trout in (a) Fitzhugh Run, (b) Greene Branch, and (c) Overshot Run.



(c)

Figure 2 (cont.). Length-frequency distributions for brown trout in (a) Fitzhugh Run, (b) Greene Branch, and (c) Overshot Run.

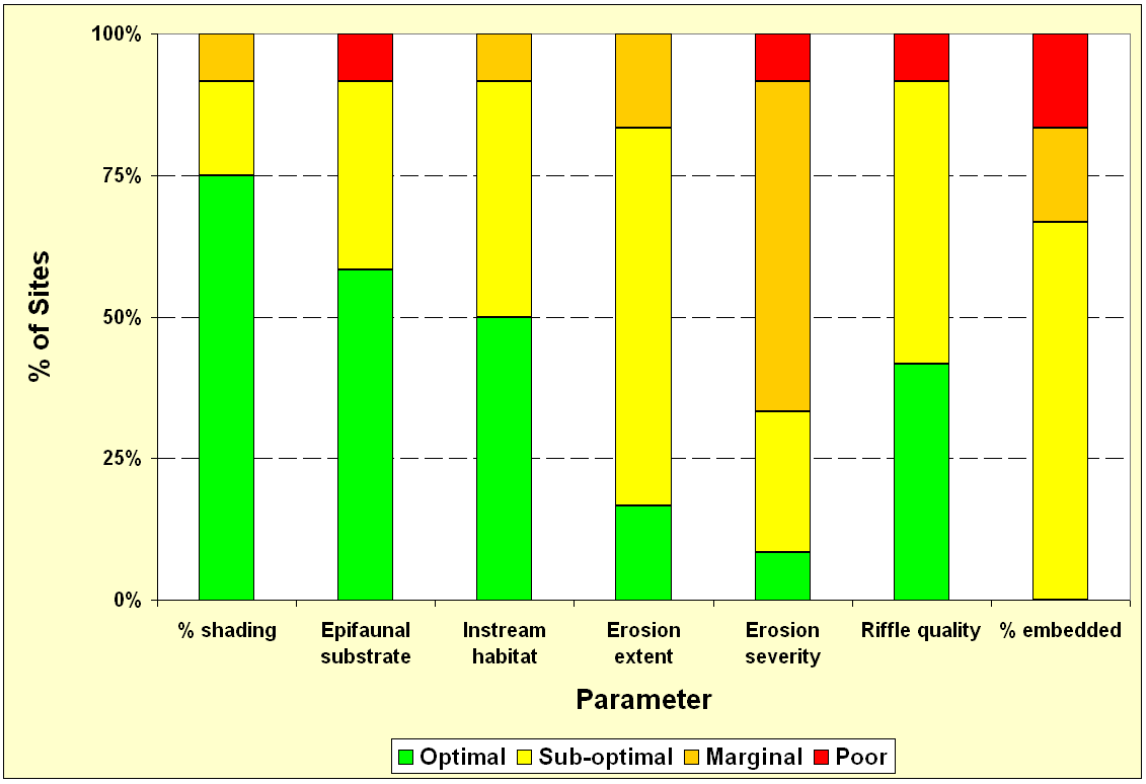


Figure 3. Percentages of Area R sites in each condition category for individual parameters of the PHI.

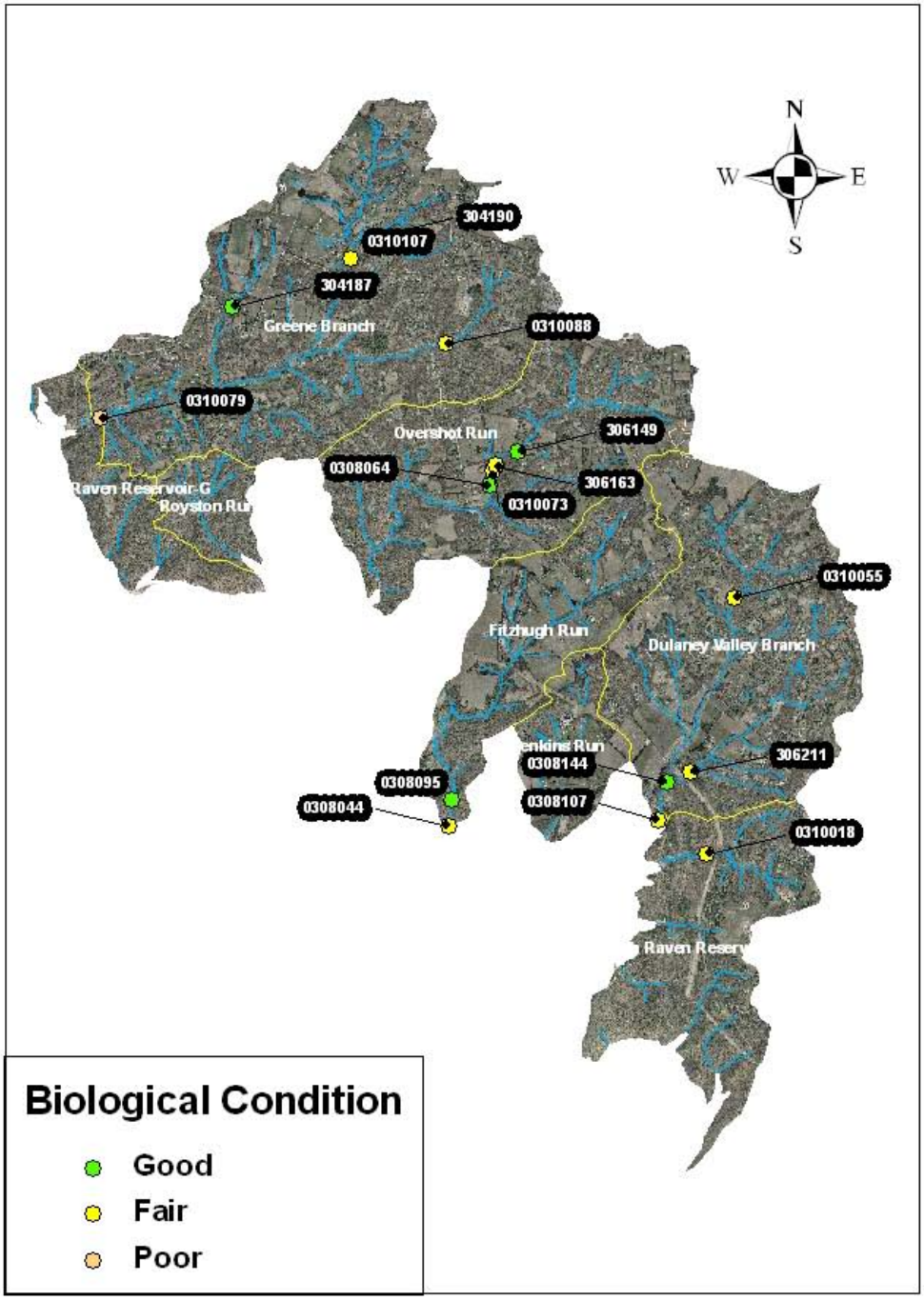


Figure 4. Area R benthic sampling locations with biological condition.

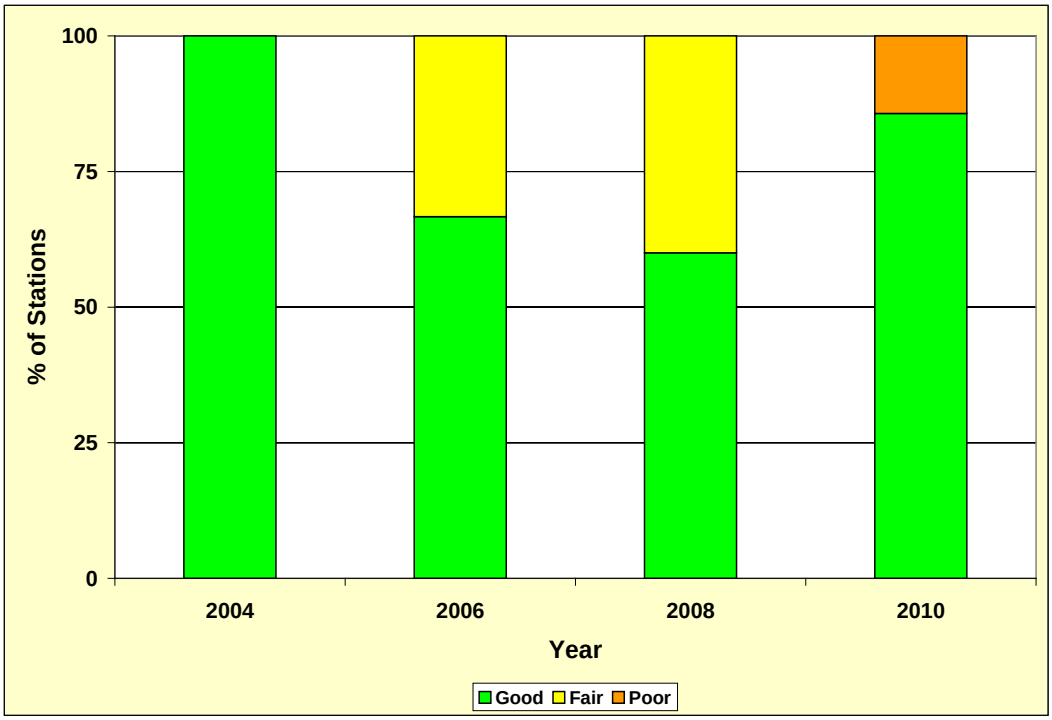


Figure 5. Percentage of BIBI values in condition categories, by year, for Loch Raven Reservoir benthic sampling stations.

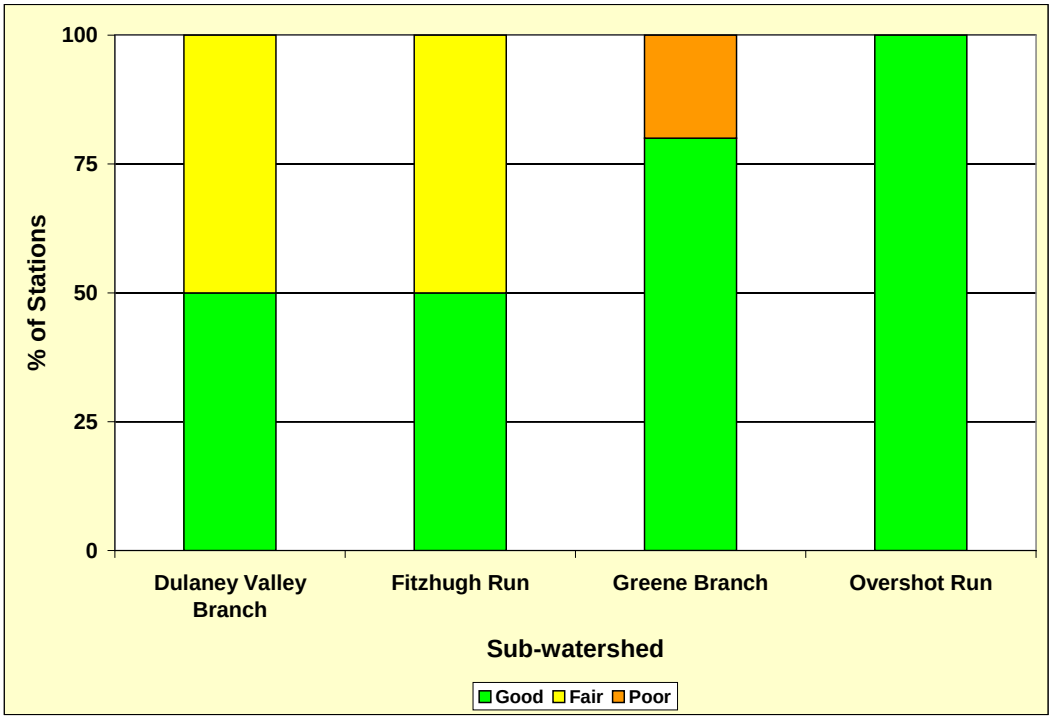


Figure 6. Percentage of BIBI values in condition categories, by sub-watershed, for Loch Raven Reservoir benthic sampling stations.

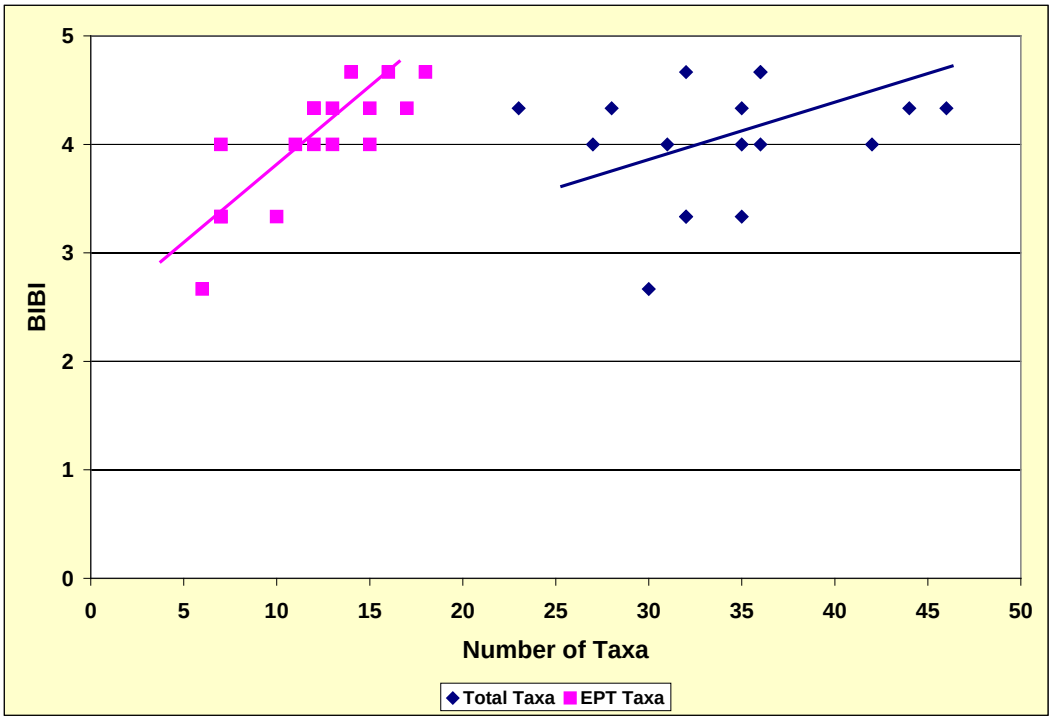


Figure 7. Total numbers of taxa and numbers of EPT taxa in relation to BIBI values for Loch Raven Reservoir benthic sampling stations.

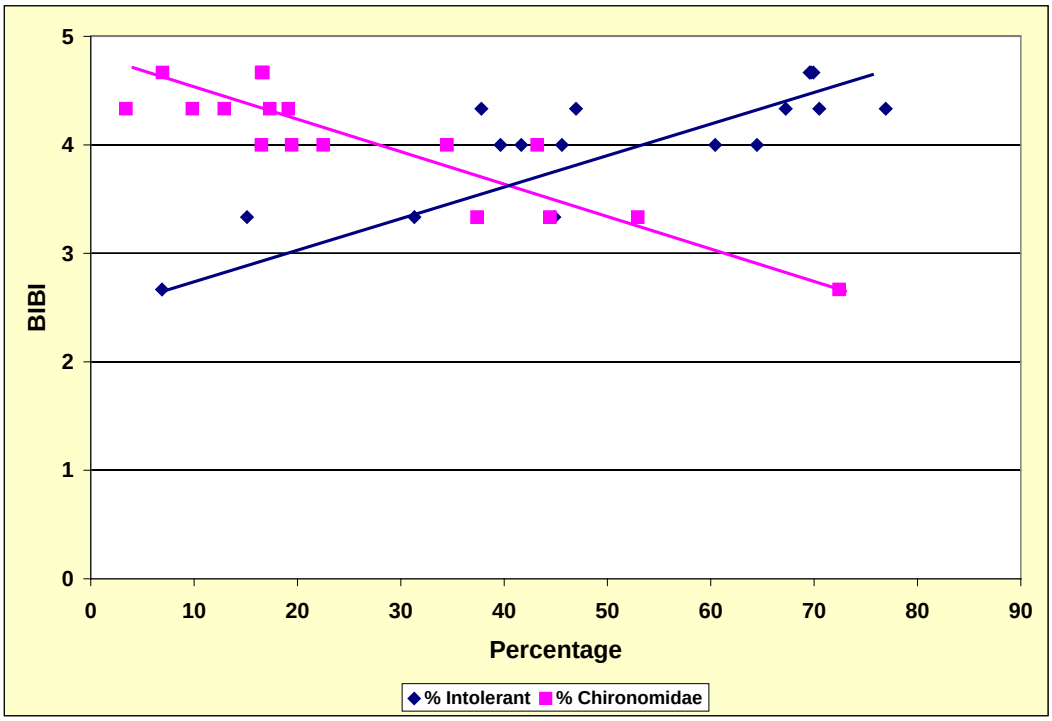


Figure 8. Percentage organisms intolerant of urban conditions and percentage organisms composed of Chironomidae in relation to BIBI values for Loch Raven Reservoir benthic sampling stations.

Table 1. Area R fish sampling station locations.

Station	Stream	Latitude	Longitude
LR Syn 1	Greene Branch	39° 30' 24.88"	76° 36' 43.16"
LR Syn 2	Overshot Run	39° 29' 46.48"	76° 34' 16.67"
LR Syn 2B	Overshot Run	39° 29' 25.91"	76° 34' 57.19"
LR Syn 3	Fitzhugh Run	39° 27' 59.53"	76° 34' 19.52"
LR Syn 5	Overshot Run	39° 30' 1.93"	76° 33' 58.75"
LR Syn 6	UNT Greene Branch	39° 30' 31.80"	76° 36' 6.80"
LR Syn 6B	UNT Greene Branch	39° 30' 38.29"	76° 36' 9.02"
LR Syn 8	UNT Loch Raven Res.	39° 27' 41.06"	76° 32' 37.19"
LR Syn 8B	UNT Loch Raven Res.	39° 27' 42.01"	76° 32' 32.18"
LR Syn 13	Fitzhugh Run	39° 28' 7.70"	76° 34' 19.68"
LR Syn 17	Royston Run	39° 29' 40.00"	76° 36' 13.26"
LR Syn 20	Greene Branch	39° 30' 40.31"	76° 35' 5.52"
MD DNR	Dulaney Valley Branch	39° 28' 12.48"	76° 32' 38.88"

Table 2. Fish community composition in the northeastern Loch Raven Reservoir watershed.

	Station												
	LR Syn 1	**LR Syn 2**	**LR Syn 2B**	**LR Syn 3**	**LR Syn 5**	**LR Syn 6**	**LR Syn 6B**	**LR Syn 8**	**LR Syn 8B**	**LR Syn 13**	**LR Syn 17**	**LR Syn 20**	**Dulaney Valley Branch**
Blacknose dace	19	51	25	47	117	148	62	63	62	33		9	Common
Bluegill	30	7	12					1	3	1			
Bluntnose minnow	6		26	108					52	80			Scarce
Brown bullhead				3					2	16			
Brown trout	10	6	39	4	4		1			6		11	93
Creek chub	3	37	23	16	62	35	14	18	16	7			Scarce
Green sunfish	4		33	13		1			16	10			
Largemouth bass				1									Scarce
Lepomis hybrid										4			
Longnose dace	39		20	10		2	7		1	10		12	Scarce
Northern hogsucker			3										
Pumpkinseed	7			2					5	3			
Redbreast sunfish								3					
Rosyside dace		5	1	11		7	3			8			
Tesselated darter		20	2		8								Scarce
White sucker		5	3		1								Scarce
Yellow bullhead	1		8	8				2	17	98			Scarce
Weight (g)	1501	2567	3241	895	1769	355	305	407	911	1241	0	496	N/A

Table 3. Fish IBI (FIBI) and Physical Habitat Index (PHI) scores for northeastern Loch Raven Reservoir fish stations. FIBI Condition Categories: 4-5=Good, 3-3.99=Fair, 2-2.99-Poor, 1-1.99=Very Poor. PHI Condition Categories: 81-100=Minimally Degraded, 66-80=Partially Degraded, 51-65=Degraded, 0-50=Severely Degraded.

Station	**FIBI**	**Condition**	**PHI**	**Condition**
LR Syn 1	3	Fair	70	Partially degraded
LR Syn 2	3	Fair	78	Partially degraded
LR Syn 2B	4	Good	83	Minimally degraded
LR Syn 3	2.33	Poor	81	Minimally degraded
LR Syn 5	3	Fair	68	Partially degraded
LR Syn 6	1.33	Very Poor	66	Partially degraded
LR Syn 6B	1.67	Very Poor	74	Partially degraded
LR Syn 8	2	Poor	69	Partially degraded
LR Syn 8B	2.33	Poor	85	Minimally degraded
LR Syn 13	2.33	Poor	77	Partially degraded
LR Syn 17	2.33	Poor	52	Degraded
LR Syn 20	2.67	Poor	66	Partially degraded

Table 4. Metric values and BIBI scores for Area R stations sampled for benthic macroinvertebrates. BIBI Condition Categories: 4-5=Good, 3-3.99=Fair, 2-2.99-Poor, 1-1.99=Very Poor.

Station	Sub-watershed	Year	No. Taxa	No. EPT Taxa	No. Ephemeroptera Taxa	% Intolerant Urban	% Chironomidae	% Clingers	BIBI	Condition
0304187	Greene Branch	2004	35	12	5	70	10	34	4.67	Good
0304190	Greene Branch	2004	23	15	8	77	3	57	4.33	Good
0306149	Overshot Run	2006	35	13	3	60	19	66	4.33	Good
0306163	Overshot Run	2006	32	14	5	70	7	77	5.00	Good
0306211	Dulaney Valley Branch	2006	32	7	4	31	44	21	3.33	Fair
0308044	Fitzhugh Run	2008	35	10	4	44	37	19	3.33	Fair
0308064	Overshot Run	2008	36	16	6	70	17	65	4.67	Good
0308095	Fitzhugh Run	2008	28	13	5	68	13	25	4.33	Good
0308107	Dulaney Valley Branch	2008	32	7	2	15	53	34	3.33	Fair
0308144	Dulaney Valley Branch	2008	31	12	4	39	34	51	4.00	Good
0310018	UNT Direct Drainage	2010	27	7	2	64	17	36	4.00	Good
0310055	Dulaney Valley Branch	2010	42	15	5	45	43	34	4.00	Good
0310073	Overshot Run	2010	44	12	5	47	20	50	4.33	Good
0310074	Overshot Run	2010	36	11	2	42	22	55	4.00	Good
0310079	Greene Branch	2010	30	6	4	7	73	15	2.67	Poor
0310088	Greene Branch	2010	46	17	5	38	18	47	4.33	Good
0310107	Greene Branch	2010	36	18	6	70	17	62	4.67	Good