UPPER GWYNNS FALLS

Final Report

SMALL WATERSHED ACTION PLAN

VOLUME 2

Prepared for
Department of Environmental
Protection and Sustainability

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Consulting Engineers

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Baltimore County Executive Kevin Kamenetz and the Baltimore County Council

Volume 2
Table of Contents

Appendix E: Upper Gwynns Falls Watershed Characterization Report

Appendix F: Gwynns Falls Watershed Quality Management Plan

Appendix G: TMDLs of Fecal Bacteria For the Non-Tidal Gwynns Falls Basin

Appendix H: TMDLs of Nitrogen and Phosphorus for the Baltimore Harbor

Appendix I: Watershed Report for Biological Impairment of the Gwynns Falls Watershed

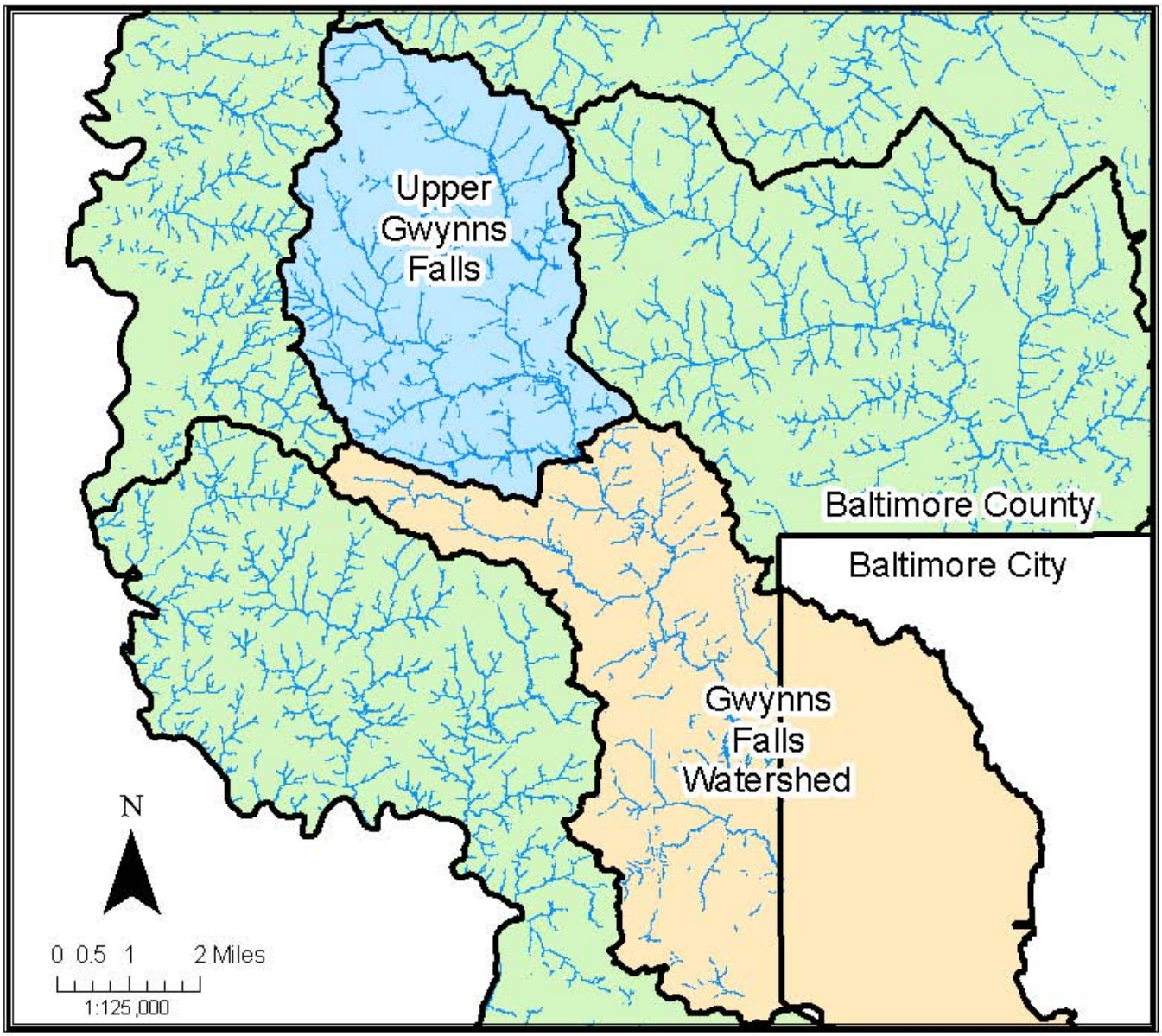
Appendix J: Water Quality Analysis of Eutrophication for the Gwynns Falls Watershed

Appendix K: TMDL of Sediment in the Gwynns Falls Watershed

APPENDIX E:

Upper Gwynns Falls Watershed Characterization Report

Upper Gwynns Falls
Watershed Characterization



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BALTIMORE COUNTY
MARYLAND

Table of Contents

CHAPTER 1: Introduction 1
1.1 Purpose of the Watershed Characterization 1
1.2 Location and Scale of Analysis 1
1.3 Subwatersheds 1
1.3.1 Upper Gwynns Falls-D 4
1.3.2 Roche's Run 4
1.3.3 Upper Gwynns Falls-B 4
1.3.4 Red Run 5
1.3.5 Horsehead Branch 5
1.4 Report Organization 5

CHAPTER 2: Landscape and Land Use 7
2.1 Introduction 7
2.2 The Natural Landscape 8
2.2.1 Climate 8
2.2.2 Physiogeographic Province and Topography 8
2.2.2.1 Location and Watershed Delineation 8
2.2.2.2 Topography 10
2.2.3 Geology 12
2.2.4 Soils 14
2.2.4.1 Hydrologic Soil Groups 14
2.2.4.2 Soil Erodibility 16
2.2.5 Forest 18
2.2.5.1 Forest Cover 18
2.2.6 Stream Systems 20
2.2.6.1 Stream System Characteristics 20
2.2.6.2 Stream Riparian Buffers 22
2.3 The Human Modified Landscape 24
2.3.1 Land Use and Land Cover 24
2.3.2 Population 27
2.3.3 Impervious Surfaces 29
2.3.4 Drinking Water 34
2.3.4.1 Public Water Supply 34
2.3.5 Wastewater 34
2.3.5.1 Septic Systems 34
2.3.5.2 Public Sewer 35
2.3.5.3 Wastewater Treatment Facilities 38
2.3.6 Stormwater 38
2.3.6.1 Storm Drainage System 38
2.3.6.2 Stormwater Management Facilities 41
2.3.7 NPDES Permits 43
2.3.8 Zoning 46
2.3.9 Historical Development 50

CHAPTER 3: Water Quality, Living Resources and Habitat 54
3.1 Introduction 54

3.2 Water Quality Monitoring Data 54
3.2.1 Baltimore County Chemical Data 54
3.2.2 Baltimore Ecosystem Study Data 59
3.2.2.1 Stream & Watershed - Upper Gwynns Falls Tributaries 60
3.2.2.2 Stream & Watershed - Upper Gwynns Falls Tributaries 61
3.2.3 Baltimore County Biological Data 63
3.2.4 Maryland Biological Stream Survey 67
3.2.5 Illicit Discharge and Elimination Program Data 69
3.2.6 Subwatershed Summary 70
3.3 Sewer Overflow Impacts 71
3.4 303(d) Listings and Total Maximum Daily Loads (TMDL) 74
3.4.1 Nutrients 75
3.4.2 Bacteria 76
3.4.3 Sediments 76
3.4.4 Chlorides and Conductivity 77
3.4.5 Maryland High Quality Waters (Tier II) 77
3.5 Pollutant Loading Analysis 77
3.6 Stormwater Management Facilities 80
3.6.1 Stormwater Management Facility Conversion Assessment 80
3.6.2 Stormwater Management Facility Pollutant Load Reductions Calculations 82
3.6.2.1 Existing Facility Pollutant Removal 84
3.6.2.2 Additional Pollutant Removal Based on Conversions of Detention Ponds 85
3.7 Stream Assessments 86
3.7.1 Stream Stability Assessment 86
3.7.2 Summary of Sites Investigated 86
3.8 Water Quality Summary 109
3.9 References 110

CHAPTER 4: Upland Assessments 112
4.1 Introduction 112
4.2 Neighborhood Source Assessment (NSA) 112
4.2.1 Assessment Protocol 112
4.2.2 Summary of Sites Investigated 115
4.2.3 General Findings 119
4.2.3.1 Downspout Disconnection 119
4.2.3.2 Fertilizer Reduction/Awareness 122
4.2.3.3 Bayscaping 124
4.2.3.4 Storm Drain Marking 126
4.2.3.5 Street Trees & Shade Trees 128
4.2.3.6 Street Sweeping 130
4.2.3.7 Neighborhood Trash Management 132
4.3 Hotspot Site Investigation (HSI) 134
4.3.1 Assessment Protocol 134
4.3.2 Summary of Sites Investigated 137
4.3.3 General Findings 139
4.4 Institutional Site Investigation (ISI) 145
4.4.1 Assessment Protocol 145
4.4.2 Summary of Sites Investigated 147
4.4.3 General Findings 150

4.4.3.1 Tree Planting ... 150
4.4.3.2 Stormwater Retrofits ... 151
4.4.3.3 Buffer Improvement ... 155
4.4.3.4 Trash Management ... 156
4.4.3.5 Future Awareness Effort ... 156
4.5 Pervious Area Assessment (PAA) ... 156
4.5.1 Assessment Protocol ... 157
4.5.2 Summary of Sites Investigated ... 158
4.5.3 General Findings ... 160

CHAPTER 5: Restoration Options ... 168
5.1 Introduction ... 168
5.2 Municipal Capital Programs ... 168
5.2.1 Stormwater Management ... 168
5.2.1.1 Detention Pond Conversion ... 168
5.2.1.2 Stormwater Retrofits ... 169
5.2.1.3 Parking Lot/Alley Retrofits ... 169
5.2.2 Stream Corridor Restoration ... 169
5.2.3 Reforestation Buffers & Open Space ... 170
5.3 Municipal Management Programs ... 170
5.3.1 Street Sweeping ... 170
5.3.2 Inlet Cleaning ... 170
5.3.3 Illicit Discharge Detection and Elimination Program ... 170
5.3.4 Land Development Review ... 171
5.3.4.1 Riparian Forest Buffers ... 171
5.3.4.2 Forest Conservation ... 171
5.3.4.3 Chesapeake Bay Critical Area ... 171
5.3.4.4 Groundwater Management ... 172
5.3.4.5 Stormwater Management ... 172
5.3.4.6 Erosion and Sediment Control ... 172
5.3.5 Trash and Recycling ... 172
5.3.5.1 Single Stream Recycling ... 172
5.3.5.2 Household Hazardous Waste Collection ... 173
5.3.6 Pollution Prevention: Public Lands Management ... 173
5.4 Volunteer Restoration Programs ... 173
5.4.1 Stream Watch Program ... 173
5.4.2 Downspout Disconnection ... 173
5.4.3 Street Trees ... 174
5.4.4 Open Space Trees ... 174
5.4.5 Stream Clean Ups ... 174
5.4.6 Pet Waste Stations ... 174
5.4.7 Storm Drain Marking ... 174
5.5 Business and Institutional Initiatives ... 175
5.5.1 Impervious Cover Removal ... 175
5.5.2 Parking Lot Retrofits ... 175
5.5.3 Open Space Planting ... 175
5.5.4 Pollution Prevention: Private Lands Management ... 175
5.6 Citizen Awareness Activities ... 176
5.6.1 Stormwater Runoff ... 176

5.6.2 Pet Waste/ Bacteria Awareness 176
5.6.3 Fertilizer Reduction 176
5.6.4 Trash and Recycling 176
5.6.4.1 Compost Bins 176
5.6.4.2 Cleaner Greener Campaign 177
5.6.4.3 Stewardship Projects 177
5.6.4.4 Reuse Directory 177
5.6.4.5 The Re-Source Newsletter 177
5.6.5 Conservation Landscaping 177
5.6.6 MD Green School Award 177

Appendices

4-1 NSA Data
4-2 HSI Data – Category and Status
4-3 HSI Data – Observed Pollution Sources
4-4 ISI Data – Retrofit Recommendations

List of Tables

Table 1-1: Upper Gwynns Falls Subwatershed Acreages 4

Table 2-1: Upper Gwynns Falls Subwatershed Slope Categories (%) 10
Table 2-2: Geological Composition by Subwatershed (%) 12
Table 2-3: Upper Gwynns Falls Subwatershed Hydrologic Soil Categories (%) 14
Table 2-4: Upper Gwynns Falls Subwatershed Soil Erodibility Categories (%) 16
Table 2-5: Upper Gwynns Falls Subwatershed Forested Area 18
Table 2-6: Upper Gwynns Falls Streams Mileage and Density 20
Table 2-7: Land Use in the 100 Foot Riparian Buffer – Acres (%) 22
Table 2-8: Upper Gwynns Falls Watershed Land Use 25
Table 2-9: Upper Gwynns Falls Subwatershed Population Data 27
Table 2-10: Estimated Impervious Surface in the Upper Gwynns Falls 31
Table 2-11: Upper Gwynns Falls Septic Systems by Subwatershed 35
Table 2-12: Sewer Piping Length 37
Table 2-13: Sewer Piping Length Per Square Mile 37
Table 2-14: Upper Gwynns Falls Storm Drain System Components 39
Table 2-15: Upper Gwynns Falls Storm Drain System Components 39
Table 2-16: Upper Gwynns Falls Stormwater Management Facilities 43
Table 2-17: Upper Gwynns Falls County Urban Areas Treated by SWM 43
Table 2-18: NPDES Permits in the Upper Gwynns Falls Watershed 44
Table 2-19: Upper Gwynns Falls Zoning 46
Table 2-20: Upper Gwynns Falls Zoning By Subwatershed 48
Table 2-21: Upper Gwynns Falls Historical Development Percentage by Decade 51

Table 3-1: Upper Gwynns Falls Planning Area Subwatershed Abbreviations 56
Table 3-2: Ratings by Nutrient Concentrations 57
Table 3-3: Upper Gwynns Falls Watershed – Baltimore County Water Quality Data 57
Table 3-4: Upper Gwynns Falls Watershed – Baltimore County Water Quality Data by Subwatershed 58

Table 3-5: Upper Gwynns Falls Watershed – BES Data by Sample Site 60
Table 3-6: Upper Gwynns Falls Watershed – BES Data by Sample Site 62
Table 3-7: Baltimore County Mean Biological Monitoring Results by Sub-Watershed 64
Table 3-8: Baltimore County Detailed Biological Monitoring Results 66
Table 3-8: Baltimore County Detailed Biological Monitoring Results, Continued 67
Table 3-9: MBSS Monitoring Results 68
Table 3-10: Stream Waders Detailed Biological Monitoring Results 68
Table 3-11: Baltimore County Storm Drain Outfall Prioritization Results 70
Table 3-12: Summary of Monitoring Data by Subwatershed 70
Table 3-13: Sewer Overflows by Year in the Upper Gwynns Falls, 2000-2008 71
Table 3-14: Baltimore Sewer Overflows and Total Pollutant Load by Subwatershed, 2000-2008 72
Table 3-15: Water Quality Impairment Listings and Status 74
Table 3-16: Annual Pollutant Loadings Rates for Gwynns Falls (lbs/acre/year) 78
Table 3-17: Reclassification of MDP LU/LC to WRE Land Cover for Upper Gwynns Falls 78
Table 3-18: Annual Pollutant Loadings Rates for Gwynns Falls 79
Table 3-19: Upper Gwynns Falls Land Cover Classification (acres) 79
Table 3-20: Annual Nitrogen Loads by Subwatershed 80
Table 3-21: Annual Phosphorus Loads by Subwatershed 80
Table 3-22: Potential Conversions of Dry Ponds to Improve Water Quality 82
Table 3-23: Percent Removal Efficiency of BMPs 84
Table 3-24: Removal of Nitrogen and Phosphorus Due to Existing Stormwater Management Facilities by Facility Type (pounds) 84
Table 3-25: Conversion of Dry Detention Ponds – Nutrient Pollutant Removal Calculations 86
Table 3-26: UGF-D General Subwatershed Conditions 89
Table 3-27: UGF-D Subwatershed Channel Evolution Stages 89
Table 3-28: UGF-D Subwatershed Bank Height Ratio Caused Erosion Potential 90
Table 3-29: UGF-D Subwatershed Bank Angle Caused Erosion Potential 90
Table 3-30: UGF-D Subwatershed Root Density Caused Erosion Potential 90
Table 3-31: UGF-D Subwatershed Canopy Cover Percent 91
Table 3-32: UGF-D Subwatershed Riparian Width by Bank 91
Table 3-33: UGF-D Subwatershed Riparian Composition by Bank 91
Table 3-34: UGF-D Subwatershed Riparian Density by Bank 91
Table 3-35: UGF-D Subwatershed Fish Blockages 92
Table 3-36: Roche's Run General Subwatershed Conditions 93
Table 3-37: Roche's Run Subwatershed Channel Evolution Stages 94
Table 3-38: Roche's Run Subwatershed Bank Height Ratio Caused Erosion Potential 94
Table 3-39: Roche's Run Subwatershed Bank Angle Caused Erosion Potential 94
Table 3-40: Roche's Run Subwatershed Root Density Caused Erosion Potential 95
Table 3-41: Roche's Run Subwatershed Canopy Cover Percent 95
Table 3-42: Roche's Run Subwatershed Riparian Width by Bank 95
Table 3-43: Roche's Run Subwatershed Riparian Composition by Bank 96
Table 3-44: Roche's Run Subwatershed Riparian Density by Bank 96
Table 3-45: Roche's Run Subwatershed Fish Blockages 97
Table 3-46: UGF-B General Subwatershed Conditions 98
Table 3-47: UGF-B Subwatershed Channel Evolution Stages 98
Table 3-48: UGF-B Subwatershed Bank Height Ratio Caused Erosion Potential 99
Table 3-49: UGF-B Subwatershed Bank Angle Caused Erosion Potential 99
Table 3-50: UGF-B Subwatershed Root Density Caused Erosion Potential 99

Table 3-51: UGF-B Subwatershed Canopy Cover Percent 100
Table 3-52: UGF-B Subwatershed Riparian Width by Bank 100
Table 3-53: UGF-B Subwatershed Riparian Composition by Bank..... 100
Table 3-54: UGF-B Subwatershed Riparian Density by Bank..... 100
Table 3-55: UGF-B Subwatershed Fish Blockages..... 101
Table 3-56: Red Run General Subwatershed Conditions 102
Table 3-57: Red Run Subwatershed Channel Evolution Stages..... 102
Table 3-58: Red Run Subwatershed Bank Height Ratio Caused Erosion Potential..... 103
Table 3-59: Red Run Subwatershed Bank Angle Caused Erosion Potential..... 103
Table 3-60: Red Run Subwatershed Root Density Caused Erosion Potential..... 103
Table 3-61: Red Run Subwatershed Canopy Cover Percent 104
Table 3-62: Red Run Subwatershed Riparian Width by Bank 104
Table 3-63: Red Run Subwatershed Riparian Composition by Bank 104
Table 3-64: Red Run Subwatershed Riparian Density by Bank..... 105
Table 3-65: Red Run Subwatershed Fish Blockages..... 105
Table 3-66: Horsehead Branch General Subwatershed Conditions..... 106
Table 3-67: Horsehead Branch Subwatershed Channel Evolution Stages 107
Table 3-68: Horsehead Branch Subwatershed Bank Height Ratio Caused Erosion Potential ... 107
Table 3-69: Horsehead Branch Subwatershed Bank Angle Caused Erosion Potential 108
Table 3-70: Horsehead Branch Subwatershed Root Density Caused Erosion Potential 108
Table 3-71: Stream Assessment Summary 109

Table 4-1: Neighborhoods Surveyed per Subwatershed..... 115
Table 4-2: Acres Addressed by Downspout Redirection..... 120
Table 4-3: Acres of Lawn Addressed by Fertilizer Reduction 122
Table 4-4: Acres of Land Addressed by Bayscaping 124
Table 4-5: Number of Inlets Addressed by Storm Drain Marking 126
Table 4-6: Street Tree Potential by Subwatershed..... 128
Table 4-7: Miles of Road Recommended for Street Sweeping 130
Table 4-8: Acres of Land Addressed by Trash Management 132
Table 4-9: Summary of Hotspot Sites Investigated in the Upper Gwynns Falls..... 137
Table 4-10: Institutional Sites by Subwatershed 148
Table 4-11: ISI Recommended Actions by Subwatershed 150
Table 4-12: Estimate of Tree Planting for ISIs by Subwatershed 150
Table 4-13: Summary of Institutions Recommended for Storm Drain Marking..... 151
Table 4-14: Summary of Institutions Recommended for Stormwater Retrofits..... 152
Table 4-15: Summary of Institutions Recommended for Downspout Disconnection..... 154
Table 4-16: Summary of PAA Results 160

List of Figures

Figure 1-1: Upper Gwynns Falls Watershed SWAP Location 2
Figure 1-2: Upper Gwynns Falls Subwatersheds..... 3

Figure 2-1: Upper Gwynns Falls SWAP Area Subwatersheds..... 9
Figure 2-2: Upper Gwynns Falls Slope Based on Soils..... 11
Figure 2-3: Upper Gwynns Falls Geology..... 13
Figure 2-4: Upper Gwynns Falls Hydrologic Soil Groups 15
Figure 2-5: Upper Gwynns Falls Soil Erodibility (Based on the K Factor) 17

Figure 2-6: Upper Gwynns Falls Forest Cover 19
Figure 2-7: Upper Gwynns Falls Stream Network 21
Figure 2-8: Upper Gwynns Falls 100 ft. Stream Buffer Classification 23
Figure 2-9: Upper Gwynns Falls Watershed Land Use 26
Figure 2-10: Upper Gwynns Falls Population Density 28
Figure 2-11. Impervious Cover Model (adapted from CWP 2003) 29
Figure 2-12: Upper Gwynns Falls Impervious Surface 32
Figure 2-13: Upper Gwynns Falls Impervious Cover Ratings 33
Figure 2-14: Upper Gwynns Falls Sewer Systems 36
Figure 2-15: Upper Gwynns Falls Storm Drain Outfalls 40
Figure 2-16: Upper Gwynns Falls Stormwater Management Facilities 42
Figure 2-17: Upper Gwynns Falls NPDES-Permitted Facilities 45
Figure 2-18: Upper Gwynns Falls Zoning 47
Figure 2-19: The Urban Rural Demarcation Line In Relation To the Upper Gwynns Falls 49
Figure 2-20: Upper Gwynns Falls Historical Development 53

Figure 3-1: Chemical Monitoring in the Upper Gwynns Falls Watershed 55
Figure 3-2: Upper Gwynns Falls Biological Monitoring Sites 65
Figure 3-3: Sanitary Sewer Overflows 2000-2008 73
Figure 3-4: Upper Gwynns Falls Stream Reach Assessments 88

Figure 4-1: Upper Gwynns Falls SWAP Neighborhood Site Assessment Locations 116
Figure 4-2: Upper Gwynns Falls SWAP NSA Pollution Severity and Restoration Opportunity Indexes 118
Figure 4-3: Directly Connected Downspouts in NSA_V_512 and NSA_V_107 Suitable for Disconnection 120
Figure 4-4: A Typical Rain Barrel Installation with Overflow Hose 120
Figure 4-5: Upper Gwynns Falls SWAP Neighborhoods Recommended for Downspout Disconnection 121
Figure 4-6: Lawn with High Fertilizer Use (NSA_V_220) 122
Figure 4-7: Upper Gwynns Falls SWAP Neighborhoods with 20-100% High Maintenance Lawns 123
Figure 4-8: Upper Gwynns Falls SWAP Neighborhoods Recommended for Bayscaping 125
Figure 4-9: Upper Gwynns Falls SWAP Neighborhoods Recommended for Storm Drain Marking 127
Figure 4-10: Upper Gwynns Falls SWAP Neighborhoods Recommended for Street Trees & Shade Trees 129
Figure 4-11: Example of a Neighborhood Recommended for Street Sweeping (NSA_V_515) 130
Figure 4-12: Upper Gwynns Falls SWAP Neighborhoods Recommended for Street Sweeping 131
Figure 4-13: Upper Gwynns Falls SWAP Neighborhoods Recommended for Trash Management 133
Figure 4-14: Upper Gwynns Falls SWAP Hot Spot Investigation Locations 138
Figure 4-15: Examples of Potential Pollution Sources at Commercial (auto-related) Hotspots (HSI_V_319 and HSI_V_506) 140
Figure 4-16: Example of Overflowing Dumpster (HSI_V_308) 140
Figure 4-17: Pollution Source from Stained Parking Lot/Leaking Dumpster (HSI_V_202) 141
Figure 4-18: Pollution Source from Illegal Dumping (HSI_V_312) 141
Figure 4-19: Pollution Source from Organic Material, Trash and Sediment (HSI_V_312) 142
Figure 4-20: Runoff from Outdoor Material Areas at Commercial Hotspots (HSI_V_202) 142

Figure 4-21: Potential Pollution Sources at Commercial Hotspots (HSI_V_504 and HIS_V_508)) 143
Figure 4-22: Potential Pollution Sources at Transport-Related Hotspots (HSI_V_303 & HSI_V_502) 144
Figure 4-23: Potential Pollution Sources at Commercial Hotspots (HSI_V_304 & HSI_V_310) 144
Figure 4-24: Upper Gwynns Falls SWAP Institutional Site Investigation Locations 149
Figure 4-25: Stormwater Retrofit Opportunities at ISI_V_311 (left) and ISI_V_401 (right) 152
Figure 4-26: Stormwater Retrofit Opportunities at ISI_V_203 (left) and ISI_V_204 (right) 153
Figure 4-27: Stormwater Retrofit Opportunity for Existing Detention Ponds at ISI_V_205 and ISI_V_104 153
Figure 4-28: Potential Impervious Cover Removal at ISI_V_101 (left) and Inlet Retrofit Potential at ISI_V_305 (right) 155
Figure 4-29: Stream Buffer Improvement Opportunity at ISI_V_305 155
Figure 4-30: PAA Locations 159
Figure 4-31: Photos of McDonogh School - PAA_V_101 161
Figure 4-32: Photos of Groff & Sons - PAA_V_301 161
Figure 4-33: Photos of Rosewood State Center - PAA_V_302 162
Figure 4-34: Photo of Chartley Town Apartments - PAA_V_401 162
Figure 4-35: Photos of Hathaway Park - PAA_V_402 163
Figure 4-36: Photo of Glyndon Elementary School - PAA_V_501 164
Figure 4-37: Photos of 605 Main Street - PAA_V_502 165
Figure 4-38: Photos of Gwynnwest Rd. Grass Lot - PAA_V_503 165
Figure 4-39: Photos of Glynlee Ct. Grass Lot - PAA_V_504 166
Figure 4-40: Photos of Chartley Shopping Center - PAA_V_505 167

CHAPTER 1

INTRODUCTION

1.1 Purpose of the Watershed Characterization

The Upper Gwynns Falls Watershed Characterization Report is intended to summarize information on geomorphological, hydrological, chemical and biological factors that may affect water quality and other natural resources. In addition, the report identifies and assesses the human impact on the upland areas of the watershed, the management framework within which this activity takes place, and finally, identifies restoration and preservation strategies and actions to achieve watershed goals. The information presented in this report, along with information provided by the Baseflow Monitoring Program, Benthic Community Assessment, the Maryland Biological Stream Survey (MBSS) data, Baltimore Ecosystem Study data, and Baltimore County Gwynns Falls Stream Stability Assessments will be used as the basis for the formulation of the Upper Gwynns Falls Small Watershed Action Plan (SWAP). This characterization report has two main objectives:

- Summarize watershed information relevant to natural resources and impacts on natural resources, and
- To describe the condition of the natural resources within the watershed.

1.2 Location and Scale of Analysis

The Upper Gwynns Falls SWAP area is a subset of the Gwynns Falls watershed located in the Patapsco/Back River Basin in the Piedmont region of Maryland. The Gwynns Falls Watershed, which is classified as the 02130905 8-digit watershed by the State of Maryland, is part of the larger Chesapeake Bay Watershed. The lower portion of the Gwynns Falls watershed is in Baltimore City where the watershed empties into the Middle Branch of the Patapsco River, but the entire Upper Gwynns Falls is in Baltimore County, Maryland (Figure 1-1 & 1-2) north of the I-795 / I-695 interchange. The area of the Upper Gwynns Falls is 13,614.8 acres (21.27 sq. mi.).

1.3 Subwatersheds

The analysis presented in this report was conducted at the subwatershed scale in addition to an analysis of the entire Upper Gwynns Falls watershed. The subwatershed scale provides information on smaller drainage areas that are often the focus of intense restoration and preservation efforts. The effect of these efforts may be more easily monitored at that level. Table 1-1 presents the labels used at the various scales and their relationship to one another. There are 5 separate subwatersheds identified for this report. Figure 1-2 depicts the location of the subwatersheds within the Upper Gwynns Falls watershed.

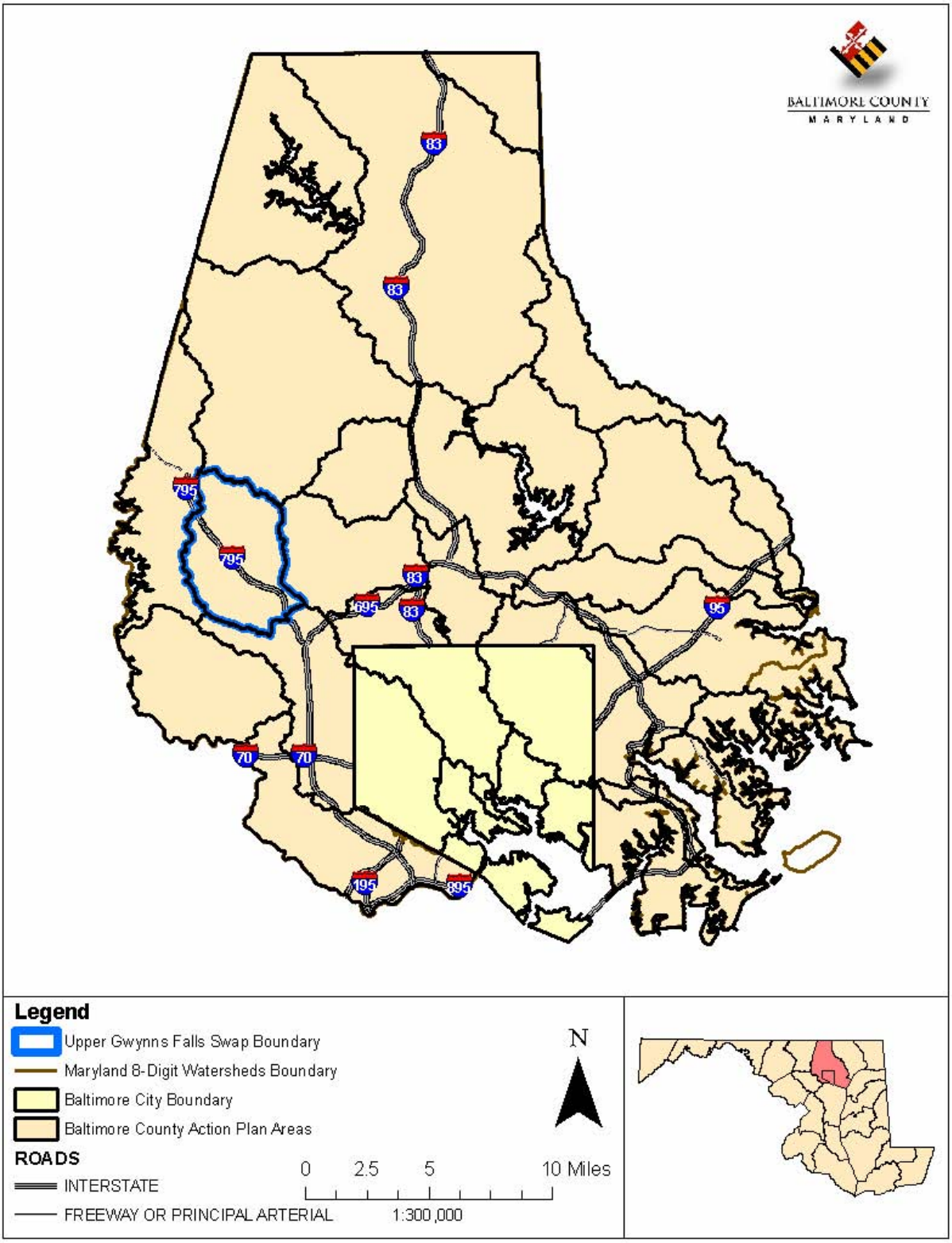

Figure 1-1: Upper Gwynns Falls Watershed SWAP Location

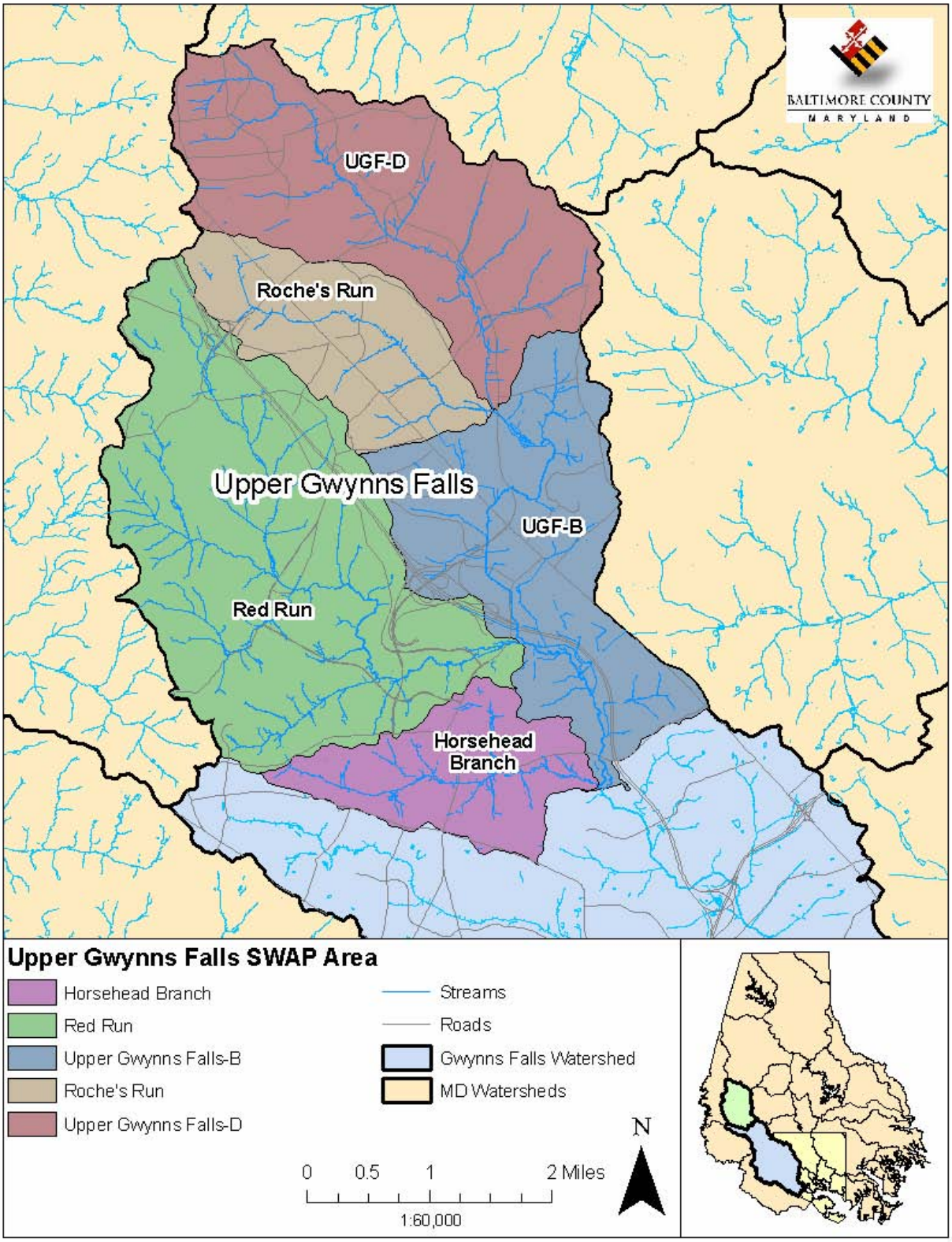

Figure 1-2: Upper Gwynns Falls Subwatersheds

Table 1-1: Upper Gwynns Falls Subwatershed Acreages

Subwatershed Scale	Acres	Sq. Mi.
Upper Gwynns Falls-D (UGF-D)	3,203.1	5.00
Roche's Run	1,537.1	2.40
Upper Gwynns Falls-B (UGF-B)	2,817.7	4.40
Red Run	4,753.4	7.43
Horsehead Branch	1,303.5	2.04
Total	**13,614.8**	**21.27**

1.3.1 Upper Gwynns Falls-D

The Upper Gwynns Falls-D (UGF-D) is the headwaters of Gwynns Falls that starts in Glyndon south of Butler Road and flows south along the train tracks and Owings Mills Boulevard where it flows into the Upper Gwynns Falls-B (UGF-B) subwatershed just south of Gwynnbrook Avenue and the Gwynnbrook Wildlife Management Area. Main Street is the northwestern boundary and the drainage divide splits Hannah More Park and several neighborhoods along Academy Avenue/Pleasant Hill Lane. The eastern subwatershed boundary roughly follows Garrison Forest Road, Thoroughbred Lane, Bond Avenue to Owings Mills Boulevard across the entrance to Camp Glyndon, up to Butler Road. The Upper Gwynns Falls-D subwatershed is home to businesses along Main Street, old and new neighborhoods, Owings Mills Jewish Community Center, Reisterstown Elementary School, Glyndon Elementary School, and Sacred Hearth Catholic Elementary School and Sacred Hearth Catholic Church.

1.3.2 Roche's Run

Roche's Run is the first major tributary of the Gwynns Falls that starts in Reisterstown to the west of Reisterstown Road at Berrymans Lane. The stream flows south and crosses Reisterstown Road and through Gwynnbrook to the Gwynns Falls at the same location that Upper Gwynns Falls-D flows into Upper Gwynns Falls-B, just south of the Gwynnbrook Wildlife Management Area. The subwatershed is bound to the north and east by the Upper Gwynns Falls-D subwatershed and to the west by the Red Run subwatershed. The western boundary line falls along I-795 to the north of Franklin Boulevard and midway between I-795 and Reisterstown Road to south of Franklin Boulevard until Pleasant Hill Road which is the southern boundary to the subwatershed and the divide between the Roche's Run Upper Gwynns Falls-B subwatersheds. Roche's Run is home to businesses along Reisterstown Road, old and new neighborhoods, Franklin High School, Cedarmere Elementary School, Timber Grove Elementary School and the front half of Hannah More Park including the original buildings.

1.3.3 Upper Gwynns Falls-B

The Upper Gwynns Falls-B (UGF-B) receives the flow from both Upper Gwynns Falls-D and Roche's Run and the stream flows through the western end of the Rosewood Center property. The Gwynns Falls then flows west under the train tracks, Reisterstown Road and Owings Mills Boulevard and through the Owings Mills Industrial Park, and under I-795 where Red Run flows into the Gwynns Falls. The stream continues south along the eastern edge of the McDonogh School property, under McDonogh Road to where Horsehead Branch flows into the mainstem. The Gwynns Falls flows along the railroad tracks out of the Upper Gwynns Falls subwatershed and into the Middle Gwynns Falls subwatershed. With the Upper Gwynns Falls-D and Roche's Run watersheds to the north the Upper Gwynns Falls-B subwatershed is bound to the west by I-

795 (including the Owings Mills Boulevard/I-795 interchange and the Owings Mills mall parking areas and the McDonogh School property). The eastern drainage divide is along Garrison Forest Road west of the Maryland National Veterans Cemetery and through the Garrison Forest School property and along Reisterstown Road to the south limits and McDonogh Road. The Upper Gwynns Falls-B subwatershed is home to businesses and neighborhoods along Reisterstown Road, Owings Mills High School, Rosewood Center, Owings Mills Commerce Center, Stevenson University, most of the Owings Mills Corporate Campus and the upper portion of the McDonogh School Campus.

1.3.4 Red Run

The Red Run is the largest subwatershed and tributary to the Gwynns Falls that starts north of Soldiers Delight Natural Environment Area near Sunnybrook Farms and flows south along the Soldiers Delight Natural Environment Area to the east and south between Red Run Boulevard and the Owings Mills/New Town neighborhoods. Red Run flows east under Owings Mills Boulevard to the south of the Owings Mills mall and under Red Run Boulevard and Painters Mill Road out of the subwatershed and into the mainstem in the Upper Gwynns Falls-B subwatershed at the Owings Mills Corporate Campus.

The Roche's Run and Upper Gwynns Falls-B subwatersheds are the eastern boundary and Painters Run Road and Lyons Mill Road are roughly the southern boundary. Deer Park Road is the western boundary and Berrymans Lane is the drainage divide to the north. The Red Run subwatershed is home to corporate centers along Red Run Boulevard, Owings Mills mall, I-795 (including the Franklin Boulevard interchange), New Town Elementary School and High School and the Soldiers Delight Natural Environment Area.

1.3.5 Horsehead Branch

The Horsehead Branch subwatershed is the most southern subwatershed and is the smallest and least developed. The tributary starts at the western edge at the Deer Park Middle School and flows east under McDonogh Road and through the southern portion of the McDonogh School property to the south of McDonogh Road out of the subwatershed into the Upper Gwynns Falls-B subwatershed as it flows south out of the Upper Gwynns Falls SWAP area.

The Horsehead Branch subwatershed is bound to the north by the Red Run subwatershed and to the east by the Upper Gwynns Falls-B subwatershed. The southern drainage divide is Winands Road. The Red Run subwatershed is home to Foxridge neighborhoods and most of the McDonogh School property.

1.4 Report Organization

This report is organized into five chapters.

Chapter 1 presents an overview of the characterization report and the scope and location of the watershed characterization.

Chapter 2 presents information on landscape characteristics that may have an effect on natural resources. Included in this chapter are some characteristics that are considered natural resources in their own right, such as, geology and soils. Data is presented on land use, impervious cover, population density, and a number of human modifications to the landscape that affect water quality.

Chapter 3 is a summary of existing water quality and water quantity data as it relates to the landscape characteristics and the potential for degradation or protection.

Chapter 4 describes the upland assessments conducted to identify major sources of stormwater pollutants and the restoration opportunities for source controls, pervious area management, and improved neighborhood and municipal maintenance.

Chapter 5 summarizes protection and restoration strategies, including activities that have taken place to date.

CHAPTER 2

LANDSCAPE AND LAND USE

2.1 Introduction

In this chapter, we will describe both the natural physical context and the human use and present state of the land in the Upper Gwynns Falls watershed. This will provide the basis for later chapters on water quality, living resources, restoration, and management.

The Upper Gwynns Falls watershed (13,615 acres) represents a portion (32%) of the larger Gwynns Falls watershed. It is one of two planning areas within the Gwynns Falls watershed. The Gwynns Falls planning area will be addressed in a future Small Watershed Action Plan.

The Upper Gwynns Falls watershed lies within the Piedmont region of Maryland. The Upper Gwynns Falls subwatershed is entirely in Baltimore County while the Gwynns Falls watershed transcends both the County and City. The natural Piedmont landscape is characterized by rolling hills, extensive forests, thick soils on deeply weathered crystalline bedrock, and abundant forest litter that minimizes overland flow. Much of the Piedmont including the Upper Gwynns Falls watershed was transformed by settlement starting in the 18th century. Virgin forests were cleared for agriculture, and agricultural land use rose steadily until peaking around the beginning of the 20th century. The Gwynns Falls watershed is a portion of the core of Baltimore City that developed around the natural harbor starting in the early 1600s. Human development spread out from this core settlement around the harbor up the stream valleys to accommodate the agricultural base needed to supply the growing population. As the commercial aspects of Baltimore City expanded, the agricultural lands nearest the harbor were converted to residential, industrial, and commercial land uses.

2.2 The Natural Landscape

The natural landscape includes many factors that provide the background context and foundation for land use. Among these factors are the physiographic province, the underlying geology and the surface soils, the climate that affects the formation and erosion of soils, the stream drainage system, and the forest and wetland cover.

2.2.1 Climate

The climate of the region can be characterized as a humid continental climate with four distinct seasons modified by the proximity of the Chesapeake Bay and Atlantic Ocean (DEPRM, 2000). Rainfall is evenly distributed through all months of the year, with most months averaging between 3.0 and 3.5 inches per month. Storms in the fall, winter, and early spring tend to be of longer duration and lesser intensity than summer storms, which are often convective in nature with scattered high intensity storm cells. The average annual rainfall, as measured at the Baltimore Washington Thurgood Marshall Airport is approximately 42 inches per year. The average annual snowfall is approximately 21 inches, with the majority of accumulation in December, January, and February.

The climate of a region affects the rate and form of soil formation and erosion patterns, and with the interaction of the underlying geology, the stream drainage network pattern and the resulting topography. The climate also affects the vegetative growth and species composition of the terrestrial ecosystem.

2.2.2 Physiogeographic Province and Topography

2.2.2.1 Location and Watershed Delineation

The Upper Gwynns Falls watershed lies within the Piedmont Physiographic Province. The highest point of the planning area is located at 756 feet in elevation along the UGF-D and Roche's Run subwatersheds boundary. The lowest points in the watershed are located where Horsehead Branch flows into the Gwynns Falls and the Upper Gwynns Falls flows into the Middle Gwynns Falls. The Piedmont Physiographic Province is characterized by rolling hills of varying steepness.

All points of land are contained in nested watersheds based on water drainage patterns. Maryland divides its waters into 138, 8-digit watersheds, a scale finer than the USGS 8-digit hydrologic unit codes. Maryland's 8-digit watersheds contain, on average, 75 square miles. The Gwynns Falls watershed is 02-13-09-05 and is below average in size containing about 41,985 acres, or 65.6 square miles. The Upper Gwynns Falls planning area is 13,615 acres or 21.3 square miles in extent. For development of the Small Watershed Action Plan the Upper Gwynns Falls has been further divided into 5 subwatersheds (Figure 2-1). All data will be presented on the basis of these subwatersheds.

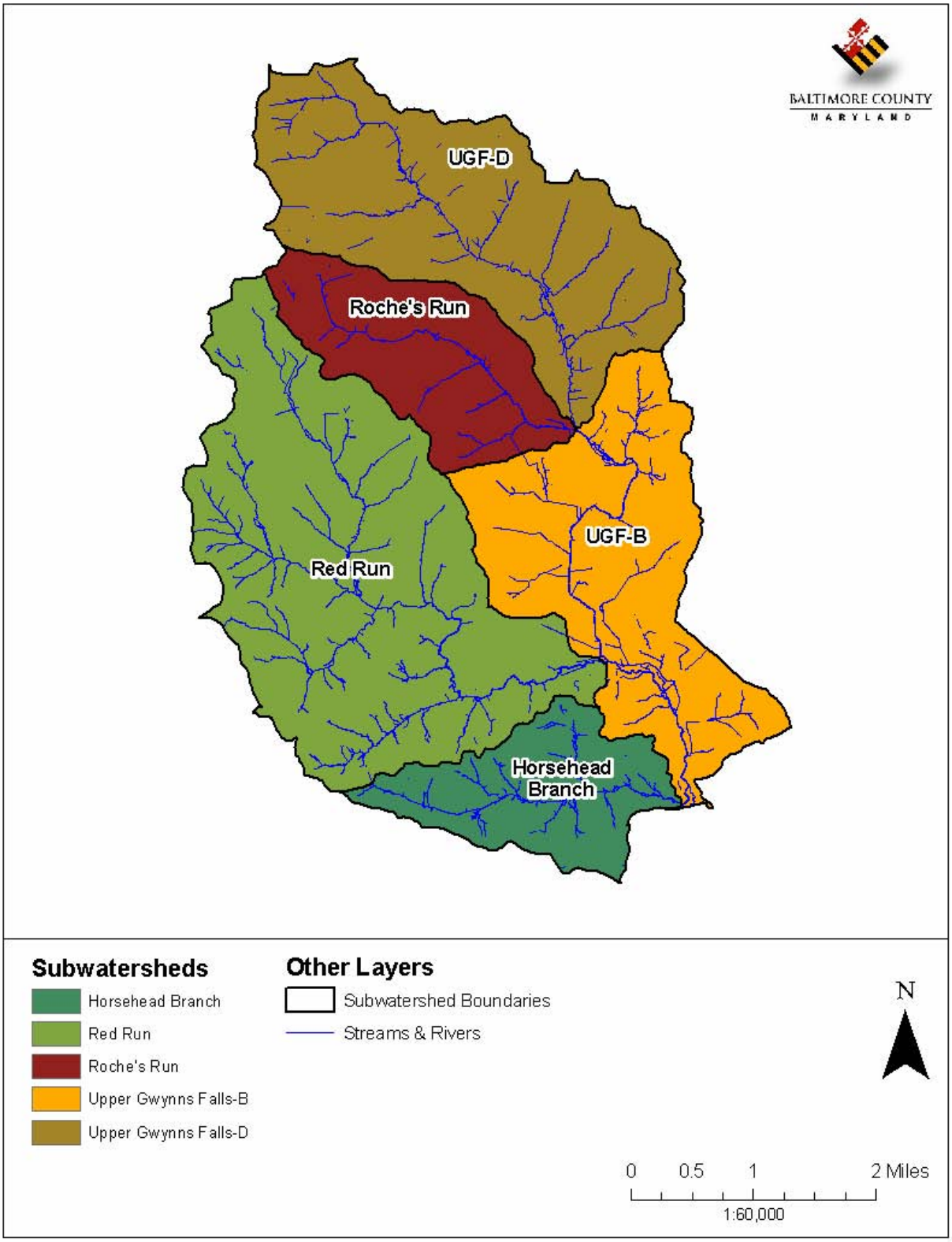

Figure 2-1: Upper Gwynns Falls SWAP Area Subwatersheds

2.2.2.2 Topography

The shape of the land, including its steepness and degree of concavity, affect surface water flows and soil erosion, as well as the suitability for development. Steep slopes are more prone to overland flow and soil erosion, and therefore have a greater potential for generation of pollutants. For this project the slopes were determined based on the soil data layers and divided into five categories: low slopes (0-3%), low to medium slopes (3 %- 8%), medium slopes (8%-15%), steep slopes (15%-25%) and extremely steep slopes (>25 %). Table 2-1 displays the results, in percentage of the area in each category, by subwatershed.

Table 2-1: Upper Gwynns Falls Subwatershed Slope Categories (%)

Subwatershed	Slope Category				
	Low (0-3%)	**Low-Medium (3-8%)**	**Medium (8-15%)**	**Steep (15-25%)**	**Extremely Steep (>25%)**
UGF-D	13.0	69.6	12.9	4.4	0.1
Roche's Run	6.6	45.7	44.3	3.4	0.0
UGF-B	10.6	57.4	17.0	10.7	4.3
Red Run	11.1	47.4	29.7	7.9	3.9
Horsehead Branch	16.5	60.5	14.0	7.6	1.4
Total	**13.0**	**54.0**	**24.2**	**6.7**	**2.1**

The majority of the Upper Gwynns Falls has Low-Medium slopes. The two subwatersheds with the highest proportion of steep and extremely steep slopes are the Red Run and UGF-B subwatersheds. This subwatershed contains relatively broken topography, making it more prone to erosion, depending on soil type and land cover. Conversely, Horsehead Branch and UGF-D have the highest proportion of relatively flat land, making it less prone to erosion, again depending on soil type and land cover. Figure 2-2 displays the distribution of the topographic slope categories throughout the Upper Gwynns Falls planning area.

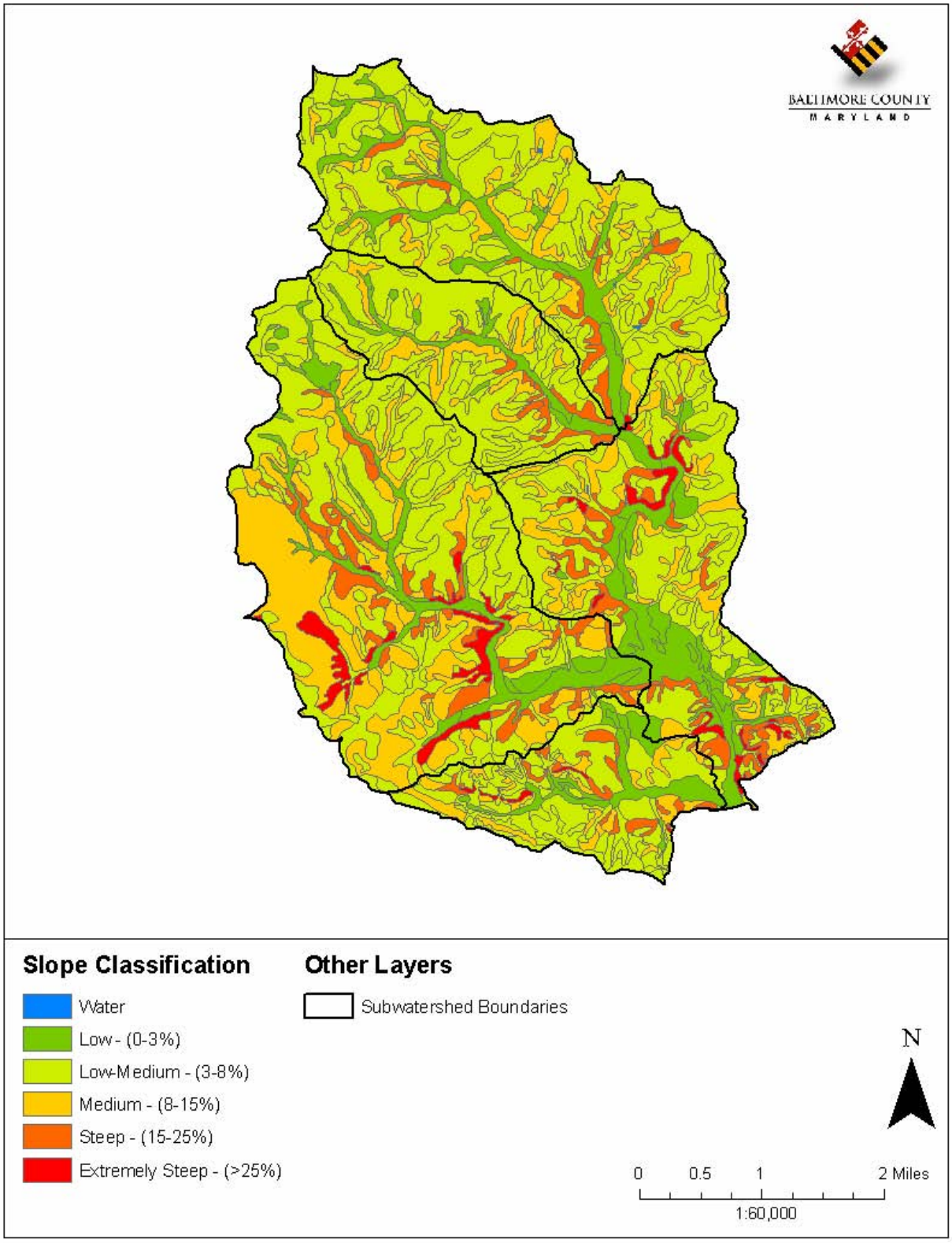

Figure 2-2: Upper Gwynns Falls Slope Based on Soils

2.2.3 Geology

Table 2-2 displays the geology of the subwatersheds, showing both the percent distribution and the geological type. The metamorphic rock that underlies the northwestern portion of the Upper Gwynns Falls watershed and much of the Piedmont consists mainly of crystalline schist and gneiss with smaller areas of marble. In general, the schist and gneiss formations have relatively low infiltration rates, giving them lower groundwater recharge rates and less vulnerability to contamination.

The geological formations of the Upper Gwynns Falls watershed are shown in Figure 2-3. These formations affect the chemical composition of surface and groundwater, as well as the recharge rate to groundwater and wells. They are also key to soil formation. As such, the geology is closely correlated with water quality in pristine systems, and affects the buffering of pollution to stream systems in developed areas.

Table 2-2: Geological Composition by Subwatershed (%)

Geology	Type	UGF-D	Roche's Run	UGF-B	Red Run	Horsehead Branch
Baltimore Gneiss	Metamorphic	0.0	0.0	34.8	8.2	23.5
Cockeysville Marble	Metamorphic	0.0	0.0	40.7	11.0	15.1
Loch Raven Schist	Metamorphic	100.0	100.0	16.1	12.5	0.0
Oella Formation	Metamorphic	0.0	0.0	0.1	9.4	45.2
Serpentine	Metamorphic	0.0	0.0	0.0	39.0	0.0
Setters Gneiss	Metamorphic	0.0	0.0	8.3	19.8	16.2

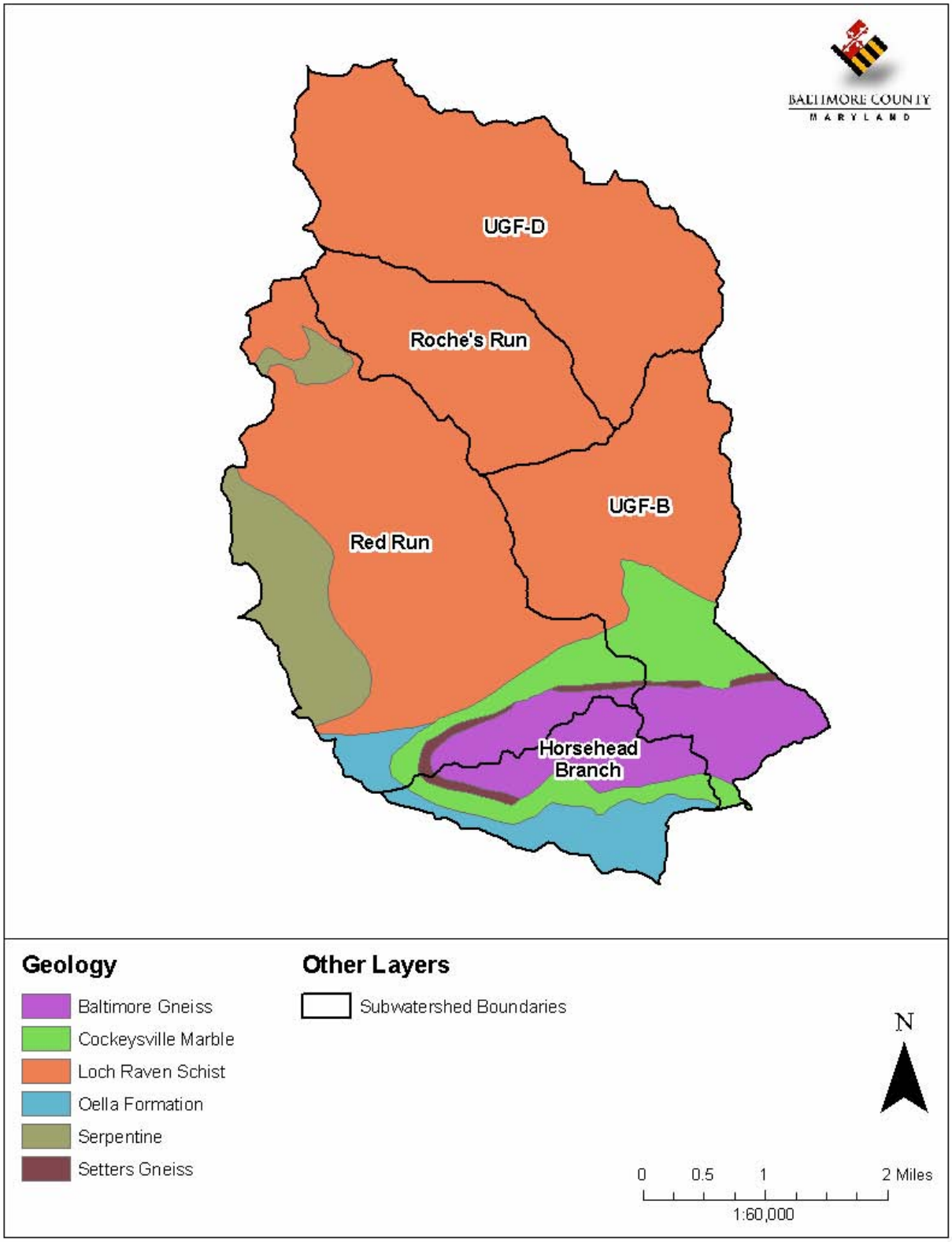

Figure 2-3: Upper Gwynns Falls Geology

2.2.4 Soils

Soil type and moisture conditions greatly affect how land may be used and the potential for vegetation and habitat on the land. Soil conditions are also one determining factor for water quality and quantity in streams and rivers. Soils are an important factor to incorporate in targeting projects aimed at improving water quality or habitat. Piedmont soils are developed from highly metamorphosed schist, gneiss, and granite. Local soil conditions vary greatly from site to site.

2.2.4.1 Hydrologic Soil Groups

The Natural Resource Conservation Service classifies soils into four Hydrologic Soil Groups (HSGs) based on the soil's runoff potential. Runoff potential is the opposite of infiltration capacity; soils with high infiltration capacity will have low runoff potential, and vice versa. The four Hydrologic Soils Groups are A, B, C and D, where A's generally have the smallest runoff potential and D's the greatest. Soils with low runoff potential will be less prone to erosion, and their higher infiltration rates result in faster throughflow of precipitation to groundwater.

Details of the hydrological soils classification can be found in 'Urban Hydrology for Small Watersheds' published by the Engineering Division of the Natural Resource Conservation Service, United States Department of Agriculture, Technical Release–55.

Group A is sand, loamy sand or sandy loam types of soils. It has low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission.
Group B is silt loam or loam. It has a moderate infiltration rate when thoroughly wetted and consists chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.
Group C soils are sandy clay loam. They have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine structure.
Group D soils are clay loam, silty clay loam, sandy clay, silty clay or clay. This HSG has the highest runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material.

The soils data analysis is based on the Baltimore County Soil Survey of Baltimore County, Maryland (Reybold, et.al. 1976). The data are summarized in Table 2-3 and Figure 2-4.

Table 2-3: Upper Gwynns Falls Subwatershed Hydrologic Soil Categories (%)

Subwatershed Scale	Hydrologic Soil Group %			
	A	B	C	D
UGF-D	0.0	80.2	11.7	8.1
Roche's Run	0.0	83.2	11.1	5.8
UGF-B	0.0	75.8	18.8	5.4
Red Run	0.0	71.0	10.8	18.2
Horsehead Branch	0.0	74.0	17.2	8.8
Total	**0.0**	**75.8**	**13.3**	**10.9**

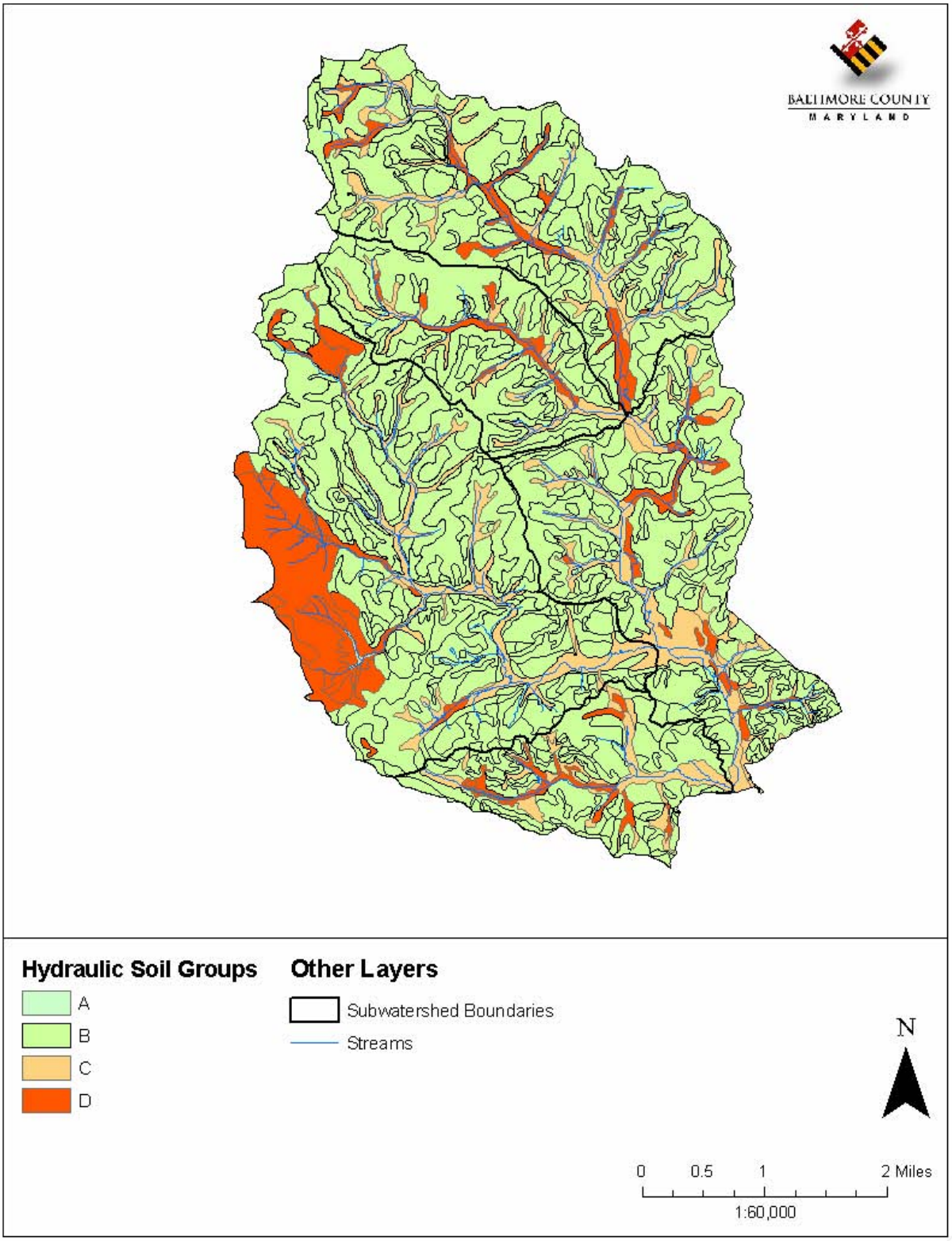

Figure 2-4: Upper Gwynns Falls Hydrologic Soil Groups

2.2.4.2 Soil Erodibility

The erodibility of the soil is its intrinsic susceptibility to erosion. It is one factor (known as the K factor) in the Universal Soil Loss Equation, which estimates the rate of erosion at a particular site. Erodibility is based on the physical and chemical properties of the soil, which determine how strongly soil particles cohere with one another. Figure 2-5 shows soil erodibility in the Upper Gwynns Falls watershed, and Table 2-4 is the summary by subwatershed. Low erodibility is defined as a K factor < .24, medium is K between .24 and .32, and high is K>.32. We chose these classes based on groupings in the data that resulted in three classes. They were also chosen as they represent the breaks used in the Baltimore County – Steep Slopes and Erodible Soils Analysis for determining riparian buffer widths. They are not the same as MDNR's or MDOP's categories, but overlap with them.

The subwatersheds with the highest values for erodibility offer the greatest potential for interventions addressing soil conservation such as riparian buffer forestation. Best management practices concerned with soil stabilization would be ideal for implementation in these watersheds. This indicator would be useful when combined with additional information about cropland, slope steepness, and distance to streams, as this would indicate areas where one best management practice--retirement of highly erodible land--would be most useful. High values for this indicator also raise warning flags about other, more urban activities near streams, such as road construction or utility placements.

Overall, the Upper Gwynns Falls watershed soil erodibility distribution shows a majority of the watershed's soils are prone to at least moderate erosion. The medium and high erodibility classes represent 94% of the distribution with 61% of that having medium erodibility. UGF-B, Horsehead Branch, and Red Run have the highest percentage of highly erodible soils. This would rate as the priority subwatersheds for maintaining protective land cover.

Table 2-4: Upper Gwynns Falls Subwatershed Soil Erodibility Categories (%)

Subwatershed Scale	Soil Erodibility Category %		
	Low	**Medium**	**High**
UGF-D	0.0	73.5	26.5
Roche's Run	0.0	72.9	27.1
UGF-B	2.0	56.5	41.5
Red Run	13.5	51.9	34.6
Horsehead Branch	5.4	58.2	36.4
Total	**5.7**	**60.9**	**33.4**

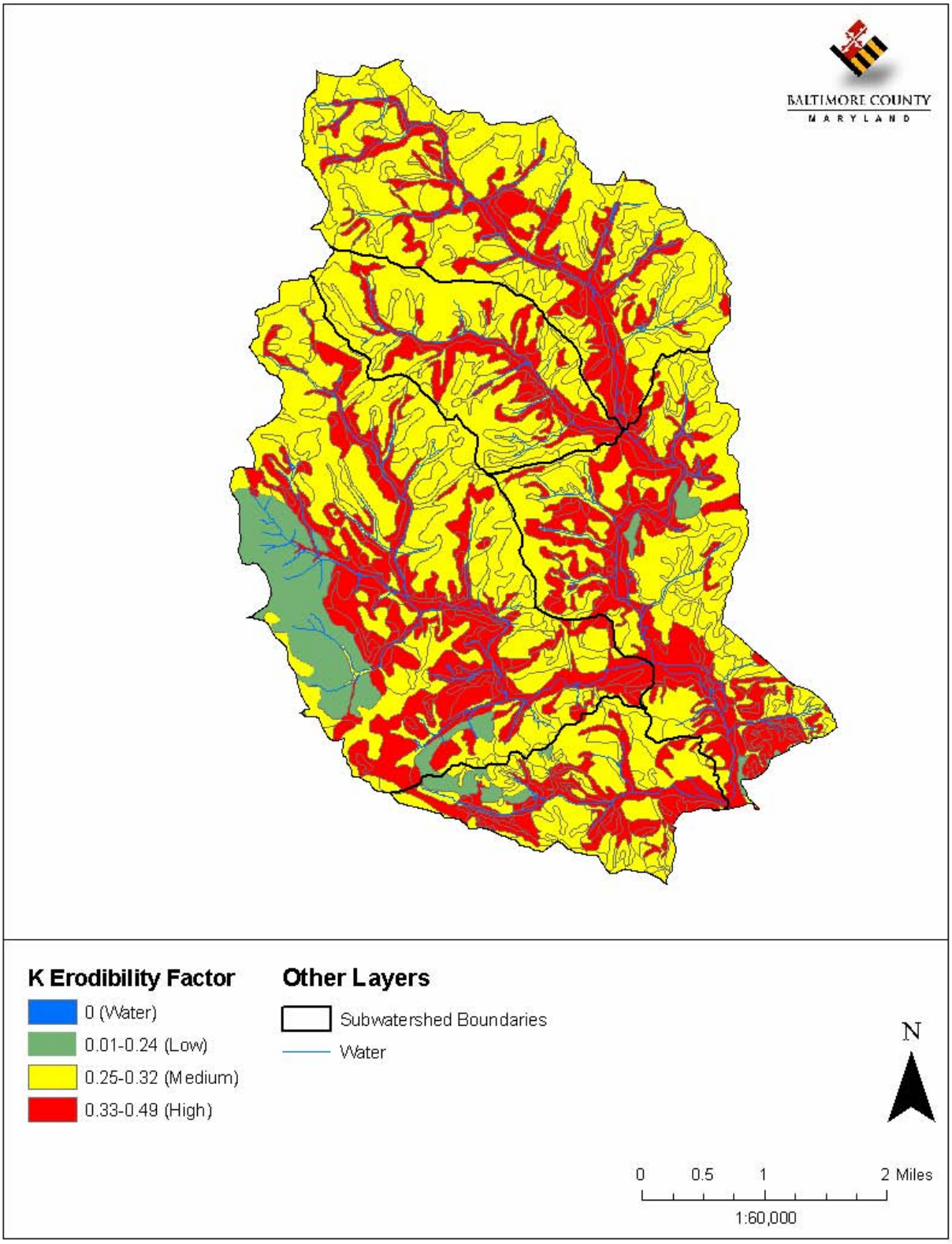

Figure 2-5: Upper Gwynns Falls Soil Erodibility (Based on the K Factor)

2.2.5 Forest

The entire Chesapeake watershed, including the Upper Gwynns Falls watershed, consisted overwhelmingly of old-growth forest at the time of European settlement. Forest cover provides the greatest protection among land cover types for the quality of the soil and water. In pristine systems, forest and soils co-evolve, and in turn shape the hydrological cycle; these systems operate within a natural range of variability, assuring healthy habitat and water quality. In human-impacted systems, forest cover still provides many of these benefits, and can help protect water quality if judiciously planned.

2.2.5.1 Forest Cover

The forest area has been greatly reduced in the Upper Gwynns Falls watershed since European settlement. Based on the Baltimore County Forest Coverage data, approximately 25% forest cover remains.

Table 2-5 show that the Upper Gwynns Falls watershed contains 3,469 acres of forest, which is 25.5% of the total area. Red Run subwatershed contains the most forested acres and has the highest percentage forested. Figure 2-6 shows forested areas and the 5 sub-watersheds.

A large portion of the forested area is in Soldier's Delight Natural Environmental Area in the Red Run subwatershed, which is described as the largest and most diverse of the disappearing serpentine barrens on the East Coast and home for over 39 rare, threatened and endangered species. Plant species include gymnosperm and angiosperm woodland plants, ferns, sedges, rushes, and grasses and some unique and rare wildflowers as well as lichens.

Table 2-5: Upper Gwynns Falls Subwatershed Forested Area

Subwatershed	Total Acres	Forested Acres	% Forested
Upper Gwynns Falls-D	3,203.1	568	17.7
Roche's Run	1,537.1	205	13.3
Upper Gwynns Falls-B	2,817.7	501	17.8
Red Run	4,753.4	1759	37.0
Horsehead Branch	1,303.5	436	33.4
Totals	**13,614.8**	**3,469**	**25.5**

The Red Run subwatershed is 37% forest and Horsehead Brach has over 33% forested coverage as it is the least developed and has large areas of forest on the McDonogh property. The UGF-D, UGF-B and Roche's Run subwatersheds have approximately 15% forest coverage mostly near the streams and the Gwynnbrook Wildlife Management Area with the rest of the land developed as residential, commercial, and industrial areas. These three areas have the most need for forested areas and provide the best opportunities for potential forest restoration.

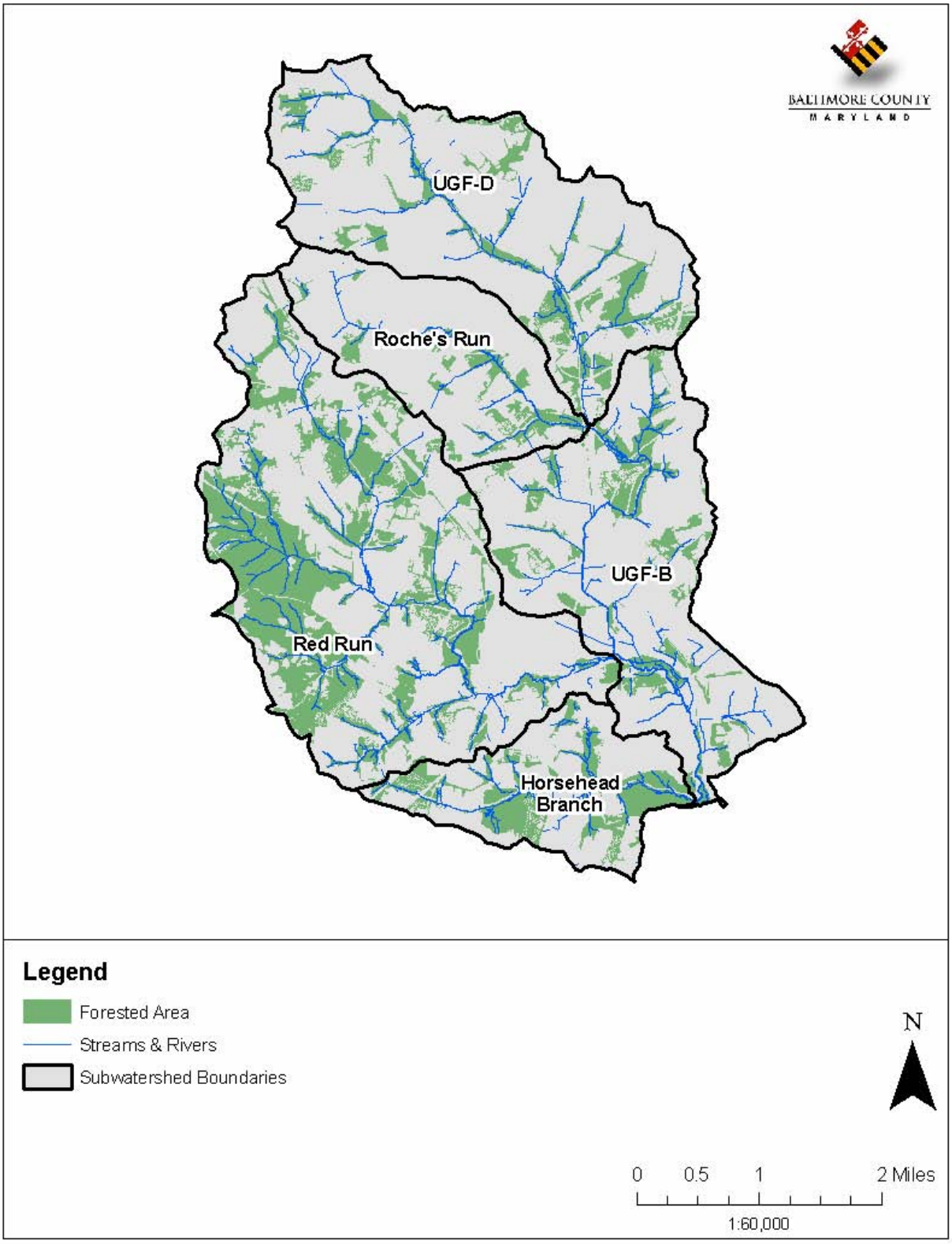

Figure 2-6: Upper Gwynns Falls Forest Cover

2.2.6 Stream Systems

Stream systems are a watershed's circulatory system, and the most visible attribute of the hydrological cycle. The stream system is an intrinsic part of the landscape, and closely reflects conditions on the land. The streams are a fundamental natural resource, with myriad benefits for plants, animals, and humans. Maintaining a healthy stream system is a priority for many individuals and organizations, and requires insuring that stream flows and water quality closely mimic the conditions found in un-impacted watersheds. Streams are the flowing surface waters, and are distinct from both groundwater and standing surface water (such as lakes), though they are connected with both of them.

2.2.6.1 Stream System Characteristics

The Upper Gwynns Falls watershed contains approximately 83.8 miles of stream channels, all of which drain to the Gwynns Falls (total of 135.6 miles of stream), which flows to the Chesapeake Bay.

The Gwynns Falls watershed, which is classified as basin code 02130905 by the State of Maryland, is part of the larger Chesapeake Bay watershed. The Upper Gwynns Falls watershed is a subset of the Gwynns Falls and is separated into 5 subwatersheds. Table 2-6 shows the stream mileage and density by subwatershed. Figure 2-7 shows the stream network and the 5 subwatersheds.

Table 2-6: Upper Gwynns Falls Streams Mileage and Density

Subwatershed	Area (sq. mi.)	Stream Miles	Stream Density (mi./sq. mi.)
UGF-D	5.00	15.38	3.08
Roche's Run	2.40	5.91	2.46
UGF-B	4.40	18.23	4.14
Red Run	7.43	33.69	4.53
Horsehead Branch	2.04	10.63	5.21
Total	**21.27**	**83.84**	**3.94**

It is important to note that the Red Run subwatershed contains Tier II, high quality waters that are suitable for trout and other highly sensitive habitat.

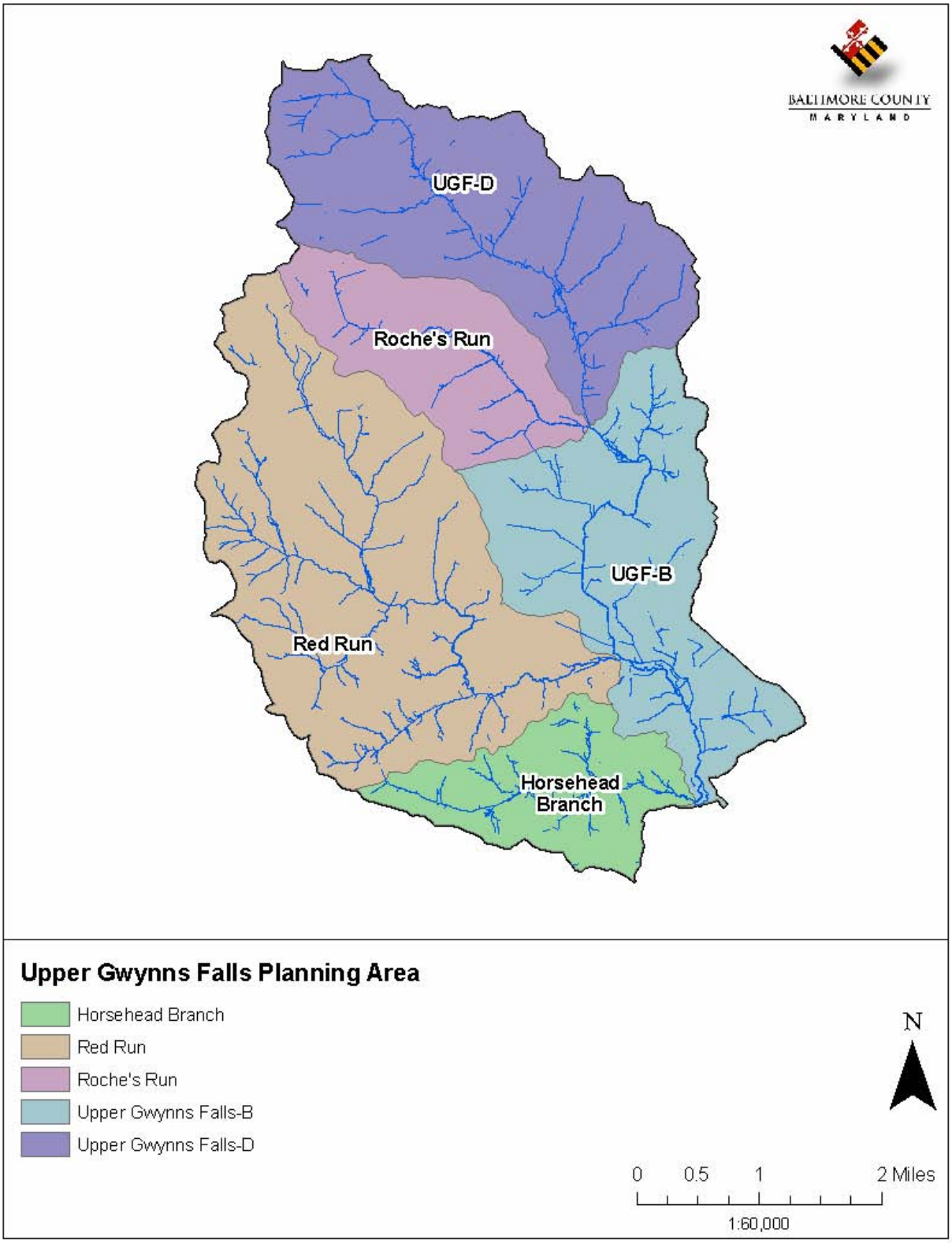

Figure 2-7: Upper Gwynns Falls Stream Network

2.2.6.2 Stream Riparian Buffers

Forested buffer areas along streams play a crucial role in increasing water quality, reducing surface runoff, stabilizing stream banks, trapping sediment, mitigating floods, and providing the required habitat for all types of stream life, including fish. Tree roots capture and remove pollutants including excess nutrients from shallow flowing water, and their structure helps prevent erosion and slow down water flow, reducing sediment load and the risk of flooding. Shading from the tree canopy provides the cooler water temperatures necessary for much stream life, especially cold-water species like trout, which are present in the Red Run subwatershed. In smaller streams such as those surveyed, terrestrial plant material falling into the stream is the primary source of plant food for stream life. Trees provide seasonal food in the form of leaves and plant parts for stream life at the base of the food chain, while fallen tree branches and trunks provide a more consistent, slow-release food source throughout the year. Tree roots and snags also provide important habitat for fish and other aquatic species. Maintaining healthy streams and forest buffers are important for reducing the nutrient and sediment loadings to the Chesapeake Bay. When stream buffers are converted from forests to agriculture or residential development, many of these benefits are lost, and the health of the stream declines.

The vegetative condition of the riparian buffer based on 100 feet of buffer on either side of the stream was analyzed by subwatershed. Three conditions were identified: forested, impervious or open pervious. Impervious areas were determined by overlaying the roads and buildings data layers over the 100-foot stream buffer layer. Similarly, the forested areas were determined using the wooded GIS layer and removing any impervious area footprint. Remaining areas were classified as open pervious areas. Stream buffer conditions are summarized by subwatershed in terms of acres and percentages in Table 2-7. The distribution of the 100-ft stream buffer classification scheme is shown in Figure 2-8.

Table 2-7: Land Use in the 100 Foot Riparian Buffer – Acres (%)

Subwatershed	Forested		Impervious		Open Pervious		Total	
	Acres	%	Acres	%	Acres	%	Acres	%
UGF-D	185.1	55.9	16.1	4.9	129.8	39.2	**331.0**	**10.3**
Roche's Run	57.2	41.2	13.2	9.5	68.5	49.3	**139.0**	**9.0**
UGF-B	148.7	34.4	41.5	9.6	241.4	55.9	**431.6**	**15.3**
Red Run	437.3	59.9	23.5	3.2	268.9	36.9	**729.7**	**15.4**
Horsehead Branch	129.8	62.0	2.9	1.4	76.6	36.6	**209.3**	**16.1**
Total	**958.1**	**52.1**	**97.3**	**5.3**	**785.2**	**42.7**	**1,840.6**	**13.5**

Red Run has the most forest buffer of which 60% is forested. Horsehead Branch is smaller in acreage but has over 62% forested riparian buffer. The lowest percentage of forested buffer is in UGF-B along Reisterstown Road and I-795. There is a relatively low amount of impervious buffer area but with the forested area just over 50% much of the buffer is open space. The open pervious condition, covering 43% (785 acres) of the riparian buffer, represents potential opportunities for reforestation of the buffer. Riparian buffer covered by impervious surfaces are less likely to be remediated, but may represent an opportunity to remove impervious cover and reforest the buffer.

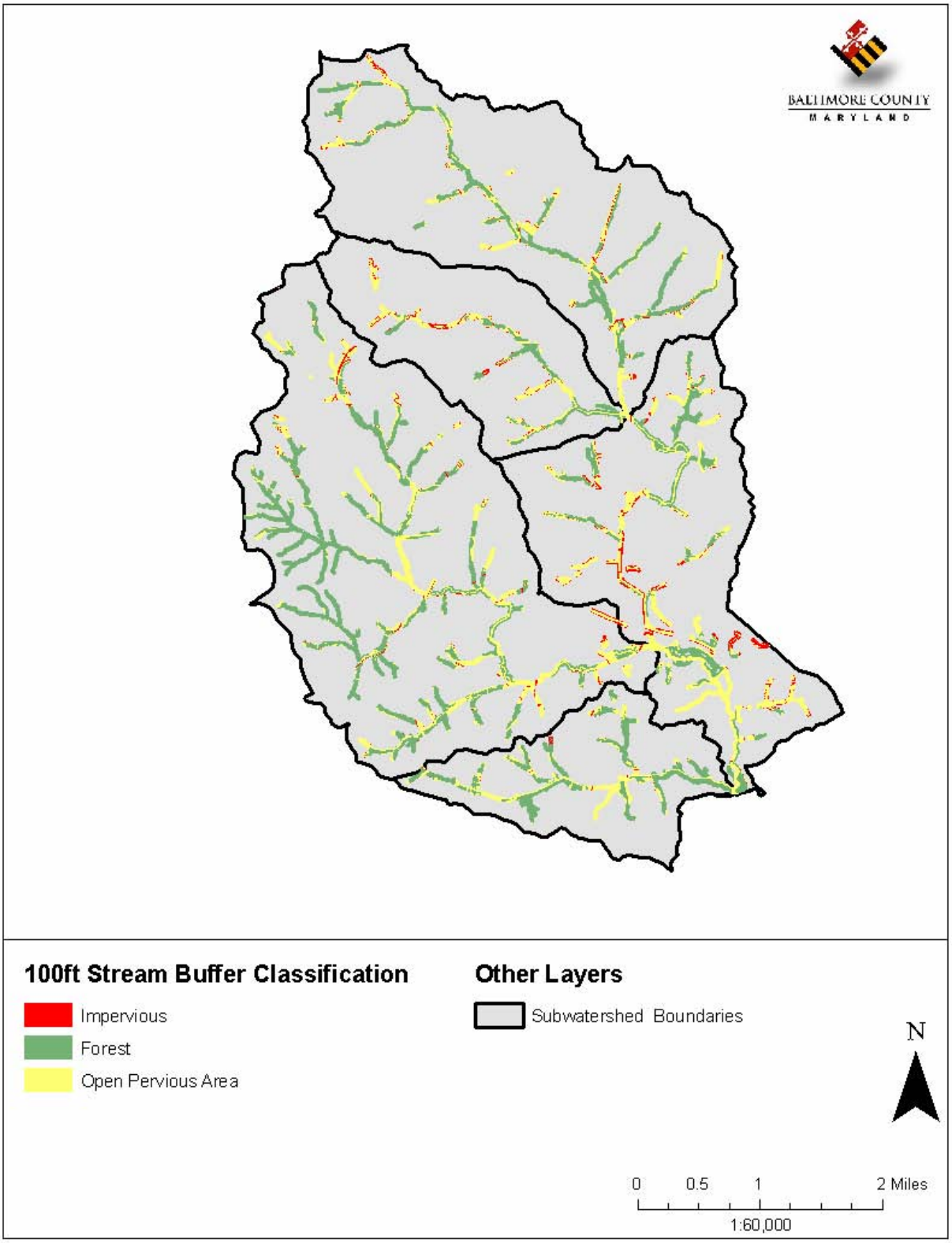

Figure 2-8: Upper Gwynns Falls 100 ft. Stream Buffer Classification

2.3 The Human Modified Landscape

The natural landscape has been modified for human use over time. The intensity of this modification has increased, starting with the colonization of Maryland in the 1600s. This modification has resulted in environmental impacts to both the terrestrial and aquatic ecosystems. This section describes the characteristics of the human modified landscape and how it is associated with impacts to the natural ecosystem. The characterization will include general characteristics of land use and land cover and more specific issues including population, impervious cover, drinking water and wastewater, storm water systems, discharge permits, zoning, and build-out analysis.

2.3.1 Land Use and Land Cover

The Upper Gwynns Falls watershed has 13,615 acres of land. The dominating land use types are: urban/residential 6,295 acres (46%), forest 3,056 acres (22%), commercial 1,072 acres (8%), agricultural 937 acres (7%), industrial 633 acres (5%) and institutional land 717 acres (5%). Land use has pronounced impacts on water quality and habitat. Different land uses generate different types and amounts of pollutants. As discussed in the previous section, a forested watershed has the capacity to absorb pollutants such as sediment and nutrients and reduce the flow rate of water into streams. Developed areas with impervious surfaces block the natural seepage of precipitation into the ground. Impervious surfaces include roads, parking lots, roofs and other human constructions. Unlike most natural surfaces, impervious surfaces tend to concentrate stormwater runoff, accelerate flow rates, and direct stormwater to the nearest stream. This can cause bank erosion and destruction of in-stream and riparian habitat. Undeveloped watersheds and those with small amounts of impervious surfaces tend to have better water quality in local streams than developed watersheds with larger amounts of impervious surfaces. In addition, agricultural land can contribute to increases in nutrients and coliform bacteria in streams if not properly managed.

The Maryland Department of Planning (MDP) develops a statewide land use/land cover GIS layer every five years to provide a general overview of predominant land cover/usage (interpreted from aerial photography and satellite imagery) and to monitor development activities throughout the state. The most recent update available and used for this characterization report is the 2007 MDP land use/land cover scheme. This was based on the 2002 land use/land cover GIS layer and updated using 2005 aerial imagery in conjunction with 2006 parcel information. The main focus of the 2007 update was to assess the state's conversion of land to development and to characterize the type of development. Two new land use/land cover categories were introduced in this version including very low density residential (large lot subdivision, 5 to 20 acres) and transportation (major highways and miscellaneous transportation features not classified elsewhere). The map of land use in the Upper Gwynns Falls watershed is summarized in Table 2-8 and presented in Figure 2-9. The data are based on the Maryland Department of Planning (MDP) 2007 land use GIS data layer.

Table 2-8: Upper Gwynns Falls Watershed Land Use

Subwatershed Scale	UGF-D %	Roche's Run %	UGF-B %	Red Run %	Horsehead Branch %	Totals %
Very Low-Density Residential	0.2	2.2	0.1	2.2	0.2	1.1
Low-Density Residential	15.9	6.8	5.3	16.1	0.0	11.2
Medium-Density Residential	41.7	38.4	9.3	6.5	28.2	21.0
High-Density Residential	9.9	27.4	11.4	14.5	12.1	14.0
Commercial	4.5	11.9	13.6	6.5	4.0	7.9
Industrial	3.2	0.0	12.1	4.0	0.0	4.7
Institutional	3.6	7.8	9.6	2.8	6.1	5.3
Extractive	0.0	0.0	0.0	1.6	0.0	0.6
Open Urban	0.4	0.4	3.5	1.9	1.4	1.7
Cropland	5.8	0.0	2.1	5.5	11.1	4.8
Feeding Operations	0.0	0.0	0.0	0.03	0.3	0.0
Pasture	0.0	0.0	5.6	0.0	9.3	2.1
Deciduous Forest	12.9	0.0	20.6	23.4	26.6	18.5
Evergreen Forest	0.0	0.0	0.0	10.6	0.0	3.7
Mixed Forest	0.5	0.4	0.0	0.3	0.8	0.2
Brush	1.3	0.3	1.0	0.4	0.0	0.7
Water	0.0	0.0	0.0	0.4	0.0	0.1
Wetlands	0.0	0.0	1.1	0.0	0.0	0.2
Bare Ground	0.0	0.0	0.6	0.1	0.0	0.2
Transportation	0.0	0.4	4.0	3.2	0.0	2.0

A limited amount of agriculture is still present in the Upper Gwynns Falls planning area, located in all subwatersheds except Roche's Run with the highest percentage in Horsehead Branch and largest acreage in Red Run. Forest cover accounts for 22% of the land use and consists mostly of deciduous forest in all subwatersheds except Roche's Run and evergreen forest in Red Run. Roche's Run has very little forested area. Urban/suburban residential development accounts for 46% of the land use in Upper Gwynns Falls watershed, with the majority (36%) in medium and high-density residential land use (<1 acre per dwelling unit).

Almost 13% of the land is commercial and industrial and is concentrated along Reisterstown Road, Red Run Boulevard and Owings Mills Boulevard. Institutional land use, consisting mainly, but not exclusively of schools represents 5% of the land cover within the Upper Gwynns Falls watershed. Many of these institutions are private schools, universities and colleges, and represent an opportunity to initiate environmentally sensitive management of the grounds.

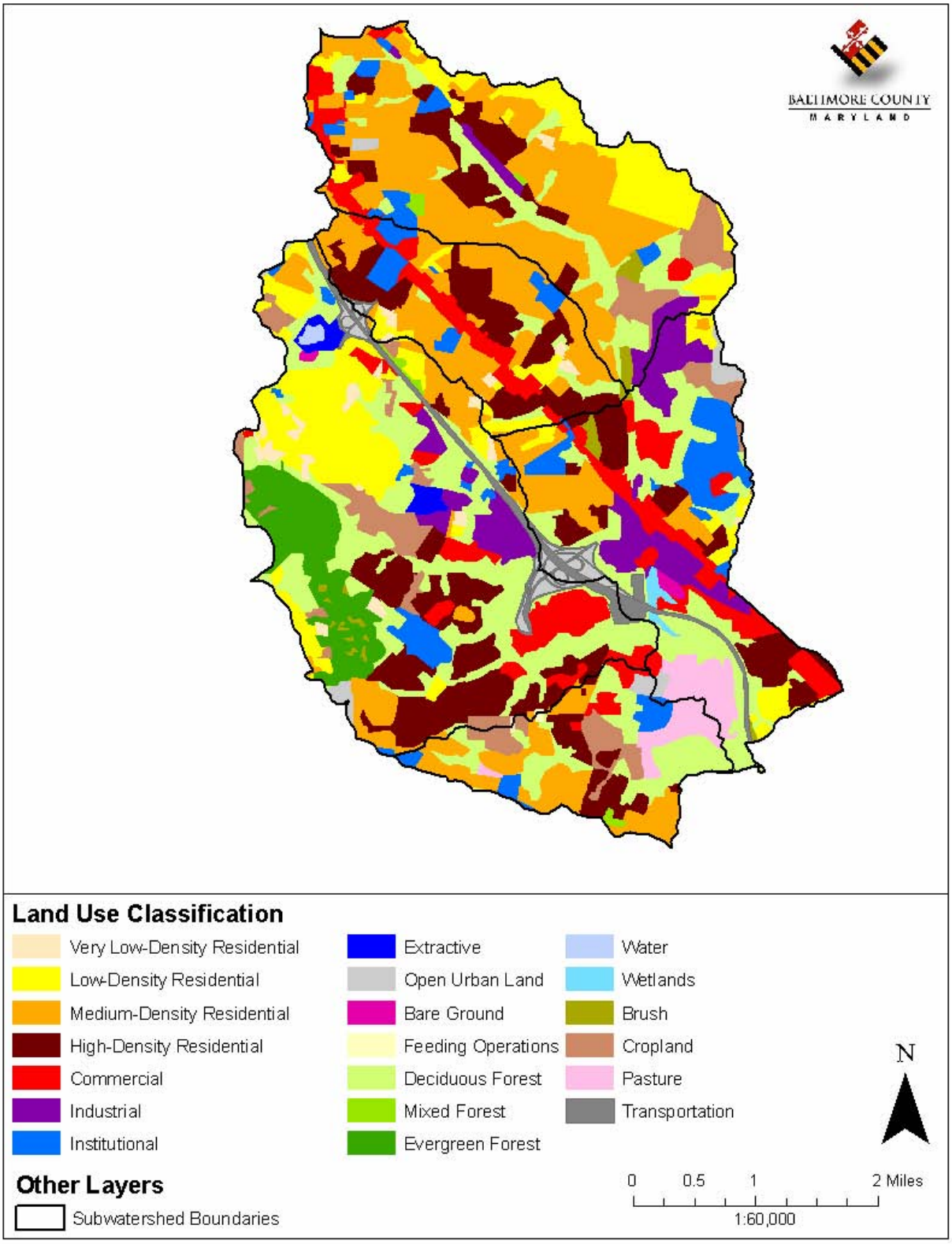

Figure 2-9: Upper Gwynns Falls Watershed Land Use

2.3.2 Population

Population estimates based on the 2000 US census were used to evaluate the intensity of land use. A higher per acre population represents a more intense use of the land and potential for environmental degradation. However, smart growth principles are intended to direct future growth to areas of existing services, mainly where development has already occurred. This will result in less land conversion to residential and supporting commercial land uses and result in the conservation of lower impact land use, such as, forest and agriculture.

Much of the degradation from urban/suburban land uses is related to the amount of impervious cover. Table 2-9 shows the subwatershed population sizes along with a calculation of the population density based on both the subwatershed acreage and the subwatershed impervious cover acreage. The population density distribution is displayed in Figure 2-10.

Table 2-9: Upper Gwynns Falls Subwatershed Population Data

Subwatershed	Total Population (2000 census)	SWAP Area (acres)	Population Density (per acre)	Population Density (per impervious acre)
UGF-D	15,592	3,203.1	4.87	24.04
Roche's Run	11,945	1,537.1	7.77	28.58
UGF-B	10,572	2,817.7	3.75	13.95
Red Run	11,576	4,753.4	2.44	15.23
Horsehead Branch	4,867	1,303.5	3.73	26.58
Total	**54,552**	**13,614.8**	**4.01**	**19.71**

A general trend of increased density in the more recently developed neighborhoods along Reisterstown Road in the UGF-D and Roche's Run subwatersheds. Red Run has the lowest population density due to Soldier's Delight Natural Environmental Area and the commercial properties. There is an area of denser population in the New Town/Owings Mills area. Population in Horsehead Branch is evenly distributed and relatively low due to the large amounts of forest and agricultural area. There are low density areas in UGF-D and UGF-B due to the Gwynnbrook Wildlife Management Area, industrial areas along Owings Mills Boulevard, and the empty Rosewood Center.

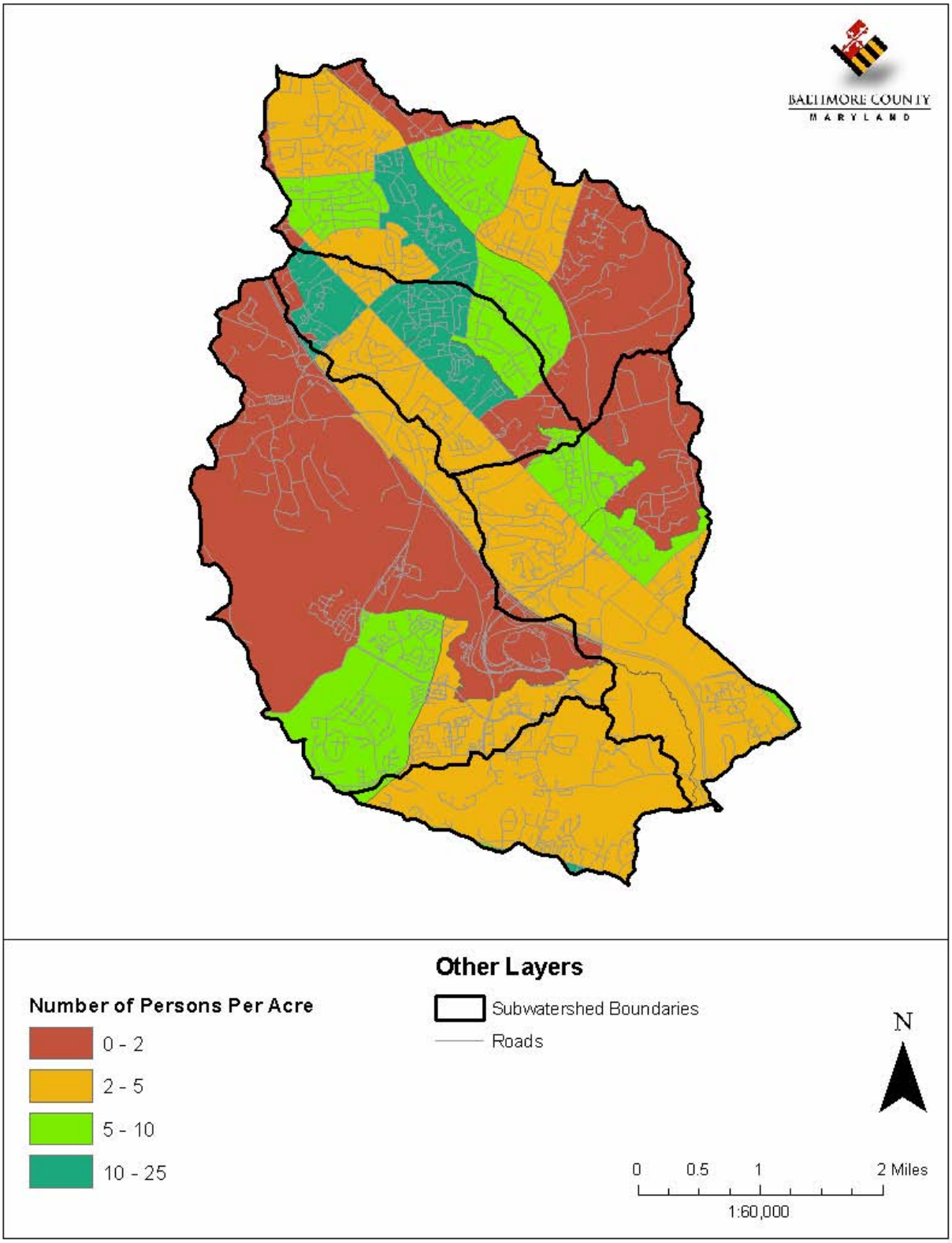

Figure 2-10: Upper Gwynns Falls Population Density

2.3.3 Impervious Surfaces

Impervious surface blocks the natural seepage of rain into the ground; these include roads, parking areas, roofs and other human constructions. Unlike many natural surfaces, impervious surface typically concentrates stormwater runoff, accelerates flow rates and directs stormwater to the nearest stream. This water has a high amount of energy and results in stream erosion that degrades 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. Some aquatic species are not present when the proportion of impervious area in the watershed reaches the threshold level. While this level varies by species, it can be low. The exact level of impervious area that can be tolerated depends partly on the watershed, and remains a topic of discussion among experts. Other species, e.g. macro-invertebrates, are also negatively impacted by increases in the impervious area, though the pertinent knowledge is often incomplete.

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

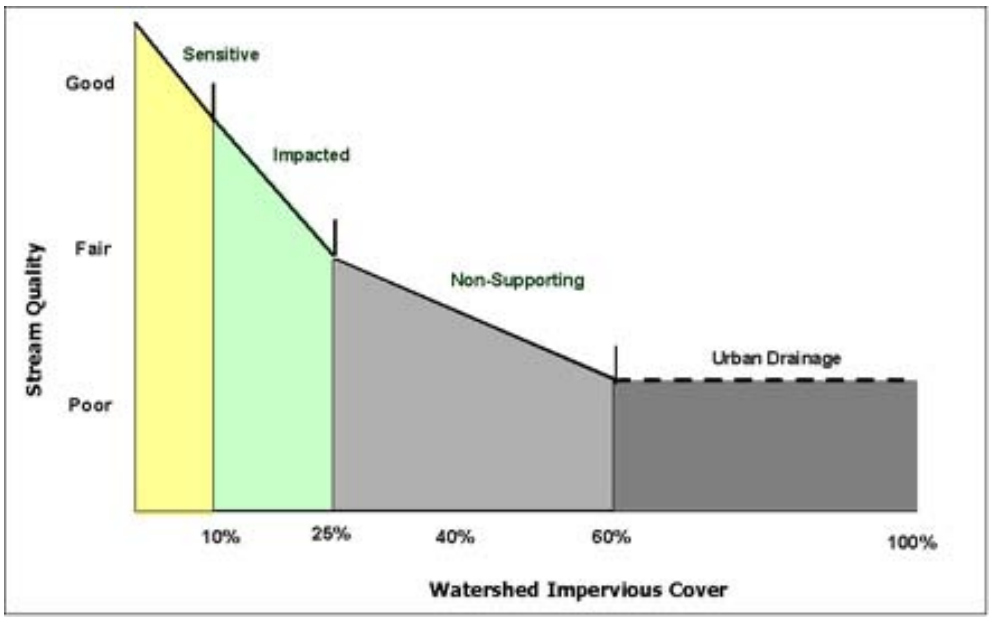

Figure 2-11. Impervious Cover Model (adapted from CWP 2003)

Based on the research compiled, CWP determined four general categories to classify and predict stream quality in terms of impervious cover. 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. The model predicts that between 10 and 25 percent impervious cover, watersheds become impacted and would show clear signs of degradation such as erosion, channel widening, and a decline in stream habitat. There is a possibility to restore streams to a somewhat natural functioning system within this category. When a watershed has more than 25 percent impervious cover, streams are classified as damaged which are characterized by fair to poor water quality, unstable channels, severe erosion, and inability to support aquatic life and provide habitat; many streams in this category are typically piped or channelized. Figure 2-11 shows that when impervious cover exceeds 60 percent, a watershed is classified as severely damaged and means that most of the natural stream system is gone. Management of damaged and severely damaged streams may focus on decreasing pollutant loads to downstream receiving waters (e.g., installing BMPs) but the ability to restore natural functions, such as habitat, is unlikely. Restoration efforts may also focus on making the remaining stream systems stable, aesthetically pleasing and an amenity to the community. It should be noted that the impervious cover model is a simplified approach for classifying the quality of urban streams. Although it is based on research, there are inherent model assumptions and limitations that should be considered such as regional variations and scale effects. In addition, while impervious cover is a relevant and significant indicator for watershed health, it is only one of many different factors affecting stream health and contributing to the cumulative impacts of development on water quality. For example, agricultural land uses contribute sediment and nutrient loads to receiving waters depending on management practices. Also, the ability of BMPs to offset adverse impacts from urbanized areas is not specifically accounted for in this model.

To derive estimates of impervious surface acreages in Upper Gwynns Falls, the roads and buildings GIS data layers from Baltimore County were used to derive impervious surface areas within the Upper Gwynns Falls watershed (see Figure 2-12). The area for each layer was determined and then combined to obtain estimates of impervious cover areas on a subwatershed scale. Table 2-10 summarizes the area of roads and buildings, total impervious area, and percent impervious area for each subwatershed.

Table 2-10: Estimated Impervious Surface in the Upper Gwynns Falls

Subwatershed	Total Area (acres)	Roads (acres)	Buildings (acres)	Impervious Area (acres)	% Impervious
UGF-D	3,203.1	356.4	292.2	648.6	20.2
Roche's Run	1,537.1	252.6	165.3	417.9	27.2
UGF-B	2,817.7	511.4	246.6	758.0	26.9
Red Run	4,753.4	508.4	251.9	760.3	16.0
Horsehead Branch	1,303.5	107.1	76.0	183.1	14.0
Total	**13,614.8**	**1,735.9**	**1,032.0**	**2,767.9**	**20.3**

Impervious cover represents about 20 percent of the watershed or 2,767 acres. Compared to urbanized watersheds in Baltimore County, this is an average amount of imperviousness. Horsehead Branch and Red Run have the least impervious area. Roche's Run and UGF-B have the most and are considered impaired using the CWP methodology. Subwatershed ratings according to the CWP impervious cover model and these impervious area estimates are shown in Figure 2-13.

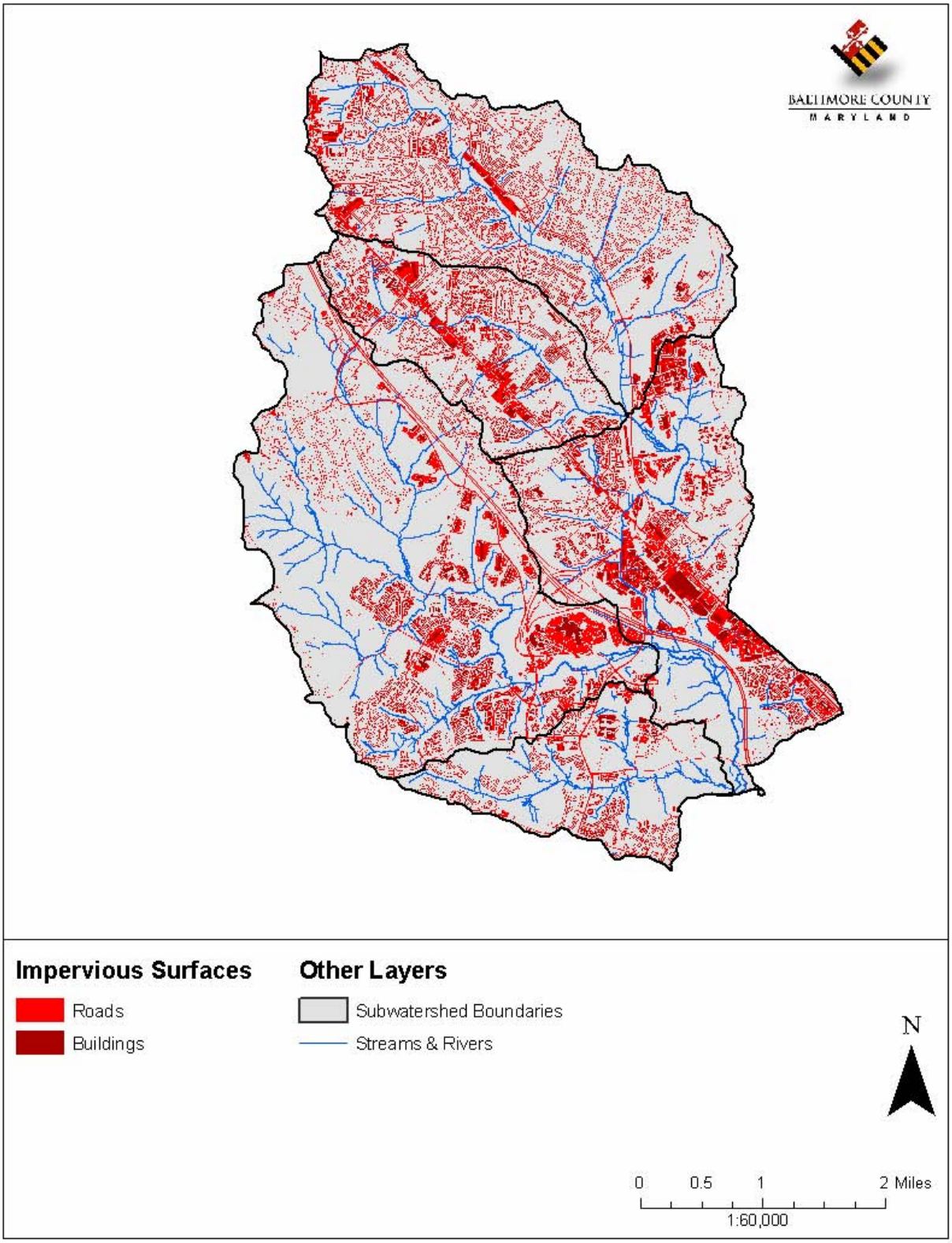

Figure 2-12: Upper Gwynns Falls Impervious Surface

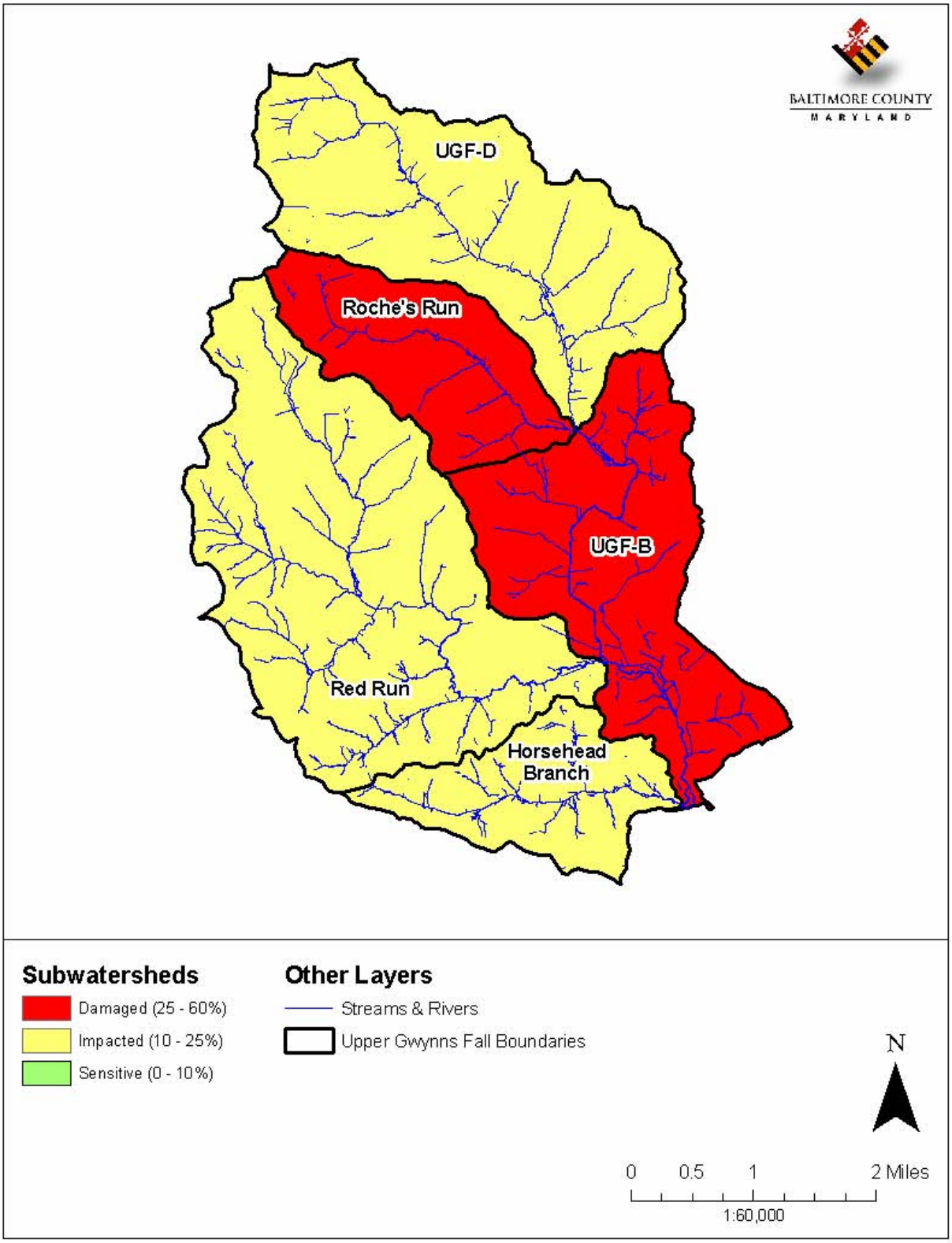

Figure 2-13: Upper Gwynns Falls Impervious Cover Ratings

2.3.4 Drinking Water

Drinking water is a fundamental need for human development. Drinking water can be supplied by either public distribution systems or by wells associated with individual properties. Adequate drinking water supply of is essential to maintaining the human population in a region. All of the developed areas within the Upper Gwynns Falls SWAP planning area are served by public water systems.

2.3.4.1 Public Water Supply

Environmental impacts associated with a public supply of water include the potential for increased residential development with the resulting impacts associated with impervious cover (see 2.3.2) and the potential for leaks from the system. Leaks from public water supply systems introduce chlorine into the aquatic system potentially resulting in the death of aquatic organisms. In addition, major leaks may cause erosion, which introduces sediment into the stream channels and which may bury aquatic benthic communities and degrade habitat. The water system is owned and maintained by the Baltimore City Department of Public Works.

2.3.5 Wastewater

Wastewater created through human use must be treated and disposed of. This may be accomplished through public conveyance to a treatment facility (sewer) or through individual wastewater treatment systems (septic) See Figure 2-14 for a graphical representation of the residential homes and businesses that utilize septic systems and the residences and business that are served by the sewer system. Residential wastewater consists of all of the water typically used by residents, including, wash water, bathing water, human waste disposal water, and any other rinse water (paint brush, floor washing, etc). Industrial operations must also dispose of any water used as part of their operation. Depending on the type the water could contain contaminants that have the potential to adversely impact the natural environment including metals, organic compounds, detergents, or synthetic compounds.

2.3.5.1 Septic Systems

Properly functioning septic systems provide treatment for virtually all of the phosphorus, but can leak 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. Table 2-11 shows the approximate number of septic systems by subwatershed as determined by Bay Restoration Fund records of September 2009. Failing systems can result in increased contamination of the aquatic environment through increased releases of nitrogen, phosphorus, and other chemicals. They can also increase the bacterial contamination of nearby streams and can be a potential concern for human health.

Table 2-11: Upper Gwynns Falls Septic Systems by Subwatershed

Subwatershed	No. of Septic Systems	% of Households
UGF-D	224	3.3
Roche's Run	225	5.3
UGF-B	100	3.3
Red Run	853	13.2
Horsehead Branch	36	1.6
Total	**1,438**	**6.3**

Although there are septic systems present in all subwatersheds only 6.3% of the Upper Gwynns Falls still utilizes them. A majority of the septic systems are in Red Run and the least are in Horsehead Branch. Red Run contains almost 60% of all septic systems in the SWAP study area and over 13% of the houses and businesses in Red Run use septic systems. With the exception of Red Run the percentage of buildings that have septic systems are 5% or less for each subwatershed.

2.3.5.2 Public Sewer

A public sewer system conveys wastewater from individual residences or businesses to a facility that treats the wastewater prior to discharge. The system itself consists of the piping system and cleanouts on the individual properties that are owned by the property owner. The individual landowner is responsible for the maintenance of this part of the system. The part of the system that is in the public right-of-way is owned and maintained by the local government. The public system consists of the gravity piping system and access manholes.

Environmental impacts associated with the public sewer system are usually the result of sewage overflows. These overflows usually result from blockages within the sewage system, pumping station failure, or rainwater inflows exceeding the capacity of the pipe. The EPA reports there are at least 40,000 of these incidents per year in the United States. The environmental and human health consequences of these overflows can be serious. E. Coli bacteria and other pathogens can be present, posing health risks to individuals who may come in contact with contaminated water. Sewer overflows can also contain high levels of nitrogen and phosphorus that are toxic to aquatic life and feed organisms that deplete oxygen in waterways. High levels of sediment are also present in these overflows, which can clog streams and block sunlight from reaching essential aquatic plants.

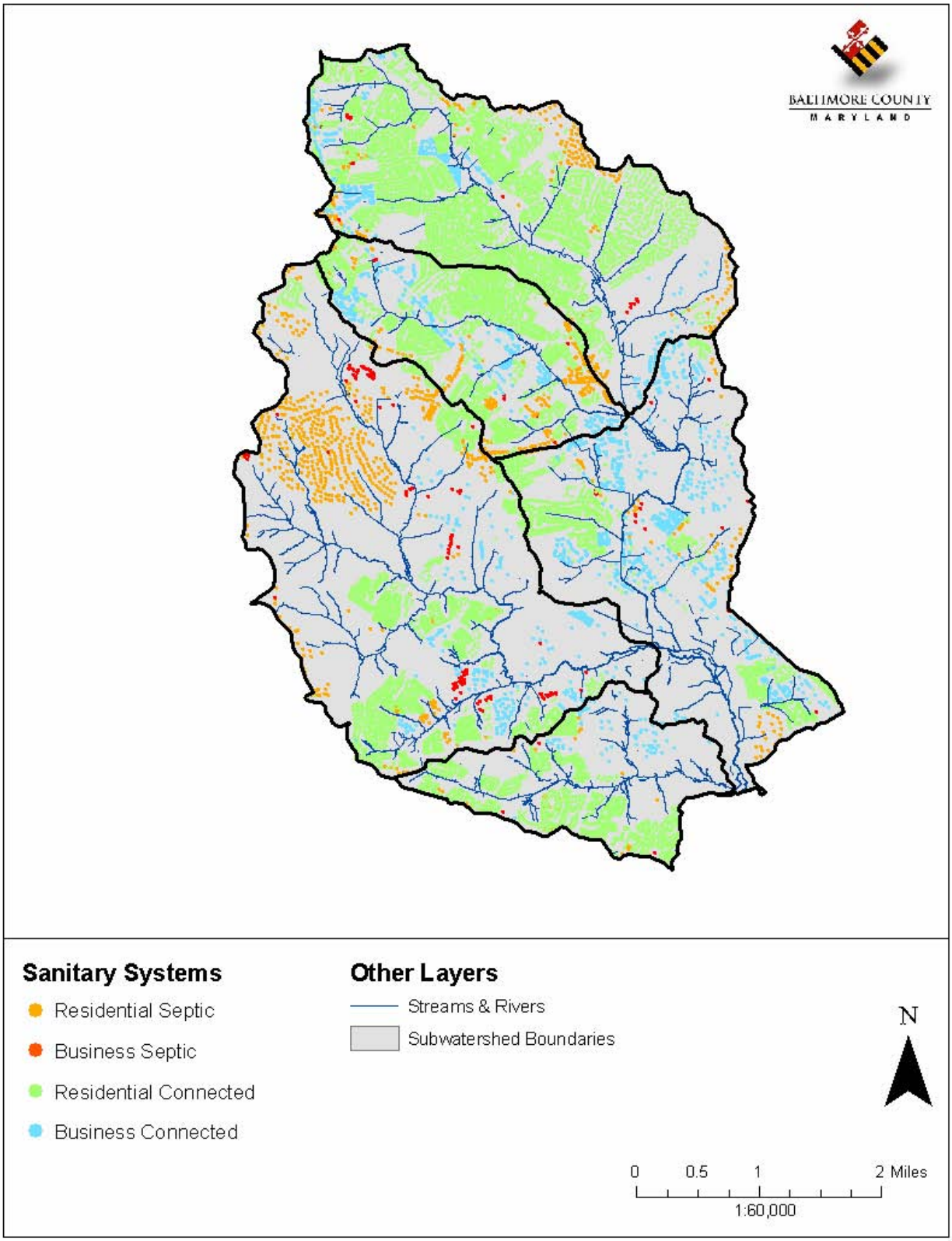

Figure 2-14: Upper Gwynns Falls Sewer Systems

Table 2-12 shows sewer piping length and number of households and businesses connected to the sewer system by subwatershed. Table 2-13 shows the sewer piping length per square mile in each subwatershed.

Table 2-12: Sewer Piping Length

Subwatershed	Pressurized Main (ft)	Pressurized Main Abandoned (ft)	Gravity Main (ft)	Gravity Main Abandoned (ft)	Houses Connected (#)	Businesses Connected (#)	Total (ft)
UGF-D	0	0	355,851	584	5,889	632	**356,435**
Roche's Run	0	0	145,008	488	3,560	454	**145,496**
UGF-B	0	0	154,738	11,642	2,080	883	**166,380**
Red Run	0	0	198,136	1,773	5,001	584	**199,909**
Horsehead Branch	0	0	95,265	419	2,045	186	**95,684**
Total	**0**	**0**	**948,998**	**14,906**	**18,575**	**2,739**	**963,904**

Table 2-13: Sewer Piping Length Per Square Mile

Subwatershed	Area (sq mile)	Pressurized Main (ft/mi^2)	Gravity Main (ft/mi^2)
UGF-D	5.00	0	71,287
Roche's Run	2.40	0	60,623
UGF-B	4.40	0	37,814
Red Run	7.43	0	26,906
Horsehead Branch	2.04	0	46,904
Total	**21.27**	**0**	**45,318**

With only 6.3% of the SWAP study area serviced by septic system, most of the buildings are connected to the public sewer system. There are no pressurized pipes or pumps in the system and the entire sewer system flows by gravity. UGF-D has the most gravity pipes as the subwatershed contains 38% of all pipe length in the SWAP study area. Horsehead Branch has the least and the Roche's Run, UGF-B and Red Run all have between 100,000 - 200,000 feet of gravity pipe length.

There are over 20,000 buildings connected to the sewer system, most of which are houses (87%). UGF-D has the most buildings connected with 5,889 and Red Run also has over 5,000 connections. Roche's Run, UGF-B and Horsehead Branch all have between 2,000 - 4,000 buildings connected. The density of gravity mains in each subwatershed yields slightly different results. UGF-D has the highest density of gravity pipes in the subwatershed but Red Run has the lowest density since it is the largest subwatershed in the SWAP study area. Roche's Run has the second highest density. Horsehead Branch has the least linear foot of pipe but is the third densest subwatershed.

2.3.5.3 Wastewater Treatment Facilities

There are no wastewater treatment facilities in the Upper Gwynns Falls subwatershed. The Gwynns Falls wastewater is treated at the Patapsco Wastewater Treatment Plant in Curtis Bay, MD.

2.3.6 Stormwater

Stormwater consists of the surface and shallow subsurface water runoff during and immediately after storm events. As indicated above, impervious surfaces increase the amount of runoff that the streams receive. Stormwater can carry pollutants from impervious surfaces and agricultural operations into the streams. The increase in the amount of runoff due to impervious surfaces (high) and agricultural operations (moderate) can result in stream erosion that destroys natural habitat and the ecosystem services of streams such as nutrient reduction.

Stormwater is water generated during and immediately after storm events. Stormwater that does not infiltrate into the ground becomes stormwater runoff and flows downstream to receiving water bodies. The amount and characteristics of stormwater runoff is affected by rainfall amount and intensity, soil properties, slope, and land use/land cover. Concerns associated with stormwater include rate and volume of runoff and water pollution amounts. For example, more runoff is generated from impervious cover and agricultural land than in undeveloped land. As previously mentioned, impervious surfaces do not allow any water to infiltrate into the ground and runoff is conveyed directly to the stream system. The increase in runoff rate and volume can cause flooding and stream erosion which in turn, results in the destruction of habitat and natural stream functions such as nutrient reduction. In addition, there is less potential for groundwater recharge when there is little or no infiltration of stormwater.

Stormwater runoff can also carry various contaminants depending on land use characteristics and human activities. Pollutants deposited on impervious surfaces and other developed lands from daily human activities are often carried by stormwater to stream systems. For example, common constituents in impervious surface runoff (e.g., highways, parking lots) include sediment, metals, bacteria, nutrients, and petroleum; pollutants such as these build-up over time from various sources such as maintenance activities (de-icing, roadside fertilizer use), vehicles (exhaust, leaks), and accidents/spills and are washed off during storm events. While the runoff from other developed areas, agriculture operations and residential areas for example, may be moderate compared to highly impervious areas, it can still carry pollutants such as nutrients, bacteria, and chemicals to receiving water bodies.

2.3.6.1 Storm Drainage System

The storm drainage system consists of either curb and gutter with associated inlets and piping system or drainage swales. The function of either system is to remove water quickly from roadways to prevent flooding and potentially hazardous situations. However, the environmental impact from the two types of systems is different. The curb and gutter system with inlets, piping and storm drain outfalls 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 untreated pollutants associated with impervious surfaces. Drainage swales (road side ditches) do not move the water as efficiently as

curb and gutter systems and therefore the water is slowed somewhat prior to entering the stream. The drainage swales also allow some infiltration into the soil thus reducing the amount of water eventually delivered. The infiltration and the slower movement of water also provide filtering of pollutants. Table 2-14 shows the components of the storm drain system by subwatershed in Upper Gwynns Falls and Table 2-15 shows the drainage area and density of drainage structures. Figure 2.15 shows the storm drain outfall locations in the watershed.

Table 2-14: Upper Gwynns Falls Storm Drain System Components

Subwatershed	Major Outfall (>3 ft)			Minor Outfall (< 3 ft)			All Outfalls		
	Outfalls (#)	Inlets (#)	Pipe (ft)	Outfalls (#)	Inlets (#)	Pipe (ft)	Outfalls (#)	Inlets (#)	Pipe (ft)
UGF-D	18	243	35,375	117	506	65,310	135	749	100,685
Roche's Run	12	103	15,810	37	215	27,634	49	318	43.444
UGF-B	16	64	12,176	47	205	26,885	63	269	39,061
Red Run	10	135	15,583	33	178	21,836	43	313	33,419
Horsehead Branch	2	26	4,533	15	85	11,887	17	111	16,420
Total	**58**	**571**	**83,477**	**249**	**1,189**	**153,552**	**307**	**1,760**	**237,029**

Table 2-15: Upper Gwynns Falls Storm Drain System Components

Subwatershed	Stormwater System Drainage Area (acre)	Area Covered by Stormwater System (%)	No. of Inlets (#)	Inlets Density (#/sq. mi.)
UGF-D	823	26	749	150
Roche's Run	771	50	318	132
UGF-B	794	28	269	61
Red Run	932	20	313	42
Horsehead Branch	130	10	111	54
Total	**3.450**	**25**	**1,760**	**83**

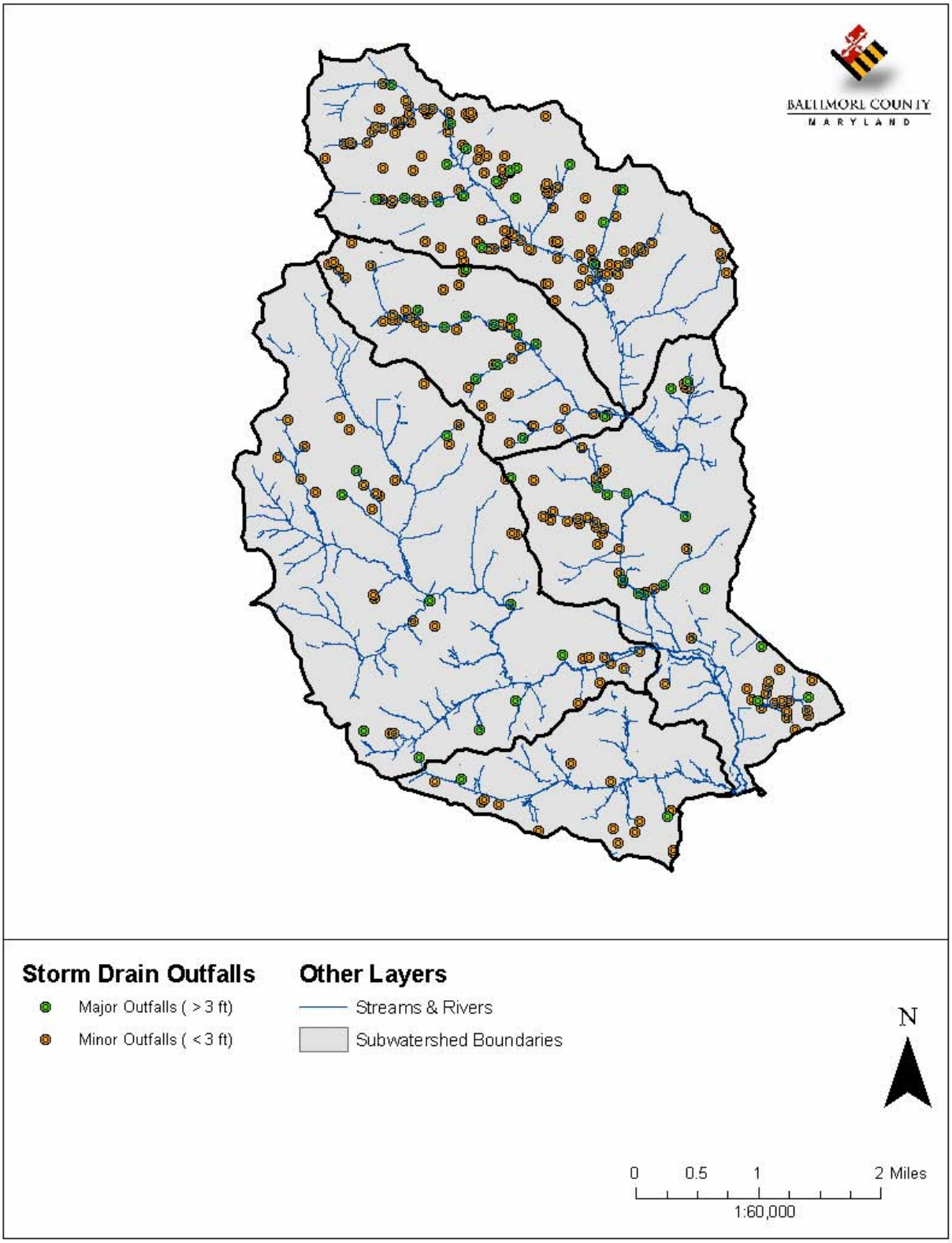

Figure 2-15: Upper Gwynns Falls Storm Drain Outfalls

2.3.6.2 Stormwater Management Facilities

Maryland was the first state to adopt stormwater regulations more than 20 years ago for new development to control the quantity of runoff. Within that set of regulations was an exemption for large lot subdivisions (>2 acres). Large lot subdivisions only had to provide stormwater management for roads. The stormwater management regulations evolved from the initial requirement of water quantity control to including water quality control in the early 1990s. Stormwater management (SWM) practices evolve as technology and research grows. It continues to be a significant consideration for new and redevelopment within the state. Management of stormwater runoff is required to reduce erosion, sedimentation, pollution, and flooding per Title 4, Subtitle 2 of the Environment Article of Annotated Code of Maryland (MDE 2000). Increased importance of water quality and water resource protection has led to the development of the Maryland Stormwater Design Manual to provide BMP design standards and environmental incentives (MDE 2000) and a general shift toward adopting practices that mimic natural hydrologic processes, are low impact, and achieve pre-development conditions. The latter is evident by the Maryland Stormwater Management Act of 2007 which requires that environmental site design (ESD) be implemented to the maximum extent practicable via nonstructural BMPs and/or other better site design techniques.

There are many types of BMPs available for managing stormwater runoff and providing stormwater quality treatment. SWM can target specific objectives depending on the BMP type such as stormwater quality, soil stabilization, stormwater flow control, and stream restoration. In addition, different SWM facilities have different pollutant removal capabilities. For example, initial dry pond designs for SWM have low pollutant removal efficiency compared to practices that filter the stormwater or allow it to infiltrate into the ground or through plant roots. Several considerations are taken into account when selecting appropriate stormwater treatment measures such as space requirement, maintenance, cost, and community acceptance.

Figure 2-16 illustrates the stormwater management facilities in the Upper Gwynns Falls watershed and shows that the stormwater management facilities are fairly well scattered throughout the watershed. A total of 457 facilities are represented.

Table 2-16 provides a summary of the different SWM facilities located within the Upper Gwynns Falls watershed by subwatershed including dry and wet ponds, wetlands, infiltration and filtration practices, extended detention, proprietary BMPs and other types of SWM facilities.

The facility type and drainage area to the facility are listed by subwatershed in Table 2-16.

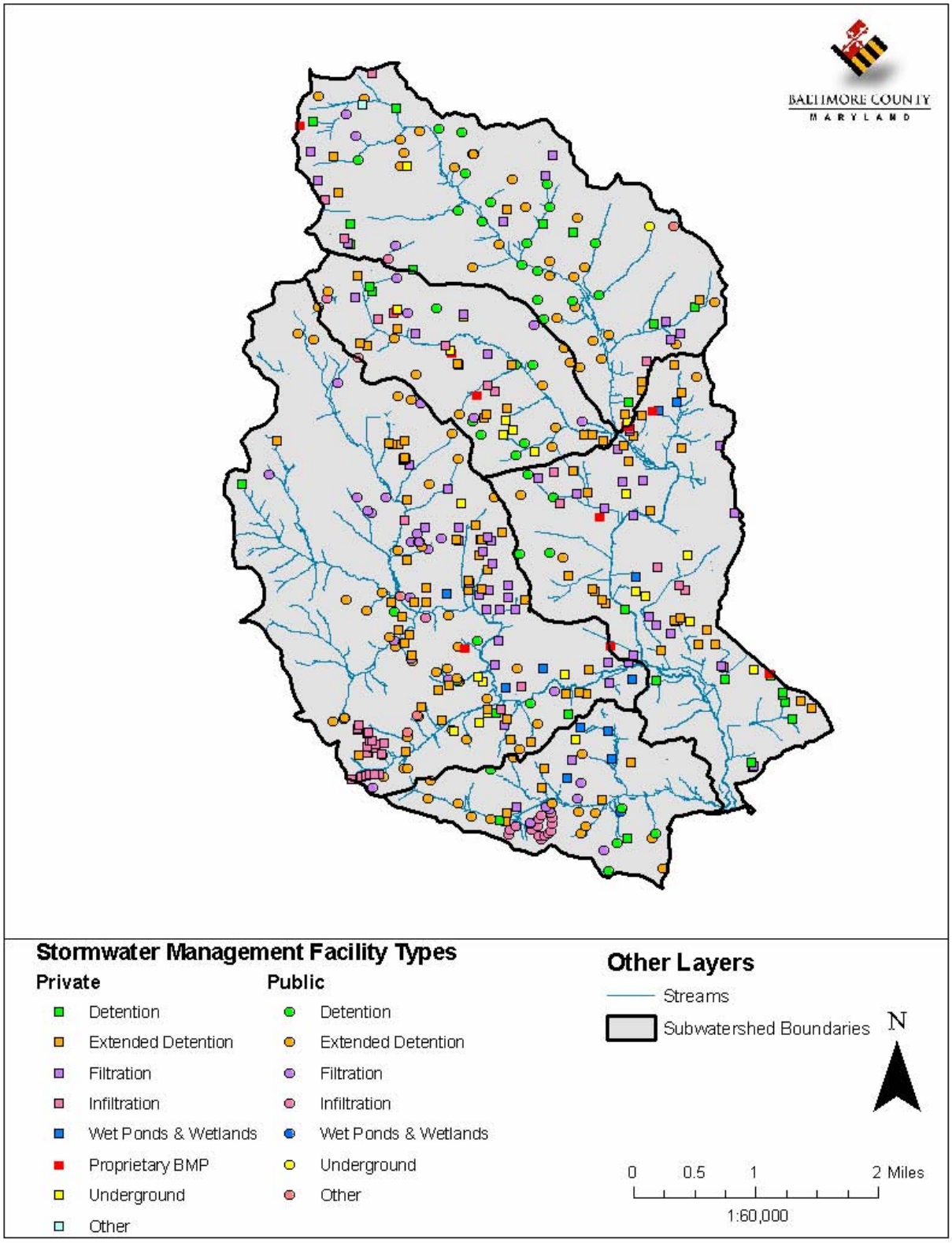

Figure 2-16: Upper Gwynns Falls Stormwater Management Facilities

Table 2-16: Upper Gwynns Falls Stormwater Management Facilities

SWM Facility	UGF-D	Roche's Run	UGF-B	Red Run	Horsehead Branch	Totals
Detention (#)	36	23	26	21	7	
Drainage Area (acres)	975.4	151.6	331.0	223.2	157.9	**2,004.8**
Wet Ponds (#)	2	0	3	5	5	
Drainage Area (acres)	16.2	0.0	68.5	100.0	183.6	**368.2**
Infiltration (#)	2	2	3	32	16	
Drainage Area (acres)	10.4	20.7	10.2	65.2	44.0	**150.3**
Filtration (#)	10	9	18	43	8	
Drainage Area (acres)	37.5	26.3	58.0	243.9	79.4	**445.1**
Extended Detention (#)	33	23	26	84	20	
Drainage Area (acres)	548.9	172.8	307.6	1,170.5	291.4	**2,512.9**
TOTAL (#)	**83**	**57**	**76**	**185**	**56**	**457**
TOTAL (acres)	**1,784.4**	**371.4**	**766.7**	**1,802.6**	**756.2**	**5,481.3**

Table 2-16 reveals that the extended detention ponds are the best-represented storm water management design in terms of number of facilities. Filtration, infiltration, and dry ponds are the next most numerous facilities. Dry ponds have the lowest pollution removal efficiency and present the best opportunities for conversion to a more efficient design to remove more pollutants before runoff reaches the streams.

Red Run has the most facilities and treats the most acres of developed land as it contains the most recent development. UGF-D and UGF-B have the next highest count of stormwater management facilities and the greatest number of dry ponds.

Table 2-17 shows the percentage of land in the Upper Gwynns Falls that is treated by stormwater management.

Table 2-17: Upper Gwynns Falls County Urban Areas Treated by SWM

Subwatershed	Total Acres	Acres Treated by SWM	Urban Land Use Treated by SWM (%)
UGF-D	3,203	1,784	56
Roche's Run	1,537	371	24
UGF-B	2,818	767	27
Red Run	4,753	1,803	38
Horsehead Branch	1,304	756	58
Total	**13,615**	**5,481**	**40**

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. Table 2-18 shows the number of NPDES permits in each

of the five subwatersheds in Upper Gwynns Falls. Figure 2-17 shows that the location of the NPDES Permit filers.

Table 2-18: NPDES Permits in the Upper Gwynns Falls Watershed

Subwatershed	# General Industrial Stormwater Permits	# Surface Industrial Discharge Permits	#Mining Permits	# of Permits
UGF-D	0	1	1	2
Roche's Run	7	0	0	7
UGF-B	4	4	0	8
Red Run	7	1	1	9
Horsehead Branch	2	0	0	2
Total	**20**	**6**	**2**	**28**

As of 2008, there are currently 28 NPDES-permitted facilities within the Upper Gwynns Falls subwatershed. Most (20 out of 28) are general industrial stormwater permits, which corresponds to stormwater discharges from various industrial areas in the watershed such as the McDonogh School and various apartment, condominiums, and townhouses.

The 6 of the remaining 8 permits are for general industrial surface water discharge permits, which are issued for industrial facilities that discharge processed water to State surface waters which must meet applicable federal effluent guidelines and/or State water quality standards. This includes Solo Cup, a SHA maintenance yard, and various manufacturing facilities.

Mining permits correspond to discharges from mineral mines, quarries, borrow pits, and concrete and asphalt plants in the watershed.

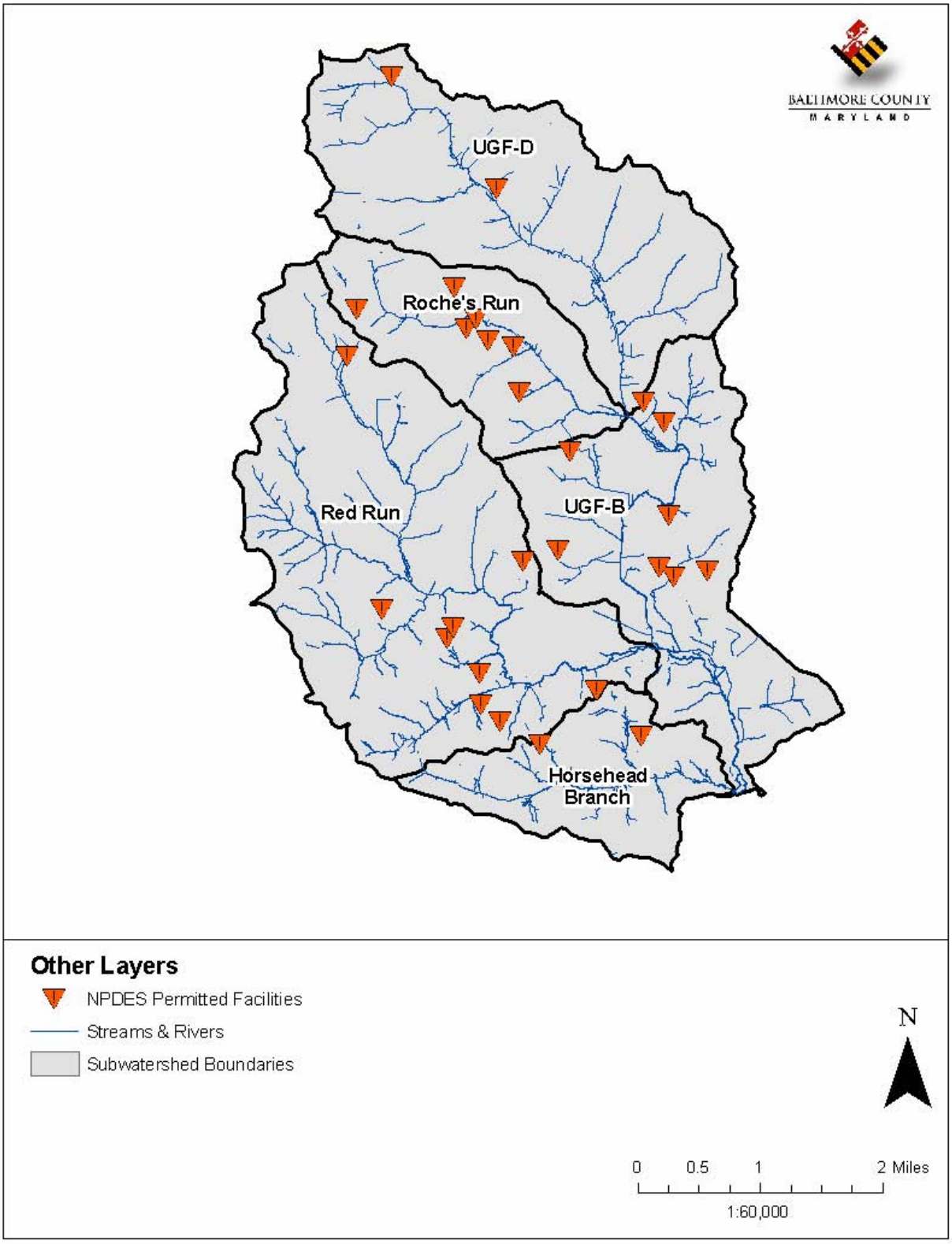

Figure 2-17: Upper Gwynns Falls NPDES-Permitted Facilities

2.3.8 Zoning

According to the Baltimore County Office of Planning (2007), zoning is defined "a system of land use regulation that controls the physical development of land and a legal mechanism by which local government is able to regulate an owner's right to use privately owned land for the sake of protecting the public health, safety, and/or general welfare." In other words, zoning manages development patterns over time throughout the county.

Zoning depends greatly on the division of urban and rural areas to better facilitate growth in urban areas and preserve important natural and agricultural resources in rural areas. The urban rural demarcation line (URDL) was established in 1967. Urban and rural zoning was adopted in 1975. In 1979, Owings Mills was identified as a designated growth area for Baltimore County. Water and sewer service were extended to the Upper Gwynns Falls, and I-795 and the Baltimore Metro (single line rapid transit system) were constructed to enhance development and business.

The current zoning and the URDL is displayed in Figure 2-18 and 2-19. As can be seen from these figures, there are a wide variety of zoning types; however, the majority fall into one of the residential zoning types. Table 2-19 shows the zoning category acreages and proportions for the SWAP study area and Table 2-20 shows the zoning data by subwatershed.

As shown in Figure 2-18 and 2-19, all office and business is grouped together as they are considered compatible land uses since population is typically concentrated in these areas. Low density and rural residential zoned areas represent potential for forest preservation and restoration opportunities. Unused agricultural areas represent potential for forest buffer enhancement. Areas zoned for industrial use are located mostly nearby streams in Red Run, UGF-B and also some in UGF-D. Commercial zoning areas are mostly near Owings Mills Boulevard, Red Run Boulevard, and Reisterstown Road.

Table 2-19: Upper Gwynns Falls Zoning

Zoning Code	Zoning Description	Allowed Units/Acre	Total (acres)	% of Watershed
DR-1	Density Residential	1	1,455	10.7
DR-2	Density Residential	2	1,063	7.8
DR-3.5	Density Residential	3.5	3,602	26.5
DR-5.5	Density Residential	5.5	664	4.9
DR-10.5	Density Residential	10.5	577	4.2
DR-16	Density Residential	16	1,116	8.2
RAE-1	Residential Apartment	40	17	0.1
RAE-2	Residential Apartment	80	74.5	0.5
RO	Residential Office	-	55	0.4
ROA	Residential Office	-	3	0.0
RC-2	Agricultural	-	765	5.6
RC-4	Watershed Protection	-	18	0.1
RC-5	Rural Residential	-	1,083	8.0
RC-7	Resource Preservation	-	19	0.1
Commercial	Office/Business	-	1,682	12.4
Manufacturing	Industrial	-	1,418	10.4
SE	Service Employment	-	6	0.0
Total			**13,615**	**100**

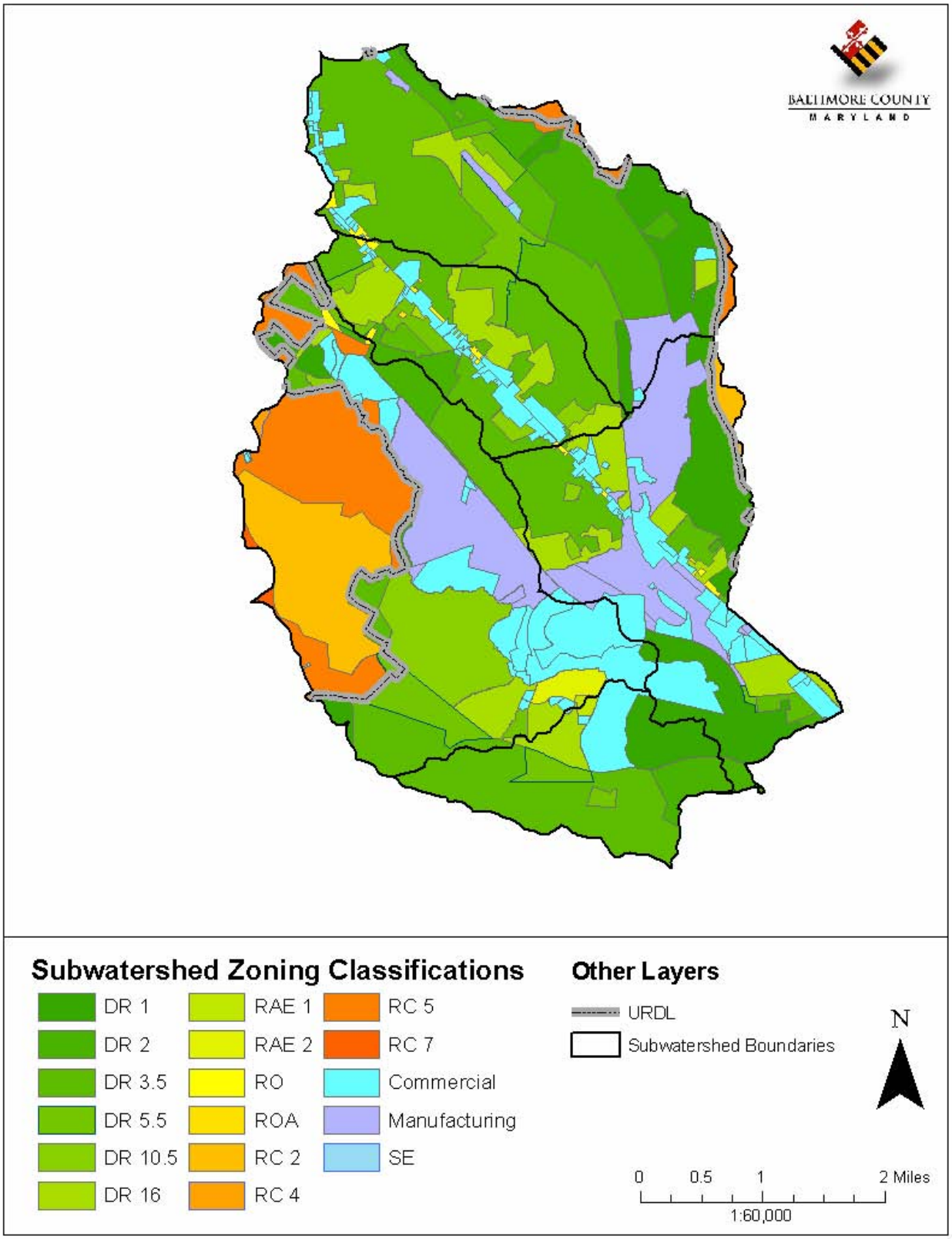

Figure 2-18: Upper Gwynns Falls Zoning

The Upper Gwynns Falls watershed has over 8,500 acres of residentially zoned area, the predominant assessment class at 63% of the watershed area. Rural residential (RC-5) zoning accounts for 8% of the land. There is a fair amount of commercial (12%) and manufacturing (10%) totaling 3,100 acres throughout the Upper Gwynns Falls watershed. Agricultural (RC-2) zoning accounts for almost 6% of the land area in the watershed. As shown in Figure 2-18, the small amount of watershed protection (RC-4) and resource preservation (RC-7) zoned land is to the west of Soldiers Delight Natural Environmental Area for the Liberty Reservoir. Note there is no land within the watershed boundaries zoned for resource conservation (RC-20, 50) or environmental enhancement (RC-8).

Table 2-20: Upper Gwynns Falls Zoning By Subwatershed

Watershed	Total (Acres)	Urban Residential (Acre)	Rural Residential (Acre)	Commercial (Acre)	Industrial (Acre)	Agricultural (Acre)
UGF-D	3,203.1	2,784.0	130.2	131.1	157.8	0.0
Roche's Run	1,537.1	1,308.1	0.0	228.9	0.1	0.0
UGF-B	2,817.7	1,522.1	3.2	522.8	700.4	69.3
Red Run	4,753.4	1,808.7	985.8	703.8	559.6	695.5
Horsehead Branch	1,303.5	1,144.5	0.0	159.0	0.0	0.0
Total	**13,614.8**	**8,567.4**	**1,119.2**	**1,745.6**	**1,417.9**	**764.8**

Urban residential zoning is the most predominant zoning classification in all subwatersheds with the most in UGF-D and the least in Horsehead Branch and Roche's Run since they are the smallest subwatersheds. There is no Rural Residential zoning in Roche's Run or Horsehead Branch and only 3.2 acres in UGF-B along the watershed boundary edge to the east. There are no areas zoned for Industrial use in Roche's Run and Horsehead Branch and less than 200 acres in UFG-D. UGF-B has the most area zoned for Industrial use. There is no agricultural land in UGF-D, Roche's Run or Horsehead Branch. There are 69 acres in UGF-B zoned for agriculture and ten times that in Red Run. There is commercial area in all subwatersheds with the most in UGF-B and Red Run, and the least in UGF-D.

Figure 2-19 shows the zoning in the Upper Gwynns Falls with respect to the URDL and shows the location of the URDL in Baltimore County

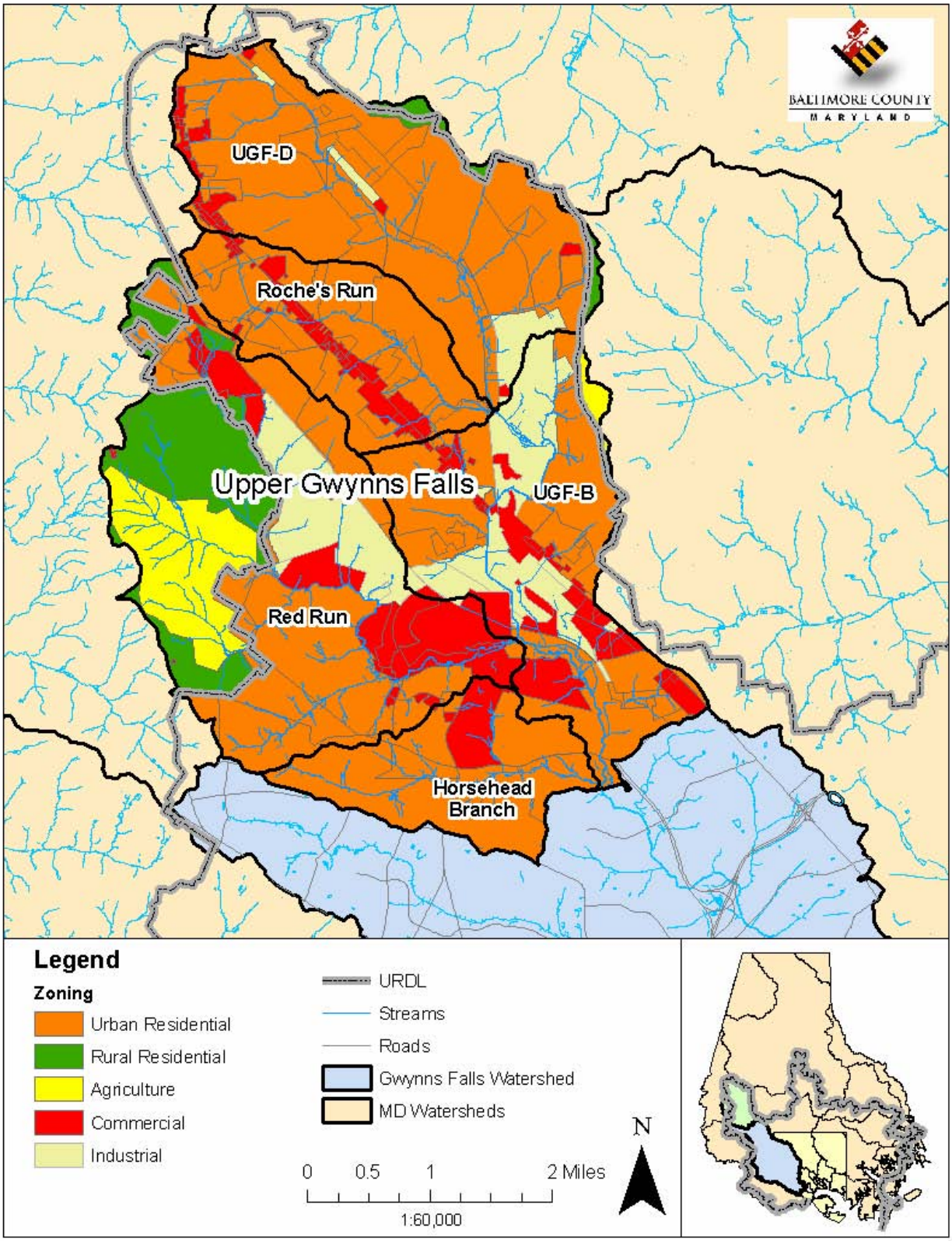

Figure 2-19: The Urban Rural Demarcation Line In Relation To the Upper Gwynns Falls

2.3.9 Historical Development

Maryland was settled in 1634 and Baltimore County established around 1659. Reisterstown is one of the oldest towns in Baltimore County and grew from the wilderness along the Conewago Road built in 1736-37 connecting Baltimore City to the western lands of Hanover. The dirt road followed old Indian trails and came to be where John Reister settled in 1758. Houses were made of logs, lighting was by candles and oil lamps, and transportation was by horse, carriage and wagon. Maryland ordered this road stoned and widened in 1773 for the use of wagons. Money ran out and the road had to be completed by private individuals, who made it a turnpike and added toll gates every few miles. This road was the main artery leading to Pittsburgh, Wheeling, West Virginia and the West. Caravans of covered wagons freighted with products of the West all passed through Reisterstown on the way to Baltimore.

The first post office was built in 1802 and schools such as the Franklin and Hannah More Academies followed soon after. The village of Glyndon started, and the Western Maryland Railway from Baltimore to Hagerstown was constructed. The McDonogh School was established in 1873 and the students worked in exchange for their studies, room, and board. Tuition started in 1922 and students started commuting daily in 1927.

Street cars came to Reisterstown in 1896 and ended when the buses took over in 1933. Then came sign posts with road names, walkways, electric lights and garbage collection. The last toll-gate (known as Owings Mills) was removed from the turnpike in 1915. The turnpike became a state road in 1921, and the stoned and dirt road was improved.

City gas came to Reisterstown in 1934 and was changed over to natural gas in 1950. City water was added in 1939, which meant that the fire department had hydrants to fight fires. The Kiwanis Club brought the first ambulance in 1948 and filling stations started being built. The first housing developments started in 1952 on Berryman's Lane. As traffic and parking were always a problem in Reisterstown, parking meters were placed in upper Reisterstown in late 1954. Additional developments and shopping centers were built into the 1960's. In 1966 the C & P Telephone Company installed underground wire for all new phones in these developments.

In the late 1960's Baltimore County began incorporating smart growth management policies and established the urban rural demarcation line (URDL). This designated the areas that would receive public water, sewer infrastructure, transportation improvements and other capital projects to accommodate urban residential, commercial and employment development. This allowed for rural areas (agriculture, natural resource protection, and low-density rural residential) to be preserved utilizing private wells and septic systems, which limits development in these areas.

The first master plan was adopted in 1972. Owings Mills and Perry Hall-White Marsh were established as designated growth areas in 1975. Subsequent Baltimore County Master Plans added the Towson Urban Center as a growth area, additional land management areas were established and the distinction between urban land use and rural land management areas were further established. The urban land management areas consist of community conservation areas (established residential and commercial areas) and employment. The rural land management areas include agricultural preservation areas, resource preservation areas, rural residential areas, and rural commercial centers.

Smart growth allowed for Priority Funding Areas to be established to preserve agricultural, natural, and cultural resources, support community conservation, and establish priorities for state

spending, enhancing opportunities for economic growth and community conservation. The Rural Legacy Program was set up to preserve areas rich in agricultural, historic, scenic, and cultural resources including parkland.

Between 1960 and 1970, the county's population increased 26% to 621,077 and another 19% increase was expected by 1980. Baltimore County reorganized land use and development planning in an orderly, environmentally sensitive manner and created the current land use framework. From 1989-2000 Baltimore County created specific management areas and policies that included growth areas, urban centers, community conservation areas, employment areas, and several kinds of rural management areas including agricultural, natural resource protection and low density rural residential growth.

Baltimore County continues to evolve, change, and address the land use challenges with greater sophistication, while preserving and enhancing the quality of life for the entire county. This is made possible through education, public safety, social services, economic development, and community stewardship. The future development of the county's urban areas must provide a balance between the built environment and the redevelopment of open space and other amenities.

Baltimore County has refined the growth management policies over the years and is now in their final phases of implementation. Growth is slowing as areas are becoming full, but future development inside the URDL will conserve and enhance existing communities and businesses, while providing needed services and housing.

A summary of the historic development within the Upper Gwynns Falls watershed is included in Table 2-21. Only records prior to 2005 were available and not all locations have data describing the year built. Therefore, all values presented are a percentage based on the available records.

Table 2-21: Upper Gwynns Falls Historical Development Percentage by Decade

Time Frame	UGF-D	Roche's Run	UGF-B	Red Run	Horsehead Branch	Total %
<1800	0.0*	0.0	0.0	0.0	0.0*	0.0
1800-1899	0.6	0.8	0.6	0.3	0.0*	0.4
1900-1909	0.7	0.7	0.6	0.2	0.0*	0.4
1910-1919	0.3	1.2	0.7	0.2	0.0*	0.4
1920-1929	0.7	2.5	1.5	0.4	0.0*	0.7
1930-1939	0.4	0.5	1.3	0.3	0.0*	0.3
1940-1949	0.4	1.4	0.9	0.8	0.1	0.5
1950-1959	4.5	11.2	36.6	4.5	0.0*	6.6
1960-1969	21.2	30.4	3.3	1.7	0.1	10.6
1970-1979	10.3	2.7	5.1	6.9	0.0	5.0
1980-1989	27.3	8.0	28.6	5.1	33.1	22.4
1990-1999	29.4	31.7	16.7	57.0	33.2	35.1
2000-2004	4.4	9.0	4.2	22.6	33.3	17.5

* There was at least one building constructed in this period, although the percentage is less than 0.0% of the total number of buildings constructed in this subwatershed.

Approximately 75% of all development has occurred since 1980 and over 90% of all development has occurred since the 1960's when smart growth management policies started. The first significant developments started post-war in the 1950's in UGF-B with growth starting in UGF-D and Roche's Run and a few developments in Red Run. Development switched to UGF-D and Roche's Run while growth in UGF-B slowed until the 1980's. Growth slowed in

the 1970's and increased rapidly in the 1980's when Horsehead Branch started consistent development. The most growth occurred in the 1990's especially in Red Run when 57% of all growth in the subwatershed occurred. Growth slowed in UGF-D, Roche's Run and UGF-B starting in 2000.

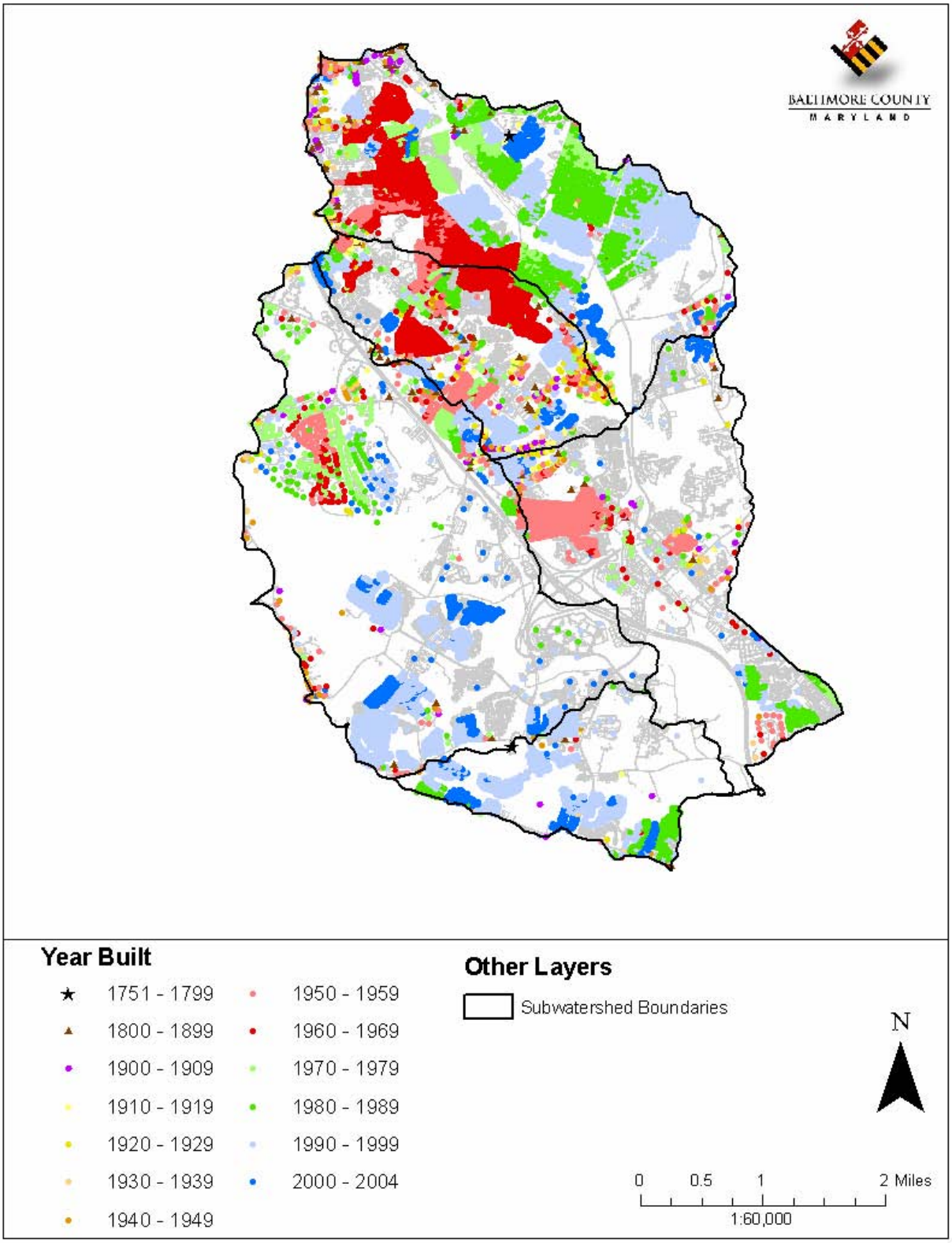

Figure 2-20: Upper Gwynns Falls Historical Development

CHAPTER 3

WATER QUALITY, LIVING RESOURCES AND HABITAT

3.1 Introduction

In addition to water quality maintenance and improvement, the Small Watershed Action Plan or SWAP program aims to provide for plants, animals, and their habitat. Natural communities require many habitat characteristics for survival. Among these are land, water, and biological conditions within ranges that provide for their needs for food, water, shelter, and reproduction. In this chapter, we will characterize the water quality, living resources and habitat of the Upper Gwynns Falls watershed based on existing data.

Water is an integral part of the habitat of all species. Living resources, including all animals and plants, require water to survive. They and their habitats are intimately connected to water quality and availability. Living resources respond to changes in water and habitat conditions in ways that help us interpret the status of water bodies and the effects of watershed conditions. In some cases, water quality is measured in terms of its ability to support specific living resources like trout or shellfish. Information on living resources is presented here both to provide a gauge of water quality and to evaluate habitat conditions in the watershed. This information can help to determine if current watershed management practices are adequately providing for the needs of natural communities.

The following sections are descriptions of the Upper Gwynns Falls including: water quality monitoring data available to date, stream corridor assessments, sewer overflow occurrences and impacts, impairments per Maryland's 303(d) listing, pollutant loading analysis for total nitrogen and total phosphorus, and stormwater management facility assessments. This includes a discussion of Tier II waters found in Red Run, which means that the samples had high Maryland Biological Stream Survey (MBSS) scores requiring additional monitoring.

3.2 Water Quality Monitoring Data

Baltimore County conducts chemical, biological, and illicit connection monitoring within the Upper Gwynns Falls planning area. Section 3.2.1 summarizes the chemical monitoring programs for the County, section 3.2.2 summarizes Baltimore Ecological Survey (BES), section 3.2.3 summarizes the County biological monitoring programs, section 3.2.4 summarizes MBSS data, and section 3.2.5 summarizes the Illicit Connection Program. Section 3.2.6 summarizes the results by subwatershed.

3.2.1 Baltimore County Chemical Data

The chemical monitoring programs of Baltimore County are mandated in part by their National Pollutant Discharge Elimination Program (NPDES) – Municipal Separate Storm Sewer System discharge permit. The permits require assessment of ambient water conditions, but do not specify the methodology. Figure 3-1 displays the locations of the county's chemical monitoring.

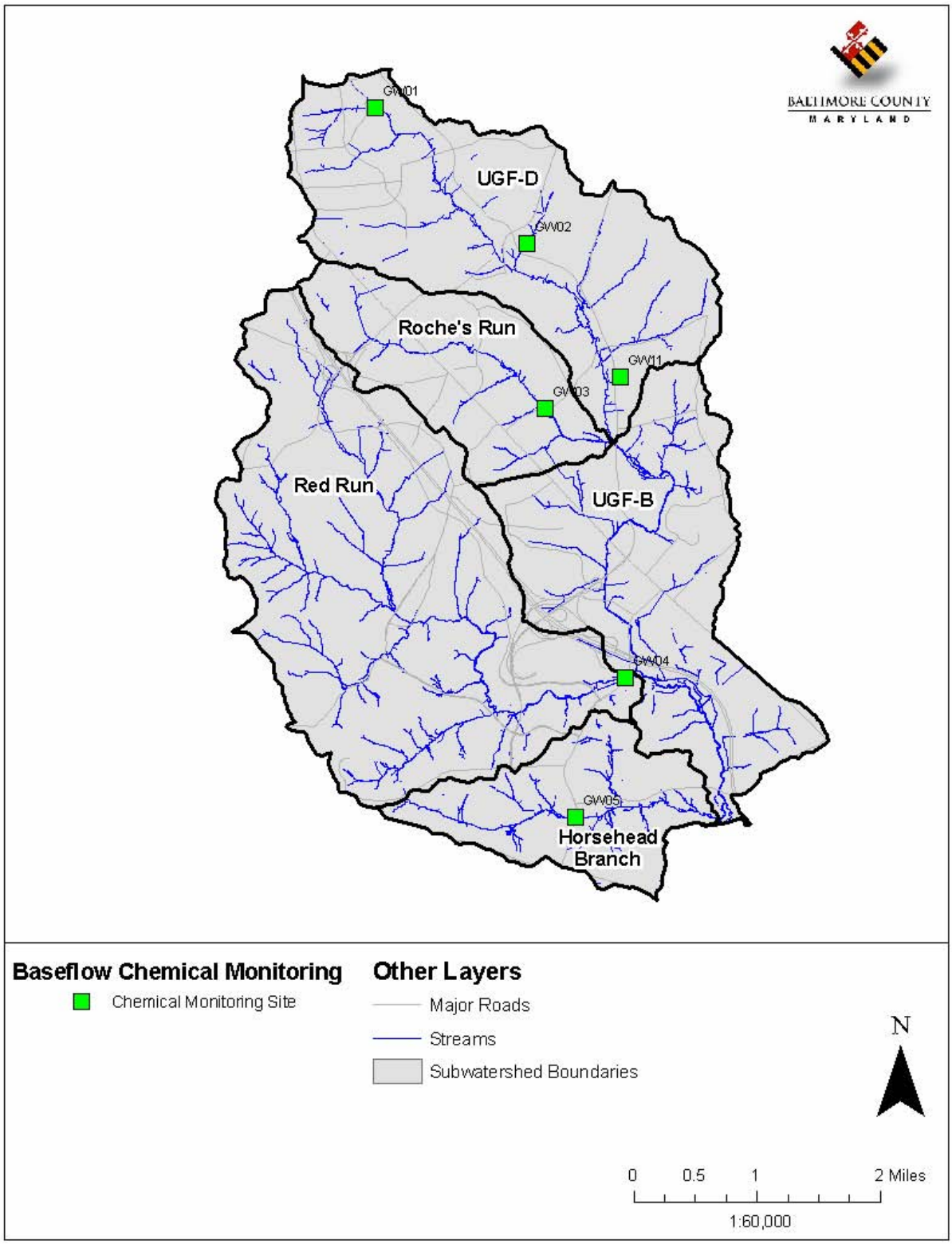

Figure 3-1: Chemical Monitoring in the Upper Gwynns Falls Watershed

This section details water quality sampling data by subwatershed for a number of key parameters from the county's monitoring programs. The subwatershed location for each monitoring site and subwatershed abbreviations are provided in Table 3-1. Key parameters were evaluated because of their importance to Total Maximum Daily Loads (TMDLs) and Bay Program Tributary Strategy goals.

Table 3-1: Upper Gwynns Falls Planning Area Subwatershed Abbreviations

Subwatershed	Water Quality Sites	Subwatershed Abbreviation
UGF-D	GW01, GW02, GW11	UGFD
Roche's Run	GW03	RoR
UGF-B	NONE	UGFB
Red Run	GW04	ReR
Horsehead Branch	GW05	HB

The Baltimore County baseflow monitoring program was initiated in 1999 targeting areas requiring Water Quality Management Plans including the Baltimore Harbor watershed. In the fall of 2000, the baseflow monitoring shifted to the Back River, Jones Falls and Gwynns Falls watersheds to address the lack of chemical monitoring information available for these three watersheds. Continuous monitoring started in the spring of 2003 (Baltimore County DEPRM, 2009).

Baseflows are monitored in the Patapsco/Back River Basin in odd-numbered years, while the Gunpowder /Deer Creek Basin is monitored in the even-numbered years. In 2007, the sampling sites were divided into two tiers. Tier 1 sites are regular sampling sites, while Tier 2 sites will only be sampled if a Small Watershed Action Plan (SWAP) or other project begins in the area. There are a total of 31 Tier 1 and nine Tier 2 sites in the Patapsco/Back River Basin. The points were chosen to maximize the number of subwatersheds monitored (Baltimore County DEPRM, 2009).

The water quality parameters measured in the Gwynns Falls includes total suspended solids (TSS), nutrients, and chloride. The importance of each of these parameters is briefly described below.

- Suspended Solids: Excessive suspended solids in water bodies can adversely impact aquatic life as it affects the light available for photosynthesis by plants and visual capability of aquatic life. Decreased light can lead to a decrease in algae communities that may limit food supplies and reduce growth rates of invertebrate and fish communities. Suspended solids can inhibit the hunting capability of visual fish predators and cause gill damage. Excessive sediment can also negatively affect habitat structure, through the burial of space between the gravel in the stream bottom (called embeddedness). Embeddedness can kill incubating fish eggs/larvae and benthic macroinvertebrates and can trap bacteria and organics on the stream bottom causing oxygen depletion.
- Nutrients: As discussed previously, over-enrichment of water bodies by excessive nutrient input can cause excessive growth of aquatic plants (algal blooms) and bacterial consumption of dissolved oxygen when the plants decompose. This can lead to significant reductions in water quality as well as abundance and diversity of aquatic life communities.

- Chloride: Chlorides come from various sources such as road salting, waste water, and agricultural runoff. High levels of chlorides can be toxic to aquatic communities including fish. The Maryland Biological Stressor Identification Process (MDE, 2009) has identified a level of 50 mg/L chloride as impacting aquatic life (http://www.mde.state.md.us/assets/document/BSID_Methodology_Final.pdf). Based on MBSS data the chloride levels in Gwynns Falls have been identified as impacting aquatic life (MDE, 2009).

Total nitrogen, total phosphorus, chloride and sediment were evaluated because the watershed is 303(d) listed for nutrient and sediment impairment and these are key Chesapeake Bay Program parameters. Table 3-2 shows stream ratings based on total nitrogen concentration data adapted from the Maryland Department of Natural Resources (2005), using loading coefficients reported by Frink (1991). Total phosphorus ratings in Table 3-2 were developed by evaluating non-tidal phosphorus data from the Chesapeake Bay Program (USGS, 1999, Figure 1). Sediment moves primarily during storm events and thus elevated concentrations of sediment were not found in these baseflow samples.

Table 3-2: Ratings by Nutrient Concentrations

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

Chloride is reported because it is linked to chronic toxicity in urban streams and the Gwynns Falls Watershed is 303(d) listed for biological impairment. The USEPA National Recommended Water Quality Criteria (USEPA, 2009) and the chronic aquatic life criterion for chloride is 230 mg/l and the acute toxicity limit is 860 mg/l (USEPA, 1988). Water criteria for suspended solids and nutrients are currently not available. Table 3-3 shows the results for the six sites located within the Upper Gwynns Falls planning area. Table 3-4 shows the monitoring results for each subwatershed in the SWAP study area. There are no sampling locations in UGF-B

Table 3-3: Upper Gwynns Falls Watershed – Baltimore County Water Quality Data

Parameter (mg/L)		Site					
		GW01*	GW02**	GW03*	GW04*	GW05*	GW11***
Subwatershed		UGF-D	UGF-D	RoR	ReR	HB	UGF-D
Chloride	Max	424.55	69.62	217.66	188.20	44.25	83.44
	Min	47.06	29.30	71.17	44.01	13.83	82.28
	Median	104.56	49.81	97.02	73.61	22.05	82.86
	Mean	132.78	52.11	103.08	78.45	23.17	82.86
	Std. Dev.	96.50	14.57	39.58	33.97	8.40	0.82
Total Nitrogen	Max	5.41	3.74	4.71	2.23	1.32	1.67
	Min	1.32	2.21	1.61	0.60	0.52	1.67
	Median	1.90	2.96	2.73	1.35	0.78	1.67
	Mean	2.24	3.00	3.18	1.41	0.85	1.67
	Std. Dev.	1.10	0.70	1.09	0.45	0.25	0.00

Table 3-3: Upper Gwynns Falls Watershed – Baltimore County Water Quality Data, Continued

Parameter (mg/L)		Site					
		GW01*	GW02**	GW03*	GW04*	GW05*	GW11***
Subwatershed		UGF-D	UGF-D	RoR	ReR	HB	UGF-D
Suspended Solids	Max	20.00	22.00	2.00	44.00	22.00	0.50
	Min	0.50	0.50	0.50	0.50	0.50	0.50
	Median	0.50	0.50	0.50	0.50	0.50	0.50
	Mean	3.50	8.14	0.75	4.33	3.69	0.50
	Std. Dev.	6.07	9.81	0.58	11.28	6.17	0.00
Total Phosphorus	Max	0.10	0.11	0.05	0.05	0.07	0.03
	Min	0.03	0.01	0.01	0.01	0.01	0.03
	Median	0.05	0.05	0.03	0.03	0.05	0.03
	Mean	0.05	0.04	0.03	0.03	0.04	0.03
	Std. Dev.	0.02	0.03	0.02	0.01	0.02	0.00

*Data sampled in 2003, 2005, 2007, and 2009
**Data sampled in 2003 and 2005
***Data sampled in 2009

The Baltimore County water quality data set is reported from 2003 to 2009. The GW03 site in Roche's Run averages high levels of total nitrogen. Two of the six sites show moderate levels of total nitrogen. These values are reported at 2.24 and 3.00 for GW01 and GW02 respectively. Two sites have slightly elevated median total nitrogen and GW11 in Horsehead Branch had baseline levels. There are no reported excessive levels of total phosphorus or suspended solids. Both GW01 and GW02 had a sample with high levels of total phosphorus but the average values for each station are at the baseline level. A sample in 2007 at GW01 exceeded the chronic aquatic life criterion for chloride, but most other samples and the average values were under half the chronic limit, so there is no data to show a chronic impact on water quality. There were no chloride samples above the acute criteria. However, the mean of five of the six sites exceeded the 50mg/L chloride level determined by the Maryland Biological Stressor Identification Process (MDE, 2009) to be detrimental to aquatic life.

Table 3-4: Upper Gwynns Falls Watershed – Baltimore County Water Quality Data by Subwatershed

Parameter (mg/L)		UGF-D	RoR	ReR	HB
Chloride	Max	424.55	217.66	188.20	44.25
	Min	29.30	71.17	44.01	13.83
	Median	82.86	97.02	73.61	22.05
	Mean	102.57	103.08	78.45	23.17
	Std. Dev.	82.66	39.58	33.97	8.40
Total Nitrogen	Max	5.41	4.71	2.23	1.32
	Min	1.32	1.61	0.60	0.52
	Median	2.25	2.73	1.35	0.78
	Mean	2.48	3.18	1.41	0.85
	Std. Dev.	1.01	1.09	0.45	0.25

Table 3-4: Upper Gwynns Falls Watershed – Baltimore County Water Quality Data by Subwatershed, Continued

Parameter (mg/L)		UGF-D	RoR	ReR	HB
Suspended Solids	Max	22.00	2.00	44.00	22.00
	Min	0.50	0.50	0.50	0.50
	Median	0.50	0.50	0.50	0.50
	Mean	4.65	0.75	4.33	3.69
	Std. Dev.	7.37	0.58	11.28	6.17
Total Phosphorus	Max	0.11	0.05	0.05	0.07
	Min	0.01	0.01	0.01	0.01
	Median	0.05	0.03	0.03	0.05
	Mean	0.05	0.03	0.03	0.04
	Std. Dev.	0.03	0.02	0.01	0.02

*There is no water quality data for UGF-B

UGF-D and Roche's Run had the highest chloride and total nitrogen levels on average and Horsehead Branch had the lowest. UGF-D, Red Run and Horsehead Branch have the highest TSS on average and Red Run has the highest concentrations sampled. All four subwatersheds have low total phosphorus on average, but UGF-D and Horsehead Branch had the highest average concentrations sampled due to several moderate ratings in UGF-D and a high rating in Horsehead Branch in 2003.

3.2.2 Baltimore Ecosystem Study Data

The Baltimore Ecosystem Study (BES) Long-Term Ecological Research project seeks to understand a major urban region as an ecological system. The program integrates biological, physical, and social sciences and seeks to understand how Baltimore's ecosystems change over time. The ecological knowledge created by BES supports educational and community-based activities, and interactions with the Baltimore community. The project focuses on a five county metropolitan region to develop simulations to project land cover, social structure, and ecological processes into the future.

In addition to stream and watershed studies, BES works with groups like Parks & People to conduct "green infrastructure" inventories in several neighborhoods in Baltimore. Neighborhood parks and gardens, street trees, vacant lots, and school grounds are surveyed and mapped to gain a better understanding of the locations and conditions of outdoor resources. Parks & People is using this information to help neighborhoods develop plans and projects for restoring and enhancing parks and other green spaces. Projects are being performed to test the feasibility and cost-effectiveness of various urban water quality restoration techniques to improve water infiltration. Another focus of the BES is the comprehensive community greening of vacant abandoned residential and industrial sites, school grounds and parks through community stewardship projects. They've built a database of "community greening" projects across Baltimore City, encompassing results from several Urban Resources Initiative (URI) projects, including the Gwynns Falls Trail User Survey, the Community Garden Survey, Green Infrastructure Inventories, and a Bibliography and Reference Guide to the Ecology and Natural Resources of the Baltimore Metropolitan Region, as well as Parks & People's Street Tree, Vacant Lot Restoration, and Community Grant programs. The BES Demographic and Social Science

team relates the data and experience-based knowledge to results of an extensive telephone survey that BES conducted. The data will be used to determine indicators of "community readiness" to successfully undertake stewardship projects, and to develop methods for strengthening community capacity in neighborhoods that may lack some of the indicators.

3.2.2.1 Stream & Watershed - Upper Gwynns Falls Tributaries

The Baltimore Ecosystem Study, Urban Long-Term Ecological Research (LTER) project is focused on the Gwynns Falls to evaluate integrated ecosystem function. The long-term sampling network includes four longitudinal sampling sites along the Gwynns Falls as well as several small (100-250 acres) watersheds located near the Gwynns Falls.

The longitudinal sites provide data on water and nutrient fluxes in the different land use zones of the watershed, and the small watersheds provide more focused data on specific land use areas. Each of the gaging sites is continuously monitored for discharge and is sampled weekly for chemistry. Weekly analyses includes nitrate, phosphate, total nitrogen, total phosphorus, chloride and sulfate, total suspended solids, turbidity, fecal coliform, temperature, dissolved oxygen and pH. Cations, dissolved organic carbon and nitrogen, and metals are measured on selected samples.

The sampling locations in the Upper Gwynns Falls SWAP study area are summarized in Table 3-5, and are described as follows:

- Glyndon has a 200-acre suburban drainage area (A detailed description of this site is posted at: http://md.water.usgs.gov/BES/ 01589180/ and streamflow data for this site are posted at: http://waterdata.usgs.gov/md/nwis/nwisman?site_no=01589180).
- Gwynnbrook/Delight has a 2,475-acre of suburban drainage area (A detailed description of this site is posted at: http://md.water.usgs.gov/BES/ 01589197/ and streamflow data for this site are posted at: http://waterdata.usgs.gov/md/nwis/nwisman?site_no=01589197)
- McDonogh at the McDonogh School has a 20-acre agricultural drainage area.

Table 3-5: Upper Gwynns Falls Watershed – BES Data by Sample Site

Pollutant (mg/L)		Glyndon	Gwynnbrook	McDonogh
Chloride	Max	2280.00	3110.00	10.00
	Min	0.05	1.73	0.49
	Median	91.30	50.10	4.73
	Mean	116.32	84.75	4.80
	Std. Dev.	158.35	204.49	0.75
Nitrate	Max	4.15	3.28	9.94
	Min	0.16	0.51	0.19
	Median	2.01	2.25	5.42
	Mean	2.02	2.17	5.39
	Std. Dev.	0.68	0.51	1.49

Table 3-5: Upper Gwynns Falls Watershed – BES Data by Sample Site, Continued

Pollutant (mg/L)		Glyndon	Gwynnbrook	McDonogh
Total Nitrogen	Max	10.35	41.76	70.91
	Min	0.49	0.82	2.16
	Median	2.10	2.41	5.56
	Mean	2.23	2.54	5.98
	Std. Dev.	0.80	2.40	4.16
Total Phosphorus	Max	0.310	0.149	0.621
	Min	0.002	0.001	0.007
	Median	0.023	0.006	0.039
	Mean	0.033	0.011	0.049
	Std. Dev.	0.036	0.015	0.049
Phosphate	Max	0.469	0.127	0.348
	Min	0.002	0.002	0.002
	Median	0.013	0.004	0.031
	Mean	0.023	0.006	0.032
	Std. Dev.	0.033	0.010	0.024
Sulfate	Max	52.16	31.60	39.46
	Min	3.40	2.52	2.07
	Median	26.88	7.03	16.40
	Mean	25.93	7.47	16.35
	Std. Dev.	5.93	3.00	2.70

There are several spikes in chloride concentration above the acute toxicity limit at the Glyndon and Gwynnbrook sites, but the average concentration is below half of the chronic aquatic life criterion. However, two of the sites have a mean above 50 mg/L, determined by MDE as detrimental to aquatic life. The McDonogh site shows very low levels of chloride with the maximum concentration 10 mg/L and the average below 5 mg/L. The maximum concentrations of total nitrogen are much greater than the excessive rating levels at all three sample sites. The average concentrations have a moderate rating in Glyndon and Gwynnbrook. The average concentrations in McDonogh are above the excessive rating value. The maximum concentrations of total phosphorus are greater than the excessive levels at Glyndon and McDonogh with McDonogh's values being twice the concentration. Gwynnbrook has a high rating for total phosphorus. The average concentrations have a baseline rating at the three sample sites.

3.2.2.2 Stream & Watershed - Upper Gwynns Falls Tributaries

The Baltimore Ecosystem Study, Stream & Watershed - Upper Gwynns Falls Tributaries, was performed by Johns Hopkins University graduate student Mark Colosimo who sampled a group of sites in the Upper Gwynns Falls watershed. The objective of his work was to evaluate the changes in physical, chemical and biological stream properties from weekly samples between April 1999 to August 2000 in the subwatersheds of Red Run, Horsehead Branch, and UGF-D (Holly Branch station). Table 3-6 shows a summary of the dissertation data results.

There were two sites in the Red Run subwatershed. Sampling station Red Run 1 (RR1) was approximately 115 feet upstream of the crossing of Painters Mill Bridge Road, and 1,150 feet upstream of the confluence with the Gwynns Falls. Sampling station Red Run 2 (RR2) was farther upstream, between the Pleasant Hill and Dolfield Road crossings. The Horsehead Branch (HH) sampling site in UGF-B was located at the McDonogh Road crossing. The Holly Branch (HLB) sampling site was located just upstream of Gwynnbrook Avenue in UGF-D. The Gwynns Falls at McDonogh School (GF5) site was located at the McDonogh Road crossing of the Gwynns Falls.

Table 3-6: Upper Gwynns Falls Watershed – BES Data by Sample Site

Parameter (mg/L)		RR1	RR2	HH	HLB	GF5
Chloride	Max	151.70	64.60	668.40	283.60	196.90
	Min	15.00	11.10	5.10	9.90	13.40
	Median	26.00	21.45	9.00	46.70	37.70
	Mean	29.77	22.70	20.24	54.02	40.49
	Std. Dev.	19.58	7.02	79.44	45.23	22.87
Nitrate	Max	2.60	2.50	1.30	3.58	2.60
	Min	0.70	0.60	0.40	1.01	0.80
	Median	1.30	1.70	0.70	2.81	1.65
	Mean	1.28	1.66	0.77	2.68	1.63
	Std. Dev.	0.33	0.36	0.17	0.52	0.36
Total Nitrogen	Max	2.60	2.80	1.80	3.94	2.90
	Min	0.80	1.10	0.50	1.74	1.40
	Median	1.50	1.85	0.90	2.96	1.90
	Mean	1.53	1.87	0.99	2.94	1.90
	Std. Dev.	0.34	0.34	0.29	0.51	0.34
Total Phosphorus	Max	0.024	0.010	0.085	0.022	0.037
	Min	0.002	0.002	0.002	0.002	0.002
	Median	0.004	0.003	0.007	0.003	0.003
	Mean	0.005	0.004	0.010	0.005	0.005
	Std. Dev.	0.005	0.003	0.014	0.005	0.006
Phosphate	Max	0.031	0.057	0.066	0.022	0.088
	Min	0.002	0.002	0.002	0.002	0.002
	Median	0.002	0.002	0.002	0.002	0.002
	Mean	0.004	0.004	0.007	0.004	0.005
	Std. Dev.	0.005	0.007	0.011	0.005	0.011
Sulfate	Max	12.00	15.50	14.30	13.50	12.20
	Min	5.10	4.50	2.90	4.80	6.60
	Median	7.55	7.45	5.50	8.05	9.00
	Mean	7.73	7.41	5.90	8.29	9.14
	Std. Dev.	1.34	1.68	2.52	1.26	1.26

The recorded concentrations of pollutants in this study were similar to the records in the Baltimore County data but are consistently higher in value. The HH sample location, in Horsehead Branch, had a sample with concentration 75% of the acute limit. The average concentrations at all sampling locations are below 25% of the chronic value for chloride concentration.

The average concentration of total nitrogen had a slightly elevated rating, with the exception of a baseline rating in Horsehead Branch and a moderate rating at the Holly Branch site in UGF-D. The site with the lowest recorded concentration of total nitrogen was Horsehead Branch and the highest was Holly Branch with a moderate rating.

The average concentrations of total phosphorus are typically slightly elevated in this data set with the HH site just below a moderate rating. The two Red Run sample sites had average concentrations with baseline ratings. The Red Run and Holly Branch sites had the lowest maximum concentrations, while Horsehead Branch had the highest concentrations. Of the five test sites, none registered in the excessive range and only the HLB site had a maximum total nitrogen concentration in the high range. Three of the remaining test sites ranked in the moderate range and one ranked in the slightly elevated range for maximum total nitrogen concentration.

3.2.3 Baltimore County Biological Data

Baltimore County conducts biological monitoring for benthic macroinvertebrates on an annual basis utilizing the Maryland Biological Stream Survey (MBSS) protocols (Kazyak, 2001). The MBSS program is described in chapter 3.2.4. Figure 3-2 shows biological sampling point locations. Benthic macroinvertebrates are organisms without a backbone large enough to be seen with the human eye that live on the bottom of streams. They are an important part of stream ecosystems as they are a source of food for aquatic life such as fish. The presence, condition, numbers, and types of benthic macroinvertebrates provide information about the quality of a water body. Red Run contains Tier II waters that have good MBSS scores that require preservation and protection. No new or expanded discharges can occur in these drainage areas that will adversely affect the quality of Tier II waters.

Sample sites are randomly selected focusing on the Patapsco/Back River Basin in odd years and the Gunpowder/Deer Creek Basin in even years. Subsets of previously sampled random sites serve as sentinel sites, and are sampled over multiple years. The program reports benthic IBI scores for each site on a bi-annual basis from 2003 to 2009 (Baltimore County DEPRM, 2009). The results for the county biological monitoring program within the Upper Gwynns Falls are averaged by sub-watershed and displayed in Table 3-7, while the detailed results are located in Table 3-8.

Table 3-7: Baltimore County Mean Biological Monitoring Results by Sub-Watershed

Subwatershed	Mean Values	
	Benthic IBI	
	Score	Rating
UGF-D	2.12	Poor
Roche's Run	1.83	Poor
UGF-B	1.88	Very Poor
Red Run	3.10	Fair
Horsehead Branch	2.98	Poor

Red Run has a fair biological IBI score and includes Tier II waters. The biological IBI scores for UGF-D, Roche's Run, and Horsehead Branch are poor while water quality in UGF-B is very poor.

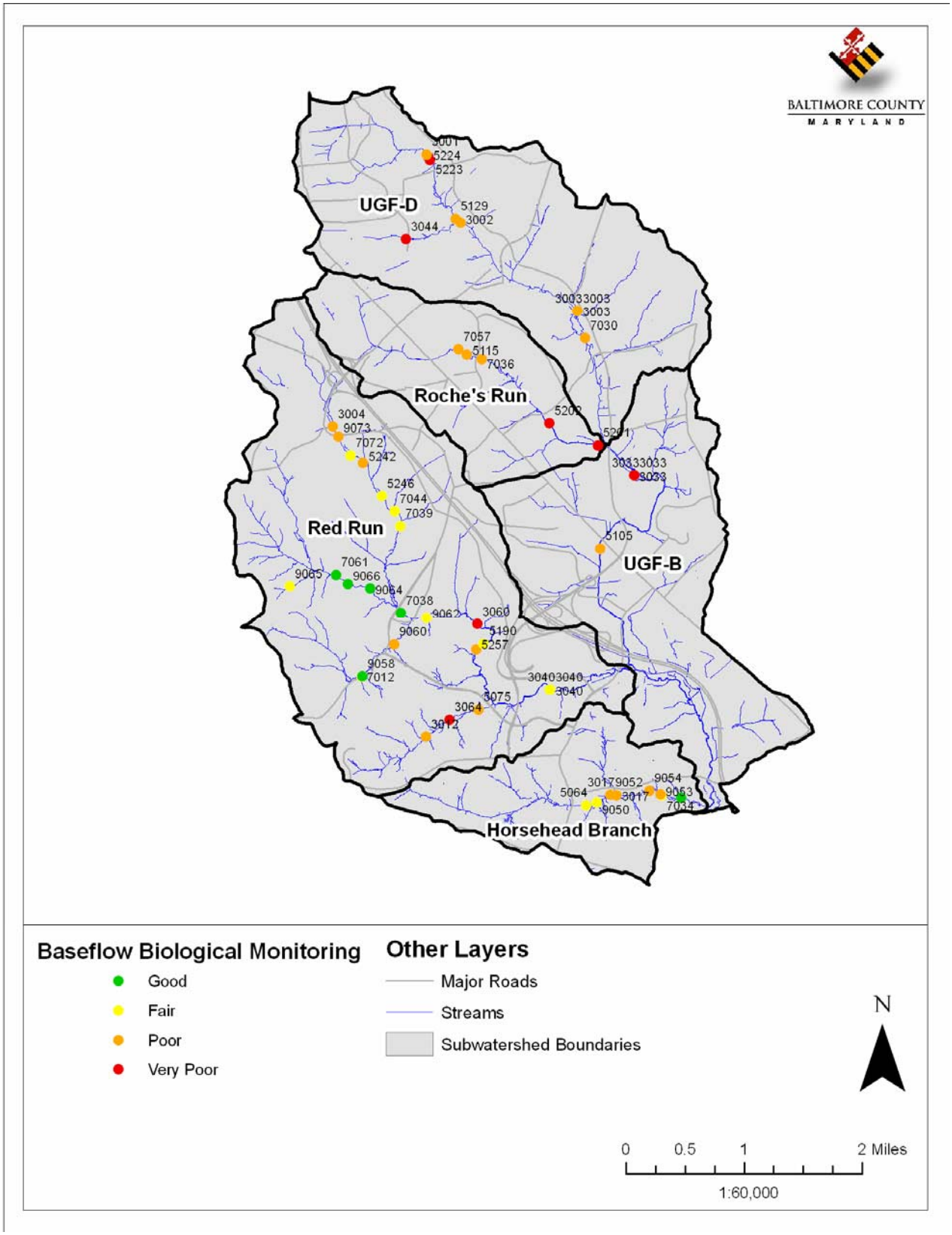

Figure 3-2: Upper Gwynns Falls Biological Monitoring Sites

Table 3-8: Baltimore County Detailed Biological Monitoring Results

Station ID	Sub-Watershed	Longitude	Latitude	Sample Year	Values	
					Benthic IBI	
					Score	Rating
703017*	HB	-76.779662	39.389415	2003	2.67	Poor
705064	HB	-76.784467	39.388188	2005	3.00	Fair
707034	HB	-76.772516	39.389423	2007	3.00	Fair
707071	HB	-76.769453	39.389117	2007	4.00	Good
703017*	HB	-76.779662	39.389415	2007	2.67	Poor
709050	HB	-76.782796	39.388556	2009	3.50	Fair
709052	HB	-76.780720	39.389460	2009	2.83	Poor
709053	HB	-76.772750	39.389565	2009	2.83	Poor
709054	HB	-76.774496	39.389958	2009	2.50	Poor
703017*	HB	-76.779662	39.389415	2009	2.83	Poor
703004	ReR	-76.824557	39.434764	2003	2.33	Poor
703012	ReR	-76.809849	39.396643	2003	2.00	Poor
703060	ReR	-76.801690	39.410514	2003	1.67	Very Poor
703064	ReR	-76.806140	39.398722	2003	1.33	Very Poor
703040*	ReR	-76.790160	39.402378	2003	2.67	Poor
705075	ReR	-76.801541	39.399963	2005	2.00	Poor
705190	ReR	-76.800675	39.408079	2005	3.33	Fair
705242	ReR	-76.819721	39.430315	2005	2.67	Poor
705246	ReR	-76.816788	39.426236	2005	3.33	Fair
705257	ReR	-76.801841	39.407347	2005	2.33	Poor
707012	ReR	-76.819990	39.404062	2007	3.33	Fair
707038	ReR	-76.813802	39.411910	2007	4.00	Good
707039	ReR	-76.813875	39.422571	2007	3.67	Fair
707044	ReR	-76.814741	39.424382	2007	3.33	Fair
707061	ReR	-76.824016	39.416602	2007	4.33	Good
707072	ReR	-76.821737	39.431232	2007	3.67	Fair
703040*	ReR	-76.790160	39.402378	2007	4.00	Good
709058	ReR	-76.819906	39.404091	2009	4.17	Good
709060	ReR	-76.814878	39.408028	2009	2.83	Poor
709062	ReR	-76.809689	39.411307	2009	3.17	Fair
709064	ReR	-76.818647	39.414925	2009	4.17	Good
709065	ReR	-76.831364	39.415199	2009	3.50	Fair
709066	ReR	-76.822183	39.415473	2009	4.17	Good
709073	ReR	-76.823668	39.433528	2009	2.83	Poor
703040*	ReR	-76.790160	39.402378	2009	3.17	Fair
703033*	UGFB	-76.776754	39.428712	2003	1.67	Very Poor
705105	UGFB	-76.782202	39.419756	2005	2.00	Poor
703033*	UGFB	-76.776754	39.428712	2007	2.00	Poor
703033*	UGFB	-76.776754	39.428712	2009	1.83	Very Poor
705115	RoR	-76.803219	39.443502	2005	2.33	Poor
705201	RoR	-76.782483	39.432398	2005	1.67	Very Poor
705202	RoR	-76.790169	39.435135	2005	1.33	Very Poor
707036	RoR	-76.800898	39.442964	2007	2.00	Poor
707057	RoR	-76.804575	39.444210	2007	2.67	Poor

Table 3-8: Baltimore County Detailed Biological Monitoring Results, Continued

Station ID	Sub-Watershed	Longitude	Latitude	Sample Year	Values	
					Benthic IBI	
					Score	Rating
703001	UGFD	-76.809555	39.468194	2003	2.00	Poor
703002	UGFD	-76.804202	39.459769	2003	2.00	Poor
703044	UGFD	-76.812867	39.457820	2003	1.67	Very Poor
703003*	UGFD	-76.785679	39.448924	2003	2.00	Poor
705129	UGFD	-76.804974	39.460312	2005	2.33	Poor
705223	UGFD	-76.809011	39.467529	2005	1.33	Very Poor
705224	UGFD	-76.809296	39.467928	2005	1.67	Very Poor
707030	UGFD	-76.784478	39.445568	2007	2.33	Poor
703003*	UGFD	-76.785679	39.448924	2007	2.33	Poor
703003*	UGFD	-76.785679	39.448924	2009	3.50	Fair

* Indicates a Sentinel Station

The Upper Gwynns Falls has 54 biological sampling sites summarized in Table 3-8. Of these sites, seven are rated as good, 13 are rated as fair, 25 are rated as poor, and nine are rated as very poor. Six of the seven sites with a Good IBI rating are in Red Run and the other is in Horsehead Branch. Correspondingly, Red Run has the highest mean IBI rating of Fair. Horsehead Branch is the only subwatershed with no stations with a Very Poor IBI rating. Sites downstream of UGF-D and Roche's Run have a poor rating. The last site in Red Run is fair and in Horsehead Branch is good.

3.2.4 Maryland Biological Stream Survey

The MBSS is a Maryland DNR initiated program based on a random design stream sampling program created in 1993 to provide unbiased, statewide estimates of the biological resources in streams and rivers. The basis of the MBSS design is lattice or multi-stratification sampling that ensures all 1st through 3rd order (now 1st through 4th order), non-tidal streams in the sampling frame have a non-zero and known probability of being sampled. The third round of statewide random sampling concluded in the summer of 2009. In 2010, MBSS will conduct special project sampling and report on the data collected from 2007-2009. Results of the MBSS protocol include a benthic Index of Biological Integrity (IBI) score based on the benthic community characteristics at a sampling site.

The MBSS stream health indicator is a measure of the ecological health of a body of water based on its fish and aquatic insect community. Aquatic insects and fish can respond to stream impacts differently, so considering the condition of the groups of aquatic animals gives a more complete indication of overall stream health. Qualitative ratings of stream biological integrity are based on IBI scores ranging from 5.0 (good) to 1.0 (very poor). The scores are described as good (denoting minimally impacted conditions), fair, poor, and very poor (indicating severe degradation). The MBSS results for each sampling location were attributed to the stream reach and presented on a color coded Interactive Map for Stream Reaches and Watersheds. The map can be found here: http://mdimap.towson.edu/streamhealth/. A green color indicates a relatively healthy, or good condition. A yellow color indicates a fair condition. A red color indicates an unhealthy, or poor condition. The MBSS monitoring results can be found in Table 3-9 and the Stream Waders IBI ratings can be found in Table 3-10.

Table 3-9: MBSS Monitoring Results

Subwatershed	Subwatershed	Sample Date(s)	Mean Values				Combined Values	
			Benthic IBI		Fish IBI		IBI	
			Score	Rating	Score	Rating	Score	Score
GWYN-107-R-2004	UGF-D	03/17/04 06/15/04	1.33	Poor	2.33	Poor	1.83	Poor
BA-P-410-203-96	UGF-D	03/19/96 06/06/96	2.67	Poor	2.67	Poor	2.67	Poor
GWYN-303-R-2004	UGF-B	03/17/96 06/16/96	2.33	Poor	3.33	Fair	2.83	Poor
BA-P-145-327-96	UGF-B*	03/11/96 07/08/96	2.33	Poor	4.00	Good	3.17	Fair
BA-P-409-102-96	Red Run	03/19/96 08/26/96	2.33	Poor	1.00	Poor	1.67	Poor
GWYN-103-R-2007	Red Run	04/17/07 06/11/07	3.33	Fair	3.00	Fair	3.17	Fair
GWYN-102-R-2004	Red Run	03/17/04 06/16/04	5.00	Good	3.00	Fair	4.00	Good
GWYN-112-R-2004	Red Run	03/17/04 06/17/04	2.33	Poor	2.67	Poor	2.50	Poor
BA-P-313-215-95	Red Run	04/03/95 06/19/95	4.33	Good	4.66	Good	4.50	Good
GWYN-105-R-2004	Horsehead Branch	03/17/04 06/16/04	2.33	Poor	2.67	Poor	2.50	Poor

* This sampling location is several hundred feet downstream of the Upper Gwynns Falls subwatershed boundary

The Stream Waders stream health indicator score uses information collected only from the aquatic insects.

Table 3-10: Stream Waders Detailed Biological Monitoring Results

Station ID	Sub-Watershed	Sample Year	Values	
			Benthic IBI	
			Score	Rating
1045-15-2004	UGF-D	2004	1.29	Poor
1045-1-2004	UGF-D	2004	1.29*	Poor
1045-03-2007	UGF-D	2007	1.29	Poor
1045-02-2004	UGF-D	2004	1.29	Poor
1045-4-2004	UGF-D	2004	2.43	Poor
1045-2-2007	UGF-D	2007	2.14	Poor
1045-3-2004	Roche's Run	2004	1.29	Poor
1045-13-2004	Roche's Run	2004	1.00	Poor
1045-5-2004	UGF-B	2004	1.29	Poor
1045-14-2004	UGF-B	2004	1.29	Poor
1044-02-2007	UGF-B**	2007	1.57	Poor
1045-01-2007	Red Run	2007	2.14	Poor
1045-12-2004	Red Run	2004	3.00	Fair
1044-6-2004	Horsehead Branch	2004	1.57	Poor

* This IBI is "provisional" as there were less than 60 organisms sampled

** Database lists as Horsehead Branch but station is located in UGF-B on the map

The MBSS data is consistent with the Baltimore County data, except the MBSS ratings do not include a "very poor" rating. The results show poor benthic and fish IBI ratings in UGF-D and Horsehead Branch. Ratings for benthic IBI were poor at both sample locations in UGF-B but the fish IBI ratings were fair and good. IBI ratings at the sample locations in Red Run varied from poor to good for both fish and benthic IBI.

The data from the stream waders benthic IBI scoring shows that the water in the Gwynns Falls mainstem and tributaries all have poor water quality with exception of one site in Red Run that achieved a fair IBI rating.

3.2.5 Illicit Discharge and Elimination Program Data

Baltimore County tracks illicit discharges through a program of routine outfall screening. The program consists of three parts:

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

The county has an outfall prioritization system based on data from the outfall screening. The system allows for a more streamlined approach in selecting outfalls to screen and provides a more efficient use of staff. In addition, the system allows for outfalls screened once or not at all *(Priority 0)* to be screened sufficiently (three or more times) and properly prioritized. The list of outfalls to be screened is generated by a Microsoft Access Query based on the prioritization scheme.

The outfall prioritization system works as follows: (1) Outfalls not screened three times are not prioritized. (2) Outfalls screened three or more times are assigned one of three priority ratings.

- *Priority 0 (Not Prioritized)* rating – Outfalls with insufficient data to determine a priority rating. This may be due to inaccessibility or only a single screening.
- *Priority 1 (Critical)* rating - Outfalls with major problems that require immediate correction and/or close monitoring, or outfalls with recurrent problems. These outfalls are sampled four times each year.
- *Priority 2 (High)* rating - Outfalls with moderate to minor problems that have the potential to become severe. These outfalls are sampled once a year.
- *Priority 3 (Low)* rating - Outfalls with minor or no problems that do not require close monitoring. These outfalls are sampled on a ten-year cycle.

A second screening is done if nearly a decade has passed since the last screening. If no pollution problems were indicated, then the outfall is considered a low priority. This allows more focus on outfalls with more potential of an illicit connection.

A second screening is also performed at an outfall when prior screening indicates that one or more of the water quality criteria were exceeded. The second screening helps determine whether the pollutant is a persistent constituent of the effluent or an anomaly. No remedial action is taken

if the second screening is within acceptable pollutant levels. However, the outfall is considered to have a potential illicit connection and is automatically queued for re-screening within one year.

If the problem is severe enough to warrant immediate correction, then an investigation begins immediately. Some sites are determined to have problems severe enough to warrant immediate investigation and/or corrective action after only one screening.

In Baltimore County, there are approximately 3,569 total outfalls; of these, approximately 2,933 outfalls are less than 36 inches in diameter. The minor outfalls are just starting to be prioritized, 109 have been prioritized so far. The county has 636 outfalls with pipe diameter of 36 inches or greater, of which 587 have a prioritization rating (Baltimore County DEPRM, 2010).

There are 49 major outfalls in the Baltimore County portion of the Upper Gwynns Falls planning area in the Stormdrain Outfalls shapefiles (outfall_maj.shp & outfall_min.shp) maintained by DEPRM. This data is older than the data discussed above but shows an accurate distribution of the subwatersheds. Table 3-11 summarizes the priority ratings by subwatershed.

Table 3-11: Baltimore County Storm Drain Outfall Prioritization Results

	UGF-D	Roche's Run	UGF-B	Red Run	Horsehead Branch	Total
Priority 0	0	0	1	0	1	**2**
Priority 1	2	0	0	1	0	**3**
Priority 2	3	3	2	6	0	**14**
Priority 3	12	9	8	1	0	**30**
Total	**17**	**12**	**11**	**8**	**1**	**49**

There are 30 Priority 3 and 14 Priority 2 outfalls. There are three Priority 1 and two Priority 0 outfalls. UGF-D has the most Priority 3, 2 & 1 outfalls, followed by Roche's Run and UGF-B. Red Run only has one Priority 3 outfall, but has the most Priority 2 outfalls with six. Horsehead Branch has only one Priority 1 outfall.

3.2.6 Subwatershed Summary

A summary of monitoring data by subwatershed is provided in Table 3-12. The table provides a summary of water quality, biological, and outfall data and values of each parameter in each subwatershed in the Upper Gwynns Falls SWAP planning area. The mean value for each water quality parameter was evaluated for each subwatershed. The total nitrogen and phosphorus are scored as described in chapter 3.2.1 and range from baseline (good) to excessive (bad) as per Table 3-2 above. The biological data is reported as very poor, poor, fair and good based on the average value for each subwatershed. The Baltimore County IBI scores from chapter 3.2.3 are shown in Table 3-12 for comparison.

Table 3-12: Summary of Monitoring Data by Subwatershed

Subwatershed	Water Quality		Biological	Outfall
	TN	TP	IBI	TP
UGF-D	Moderate	Baseline	Poor	Baseline
Roche's Run	High	Baseline	Poor	Baseline
UGF-B	N/A	N/A	Very Poor	High
Red Run	Slightly Elevated	Baseline	Fair	Excessive
Horsehead Branch	Baseline	Baseline	Poor	N/A

N/A = no data available

Water quality data reported moderate and high average total nitrogen values for UGF-D and Roche's Run, respectively. All four subwatersheds with water quality data reported baseline average total phosphorus values. One subwatershed, UGF-B, was not sampled for water quality. Stormwater outfalls in four subwatersheds were sampled, but ammonia and total nitrogen were not reported. Average total phosphorus concentrations in Red Run and UGF-B outfalls were excessive and high, respectively. UGF-D and Roche's Run samples were baseline values and no data was reported for Horsehead Branch.

3.3 Sewer Overflow Impacts

At present, sanitary sewer overflows (SSOs) and combined sewer overflows (CSOs) are inevitable byproducts of our expanding population and aging sewer systems. Possible causes for sewer overflows are severe weather, blockages, insufficient maintenance, infiltration from groundwater, inflow from leaking storm drains, and vandalism. When a sanitary sewer system is overwhelmed by volume or the infrastructure fails, raw sewage can enter nearby streams. The EPA reports there are at least 40,000 of these incidents in the country per year. The environmental and human health consequences of these overflows can be serious. *E. coli* bacteria and other pathogens can be present, posing health risks to individuals who may come in contact with contaminated water. Sewer overflows can also contain high levels of nitrogen and phosphorus that are toxic to aquatic life and feed organisms that deplete oxygen in waterways. High levels of sediment are also present in these overflows, which can clog streams and block sunlight from reaching essential aquatic plants. Table 3-13 shows the volume and number of incidents by year.

In 2005, EPA and MDE issued a consent decree to Baltimore County to reduce and eliminate sanitary sewer overflows. Residential and commercial awareness programs have been developed as part of the consent decree. Implementation of the requirements of the consent decrees will result in a reduction of nutrients and bacteria entering the streams in the Upper Gwynns Falls. The consent decree, however, may not address all of the impacts associated with the sanitary sewer system, as they are targeted at overflows. The sanitary sewer system may leak without resulting in an overflow. Depending on the locations of the leaks (typically from joints) there may be impacts to the stream system.

Table 3-13: Sewer Overflows by Year in the Upper Gwynns Falls, 2000-2008

Year	Number of Incidents	Total Volume (Gallons)
2000	2	1,500
2001	3	750
2002	4	1,340
2003	4	2,640
2004	7	3,505
2005	3	650
2006	4	1,800
2007	0	0
2008	3	10,520
Total	**30**	**22,705**

Table 3-14 shows estimated volumes and pollutant amounts by subwatershed over a nine-year period. Total pollutant load estimates were determined using the following:

Total Nitrogen (TN) – A conversion factor of 2.5×10^{-4} is used for converting gallons of overflow to pounds of pollutant. This is based on a 30 mg/L nitrogen concentration for raw sewage and a multiplier of 8.32×10^{-6}.

Total Phosphorus (TP) – A conversion factor of 8.32×10^{-5} is used for converting gallons of overflow to pounds of pollutant. This is based on 10 mg/L phosphorus concentration for raw sewage and a multiplier of 8.32×10^{-6}.

Total Suspended Solids (TSS) – A conversion factor of 1.87×10^{-3} is used for converting gallons of overflow to pounds of pollutant. This is based on 225 mg/L concentration for raw sewage and a multiplier of 8.32×10^{-6}.

Fecal Coliform (FC) – A conversion factor of 2.4×10^{8} MPN/gal is used for converting gallons of overflow to MPN fecal coliform. This is based on a multiplier of 6.4×10^{6} MPN*/100 mL.
*most probable number

Table 3-14: Baltimore Sewer Overflows and Total Pollutant Load by Subwatershed, 2000-2008

Subwatershed	# of SSO Events	Total Volume (Gallons)	TN (lbs)	TP (lbs)	TSS (lbs)	FC (MPN)
UGF-D	10	10,675	2.67	0.89	19.96	2.56×10^{12}
Roche's Run	7	6,000	1.50	0.50	11.22	1.44×10^{12}
UGF-B	6	2,890	0.72	0.24	5.40	6.94×10^{11}
Red Run	2	1,700	0.43	0.14	3.18	4.08×10^{11}
Horsehead Branch	5	1,440	036	0.12	2.69	3.46×10^{11}
Total	**30**	**22,705**	**5.68**	**1.89**	**42.46**	**5.45×10^{12}**

Figure 3-3 shows the volume and location of sanitary sewer overflows through the years 2000-2008. The frequency and volume of sewer overflows is relatively low. In 2007 there were no overflow events and two other years the total overflow was less than 1,000 gallons. Overflows were most frequent in 2004, the year before the consent decree was implemented. Almost half of the volume of overflow in the nine-year period occurred in the UGF-D subwatershed, and most of that volume comes from one occurrence. Slightly over one quarter of all overflows occurred in Roche's Run with 6,000 of the 22,705 total gallons. UGF-B, Red Run and Horsehead Branch combine for the remaining quarter. Overflows occur more frequently in densely populated areas due to grease blockages.

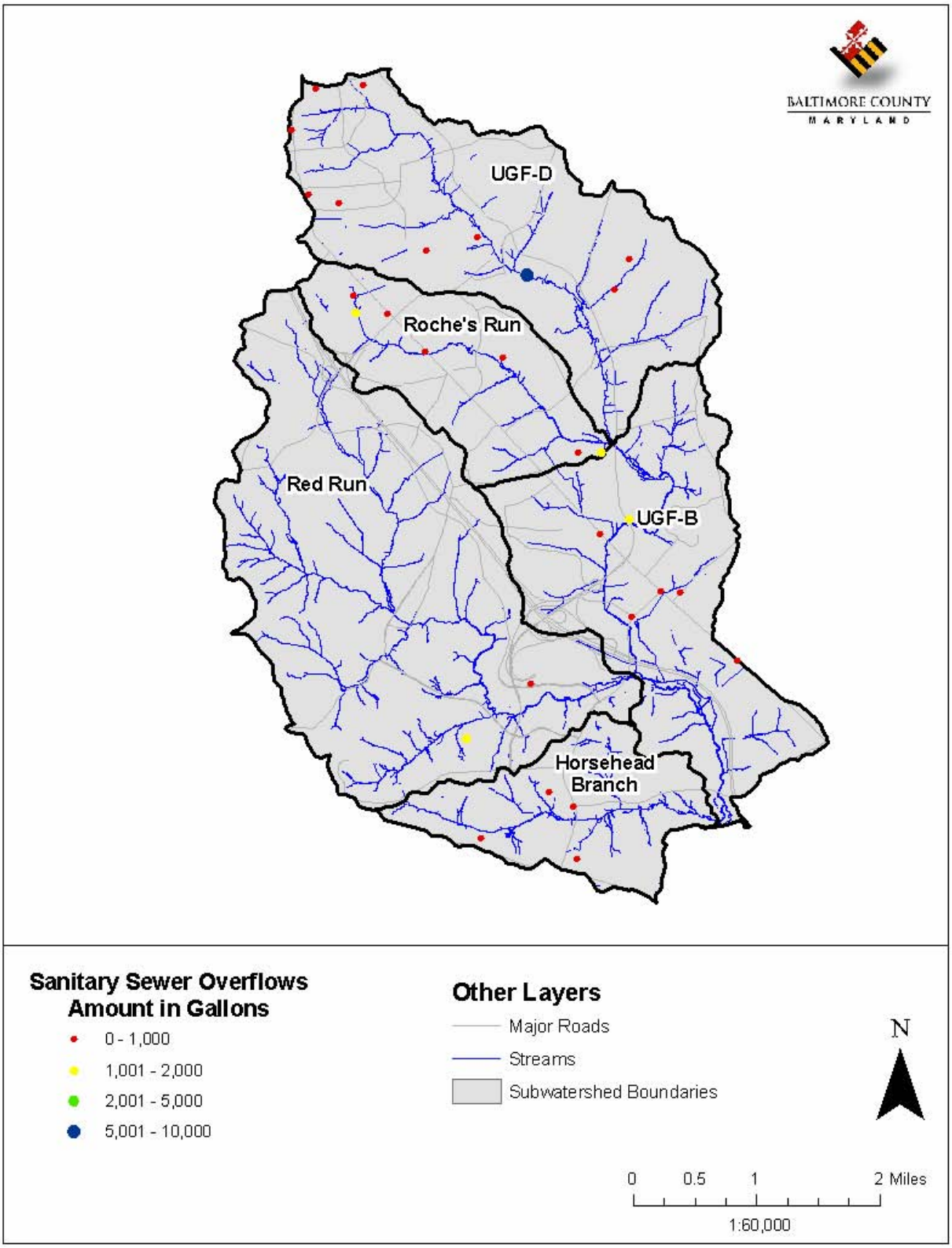

Figure 3-3: Sanitary Sewer Overflows 2000-2008

3.4 303(d) Listings and Total Maximum Daily Loads (TMDL)

Section 303(d) of the 1972 Clean Water Act requires states to assess waters not meeting water quality standards, and develop a list of impaired waters that fail to meet applicable state water quality standards defined by their designated uses. Designated uses include activities such as fishing, swimming, drinking water supply, and oyster propagation and harvest. States must also establish priority rankings and develop Total Maximum Daily Loads (TMDLs) for waters on the 303(d) list contained in the Integrated Report of Surface Water Quality (IR). According to the Environmental Protection Agency (EPA), 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 to protect the use of that water body. TMDLs can be developed for a single pollutant or group of pollutants of concern, which generally include sediment, metals, bacteria, nutrients, and pesticides.

The Gwynns Falls designated water use for the mainstem and its tributaries is Use I (Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life), except for the Gwynns Falls mainstem and its tributaries above Reisterstown Road and Red Run and its tributaries, which are designated as Use III (Nontidal Cold Water), and Dead Run and its tributaries, which are classified as Use IV (Recreational Trout Waters). The designated water uses in the Upper Gwynns Falls SWAP study area are Use I & III. The Gwynns Falls watershed has been listed as being impaired in the Maryland 303(d) list of impaired waters for various pollutants, as summarized in Table 3-15 below. The listings are for the non-tidal portion of the watershed (basin number 02130905) with designated use for aquatic life and wildlife. In addition, impairment in Baltimore Harbor and the Chesapeake Bay is related to pollutants coming from the Gwynns Falls watershed. Therefore, Baltimore Harbor and the Chesapeake Bay TMDLs require pollutant reductions in the Gwynns Falls.

Impairment listings reflect the inability to meet water quality standards for these designated uses. Water Quality Assessments are performed to determine if the pollutant is actually impairing the waters. If it is found that the pollutant is not impairing the receiving waters, then a report documenting the findings is submitted to the EPA for concurrence. Maryland's 2008 IR was the first edition that fully combined the 305(b) and 303(d) report and was approved by the EPA. Table 3-15 displays the status of the impairment listings for the Gwynns Falls based on the draft 2010 IR.

Table 3-15: Water Quality Impairment Listings and Status

Impairment	Applicable Segment	Status	Approval Date
Nutrients (Phosphorus)	MD-02130905	Water Quality Assessment	2010
Chlorides	MD-02130905	Impaired	
Sediments (Total Suspended Solids)	MD-02130905	TMDL Complete	2010
Bacteria (Fecal Coliform)	MD-02130905	TMDL Complete	2008

The Gwynns Falls watershed has four impairment listings: nutrients, chlorides, sediments, and fecal coliform. The nutrient and sediment listings were refined to phosphorus and total suspended solids. The stream biological community listing has been replaced by the TSS and chlorides. A Biological Stressor Identification analysis was prepared in June 2009 and has indicated what is likely degrading the biological communities within the Gwynns Falls

watershed (MDE, 2009b). Inorganic pollutants (chlorides and conductivity), ammonia toxicity, and flow/sediment stressors are associated with impacts to biological communities. The listing for impacts to biological communities will be addressed at a future date after additional data has been collected.

Two TMDLs and one Water Quality Assessment have been completed. The Water Quality Assessment concluded that a TMDL for nutrients is not necessary to achieve water quality standards in the Gwynns Falls, and EPA concurred (MDE, 2009a). In addition, Gwynns Falls is listed under Category 3 of the Integrated Report of Surface Water Quality in Maryland for potential presence of PCBs in fish tissue (MDE, 2010). The Gwynns Falls Watershed Biological Stressor Identification Analysis can be found here:
http://www.mde.state.md.us/assets/document/Gwynns%20Falls%20BSID%20Report%20060809%20Final.pdf

The Water Quality Assessment and the two TMDLs that have been approved by EPA are briefly discussed below.

3.4.1 Nutrients

According to the Water Quality Assessment, biological stressor identification analysis did not identify a significant association between nutrient stressors and degraded biological conditions in the Gwynns Falls watershed. These results combined with analysis of recent water quality data indicates that the Gwynns Falls is not being impaired by nutrients. The Water Quality Assessment concludes that a TMDL for nutrients is not necessary to achieve water quality standards in the Gwynns Falls, and the EPA concurred stating that chlorophyll-*a* levels and dissolved oxygen concentrations meet water quality criteria. There is thought to be no link between degraded biological conditions and current nutrient levels as determined by the Biological Stressor Identification analysis.

However, impairment in the tidal waters of Baltimore Harbor is related to pollutants coming from the watershed. Therefore, the Baltimore Harbor TMDL requires nutrient reductions in Gwynns Falls necessary to meet water quality standards in the Harbor. The TMDLs of nitrogen and phosphorus for urban stormwater require a 15% reduction based on the Baltimore Harbor TMDL. An additional reduction target to meet the Chesapeake Bay Program goals has been identified as a 24% reduction for nitrogen and a 42% reduction of phosphorus from urban stormwater non-point source loads estimated for the average annual TMDL scenario. Additional reductions may be required by the Chesapeake Bay TMDL, which is still in development. The Upper Gwynns Falls SWAP intends to address the actions needed to achieve the required reduction in phosphorus to meet water quality standards.

The Water Quality Assessment document for the Gwynns Falls can be found here:
http://www.mde.state.md.us/assets/document/Gwynns_Nut_WQA_090109_final.pdf

The EPA decision letter can be found here:
http://www.epa.gov/reg3wapd/tmdl/MD_TMDLs/GwynnsFallsEutrophWQA/GwynnsFallsEutrophWQA_AL.pdf

The TMDLs of Nitrogen and Phosphorus for the Baltimore Harbor can be found here:
http://www.mde.state.md.us/assets/document/harbor-main-121406_final.pdf

3.4.2 Bacteria

Using monthly samples from four locations and a bacterial source tracking method, MDE was able to identify the sources of the bacteria. They found that ~56% of the bacteria could be attributed to human sources, ~16% to domestic pets, ~15% to wildlife, and 0% to livestock. The source of the remaining 13% was unknown. The reductions needed to meet water quality standards range between 67.2% - 93.2% and will require a near total elimination of human and domestic pet waste, as well as a significant portion of the wildlife source. These reductions are likely beyond practical limits. In this case, implementation of required reductions will take a staged approach, beginning with maximum practicable reduction. The reduction will be an iterative process, first addressing 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. Follow-up monitoring plans will be established to track progress. Much, but not all, of the human source reduction will be achieved through implementation of the requirements documented in the Baltimore County Consent Decree. The document entitled *Total Maximum Daily Loads of Fecal Bacteria for the Non-Tidal Gwynns Falls Basin in Baltimore City and Baltimore County, Maryland* can be found on the MDE website at:

http://www.mde.state.md.us/programs/Water/TMDL/ApprovedFinalTMDLs/Pages/Programs/WaterPrograms/TMDL/approvedfinaltmdl/tmdl_final_gwynns_fc.aspx

3.4.3 Sediments

Biological stressor identification analysis identified three sediment-related stressors (channelization, channel alteration, and bar formation) as being probable causes of biological impairment in the Gwynns Falls watershed. The TMDL will ensure sediment loads are at a level that supports the Use I/III/IV designations of the Gwynns Falls watershed. The sediment TMDL will not completely resolve the impairment to biological communities since other possible stressors identified by the analysis such as chlorides still need to be addressed. A Maximum Daily Load for Sediment/TSS of 13,996.2 tons/year and 558.7 tons/day was determined based on the amount of sediment the watershed would produce in forested conditions. This represents a 36.5% reduction in sediment loads to meet the narrative water quality criteria to support the Use I/III/IV designations. The reduction requirements range from 23.5% - 44.6%

The total allowable load shall be the sum of individual Waste Load Allocations (WLAs) for point sources and the land based Load Allocations (LAs) for nonpoint sources. The process water sources with TSS limits have no reductions as they make up 1% of the land and there would be no discernable water quality benefit. The NPDES permits in the watershed have no TSS limits associated with them so the NPDES stormwater loads are expressed as a single WLA with a 40.1% reduction from the baseline load. The nonpoint source of sediment loads from urban land was identified as the most predominant controllable source in the watershed and is included in the WLA. Implementation of best management practices to reduce TSS is expected to take place primarily via the municipal separate storm sewer system permitting process. The document entitled *The Total Maximum Daily Load of Sediment in the Gwynns Falls Watershed, Baltimore City and Baltimore County, Maryland* can be found on the MDE website at:

http://www.mde.state.md.us/programs/Water/TMDL/ApprovedFinalTMDLs/Pages/Programs/WaterPrograms/TMDL/approvedfinaltmdl/tmdl_final_gwynns_falls_sediment.aspx

3.4.4 Chlorides and Conductivity

Chloride in the form of salt is imported to the study watersheds from several major sources: roadway, parking lot, and individual homeowner deicing, food waste (e.g., sewage), water softeners, atmospheric deposition, and roadway salt pile runoff. All of the chloride imported to the watershed is eventually delivered to the impaired reach through stormwater runoff and groundwater flow. Stormwater flow through municipal storm sewer systems (MS4) covered by the Phase II stormwater program regulations will be considered a point source for this TMDL.

3.4.5 Maryland High Quality Waters (Tier II)

Waters that exceed water quality standards are considered Tier II, high quality waters, and are protected by additional regulatory permit requirements such as environmental site design, stream buffers, and pre/post project monitoring. When the Maryland Biological Stream Survey (MBSS) data for both fish and macroinvertebrate have index of biotic integrity (IBI) scores above 4 they are classified as Tier II waters. As part of the Clean Water Act antidegredation policy is implemented to ensure that no activity will lower water quality to support existing uses and maintain high quality waters. If proposed projects have the potential to impact Tier II waters then a detailed antidegredation review or socio-economic justification (SEJ) could be required by MDE as a way to evaluate permit approvals. Currently, 1.63 miles of Red Run are Tier II waters with fish and macroinvertebrate IBI scores of 4.67 and 4.17 respectively.

3.5 Pollutant Loading Analysis

This section presents results of the watershed pollutant loading analysis to estimate current nutrient loads generated by non-point sources within the Upper Gwynns Falls watershed. The assessment has been conducted by A. Morton Thomas & Associates, Inc. in association with Baltimore County Department of Environmental Resource Management (DEPRM). Baltimore County derived watershed-specific pollutant loading rates for nitrogen, phosphorus, total suspended solids and *E. coli* based on two sources: the technical guidance provided by MDE's *User's Guide for Nutrient Load Analysis Spreadsheet in Support of the Water Resources Element (WRE)* (MDE, 2008) for non-urban land uses and the Chesapeake Bay Program (CBP) – Watershed Model Phase 4.3 and Phase 5.2 (CBP, 1998) for urban land uses. The MDE technical guidance provided loading rates for Baltimore County based on three basins, Western Shore (above the fall line), Western Shore (below the fall line), and Susquehanna (above the fall line). These loading rates are based on the Chesapeake Bay Program Watershed Phase 4.3 and include the full implementation of the Maryland Tributary Strategy for nutrient reduction, thereby eliminating the need to consider nutrient controls.

The Chesapeake Bay Program Watershed Model Phase 5.2 provides loading rates by model segment with the urban land uses divided into pervious urban and impervious urban. Pollutant loading rates developed by Baltimore County for different land types and used to estimate pollutant loadings for the Upper Gwynns Falls watershed are summarized in Table 3-16 below. More details regarding pollutant loading rates and analysis methods are presented in Baltimore County's, Baltimore *WRE Technical Memo – B, Pollutant Loading Analysis*. http://www.baltimorecountymd.gov/Agencies/planning/masterplanning/index.html

Table 3-16: Annual Pollutant Loadings Rates for Gwynns Falls (lbs/acre/year)

WRE Land Use	Nitrogen per acre	Phosphorous per acre
Impervious Urban	14.10	2.26
Pervious Urban	7.25	0.43
Cropland	16.55	0.72
Pasture	7.35	0.73
Livestock	24.87	1.18
Forest and Wetlands	1.41	0.02
Water	10.05	0.57
Bare Soil	7.35	0.73

As discussed in Chapter 2, land use information for the Upper Gwynns Falls watershed was obtained from Maryland Department of Planning's (MDP) 2007 Land Use/Land Cover (LU/LC) GIS layer. For the purposes of watershed-scale pollutant loading analyses, Baltimore County uses a consolidated version of MDP's 2002 Land Use/Land Cover (LU/LC) FIS layer since loading rates do not differ significantly between certain land use classes (e.g., various forest types). The MDP LU/LC categories present in the Upper Gwynns Falls and the corresponding WRE land cover classes used for the pollutant loading analyses are summarized in the Table 3-17.

Table 3-17: Reclassification of MDP LU/LC to WRE Land Cover for Upper Gwynns Falls

MDP LU/LC Classification	WRE Land Cover
Very Low Density Residential	Urban*
Low Density Residential	Urban*
Medium Density Residential	Urban*
High Density Residential	Urban*
Commercial	Urban*
Industrial	Urban*
Institutional	Urban*
Extractive	Bare Ground
Open Urban	Urban*
Cropland	Cropland
Feeding Operations	Pasture
Pasture	Pasture
Deciduous Forest	Forest and Wetlands
Evergreen Forest	Forest and Wetlands
Mixed Forest	Forest and Wetlands
Brush	Forest and Wetlands
Water	Water
Wetlands	Forest and Wetlands
Bare Ground	Bare Ground
Transportation	Urban*

*These categories were split into pervious urban and impervious urban areas using Baltimore County's roads and buildings layers.

Consolidated land uses were used to determine the total acreage for each WRE land cover category. These were multiplied by the corresponding loading rates presented in Table 3-18. Resulting annual pollutant loads for total nitrogen and total phosphorus from the Upper Gwynns Falls watershed are summarized in the Table 3-20 and 3-21 respectively.

Table 3-18: Annual Pollutant Loadings Rates for Gwynns Falls

WRE Land Use	Area (ac)	NITROGEN		PHOSPHOROUS	
		Rate (lb/ac)	Load (lbs)	Rate (lb/ac)	Load (lbs)
Impervious Urban	2,768	14.10	39,029	2.26	6,256
Pervious Urban	6,595	7.25	47,814	0.43	2,836
Cropland	652	16.55	10,791	0.72	469
Pasture	279	7.35	2,051	0.73	204
Livestock	5	24.87	124	1.18	6
Forest and Wetlands	3,196	1.41	4,506	0.02	64
Water	17	10.05	171	0.57	10
Bare Soil	102	7.35	750	0.73	74
Total	**13,614**		**123,329**		**12,756**

Nutrient loadings were also calculated on a subwatershed basis using the same loading rates and land cover designations. These estimates will provide baseline nutrient loads before implementation of restoration projects and will allow a better assessment of both progress made to date and further progress needed to meet TMDL goals for urban nonpoint source reduction. Table 3-19 summarizes acreages of land cover categories by subwatershed.

Table 3-19: Upper Gwynns Falls Land Cover Classification (acres)

WRE Land Use	Horsehead Branch	Red Run	UGF-B	Roche's Run	UGF-D	Total
Impervious Urban	183	760	758	418	649	2,768
Pervious Urban	493	1,979	1,184	1,045	1,894	6,595
Cropland	145	260	59	1	187	652
Pasture	121	0	158	0	0	279
Livestock	3.7	1.3	0	0	0	5
Forest and Wetlands	357	1,651	642	73	473	3,196
Water	0	17	0	0	0	17
Bare Soil	0	85	17	0	0	102
Total	**1,303**	**4,753**	**2,818**	**1,537**	**3,203**	**13,614**

The resulting nutrient loads for the five subwatersheds in the Upper Gwynns Falls are summarized in Table 3-20 and Table 3-21. These tables also include nitrogen and phosphorus loading rates (lbs/ac/yr) for each subwatershed. The tables below show that the subwatersheds generating the greatest annual pollutant loads are Roche's Run and UGF-D and are coincidently the most densely populated. Note, however, that the loads are only slightly larger than the loads from the other subwatersheds that are typically ~1 lbs/acre/year below the average. Horsehead Branch has the lowest nutrient loading amounts in the Upper Gwynns Falls SWAP study area.

Table 3-20: Annual Nitrogen Loads by Subwatershed

Subwatershed	Total Area (acres)	Impervious Urban	Pervious Urban	Cropland	Pasture	Forest	Water	Bare Soil	Total Nitrogen Load (lbs/yr)	Total Nitrogen Load (lbs/acre/yr)
Horsehead Branch	1,303	2,580	3,574	2,400	889	503	0	0	9,947	7.6
Red Run	4,753	10,716	14,348	4,303	0	2,328	171	625	32,490	6.8
UGF-B	2,818	10,688	8,584	976	1,161	905	0	125	22,440	8.0
Roche's Run	1,537	5,894	7,576	17	0	103	0	0	13,590	8.8
UGF-D	3,203	9,151	13,732	3,095	0	667	0	0	26,644	8.3
Total	13,614	39,029	32,748	10,791	2,087	4,506	171	750	105,111	7.7

Table 3-21: Annual Phosphorus Loads by Subwatershed

Subwatershed	Total Area (acres)	Impervious Urban	Pervious Urban	Cropland	Pasture	Forest	Water	Bare Soil	Total Phosphorous Load (lbs/yr)	Total Phosphorous Load (lbs/acre/yr)
Horsehead Branch	1,303	414	212	104	88	7	0	0	825	0.63
Red Run	4,753	1,718	851	187	0	33	10	62	2,861	0.60
UGF-B	2,818	1,713	509	42	115	13	0	12	2,405	0.85
Roche's Run	1,537	945	449	1	0	1	0	0	1,396	0.91
UGF-D	3,203	1,467	814	135	0	9	0	0	2,425	0.76
Total	13,614	6,256	2,836	469	204	64	10	74	9,913	0.73

The calculations of the subwatershed pollutant loadings will be used in the prioritization of the subwatersheds for restoration efforts. The total planning pollutant load will be used to determine the necessary reductions needed to meet TMDL and Tributary Strategies reductions.

3.6 Stormwater Management Facilities

3.6.1 Stormwater Management Facility Conversion Assessment

The existing stormwater management (SWM) facilities located within the Upper Gwynns Falls watershed planning area were investigated for potential conversion to water quality management. The Baltimore County Department of Environmental Protection and Resource Management (DEPRM) database on stormwater management facilities indicated that a total of 457 stormwater management facilities have been constructed in the watershed planning area. These include dry and wet ponds, wetlands, infiltration/filtration practices, extended detention facilities and proprietary BMPs. Filtration/infiltration practices or extended detention facilities are considered to have higher pollutant removal capabilities, since stormwater has a chance to infiltrate into the ground or through plant roots, compared to conventional SWM techniques which are designed for quantity control without water quality improvement features.

Of the 457 SWM facilities, 57 were determined to be of a type that is potentially suitable for conversion to a type of facility that provides greater water quality benefits. These facilities were designed as dry detention facilities to address water quantity only. The facilities were field assessed to determine their suitability for conversion. Data was collected on the pond condition and the potential for conversion. The data was then used in a ranking system to prioritize the ponds that had conversion potential.

The office assessment included:

- A determination of pond design type from the database, with only those labeled as dry detention ponds being selected for field review
- The pond drainage area was determined based on information in the database
- Ownership – private or public was determined
- Location – ADC map reference and nearest road was used

The office assessment was used in conjunction with a Geographic Information System (GIS) to produce a set of maps that enhanced efficiency in pond location and routing of the field investigations.

The field assessment included:

1. Verification of the facility type based on the configuration of the riser structure
2. The condition of the riser (good, damaged, with a description of the damage)
3. Embankment condition (no problems, trees on embankment, erosion, embankment holes)
4. Vegetative condition of the pond bottom (wetland vegetation, tree, bare soil, mowed grass)
5. Condition of the fence/gate
6. Conversion potential factors
    - Pond field type conducive to conversion (yes or no)
    - Pond is on line (yes or no) – if online generally have greater difficulties with conversion
    - Ease of access (easy, moderate, difficult)
    - Flow routing (short flow path, long flow path)
    - Comments on conversion potential

The information derived from the field assessment was used first to determine if any conversion potential existed and second to develop a ranking score to be used in prioritizing the facilities for conversions. The ranking system is as follows:

7. Field pond type – Only the detention pond type is considered as having potential. For those ponds that have a different field pond type (database is incorrect) or those where it was not possible to determine the pond type in the field, no further consideration was given.

8. Pond ownership – High priority was given to public ownership with a score of 5, whereas private ownership was given only a score of 1.

9. Drainage area (acres) – Score of pond ranking increased with drainage area size.
    - < 5 acres = 1
    - 5-10 acres = 2
    - 10-20 acres = 3
    - 20-50 acres = 4
    - >50 acres = 5

10. Pond online – Negative 10 points were given to ponds that were online (had a stream flowing through them) and 5 points were given if the pond was off line.
11. Accessibility – Easy access to the site was given 5 points, whereas moderate and difficult accessibility were given 3 and 1 point, respectively.
12. Flow routing - (Distance between the inflow into the pond and outflow from the pond) 1 point was given for short flow paths and -5 points were given for long flow paths.
13. Vegetation on the pond bottom – The point system is based on whether the existing vegetation is already providing some water quality improvement
    - Grass/bare soil = 5
    - Wetland vegetation = -2
    - Trees = -1
14. Riser – If the riser was damaged, nonexistent, lacked a low flow orifice or had any other problems a higher score of 5 was given. No damage or issues was scored as 1.
15. Embankment – If any problems were present a 5 was given, otherwise a 0 was received.
16. Notes Factor – If the notes indicated a high potential by the field reviewer it was scored 5 point, whereas low potential received –5 points.

Of the 57 stormwater management facilities assessed, only 51 were found to have conversion potential and ranked for conversion. Reasons for not considering the balance of the ponds were:

- 1 was currently under construction
- 5 had the wrong field type and were field identified as wet ponds (database was wrong)

The results of the application of the ranking methodology described above are presented in Table 3-22. The table presents the ownership, drainage area to the facility, the total score and the subwatershed that the pond is located. A score of 1-10 resulted in low priority, a score of 11-20 resulted in medium priority, and a score of 21-30 resulted in high priority.

Table 3-22: Potential Conversions of Dry Ponds to Improve Water Quality

Pond Number	Ownership	Acres	Total Score	Rank	Subwatershed
42	PUBLIC	9.56	30	High	UGF-D
870	PUBLIC	10.85	29	High	UGF-D
25	PUBLIC	17.15	28	High	UGF-D
437	PRIVATE	1.20	28	High	UGF-B
976	PRIVATE	24.83	28	High	Horsehead Branch
964	PRIVATE	4.39	27	High	Red Run
58	PUBLIC	8.36	25	High	UGF-D
174	PUBLIC	29.85	25	High	UGF-D
1190	PUBLIC	4.03	24	High	Horsehead Branch
17	PRIVATE	1.90	23	High	UGF-D
19	PRIVATE	3.21	23	High	UGF-D

Table 3-22: Potential Conversions of Dry Ponds to Improve Water Quality - Continued

Pond Number	Ownership	Acres	Total Score	Rank	Subwatershed
44	PUBLIC	10.19	23	High	UGF-D
15	PRIVATE	8.80	22	High	UGF-D
27	PUBLIC	25.28	22	High	UGF-D
47	PUBLIC	27.50	22	High	UGF-D
698	PRIVATE	11.16	22	High	UGF-B
3127	PUBLIC	14.48	22	High	Red Run
283	PRIVATE	10.65	21	High	UGF-B
697	PRIVATE	11.00	21	High	UGF-B
865	PUBLIC	156.81	21	High	UGF-D
1688	PUBLIC	5.43	21	High	Roche’s Run
40	PRIVATE	18.14	20	High	UGF-D
1264	PUBLIC	45.58	20	High	UGF-B
1278	PUBLIC	10.32	20	High	UGF-B
3389	PUBLIC	12.85	20	High	Horsehead Branch
172	PUBLIC	29.24	19	High	UGF-D
746	PUBLIC	5.36	19	High	Horsehead Branch
1054	PUBLIC	34.87	19	High	Roche’s Run
281	PRIVATE	12.30	18	Medium	UGF-D
33	PUBLIC	21.56	17	Medium	UGF-D
949	PRIVATE	12.85	17	Medium	Red Run
41	PRIVATE	11.41	16	Medium	UGF-D
1715	PUBLIC	15.58	16	Medium	Red Run
23	PRIVATE	0.84	15	Medium	Roche’s Run
28	PUBLIC	5.36	15	Medium	Roche’s Run
26	PUBLIC	19.36	14	Medium	UGF-D
1687	PUBLIC	3.85	14	Medium	Roche’s Run
1754	PUBLIC	1.65	14	Medium	Roche’s Run
93	PUBLIC	215.53	12	Medium	UGF-D
775	PUBLIC	2.06	12	Medium	UGF-B
110	PUBLIC	75.52	11	Medium	UGF-D
759	PUBLIC	64.33	11	Medium	Roche’s Run
261	PRIVATE	6.42	10	Medium	Red Run
696	PRIVATE	49.88	9	Low	UGF-B
50	PRIVATE	7.69	8	Low	UGF-D
51	PRIVATE	3.03	8	Low	UGF-D
1446	PUBLIC	5.16	6	Low	Horsehead Branch
22	PRIVATE	1.52	5	Low	Roche’s Run
3908	PRIVATE	29.90	5	Low	UGF-B
46	PUBLIC	40.27	3	Low	UGF-D
1426	PUBLIC	83.59	1	Low	Red Run

3.6.2 Stormwater Management Facility Pollutant Load Reductions Calculations

3.6.2.1 Existing Facility Pollutant Removal

The drainage areas for 218 built stormwater management facilities have been digitized into a Geographic Information System (GIS) data layer. This, along with the land use data layer, permits the calculation of pollutant loads delivered to the facility based on the per acre loads in Table 3-20 and Table 3-21. The amount of reduction is dependant on the type of facility that receives the stormwater. Table 3-23 presents the pollutant removal efficiencies of various types of urban stormwater management BMPs. These efficiencies are derived from the Chesapeake Bay Program BMP efficiency table. These efficiencies may be changed in the future as a result of a current effort to assess the literature and factors that affect the efficiencies.

Table 3-23: Percent Removal Efficiency of BMPs

BMP	Pollutants		
	TSS	TP	TN
Detention Facilities	10	10	5
Extended Detention Facilities	60	20	20
Wet Ponds and Wetlands	60	45	20
Infiltration Practices	95	85	85
Filtration Practices	80	60	40

Detention Facilities = Detention Pond and Hydrodynamic Devices (DP, OGS, and UGS)
Extended Detention Facilities = Extended Detention Ponds (EDSD, EDSW, ED)
Wet Ponds and Wetlands = Wet Pond and Shallow Marsh (WP and SM)
Infiltration Practices = Infiltration Trench and Infiltration Basins (IT, IB, and ITWQC), Porous Paving (PP), and Dry Wells (DW)
Filtration Practices = Sand filters and Bioretention Facilities (SF, BIO)

The analysis was done on a subwatershed basis and is presented in Table 3-24.

Table 3-24: Removal of Nitrogen and Phosphorus Due to Existing Stormwater Management Facilities by Facility Type (pounds)

Subshed	Facility Type	Acres	# Facilities	Nitrogen #s		Phosphorus #s	
				Load	Reduction	Load	Reduction
UGF-D	Detention	1,141.1	36	10,589.3	529.5	1,106.9	110.7
	Extended Detention	579.4	33	5,376.4	1,075.3	562.0	112.4
	Filtration	37.5	10	348.4	139.3	36.4	21.8
	Wet Ponds	16.2	2	150.2	30.0	15.7	7.1
	Infiltration	10.2	2	94.7	80.5	9.9	8.4
	Subwatershed Total	**1,784.4**	**83**	**16,558.9**	**1,854.6**	**1,730.8**	**260.4**
Roche's Run	Detention	151.6	23	1,407.2	70.4	147.1	14.7
	Extended Detention	172.8	23	1,603.8	320.8	167.6	33.5
	Filtration	26.3	9	243.8	97.5	25.5	15.3
	Wet Ponds	0.0	0	0.0	0.0	0.0	0.0
	Infiltration	20.7	2	191.9	163.1	20.1	17.1
	Subwatershed Total	**371.4**	**57**	**3,446.7**	**651.8**	**360.3**	**80.6**

Table 3-24: Removal of Nitrogen and Phosphorus Due to Existing Stormwater Management Facilities by Facility Type (pounds) (Continued)

Subshed	Facility Type	Acres	# Facilities	Nitrogen #s		Phosphorus #s	
				Load	Reduction	Load	Reduction
UGF-B	Detention	331.0	26	3,072.0	153.6	321.1	32.1
	Extended Detention	298.9	26	2,773.6	554.7	289.9	58.0
	Filtration	58.0	18	538.5	215.4	56.3	33.8
	Wet Ponds	68.5	3	635.8	127.2	66.5	29.9
	Infiltration	10.2	3	94.9	80.7	9.9	8.4
	Subwatershed Total	**766.7**	**76**	**7,114.8**	**1,131.6**	**743.7**	**162.2**
Red Run	Detention	223.2	21	2,070.8	103.5	216.5	21.6
	Extended Detention	1,170.5	84	10,861.8	2,172.4	1,135.3	227.1
	Filtration	243.9	43	2,263.2	905.3	236.6	141.9
	Wet Ponds	100.0	5	927.6	185.5	97.0	43.6
	Infiltration	65.2	32	604.8	514.1	63.2	53.7
	Subwatershed Total	**1,802.6**	**185**	**16,728.2**	**3,880.8**	**1,748.5**	**488.0**
Horsehead Branch	Detention	157.9	7	1,465.2	73.3	153.2	15.3
	Extended Detention	291.4	20	2,704.3	540.9	282.7	56.5
	Filtration	79.4	8	736.4	294.5	77.0	46.2
	Wet Ponds	183.6	5	1,703.7	340.7	178.1	80.1
	Infiltration	44.0	16	408.3	347.1	42.7	36.3
	Subwatershed Total	**756.2**	**56**	**7,017.9**	**1,596.5**	**733.6**	**234.4**

* The drainage area to these infiltration facilities was estimated by average watershed infiltration drainage areas.

3.6.2.2 Additional Pollutant Removal Based on Conversions of Detention Ponds

The increased load reductions due to conversion of existing dry detention ponds to water quality facilities is predicated on the assumption that the facility is converted to a type with a shallow marsh and at least partial extended detention. This results in improved pollutant removal efficiencies based on the efficiencies in Table 3-23 above. Nitrogen removal would improve from 5% to 20% and phosphorus removal would improve from 10% to 45%. Table 3-25 presents the summary results by subwatershed.

Table 3-25: Conversion of Dry Detention Ponds – Nutrient Pollutant Removal Calculations

Subshed	# of Facilities	Acres	Nitrogen (pounds)			Phosphorus (pounds)		
			Load to Facility	Current Removal	Converted Removal	Load to Facility	Current Removal	Converted Removal
UGF-D	23	763.5	6,351.3	317.6	1,270.3	578.1	57.8	260.2
Roche's Run	8	117.9	1,042.0	52.1	208.4	107.1	10.7	48.2
UGF-B	9	171.8	1,367.6	68.4	273.5	146.6	14.7	66.0
Red Run	7	150.2	1,026.4	51.3	205.3	90.4	9.0	40.7
Horsehead Branch	4	39.4	300.7	15.0	60.1	25.0	2.5	11.2
Total	**51**	**1,242.7**	**10,088.0**	**504.4**	**2,017.6**	**947.1**	**94.7**	**426.2**

The conversion of all 51 dry ponds would result in an increase in the removal of nitrogen from ~504 pounds to ~2,018 pounds, and for phosphorus from ~95 pounds to ~426 pounds.

3.7 Stream Assessments

3.7.1 Stream Stability Assessment

Baltimore County contracted with Parsons Brinkerhoff, Inc. to conduct a Stream Stability Assessment (SSA) in the Gwynns Falls watershed to follow up on the U.S. Army Corps of Engineers (USACOE) study of the Gwynns Falls mainstem reaches. Parsons Brinckerhoff assessed all tributaries and assessed the accuracy and consistency of USACOE's study with the assessment of the tributary reaches. The document can be found in Appendix A-3 of the Gwynns Falls Water Quality Management Plan. Figure 3-4 shows the streams assessed by Parsons Brinckerhoff (Cruised) and the USACOE.

The purpose of the Stream Stability Assessment was to identify both sources of stream impairment and restoration opportunities.

Approximately 26 miles of stream were assessed in the Upper Gwynns Falls watershed during the summer of 2004. The streams were assessed by performing rapid field assessments and were divided into reaches of approximately 750 feet in length. The items included in the rapid assessment were divided into four major categories: channel morphology, channel disturbances, channel habitat, and restoration opportunities.

The study found that the cruised reaches of the streams have a medium to high erosion potential with the majority of high erosion potential occurring in UGF-B, Roche's Run, and UGF-D. Restoration opportunities were identified in nine separate categories. These opportunities included stream restoration, buffer enhancement, bank plantings, utility conflict resolution, habitat enhancement, trash clean-ups, yard waste cleanup, invasive species removal, and combination projects. The results of the Stream Stability Assessment will be used to identify restoration actions.

3.7.2 Summary of Sites Investigated

The following sections summarize characteristics of each subwatershed in the Upper Gwynns Falls watershed according to the data from the SSA performed by Parsons Brinckerhoff, Inc.

UGF-D

Existing Condition

The UGF-D subwatershed begins in the Glyndon area and continues south through Reisterstown to Walgrove Road, also encompassing the area east of Timber Grove Elementary School south to where Crondall Lane crosses Owings Mills Boulevard. Table 3-26 summarizes the general subwatershed conditions. The corridor along Reisterstown Road is the main commercial and industrial zone within the watershed. Currently, commercial and industrial land uses comprise only approximately 11.3% of the subwatershed. This subwatershed has experienced significant growth in the past twenty years, particularly due to transportation improvements such as I-795. Residential areas, predominantly low- and medium-density residential housing comprises 67.7% of the existing land area.

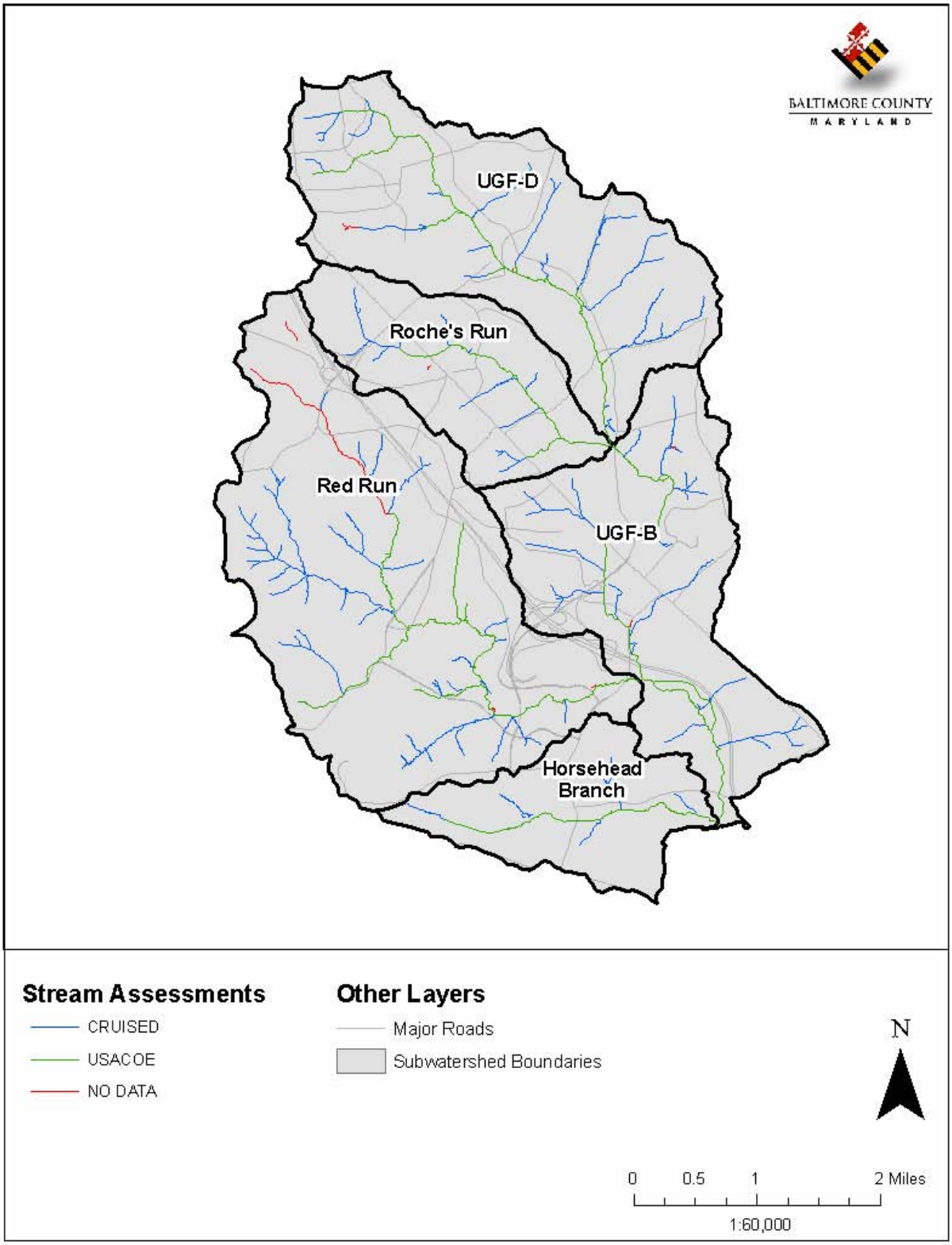

Figure 3-4: Upper Gwynns Falls Stream Reach Assessments

Table 3-26: UGF-D General Subwatershed Conditions

Drainage Area:	5.00 square miles			
Stream Length:	15.4 miles			
Physiography:	Piedmont			
Soil Association(s):	80% B, 12% C, 8% D			
Dominant Bed Materials:	Silt and Gravel			
Dominant Flow Regime:	Perennial			
Dominant Rosgen Level II Classification:	A – 0% B - 22%	C – 10% D – 0%	E – 20% F – 7%	**G - 41%**

Stream Stability

Sixty cruised reaches and 35 USACOE reaches were assessed in the UGF-D subwatershed. The combined cruised and USACOE reaches were predominantly classified as Rosgen type G. Type G streams or gullies are unstable and typically have very high erosion rates and sediment supplies. Channel degradation and side slope rejuvenation are typical for type G streams. Type G stream channels have a low width to depth ratio and low sinuosity (except when deeply incised in a previously sinuous channel). The most likely stream types to have unstable banks are typically type F and G channels. These stream types comprise approximately 48% of the cruised stream reaches. Stages I and V of Schumm's channel evolution model indicate completely stable streams. Approximately 17% of the UGF-D streams fit into these categories. Approximately 44% of the streams were classified as degrading and an additional 5% were classified as aggrading. Table 3-27 shows the percentage of each stage found within the cruised reach assessment of the UGF-D subwatershed.

Table 3-27: UGF-D Subwatershed Channel Evolution Stages

Channel Evolution Stage	Percent of UGF-D Subwatershed
Stage I	10
Stage II	20
Stage III	48
Stage IV	15
Stage V	7

Three primary factors were used to assess bank stability in addition to the unstable to stable ratio described above: bankfull height to bank height, bank angle and root density. Tables 3-28 through 3-30 show the detailed breakdown of each category for the cruised reaches. The bankfull height was compared with the bank height of the cruised reach. In a stable stream the bankfull height is connected to its floodplain and the bankfull height will be equal to the bank height of the channel. If the bankfull height falls within the upper half of the bank, the channel is slightly to moderately entrenched, and has higher erosion potential. If the bankfull height is in the lower half of the bank, the channel is entrenched, and has the highest erosion potential. The bank angle

was considered in relation to the stream channel to assess bank stability. For example, if the bank angle was sloping away from the stream channel, the reach has low erosion potential. Banks that were nearly vertical have medium erosion potential and banks that were undercut or sloping towards the stream have high erosion potential. The density of root mass within the banks is an important factor in considering bank stability. Fifteen percent of the cruised stream banks have a dense root network for the entire depth of the stream bank. The majority of streams (65%) typically only have a dense root network in the upper half of the streambank leaving the lower portion of the bank unprotected and susceptible to erosion. The streams are even more susceptible to erosion if the stream is entrenched. Approximately 20% of the reaches had minimal roots in the banks. The majority of streambanks in the UGF-D subwatershed fall into the medium to high erosion potential category. Thus, a typical stream bank could be described as having its bankfull height found in the upper half of its banks, dense roots throughout the upper portion of the streambank and banks nearly vertical.

Table 3-28: UGF-D Subwatershed Bank Height Ratio Caused Erosion Potential

Erosion Potential	Percent of UGF-D Subwatershed
High, Bankfull in lower half of bank	40
Medium, Bankfull in upper half of bank	50
Low, Bankfull at top of bank	10

Table 3-29: UGF-D Subwatershed Bank Angle Caused Erosion Potential

Erosion Potential	Percent of UGF-D Subwatershed
High, Undercut banks	2
Medium, Nearly vertical banks	67
Low, Banks sloping away from stream	31

Table 3-30: UGF-D Subwatershed Root Density Caused Erosion Potential

Erosion Potential	Percent of UGF-D Subwatershed
High, Minimal roots	20
Medium, Dense roots in upper bank	65
Low, Dense roots throughout bank	15

Forest Assessment

Approximately 13.4% of the existing subwatershed contains forested lands. The largest forested area within this subwatershed is the Gwynnbrook Wildlife Management Area located at the intersection of Owings Mills Boulevard and Gwynnbrook Avenue. Several sites in this subwatershed were assessed as a PAA and have been recommended for reforestation. Refer to Chapter 4 of this report for further descriptions of these sites.

Stream Buffer Condition

The majority of the mainstem of the Gwynns Falls has a forested stream buffer. The vegetative stability of the stream channel and buffer were defined in the cruised reach assessment in four primary categories. Tables 3-31 through 3-34 summarize the vegetative data collected in the UGF-D watershed. Approximately 29% of the streams within UGF-D have more than 50% canopy cover and stream buffers of greater than 150 feet on each side. This subwatershed has high quality riparian buffers; approximately 59% of the buffers are composed of deciduous overstory with grass/brush understory and 18% consists of wetland vegetation. This is evident in the land use mapping.

Table 3-31: UGF-D Subwatershed Canopy Cover Percent

Cover Percent Canopy	UGF-D Subwatershed Percent of Cruised Reaches
0-10	10
10-25	20
25-50	41
50-75	22
75-100	7

Table 3-32: UGF-D Subwatershed Riparian Width by Bank

Riparian Width	Percent of Reaches (Left Bank)	Percent of Reaches (Right Bank)
x <= 10	34	36
10 < x <= 25	11	12
25 < x < = 50	15	12
50 < x < = 75	8	12
75 < x < = 150	18	13
> 150	14	15

Table 3-33: UGF-D Subwatershed Riparian Composition by Bank

Riparian Composition	Percent of Reaches (Left Bank)	Percent of Reaches (Right Bank)
Brush	2	5
Deciduous overstory w/ brush grass understory	59	59
Deciduous overstory	5	7
Grass & forbs	11	9
Wetland Vegetation	23	18
Bare	0	2

Table 3-34: UGF-D Subwatershed Riparian Density by Bank

Riparian Density	Percent of Reaches (Left Bank)	Percent of Reaches (Right Bank)
Low	2	5
Moderate	56	58
High	42	37

Stream Classification

The entire UGF-D tributary in this subwatershed is classified by the Maryland Department of the Environment (MDE) as a Use III stream, Natural Trout Waters. DNR monitoring has found trout in this subwatershed.

Habitat Condition

The MBSS IBI scores and fish blockage data were used to assess the habitat condition. The IBI scores for benthic and fish communities in the subwatershed are the mean value of all available DNR MBSS data summarized in chapter 3.2.4. The fish blockage data is summarized from the cruised reach portion of the SSA.

The benthic and fish habitat condition is poor in the UGF-D subwatershed.

Eighty-two percent of the cruised reaches contained some sort of fish blockage or barrier, primarily due to shallow flow depth. Table 3-35 shows the breakdown of fish blockages in UGF-D. All of the cruised reach fish blockages occurred on the tributaries, rather than the mainstem of the Gwynns Falls.

Table 3-35: UGF-D Subwatershed Fish Blockages

Fish Blockages Caused By:	Percent of UGF-D Subwatershed
Excessive Debris	18
Excessive Height	2
Shallow Flow Depth	62
No Blockage	18

Subwatershed Summary

The UGF-D is an urbanized subwatershed that is still undergoing development. The watershed characteristics are summarized below:

Streams

- Use III stream in entire subwatershed
- 48% of the streams are F or G stream types
- 44% of the streams are degrading and 5% are aggrading
- Cruised reaches have a medium to high stream bank erosion potential

Forest Buffers

- 70% of the watershed has less than 50% canopy cover and less than 50’ riparian width
- Over 50% of the buffers are comprised of medium density, deciduous overstory with brush/grass understory

Roche's Run

Existing Condition

The Roche's Run watershed lies entirely within Baltimore County. The subwatershed begins in Reisterstown and continues south to Pleasant Hill Road in Owings Mills, with I-795 as its western border and the edge of Gwynnbrook Wildlife Management Area as its eastern border. Table 3-36 summarizes the general subwatershed conditions. The corridor along Reisterstown Road is the main commercial and industrial zone within the watershed. Currently, commercial and industrial land uses comprise approximately 19.7% of the subwatershed. This subwatershed has experienced significant growth in the past twenty years, particularly due to transportation improvements such as I-795. 75.1% of the existing land is comprised of residential areas, predominantly medium- and high-density residential housing.

Table 3-36: Roche's Run General Subwatershed Conditions

Drainage Area:	2.40 square miles			
Stream Length:	6 miles			
Physiography:	Piedmont			
Soil Association(s):	83% B, 11% C, 6% D			
Dominant Bed Materials:	Cobble			
Dominant Flow Regime:	Perennial			
Dominant Rosgen Level II Classification:	A – 0% B - 20%	C – 0% D – 0%	**E - 33%** F -27%	G - 20%

Stream Stability

Twenty-one cruised reaches and 13 USACOE reaches were assessed in the Roche's Run subwatershed. The combined cruised and USACOE reaches were predominantly classified as Rosgen type E. Type E streams are typically low gradient, meandering, riffle/pool streams with low width to depth ratios and little deposition. They are very efficient and stable. Type E streams typically have a high meander width ratio. While type E streams are highly stable systems, they are sensitive to disturbance and can be converted into other stream types in a relatively short period of time. The most likely stream banks to have unstable banks are typically type F and G channels. These stream types comprise approximately 47% of the cruised stream reaches. Stages I and V of Schumm's channel evolution model indicate completely stable streams. Approximately 25% of the Roche's Run streams fit into these categories. Approximately 12% of the streams were classified as degrading and none were classified as aggrading. Table 3-37 shows the percentage of each stage found within the cruised reach assessment of the Roche's Run subwatershed.

Table 3-37: Roche's Run Subwatershed Channel Evolution Stages

Channel Evolution Stage	Percent of Roche's Run Watershed
Stage I	25
Stage II	12
Stage III	50
Stage IV	13
Stage V	0

Three primary factors were used to assess bank stability in addition to the unstable to stable ratio described above: bankfull height to bank height, bank angle and root density. Tables 3-38 through 3-40 show the detailed breakdown of each category for the cruised reaches. The bankfull height was compared with the bank height of the cruised reach. In a stable stream the bankfull height is connected to its floodplain and the bankfull height will be equal to the bank height of the channel. If the bankfull height falls within the upper half of the bank, the channel is slightly to moderately entrenched, and has higher erosion potential. If the bankfull height is in the lower half of the bank, the channel is entrenched, and has the highest erosion potential. The bank angle was considered in relation to the stream channel to assess bank stability. For example, if the bank angle was sloping away from the stream channel, the reach has low erosion potential. Banks that were nearly vertical have medium erosion potential, and banks that were undercut or sloping towards the stream have high erosion potential. The density of root mass within the banks is an important factor in considering bank stability. Approximately 6% of the cruised stream banks have a dense root network for the entire depth of the stream bank. The majority of streams (88%) typically only have a dense root network in the upper half of the streambank leaving the lower portion of the bank unprotected and susceptible to erosion. The streams are even more susceptible to erosion if the stream is entrenched. Approximately 6% of the reaches had minimal roots in the banks. The majority of streambanks in the Roche's Run subwatershed fall into the medium to high erosion potential category. Thus, a typical stream bank could be described as having its bankfull height found in the lower half of its banks, dense roots throughout the upper portion of the streambank and nearly vertical stream banks.

Table 3-38: Roche's Run Subwatershed Bank Height Ratio Caused Erosion Potential

Erosion Potential	Percent of Roche's Run Subwatershed
High, Bankfull in lower half of bank	56
Medium, Bankfull in upper half of bank	25
Low, Bankfull at top of bank	19

Table 3-39: Roche's Run Subwatershed Bank Angle Caused Erosion Potential

Erosion Potential	Percent of Roche's Run Subwatershed
High, Undercut banks	0
Medium, Nearly vertical banks	88
Low, Banks sloping away from stream	12

Table 3-40: Roche's Run Subwatershed Root Density Caused Erosion Potential

Erosion Potential	Percent of Roche's Run Subwatershed
High, Minimal roots	6
Medium, Dense roots in upper bank	88
Low, Dense roots throughout bank	6

Forest Assessment

Approximately 4.8% of the existing subwatershed contains forested lands. The largest forested area within this subwatershed is Roche's Run Park located at the intersection of Reisterstown Road and Valley Road, as well as part of the Hannah More Park located at the intersection of Hannah More Road and Reisterstown Road. Under the current Baltimore County zoning, ultimate development of forest lands could be reduced to 0% of the subwatershed area. Several sites in this subwatershed were assessed as a PAA and have been recommended for reforestation. Refer to Chapter 4 of this report for further descriptions of these sites.

Stream Buffer Condition

The majority of Roche's Run stream has a forested stream buffer. The vegetative stability of the stream channel and buffer were defined in the cruised reach assessment in four primary categories. Because the stream channel may have different buffer characteristics on both stream banks, the data was collected for both the right and left overbank areas. Tables 3-41 through 3-44 summarize the vegetative data collected in the Roche's Run watershed. Approximately 69% of the streams within Roche's Run have more than 50% canopy cover, and 10% have stream buffers of greater than 150 feet on each side. This subwatershed has high quality riparian buffers; approximately 75% of the buffers are composed of deciduous overstory with grass/brush understory and 12% of the buffers consist of wetland vegetation. This is evident in the land use mapping.

Table 3-41: Roche's Run Subwatershed Canopy Cover Percent

Cover Percent Canopy	Roche's Run Subwatershed Percent of Cruised Reaches
0-10	13
10-25	12
25-50	6
50-75	44
75-100	25

Table 3-42: Roche's Run Subwatershed Riparian Width by Bank

Riparian Width	Percent of Reaches (Left Bank)	Percent of Reaches (Right Bank)
< 10	33	43
10 < x <= 25	19	10
25 < x < = 50	33	19
50 < x < = 75	5	0
75 < x < = 150	0	9
> 150	10	19

Table 3-43: Roche's Run Subwatershed Riparian Composition by Bank

Riparian Composition	Percent of Reaches (Left Bank)	Percent of Reaches (Right Bank)
Brush	0	0
Deciduous overstory w/ brush grass understory	75	75
Deciduous overstory	0	0
Grass & forbs	13	13
Wetland Vegetation	12	12
Bare	0	0

Table 3-44: Roche's Run Subwatershed Riparian Density by Bank

Riparian Density	Percent of Reaches (Left Bank)	Percent of Reaches (Right Bank)
Low	12	25
Moderate	50	31
High	38	44

Stream Classification

The entire Roche's Run, which is a tributary to the Gwynns Falls, in this subwatershed is classified by the Maryland Department of the Environment (MDE) as a Use III stream, Natural Trout Waters. DNR monitoring has found trout in this subwatershed.

Habitat Condition

The MBSS IBI scores and fish blockage data were used to assess the habitat condition. The IBI scores for benthic and fish communities in the subwatershed are the mean value of all available DNR MBSS data summarized in chapter 3.2.4. The fish blockage data is summarized from the cruised reach portion of the SSA.

The benthic habitat condition is poor in the Roche's Run subwatershed. There was no fish habitat data collected.

Forty-four percent of the cruised reaches contained some sort of fish blockage or barrier, primarily due to debris blockages. Table 3-45 shows the break down of fish blockages in Roche's Run. All of the cruised reach fish blockages occurred on the tributaries, rather than the mainstem of the Gwynns Falls.

Table 3-45: Roche's Run Subwatershed Fish Blockages

Fish Blockages Caused By:	Percent of Roche's Run Subwatershed
Excessive Debris	32
Excessive Height	6
Shallow Flow Depth	6
No Blockage	56

Subwatershed Summary

The Roche's Run is an urbanized subwatershed that is undergoing further development. The watershed characteristics are summarized below:

Streams

- Use III stream
- 47% of the streams are F or G stream types
- 12% of the streams are degrading and no streams were classified as aggrading
- Cruised reaches have a medium to high stream bank erosion potential

Forest Buffers

- 31% of the watershed has less than 50% canopy cover, and over 70% have less than 50' riparian width
- Over 38% of the buffers are comprised of high density, deciduous overstory with brush/grass understory

UGF-B

Existing Condition

The UGF-B subwatershed lies entirely within Baltimore County. The subwatershed is entirely within the limits of Owings Mills, along Reisterstown Road from Pleasant Hill Road to McDonogh Road. Both Rosewood State Center and Owings Mills Corporate Campus are included in the UGF-B subwatershed. Table 3-46 summarizes the general subwatershed conditions. The corridor along Reisterstown Road is the main commercial and industrial zone within the watershed, with additional industrial and commercial area along Dolfield Road South. Currently, commercial and industrial land uses comprise approximately 39.3% of the subwatershed. This subwatershed has experienced significant growth in the past twenty years, particularly due to transportation improvements such as I-795 and the Metro stop in Owings Mills. 26.1% of the existing land is comprised of residential areas, predominantly medium- and high-density residential housing.

Table 3-46: UGF-B General Subwatershed Conditions

Drainage Area:	4.40 square miles			
Stream Length:	19.3 miles			
Physiography:	Piedmont			
Soil Association(s):	76% B, 19% C, 5% D			
Dominant Bed Materials:	Cobble and Sand			
Dominant Flow Regime:	Perennial			
Dominant Rosgen Level II Classification:	A – 0% **B - 45%**	C – 0% D – 0%	E - 16% F - 13%	G - 26%

Stream Stability

Fifty-one cruised reaches and 23 USACOE reaches were assessed in the UGF-B subwatershed. The combined cruised and USACOE reaches were predominantly classified as Rosgen type B. Type B streams are moderately entrenched, have moderate gradients and are riffle dominated channels with infrequently spaced pools. Streambank erosion rates and aggradation/degradation rates are typically low for type B streams. The most likely streams to have unstable banks are typically type F and G channels. These stream types comprise approximately 39% of the cruised stream reaches. Stages I and V of Schumm's channel evolution model indicate completely stable streams. Approximately 25% of the UGF-B streams fit into these categories. Approximately 24% of the streams were classified as degrading and an additional 8% were classified as aggrading. Table 3-47 shows the percentage of each stage found within the cruised reach assessment of the UGF-B subwatershed.

Table 3-47: UGF-B Subwatershed Channel Evolution Stages

Channel Evolution Stage	Percent of UGF-B Subwatershed
Stage I	22
Stage II	11
Stage III	32
Stage IV	32
Stage V	3

Three primary factors were used to assess bank stability in addition to the unstable to stable ratio described above: bankfull height to bank height, bank angle and root density. Tables 3-48 through 3-50 show the detailed breakdown of each category for the cruised reaches. The bankfull height was compared with the bank height of the cruised reach. In a stable stream the bankfull height is connected to its floodplain and the bankfull height will be equal to the bank height of the channel. If the bankfull height falls within the upper half of the bank the channel is slightly to moderately entrenched and has higher erosion potential. If the bankfull height is in the lower half of the bank, the channel is entrenched and has the highest erosion potential. The bank angle was considered in relation to the stream channel to assess bank stability. For example, if the bank

angle was sloping away from the stream channel, the reach has low erosion potential. Banks that were nearly vertical have medium erosion potential and banks that were undercut or sloping towards the stream have high erosion potential. The density of root mass within the banks is an important factor in considering bank stability. Approximately 20% of the cruised stream banks have a dense root network for the entire depth of the stream bank. The majority of streams (80%) typically only have a dense root network in the upper half of the streambank leaving the lower portion of the bank unprotected and susceptible to erosion. The streams are even more susceptible to erosion if the stream is entrenched. The majority of streambanks in the UGF-B subwatershed fall into the medium to high erosion potential category. Thus, a typical stream bank could be described as having its bankfull height found in the lower half of its banks, dense roots throughout the upper portion of the streambank and nearly vertical banks.

Table 3-48: UGF-B Subwatershed Bank Height Ratio Caused Erosion Potential

Erosion Potential	Percent of UGF-B Subwatershed
High, Bankfull in lower half of bank	68
Medium, Bankfull in upper half of bank	32
Low, Bankfull at top of bank	0

Table 3-49: UGF-B Subwatershed Bank Angle Caused Erosion Potential

Erosion Potential	Percent of UGF-B Subwatershed
High, Undercut banks	5
Medium, Nearly vertical banks	79
Low, Banks sloping away from stream	16

Table 3-50: UGF-B Subwatershed Root Density Caused Erosion Potential

Erosion Potential	Percent of UGF-B Subwatershed
High, Minimal roots	0
Medium, Dense roots in upper bank	80
Low, Dense roots throughout bank	20

Forest Assessment

Approximately 22.8% of the existing subwatershed contains forested lands. The largest forested area within this subwatershed is on the campuses of Rosewood State Center and McDonogh School. Under the current Baltimore County zoning, ultimate development of forest lands could be reduced to 0% of the subwatershed area. Several sites in this subwatershed were assessed as a PAA and have been recommended for reforestation. Refer to Chapter 4 of this report for further descriptions of these sites.

Stream Buffer Condition

The majority of UGF-B stream has a forested stream buffer. The vegetative stability of the stream channel and buffer were defined in the cruised reach assessment in four primary categories. Because the stream channel may have different buffer characteristics on both stream banks, the data was collected for both the right and left overbank areas. Tables 3-51 through 3-54

summarize the vegetative data collected in the UGF-B watershed. Approximately 69% of the streams within UGF-B have more than 50% canopy cover and over 35% of stream buffers of greater than 150 feet on each side. This subwatershed has high quality riparian buffers; approximately 81% of the buffers are composed of deciduous overstory with grass/brush understory.

Table 3-51: UGF-B Subwatershed Canopy Cover Percent

Cover Percent Canopy	UGF-B Subwatershed Percent of Cruised Reaches
0-10	12
10-25	0
25-50	19
50-75	35
75-100	34

Table 3-52: UGF-B Subwatershed Riparian Width by Bank

Riparian Width	Percent of Reaches (Left Bank)	Percent of Reaches (Right Bank)
< 10	12	7
10 < x <= 25	15	12
25 < x < = 50	19	19
50 < x < = 75	7	4
75 < x < = 150	12	19
> 150	35	38

Table 3-53: UGF-B Subwatershed Riparian Composition by Bank

Riparian Composition	Percent of Reaches (Left Bank)	Percent of Reaches (Right Bank)
Brush	0	0
Deciduous overstory w/ brush grass understory	88	81
Deciduous overstory	0	0
Grass & forbs	8	11
Wetland Vegetation	4	8
Bare	0	0

Table 3-54: UGF-B Subwatershed Riparian Density by Bank

Riparian Density	Percent of Reaches (Left Bank)	Percent of Reaches (Right Bank)
Low	4	0
Moderate	69	69
High	27	31

Stream Classification

The entire Gwynns Falls in this subwatershed is classified by the Maryland Department of the Environment (MDE) as a Use III stream, Natural Trout Waters. DNR monitoring has found trout in this subwatershed.

Habitat Condition

The MBSS IBI scores and fish blockage data were used to assess the habitat condition. The IBI scores for benthic and fish communities in the subwatershed are the mean value of all available DNR MBSS data summarized in chapter 3.2.4. The fish blockage data is summarized from the cruised reach portion of the SSA.

The benthic habitat condition is poor and the fish habitat condition is fair in the UGF-B subwatershed.

Approximately 74% of the cruised reaches contained some sort of fish blockage or barrier, primarily due to debris blockages. Table 3-55 shows the fish blockages in UGF-B. All of the cruised reach fish blockages occurred on the tributaries, rather than the mainstem of the Gwynns Falls. Fish blockages were not one of the factors considered for the USACOE analyses.

Table 3-55: UGF-B Subwatershed Fish Blockages

Fish Blockages Caused By:	Percent of UGF-B Subwatershed
Excessive Debris	39
Excessive Height	9
Shallow Flow Depth	26
No Blockage	26

Subwatershed Summary

The UGF-B is a suburbanized subwatershed that may undergo redevelopment. The watershed characteristics are summarized below:

Streams

- Use III stream
- 39% of the streams are F or G stream types
- 24% of the streams are degrading and 8% are aggrading
- Cruised reaches have a medium to high stream bank erosion potential

Forest Buffers

- 69% of the streams within UGF-B have more than 50% canopy cover and over 35% of stream buffers of greater than 150 feet on each side
- Over 80% of the buffers are comprised of medium density, deciduous overstory with brush grass understory

Red Run

Existing Condition

The Red Run subwatershed is the most recently developed subwatershed in the Upper Gwynns Falls. This subwatershed underwent significant development during the 1990s, particularly in the Owings Mills Newtown area. The Soldiers Delight Environmental Area is located in the western part of the subwatershed. This is the largest forested area remaining in this subwatershed. Table 3-56 summarizes the characteristics of Red Run.

Table 3-56: Red Run General Subwatershed Conditions

Drainage Area:	7.43 square miles			
Stream Length	34.1 miles			
Physiography:	Piedmont			
Soil Association(s):	71% B, 11% C, 18% D			
Dominant Bed Materials:	Gravel and Cobble			
Dominant Flow Regime:	Perennial			
Dominant Rosgen Level II Classification:	A – 2% B - 15%	C - 5% D – 0%	**E - 51%** F - 11%	G - 16%

Stream Stability

One-hundred and six cruised reaches and 26 USACOE reaches were assessed in the Red Run subwatershed. The combined cruised and USACOE reaches were predominantly classified as Rosgen type E. Type E streams are typically low gradient, meandering, riffle/pool streams with low width to depth ratios and little deposition. They are very efficient and stable. Type E streams typically have a high meander width ratio. While type E streams are highly stable systems, they are sensitive to disturbance and can be converted into other stream types in a relatively short period of time. The most likely streams to have unstable banks are typically type F and G channels. These stream types comprise approximately 27% of the cruised stream reaches. Stages I and V of Schumm's channel evolution model indicate completely stable streams. Approximately 48% of the Red Run streams fit into these categories. Approximately 45% of the streams were classified as degrading and an additional 7% were classified as aggrading. Table 3-57 shows the percentage of each stage found within the cruised reach assessment of the Red Run subwatershed.

Table 3-57: Red Run Subwatershed Channel Evolution Stages

Channel Evolution Stage	Percent of Red Run Subwatershed
Stage I	28
Stage II	25
Stage III	20
Stage IV	7
Stage V	20

Three primary factors were used to assess bank stability in addition to the unstable to stable ratio described above: bankfull height to bank height, bank angle and root density. Tables 3-58 through 3-60 show the detailed breakdown of each category for the cruised reaches. The bankfull height was compared with the bank height of the cruised reach. In a stable stream the bankfull height is connected to its floodplain and the bankfull height will be equal to the bank height of the channel. If the bankfull height falls within the upper half of the bank, the channel is slightly to moderately entrenched and has higher erosion potential. If the bankfull height is in the lower half of the bank, the channel is entrenched and has the highest erosion potential. The bank angle was considered in relation to the stream channel to assess bank stability. For example, if the bank angle was sloping away from the stream channel, the reach has low erosion potential. Banks that were nearly vertical have medium erosion potential, and banks that were undercut or sloping towards the stream have high erosion potential. The density of root mass within the banks is an important factor in considering bank stability. Approximately 31% of the cruised stream banks have a dense root network for the entire depth of the stream bank. The majority of streams (58%) typically only have a dense root network in the upper half of the streambank, leaving the lower portion of the bank unprotected and susceptible to erosion. The streams are even more susceptible to erosion if the stream is entrenched. Approximately 11% of the reaches had minimal roots in the banks. The majority of streambanks in the Red Run subwatershed fall into the low to medium erosion potential category. Thus, a typical stream bank could be described as having its bankfull height found in the upper half of its banks, dense roots throughout the upper portion of the streambank, and banks sloping away from the stream.

Table 3-58: Red Run Subwatershed Bank Height Ratio Caused Erosion Potential

Erosion Potential	Percent of Red Run Subwatershed
High, Bankfull in lower half of bank	32
Medium, Bankfull in upper half of bank	40
Low, Bankfull at top of bank	28

Table 3-59: Red Run Subwatershed Bank Angle Caused Erosion Potential

Erosion Potential	Percent of Red Run Subwatershed
High, Undercut banks	7
Medium, Nearly vertical banks	52
Low, Banks sloping away from stream	41

Table 3-60: Red Run Subwatershed Root Density Caused Erosion Potential

Erosion Potential	Percent of Red Run Subwatershed
High, Minimal roots	11
Medium, Dense roots in upper bank	58
Low, Dense roots throughout bank	31

Forest Assessment

Approximately 38% of the existing subwatershed contains forested lands. The three largest forested areas within this subwatershed are the Soldiers Delight Natural Environment Area, the Pikesville Sportsmen Club and the area west of Owings Mills Town Center. While the Soldiers Delight area is protected parkland, the other two areas are not.

Stream Buffer Condition

The vegetative stability of the stream channel and buffer were defined in the cruised reach assessment in four primary categories. Because the stream channel may have different buffer characteristics on both stream banks, the data was collected for both the right and left overbank areas. Tables 3-61 through 3-64 summarize the vegetative data collected in the Red Run subwatershed. Approximately 72% of the streams within Red Run have more than 50% canopy cover and stream buffers of greater than 150 feet on each side. This subwatershed has high quality riparian buffers, approximately 90% of the buffers are composed of deciduous overstory with grass/brush understory. This is evident in the existing aerial orthophotography.

Table 3-61: Red Run Subwatershed Canopy Cover Percent

Cover Percent Canopy	Red Run Subwatershed Percent of Cruised Reaches
0-10	3
10-25	7
25-50	18
50-75	36
75-100	36

Table 3-62: Red Run Subwatershed Riparian Width by Bank

Riparian Width	Percent of Reaches (Left Bank)	Percent of Reaches (Right Bank)
< 10	1	1
10 < x <= 25	8	6
25 < x < = 50	5	6
50 < x < = 75	0	1
75 < x < = 150	19	12
> 150	67	74

Table 3-63: Red Run Subwatershed Riparian Composition by Bank

Riparian Composition	Percent of Reaches (Left Bank)	Percent of Reaches (Right Bank)
Brush	2	1
Deciduous overstory w/ brush grass understory	86	92
Deciduous overstory	1	0
Grass & forbs	8	6
Wetland Vegetation	3	1
Bare	0	0

Table 3-64: Red Run Subwatershed Riparian Density by Bank

Riparian Density	Percent of Reaches (Left Bank)	Percent of Reaches (Right Bank)
Low	7	2
Moderate	31	38
High	62	60

Stream Classification

The entire Red Run tributary is classified by the Maryland Department of the Environment (MDE) as a Use III stream, Natural Trout Waters. DNR monitoring confirms that trout exist in this subwatershed.

Habitat Condition

The MBSS IBI scores and fish blockage data were used to assess the habitat condition. The IBI scores for benthic and fish communities in the subwatershed are the mean value of all available DNR MBSS data summarized in chapter 3.2.4. The fish blockage data is summarized from the cruised reach portion of the SSA.

The benthic habitat condition is fair and the fish habitat condition is poor in the subwatershed. Although the average value is poor, several stream reaches had fair and good scores. Red Run has the highest physical habitat rating in the entire Gwynns Falls watershed.

28% of the cruised reaches contained some sort of fish blockage or barrier, primarily due to debris blockages. Table 3-65 shows the break down of fish blockages in Red Run.

Table 3-65: Red Run Subwatershed Fish Blockages

Fish Blockages Caused By:	Percent of Red Run Subwatershed
Excessive Debris	6
Excessive Height	19
Shallow Flow Depth	3
No Blockage	72

Subwatershed Summary

Red Run was developed under regulations for stream buffer protection, forest conservation and stormwater management. Consequently, it has one of the lowest unstable to stable stream ratios (29%). This subwatershed is a Use III, Natural Trout stream. Focus on this subwatershed should be to maintain and improve the existing stream condition and habitat. Subwatershed characteristics are summarized below:

Streams

• Use III Trout stream – entire subwatershed

• Only 27% of streams are Type F and G; 51% are E channels

• 48% of the stream channels fit into Schumm's stable categories

• Cruised reaches have medium stream bank erosion potential

Forest Buffers

• More than 50% of the streams have between 50 and 100% canopy cover

• More than 2/3 of the subwatershed has high density, deciduous overstory with brush/grass understory and riparian widths greater than 150 feet

Horsehead Branch

Existing Condition:

Horsehead Branch is the smallest subwatershed in the Gwynns Falls with a drainage area of just over two square miles and it is located entirely within Baltimore County. It contains the communities of Lyonswood, Owings Choice and Fox Ridge. The existing land use consists primarily of residential development, forest and agricultural land uses. Horsehead Branch drains into the mainstem of the Gwynns Falls inside the forested area in the Owings Mills Corporate Campus just south of McDonogh Road. Much of the development has occurred in the subwatershed since the 1980's. Table 3-66 summarizes the subwatershed characteristics of Horsehead Branch.

Table 3-66: Horsehead Branch General Subwatershed Conditions

Drainage Area:	2.04 square miles		
Stream Length	10.7 miles		
Physiography:	Piedmont		
Soil Association(s):	74% B, 17% C, 9% D		
Dominant Bed Materials:	Gravel		
Dominant Flow Regime:	Perennial		
Dominant Rosgen Level II Classification:	A – 0% B - 6%	C - 9% D – 12%	**E - 41%** F - 16%

Stream Stability

14 USACOE reaches and 15 cruised reaches were assessed in this subwatershed. Over 40% of the assessed stream reaches are classified as Rosgen type E streams. Type E streams are typically low gradient, meandering, riffle/pool systems with low width to depth ratios and very little deposition. They are very efficient and stable streams. There are approximately 16% of type F and G streams in the subwatershed. These streams are more likely to develop unstable banks and contribute sediment loads downstream. A large percentage of the type F and G streams occur in the Horsehead Branch mainstem, particularly southeast of the Painters Mill and McDonogh Road intersection. This area has seen a rapid increase in medium to high density housing during the

1990s. Stages I and V of Schumm's channel evolution model indicate completely stable streams. Over 58% of Horsehead Branch's cruised reaches fit into this category. The remaining 42% of cruised reaches were classified as degrading. Refer to Table 3-67.

Table 3-67: Horsehead Branch Subwatershed Channel Evolution Stages

Channel Evolution Stage	Percent of Horsehead Branch Subwatershed
Stage I	50
Stage II	42
Stage III	0
Stage IV	0
Stage V	8

The results of the Channel Evolution model are substantiated by the results of the bank stability assessments. Only 21% of the cruised reaches are moderately entrenched, the remainders have either slight or no entrenchment. Approximately 57% of the streams have high erosion potential because the maximum bankfull height was in the lower half of bank. Degrading streams can cause many problems in the stream system including increased sediment supply, fish blockages and utility problems. Over 54% of the cruised reaches have low to medium erosion potential due to the bank to bankfull ratio. Approximately 46% of the streams have the bankfull height located in the lower half of the bank. This indicates that many of the streams in this subwatershed are entrenched. Table 3-68 shows the erosion potential due to the bank to bankfull ratio.

Table 3-68: Horsehead Branch Subwatershed Bank Height Ratio Caused Erosion Potential

Erosion Potential	Percent of Horsehead Branch Subwatershed
High, Bankfull in lower half of bank	46
Medium, Bankfull in upper half of bank	27
Low, Bankfull at top of bank	27

The bank angle was used as another factor to assess bank stability. Table 3-69 shows the erosion potential in the Horsehead Branch subwatershed due to bank angle. The bank angle was considered in relation to the stream channel. For example, if the bank angle slopes away from the stream channel, the reach has low erosion potential. Banks that are nearly vertical have medium erosion potential, and banks that are undercut or sloping towards the stream have high erosion potential. Only 9% of the cruised stream reaches have high erosion potential with undercut banks and are composed of gravel and silts. HB-04-00-02 is one cruised reach with high erosion potential. It receives discharges from the developed portion of the Owings Mills Corporate Campus. As development increases in the subwatershed, other stream reaches will be subject to higher erosion potentials. Currently, 91% of the cruised reaches have a low or medium erosion potential based on bank angle.

Table 3-69: Horsehead Branch Subwatershed Bank Angle Caused Erosion Potential

Erosion Potential	Percent of Horsehead Branch Subwatershed
High, Undercut banks	9
Medium, Nearly vertical banks	55
Low, Banks sloping away from stream	36

The density of root mass within the banks is an important factor in considering bank stability. Approximately 36% of the cruised stream banks have a dense root network for the entire depth of the stream bank and the remaining streams (64%) typically only have a dense root network in the upper half of the streambank leaving the lower portion of the bank unprotected and susceptible to erosion. The streams are even more susceptible to erosion if the stream is entrenched. None of the cruised reaches exhibited minimal roots in the banks. Table 3-70 shows the erosion potential due to root density.

Table 3-70: Horsehead Branch Subwatershed Root Density Caused Erosion Potential

Erosion Potential	Percent of Horsehead Branch Subwatershed
High, Minimal roots	0
Medium, Dense roots in upper bank	64
Low, Dense roots throughout bank	36

Forest Assessment

No forest patch assessment was completed in the Horsehead Branch subwatershed. Horsehead Branch ranks second in the amount of existing forested lands. These forested lands are not protected as parks or resource conservation zones, but are primarily zoned with residential land uses. Consequently, Horsehead Branch could have a large reduction in forested area. The two largest forest patches surround the mainstem of Horsehead Branch. The largest patch is just south of McDonogh Road and includes a large portion of the Owings Mills Corporate Campus. This area is located near the confluence with the Gwynns Falls Mainstem. The second largest patch is in the central portion of the subwatershed between Lyonswood Drive and Sihler Oaks Trail.

Stream Classification

Horsehead Branch, like the majority of other Gwynns Falls tributaries is classified as a Class I stream. The designated use of Class I streams is protection of fish and aquatic life and contact recreation (i.e. fishable/swimmable).

Habitat Condition

The MBSS IBI scores and fish blockage data were used to assess the habitat condition. The IBI scores for benthic and fish communities in the subwatershed are the mean value of all available

DNR MBSS data summarized in chapter 3.2.4. The fish blockage data is summarized from the cruised reach portion of the SSA.

The benthic habitat condition is fair and the fish habitat condition is poor in the Horsehead Branch subwatershed.

There were no fish blockages noted in the cruised reach assessment of Horsehead Branch.

Subwatershed Summary

The Horsehead Branch is the least developed subwatershed in the Gwynns Falls. The subwatershed characteristics are summarized below:

Streams

- Use I stream type
- 31% F and G stream channels; 41% type E channels
- Schumm's channel evolution rating shows 66% of stream channels are stable
- Cruised reaches have medium stream bank erosion potential

Forest Buffers

- When forested buffers exist, they are typically greater than 100 feet and consist of medium density, deciduous overstory with brush grass understory
- Select opportunities for riparian enhancement and habitat improvement along mainstem

3.8 Water Quality Summary

Table 3-71 summarizes the water quality assessment for each subwatershed in the Upper Gwynns Falls SWAP study area.

Table 3-71: Stream Assessment Summary

Subwatershed	Channel Evolution Stage, %			Rosgen Stream Classification %		Fish Blockages %	Mean IBI Score		< 50% Canopy Cover
	II	III	IV	F	G		Benthic	Fish	
Horsehead Branch	42	0	0	16	16	N/A	1.95	2.67	N/A
Red Run	25	20	7	11	16	28	3.21	2.87	28
UGF-B	11	32	32	13	26	74	1.76	3.67	31
Roche's Run	12	50	13	27	20	44	1.15	N/A	31
UGF D	20	48	15	7	41	82	1.56	2.50	71

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CHAPTER 4

UPLAND ASSESMENTS

4.1 Introduction

Upland areas were assessed according to the Unified Subwatershed and Site Reconnaissance (USSR) Manual developed by CWP (CWP 2004) to identify potential pollution sources influencing water quality and restoration project opportunities. The USSR manual is the last manual in a series of 11 regarding techniques for restoring urban watersheds. It provides detailed guidance for field survey techniques and was developed to help watershed groups, municipal staff, and consultants to quickly identify major stormwater pollution sources and assess subwatershed restoration potential for source controls, pervious area management, and improved municipal maintenance such as awareness, retrofits, street sweeping, and open space management.

The field survey of upland areas in the Upper Gwynns Falls watershed included four major components:

- 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.

4.2 Neighborhood Source Assessment (NSA)

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

4.2.1 Assessment Protocol

Prior to conducting NSAs in the field, neighborhoods were delineated in the office using ADC street maps and Geographic Information System (GIS) data such as tax parcels, historical development information and aerial photographs, see Figure 4-1. A neighborhood was delineated based on a group of homes with similar characteristics including lot sizes, road widths, set backs, year of construction, and house types (apartment complex, rowhomes, single family detached, etc.) NSAs were each given unique names, for example “NSA_V_123”. “V” denotes the Upper Gwynns Falls watershed study area. The number consists of a first digit which classifies it’s subwatershed with the following two digits assigned sequentially to each neighborhood as they were delineated. Subwatersheds were assigned the following unique numbers for the purposes of HSIs, ISIs, and PAAs: (1) Horsehead Branch; (2) Red Run; (3) UGF-B; (4) Roche’s Run; and (5) UGF-D.

Neighborhoods that were delineated in the office using available GIS and aerial information were analyzed during field assessments for consistency. Adjustments were made as necessary during field assessments to adjust for similarities or differences not seen during office delineation. If NSA boundaries were modified during field assessments, the neighborhood name was adjusted.

The assessment team drove through every street in a defined neighborhood to identify potential pollution sources and restoration opportunities. Data was collected in each neighborhood for four main source areas: yards and lawns; driveways, sidewalks and curbs; rooftop runoff; and common areas. Each assessment area is described briefly below.

Yards and Lawns

Yards and lawns typically represent a significant portion of the pervious cover in the Upper Gwynns Falls watershed and therefore, can be a major source of nutrients, pesticides, sediment, and runoff. Maintenance behaviors tend to be similar within individual neighborhoods and certain activities can impact subwatershed quality such as fertilization, pesticide use, watering, landscaping, and waste. Potential pollution sources evaluated under this source category include grass cover and management status (fertilization and irrigation methods), bare soil, outdoor swimming pools, and trash or waste. The amount of existing tree cover and landscaping in neighborhoods was also noted to evaluate potential for increasing these features to provide water quality benefits through interception and filtration of stormwater runoff.

Driveways, Sidewalks, and Curbs

Driveways, sidewalks, and curbs are common in the Upper Gwynns Falls watershed and link neighborhood runoff to the storm drain system. Activities such as car washing, deicing, and improper chemical storage can contribute pollutants such as nutrients, oil, sediment, and chlorides into the storm drain system. While assessing individual neighborhoods, data was collected for potential pollution sources including stained/dirty driveways, sidewalks covered with lawn clippings/leaves or receiving non-target irrigation (source of nutrients and sediment), pet waste (bacteria), long-term car parking (unused old cars with potential to leak chemicals, oil, and/or grease) and amount of sediment, organic matter, and/or trash present along curbs. Potential for street tree planting and street sweeping was also evaluated based on some of the above factors.

Rooftops

Rooftop runoff is another pollution source in neighborhoods. Downspout retrofits can help reduce runoff and pollutants introduced to local streams. The field team identified where rooftop runoff was discharged (pervious areas, rain barrel, impervious surfaces and/or directly to the storm drain system) and the proportion of each type of discharge within a neighborhood. The potential for disconnection and redirecting runoff to a retrofit (rain barrel or rain garden) was also evaluated.

Common Areas

Common areas such as community parks, parking lots and alleys are good opportunities to observe community behaviors such as pet waste disposal, storm water management, storm drain marking, and how natural areas or buffers are managed. Areas that are well maintained indicate that residents or a homeowner's association are active and it may be an ideal opportunity for restoration projects. Data was collected on the condition of storm drain inlets (clean or filled with debris), presence of pet waste, and/or dumping in common areas to identify potential pollution sources in a neighborhood. The potential for storm drain marking, storm water management practices, and stream buffer planting was also evaluated.

In addition to these four source areas, potential pollution sources were identified in individual neighborhoods by collecting basic information regarding presence of sewer service and amount of remodeling or redevelopment activities. Basic neighborhood information collected to help rate restoration potential included lot size, house types, fraction of houses with basements and garages, and whether a homeowner's association exists for the community. After assessing an entire neighborhood and completing the basic information and four major source area sections, any pollutants that are potentially being generated by the neighborhood based on the previous sections are indicated on the field form including nutrients, oil and grease, trash/litter, bacteria, and sediment. For example, if a neighborhood had several stained driveways and/or several long term parked vehicles/boats, oil and grease would be flagged as a potential major pollutant being generated in that neighborhood. The presence of trash in several yards or dumping in common areas would be a significant indicator for trash/litter generated in a neighborhood. Sediment was flagged as a major pollutant source if erosion or bare soil was observed, significant amount of remodeling/redevelopment was occurring, and/or a considerable portion of the curb and gutters were covered with sediment.

After assessing an entire neighborhood, specific actions were recommended for neighborhood restoration or retrofits based on initial field observations. Recommended actions included in the Upper Gwynns Falls watershed NSAs included:

- Downspout disconnection
- Fertilizer reduction/awareness
- Bayscaping
- Storm drain marking
- Street tree planting
- Trash management

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

4.2.2 Summary of Sites Investigated

A total of 79 neighborhoods were assessed throughout the Upper Gwynns Falls watershed (see Figure 4-1). The number of neighborhoods within each subwatershed is summarized in Table 4-1. Note that a neighborhood may encompass more than one subwatershed; in this case it counts for each subwatershed in which it falls. Analyses of acres of land or miles of road addressed by recommended actions, however, are based on the actual proportion of the neighborhood that falls within each subwatershed. This is explained further in subsequent sections.

Table 4-1: Neighborhoods Surveyed per Subwatershed

Subwatershed	# of NSAs Performed
Horsehead Branch	10
Red Run	22
UGF-B	11
Roche's Run	14
UGF-D	22
Total	**79**

Over 25% (21 out of 79) of the assessed neighborhoods were rated as having a high PSI. Of these 21, 7 neighborhoods are considered as having a high ROI and 14 have a moderate ROI.

The majority of the neighborhoods assessed (55) were considered as having a moderate PSI with either a high or moderate ROI. The remaining three neighborhoods are considered as having a low ROI. The 7 neighborhoods with high PSI and high ROI ratings represent the best areas to initially target for restoration. The distribution of PSI and ROI ratings among the NSAs are shown in Figure 4-2.

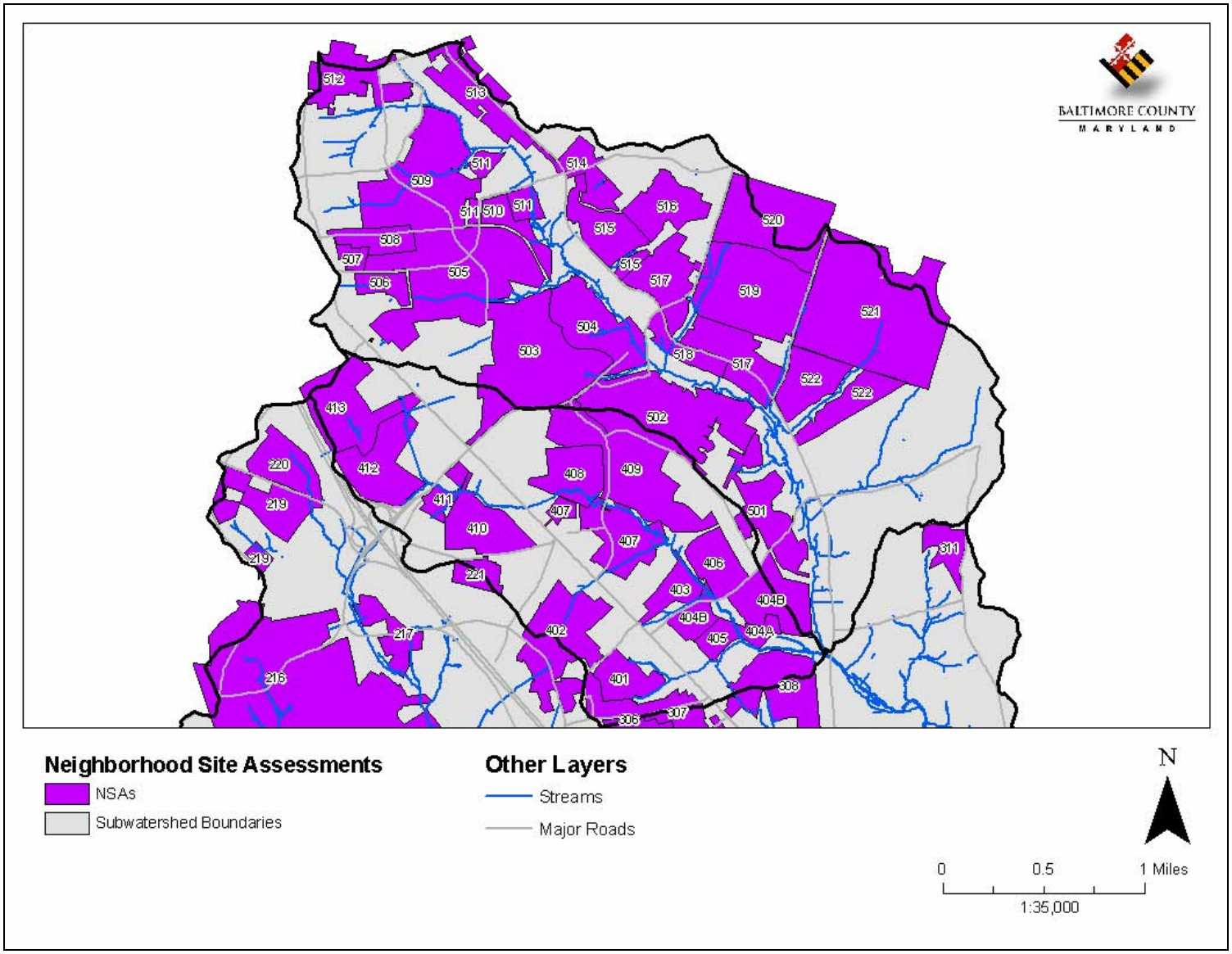

Figure 4-1: Upper Gwynns Falls SWAP Neighborhood Site Assessment Locations

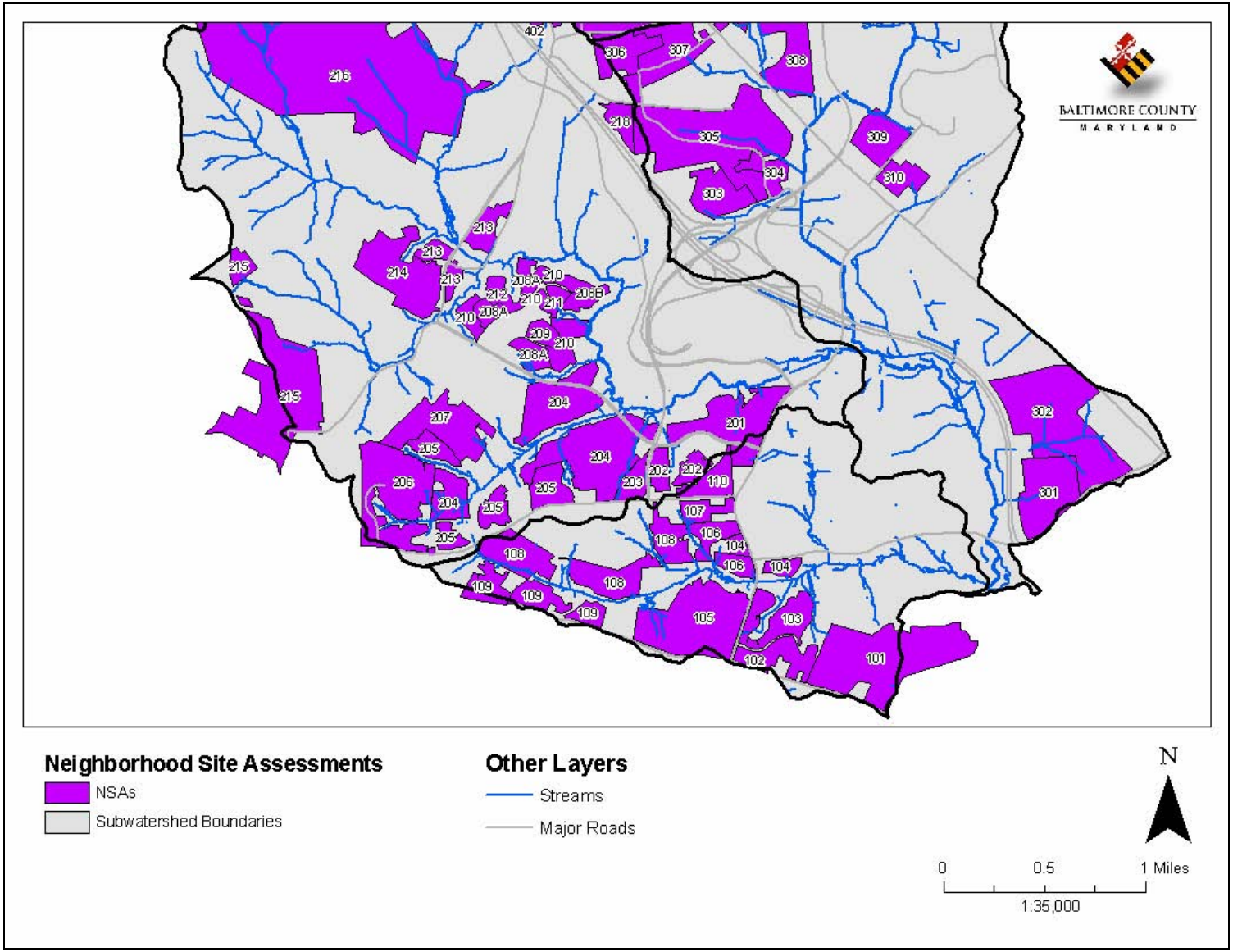

Figure 4-1: Upper Gwynns Falls SWAP Neighborhood Site Assessment Locations (continued)

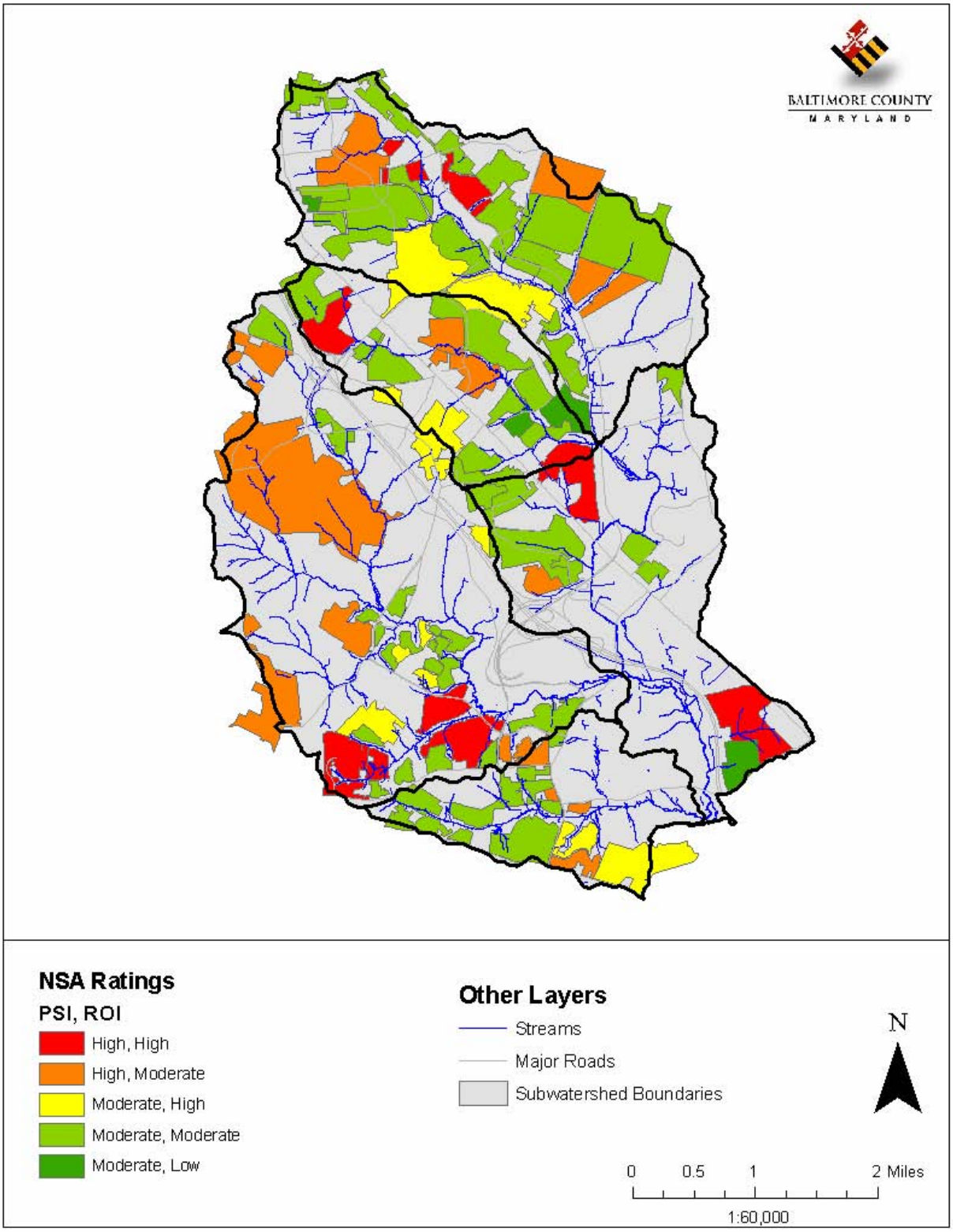

Figure 4-2: Upper Gwynns Falls SWAP NSA Pollution Severity and Restoration Opportunity Indexes

4.2.3 General Findings

The following subsections describe the actions recommended based on the NSAs. This includes an explanation of the methodologies and criteria used to evaluate the potential for recommended actions and results expected if these actions were applied. Figures showing general locations of NSAs recommended for certain actions are included in each subsection. Appendix A-1 includes a list of NSA data collected and recommended actions by individual neighborhoods.

4.2.3.1 Downspout Disconnection

Rooftop runoff is managed via downspouts which are considered as either connected or disconnected. Directly connected downspouts extend underground, discharging runoff directly into the storm drain system without treatment. Indirectly connected downspouts drain to impervious surfaces such as paved driveways, sidewalk, or curb and gutter system with little or no treatment. Disconnected downspouts allow rooftop runoff to infiltrate into the ground and enter streams through the groundwater system in a slower more natural fashion. Downspout disconnection is desirable because it decreases flow to local streams during storm events; this helps prevent erosion and reduces pollutant loads to streams. Disconnection may involve redirecting connected downspouts from impervious areas or the storm drain system onto pervious areas such as yards and lawns. This requires at least 15 feet of pervious area down gradient from the downspout for infiltration to occur. Rain barrels and rain gardens are other disconnection options that can be recommended in lieu of redirection if certain conditions exist. Rain barrels, for example, may be used to store rooftop runoff for irrigation if there is limited pervious area available for downspout redirection. Rain gardens are the most desirable option in terms of water quality because they consist of native plants that capture and treat runoff; this is a potential option for disconnection if the typical neighborhood has several hundred square feet of lawn area available down gradient from the downspout.

Downspout redirection is recommended for neighborhoods where at least 25 percent of the downspouts are connected to impervious area or directly to the storm drain system and where the average lot has at least 15 feet of pervious area available down gradient from the connected downspout for redirection. Table 4-2 includes a summary of the number of neighborhoods recommended for downspout redirection and the acres of rooftop addressed if downspout redirection were implemented by subwatershed. Table 4-2 also lists the percent of impervious rooftop area addressed if downspout redirection were initiated; total impervious rooftop area per subwatershed was calculated using Baltimore County’s buildings GIS layer.

Table 4-2: Acres Addressed by Downspout Redirection

Subwatershed	# of NSAs with Greater than 25% of Downspouts Directly Connecting to S/D and/or Impervious Land	# of Neighborhoods with Downspout Redirection Recommended*	Acres of Impervious Rooftop in Target Neighborhoods	Acres of Impervious Rooftop in Target Neighborhoods that can be Redirected	Percent of Impervious Rooftop in Target Neighborhoods that can be Redirected
Horsehead Branch	4	1	11.3	2.6	23%
Red Run	13	12	95.4	60.8	64%
UGF-B	4	4	19.7	12.1	61%
Roche's Run	5	2	31.5	7.3	23%
UGF-D	9	4	78.4	13.8	18%
Total	**35**	**23**	**236**	**97**	**38%**

*(It is feasible to disconnect at least 25% of the connected downspouts)

Figure 4-3: Directly Connected Downspouts in NSA_V_512 and NSA_V_107 Suitable for Disconnection

Figure 4-3 shows two examples of downspouts suitable for disconnection. Figure 4-5 illustrates the location of neighborhoods recommended for downspout redirection. Out of the 79 neighborhoods assessed, 35 have the potential for downspout disconnection through redirection. If implemented, this could address approximately 44 percent of the total impervious rooftop area in the watershed. Figure 4-4 shows a rain barrel being used to catch water for irrigation purposes.

Figure 4-4: A Typical Rain Barrel Installation with Overflow Hose

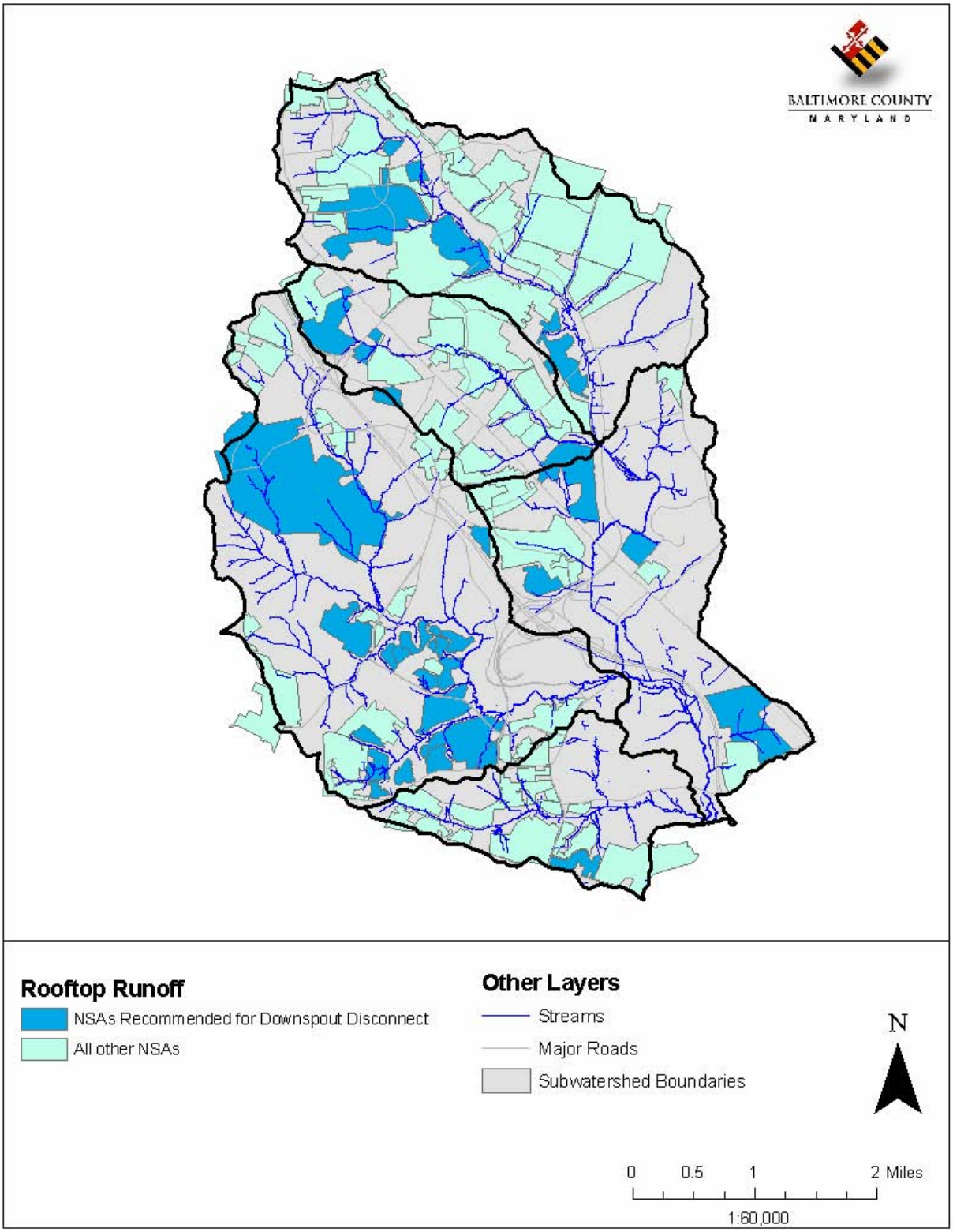

Figure 4-5: Upper Gwynns Falls SWAP Neighborhoods Recommended for Downspout Disconnection

4.2.3.2 Fertilizer Reduction/Awareness

A well-maintained lawn can be beneficial to the watershed. However, lawn maintenance activities often involve over-fertilization, overly aggressive pest-management, and over-watering, which results in polluted stormwater runoff to local streams. Lawns with a dense, uniform grass cover or signs designating poisonous lawn care indicate high lawn maintenance activities (see Figure 4-6). Neighborhoods where 20 percent or more of the homes appeared to employ high lawn maintenance practices were recommended for fertilizer reduction/awareness. Table 4-3 includes a summary of the number of neighborhoods recommended for fertilizer reduction/awareness and the acres of lawn addressed if this action were initiated by subwatershed. Note that the acres of lawn addressed were calculated based on the percentage of high maintenance lawns present within each neighborhood recommended for this action. Table 4-3 also lists the percent of the total subwatershed area that would be addressed by implementing fertilizer reduction/awareness in the recommended neighborhoods.

Figure 4-6: Lawn with High Fertilizer Use (NSA_V_220)

Table 4-3: Acres of Lawn Addressed by Fertilizer Reduction

Subwatershed	Number of Neighborhoods Recommended for Fertilizer Reduction	Acres of Lawn Addressed by Fertilizer Reduction	% of Subwatershed Addressed by Fertilizer Reduction
Horsehead Branch	7	257.9	20%
Red Run	12	843.2	18%
UGF-B	5	168.1	6%
Roche's Run	6	173.2	11%
UGF-D	9	597.8	19%
Total	**39**	**2040.2**	**15%**

Figure 4-7 illustrates the location of neighborhoods recommended for fertilizer reduction/awareness (neighborhoods with 20 – 100% high maintenance lawns). Out of the 79 neighborhoods assessed, 39 (49%) were recommended for fertilizer reduction/awareness, which would address 15% of the Upper Gwynns Falls.

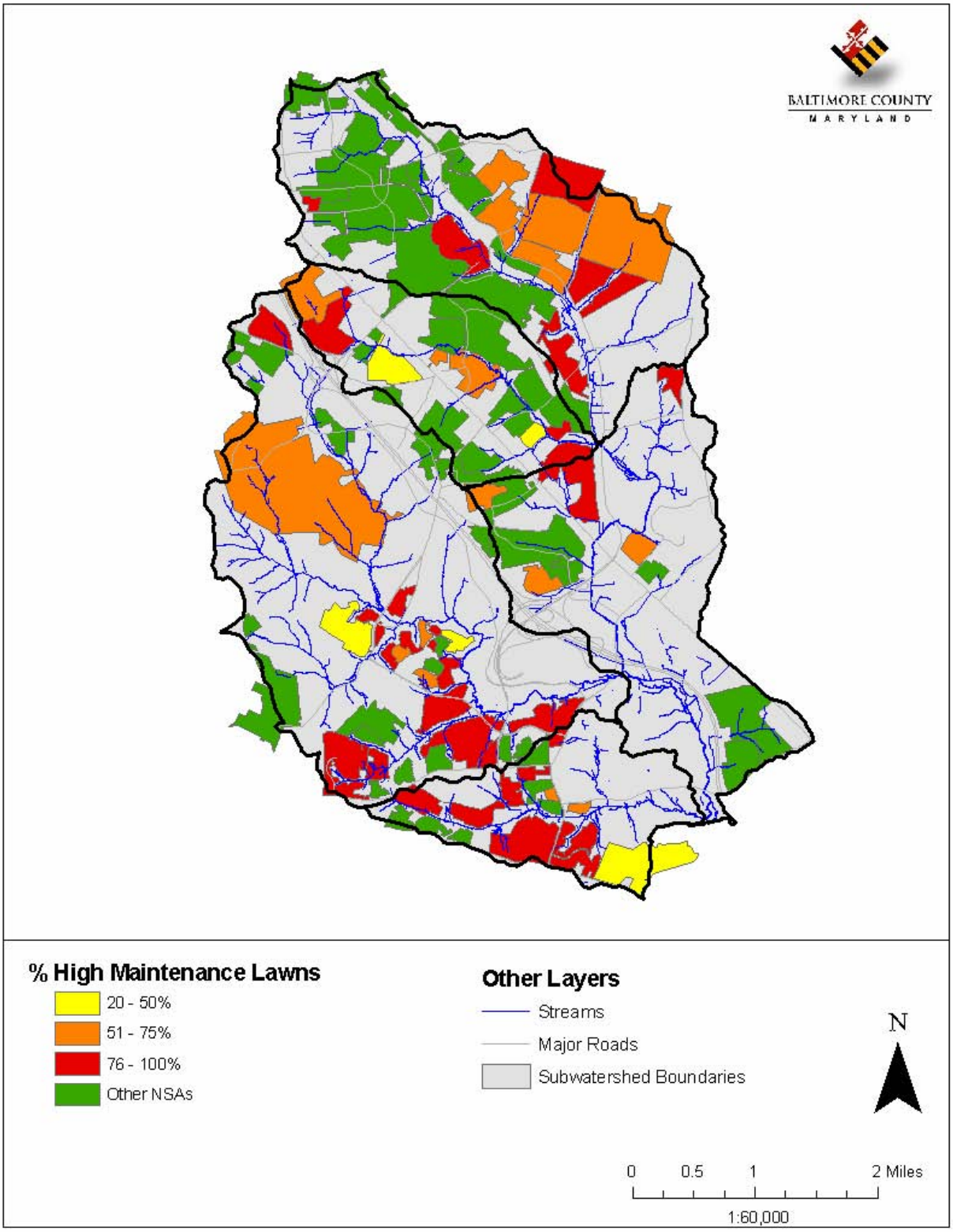

Figure 4-7: Upper Gwynns Falls SWAP Neighborhoods with 20-100% High Maintenance Lawns

4.2.3.3 Bayscaping

Bayscaping refers to the use of plants native to the Chesapeake Bay watershed for landscaping. because they are native to the region, these plants require less irrigation, fertilizers, and pesticides as compared to non-native or exotic plants. This means less stormwater pollution and lawn maintenance requirements. Bayscaping is also beneficial to wildlife.

Bayscaping was recommended in neighborhoods where the typical lot was at least ¼ acre in size, was less than 25 percent landscaped, and where there was sufficient grass area available (i.e., where impervious cover on the lot would not inhibit improvement of this percentage). Table 4-4 includes a summary of the number of neighborhoods recommended for Bayscaping based on these criteria and the acres of land addressed if this action were initiated by subwatershed. Table 4-4 also lists the percent of the total subwatershed area that would be addressed by implementing Bayscaping in the recommended neighborhoods.

Table 4-4: Acres of Land Addressed by Bayscaping

Subwatershed	Number of Neighborhoods with Bayscaping Recommended	Acres of Land Addressed	% of Subwatershed Area Addressed
Horsehead Branch	9	506.7	39%
Red Run	23	1,625.9	34%
UGF-B	11	665.7	24%
Roche's Run	12	700.7	46%
UGF-D	20	1,810.1	57%
Total	**75**	**5309.1**	**40%**

Figure 4-8 illustrates the location of neighborhoods recommended for Bayscaping. Out of the 79 neighborhoods assessed, 75 (95%) met the criteria and were recommended for Bayscaping. Table 4-4 shows that a large portion of the total watershed area would be addressed by this action; this is because many of the neighborhoods have a sizeable amount of area available due moderate to large lot sizes in many developments.

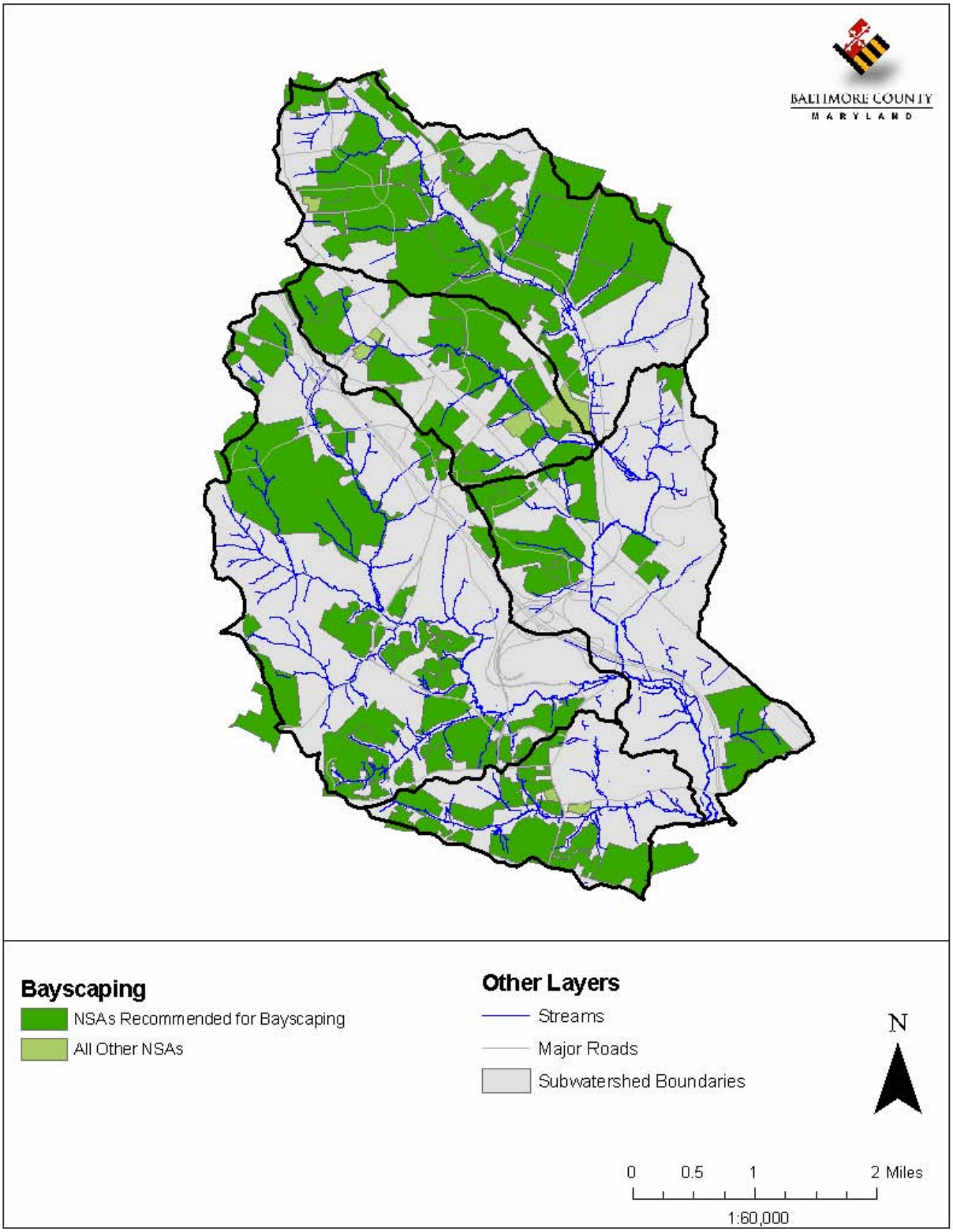

Figure 4-8: Upper Gwynns Falls SWAP Neighborhoods Recommended for Bayscaping

4.2.3.4 Storm Drain Marking

Most of the neighborhoods in the Upper Gwynns Falls watershed have roads with curb and gutter systems including storm drain inlets that convey stormwater runoff quickly and directly to the stream system and ultimately to the Chesapeake Bay. Some neighborhoods have inlets with faded storm drain stenciling but most did not have any indicators that the inlets drain to the Upper Gwynns Falls watershed and eventually the Chesapeake Bay. Since there is little or no infiltration of stormwater in this type of system, there is more potential for pollutants to be carried to the stream system. 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 and where less than 10 percent of the existing inlets were already marked and legible. Table 4-5 includes a summary of the number of neighborhoods recommended for storm drain marking and the number of inlets addressed if this action were initiated by subwatershed. The number of inlets addressed was estimated based on the inlet densities calculated by subwatershed in Chapter 2.3.6. Table 4-5 also lists the percent of the inlets that would be addressed if storm drain marking was implemented in the recommended neighborhoods.

Table 4-5: Number of Inlets Addressed by Storm Drain Marking

Subwatershed	Number of Neighborhoods with Storm Drain Marking Recommended	Acres of Neighborhood Addressed by Storm Drain Marking	% of Subwatershed Addressed by Storm Drain Marking	Approx. # of Inlets Addressed	% of Sub-watershed Inlets Addressed
Horsehead Branch	9	482.3	37%	41	37
Red Run	18	939.7	20%	62	20
UGF-B	10	635.3	23%	61	23
Roche's Run	13	797.8	52%	165	52
UGF-D	21	1,721.7	54%	404	54
Total	**71**	**4,576.8**	**34%**	**731**	**42**

Figure 4-9 illustrates the location of neighborhoods recommended for storm drain marking. Out of the 79 neighborhoods assessed, 71 (90%) met the criteria and were recommended for storm drain marking.

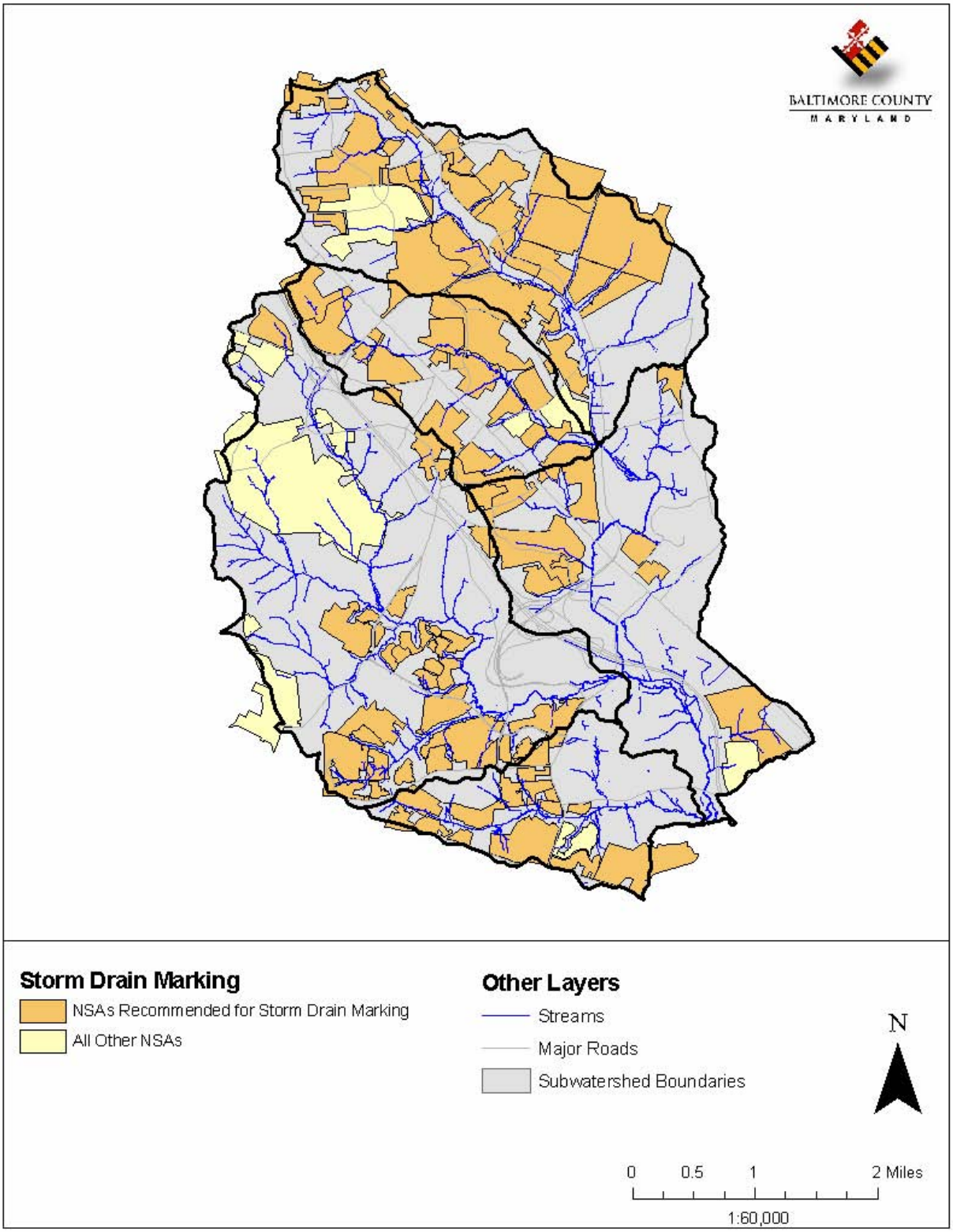

Figure 4-9: Upper Gwynns Falls SWAP Neighborhoods Recommended for Storm Drain Marking

4.2.3.5 Street Trees & Shade Trees

Street trees and shade trees are not only an asset to a neighborhood aesthetically but also provide air and water quality improvements since they intercept precipitation with their leaves and can absorb precipitation and nutrients through their root systems as well as provide shade for thermal benefits. This infiltration of precipitation through leaves or the root system slows overland flow and provides treatment before stormwater runoff reaches the stream system.

Street trees were recommended for neighborhoods where at least 25 percent of the streets had a minimum width of 4 feet of greenspace between the sidewalk and curb and less than 75 percent of these areas had trees planted. The number of trees was estimated based on a spacing of one tree per 15 to 20 feet. Street tree estimates were capped at a maximum of 100 per neighborhood but the potential for more than 100 street trees was noted in these cases.

Neighborhoods where homeowners have large lots with grass cover exceeding 50% were recommended for shade trees to help reduce the amount of turf management required and to benefit the air and biodiversity. In many cases no room exists for street trees but ample space is present for shade trees which would provide similar benefits as explained above. Table 4-6 includes a summary of the number of neighborhoods recommended for street tree and shade tree planting and the number of trees proposed per subwatershed.

Table 4-6: Street Tree Potential by Subwatershed

Subwatershed	Number of Neighborhoods with Street Tree Potential	Number of Neighborhoods with Shade Tree Potential	Number of Street Trees Recommended for Planting	Number of Shade Trees Recommended for Planting
Horsehead Branch	3	7	285	610
Red Run	10	17	470	1050
UGF-B	7	7	350	280
Roche's Run	7	13	545	520
UGF-D	11	18	805	1000
Total	**38**	**62**	**2455**	**3460**

Figure 4-10 illustrates the location of neighborhoods where street trees could be planted. Out of the 79 neighborhoods assessed, 38 (48%) met the criteria and were recommended for street trees and 62 (79%) met the criteria for shade trees. For the most part, neighborhoods not recommended for street trees either did not have sidewalks and a curb and gutter system or there was insufficient greenspace between the sidewalk and curb. There is potential for planting over 2,450 street trees and 3,450 shade trees throughout the watershed.

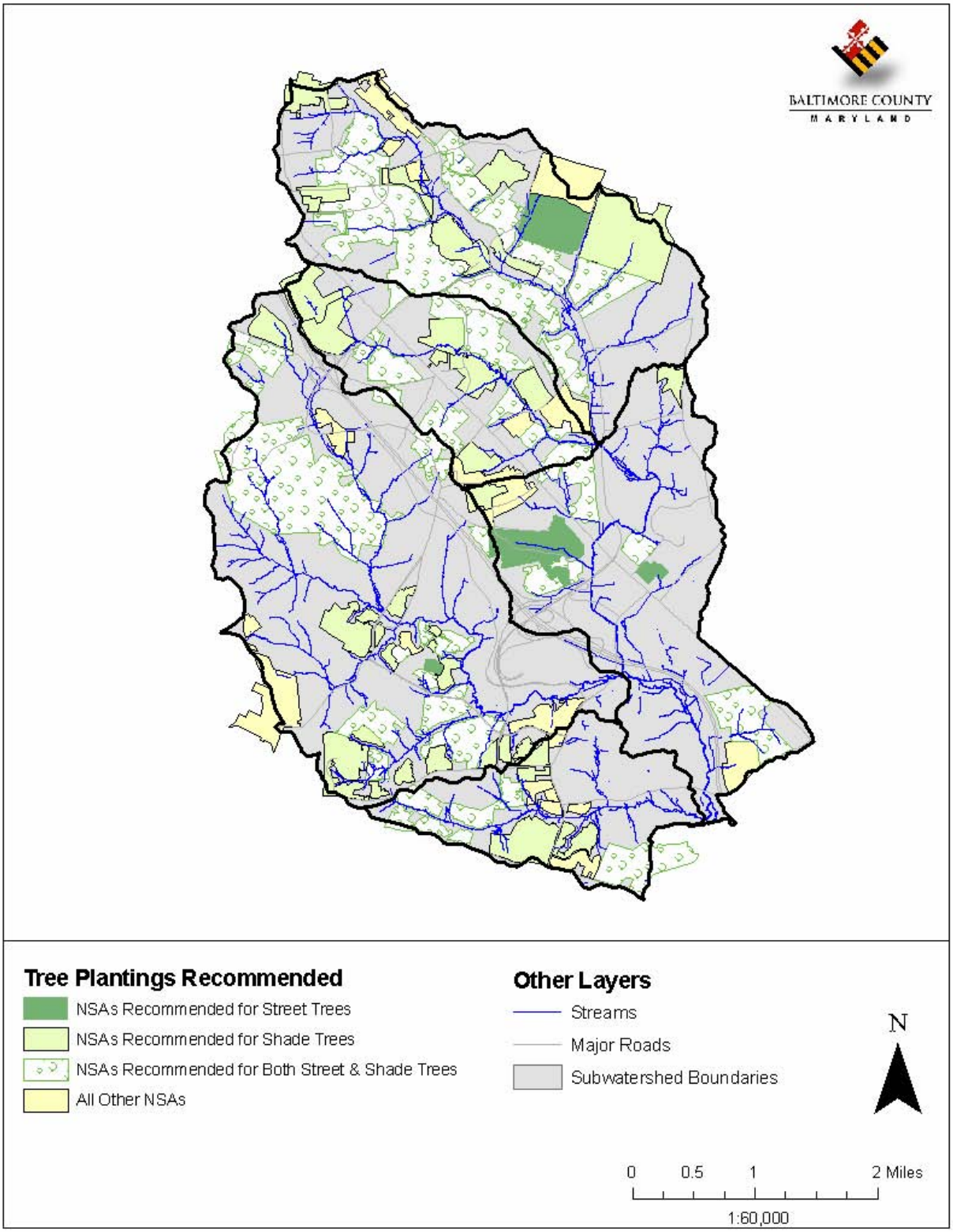

Figure 4-10: Upper Gwynns Falls SWAP Neighborhoods Recommended for Street Trees & Shade Trees

4.2.3.6 Street Sweeping

Street sweeping helps remove trash, sediment and other organic matter such as leaves and grass clippings from the curb and gutter system and prevents them from entering the storm drain system and nearby streams (Figure 4-11). Street sweeping also reduces sediment and other pollutant loads such as oil and metals to the stream system. Excessive organic matter, sediment, and trash can clog streams and the storm drain system resulting in costly maintenance and stream health impairment. Also, higher levels of oxygen than normal are used by the decay of an unbalanced amount of organic matter in a stream which deprives other aquatic life including fish of their oxygen supply. An aggressive street sweeping initiative can ease the effects of a curb and gutter storm drain system on receiving streams.

Neighborhoods where 20 percent or more of the curbs and gutters were covered with excessive trash, sediment, and/or organic matter were recommended for street sweeping (Figure 4-8). Table 4-7 includes a summary of the number of neighborhoods recommended for street sweeping and the miles of street addressed if it was implemented by subwatershed. Miles addressed by street sweeping were estimated using Baltimore County's roads GIS layer and determining the miles of roads within each neighborhood recommended for street sweeping.

Table 4-7: Miles of Road Recommended for Street Sweeping

Subwatershed	Number of Neighborhoods Recommended for Street Sweeping	Miles of Road Recommended for Street Sweeping
Horsehead Branch	2	2.55
Red Run	8	20.20
UGF-B	3	5.76
Roche's Run	6	14.25
UGF-D	8	19.48
Total	**27**	**62.23**

Figure 4-12 illustrates the location of neighborhoods recommended for street sweeping. Out of the 79 neighborhoods assessed, 27 (34%) met the criteria for street sweeping. If initiated, this could address approximately 62 miles of road within all neighborhoods surveyed.

Figure 4-11: Example of a Neighborhood Recommended for Street Sweeping (NSA_V_515)

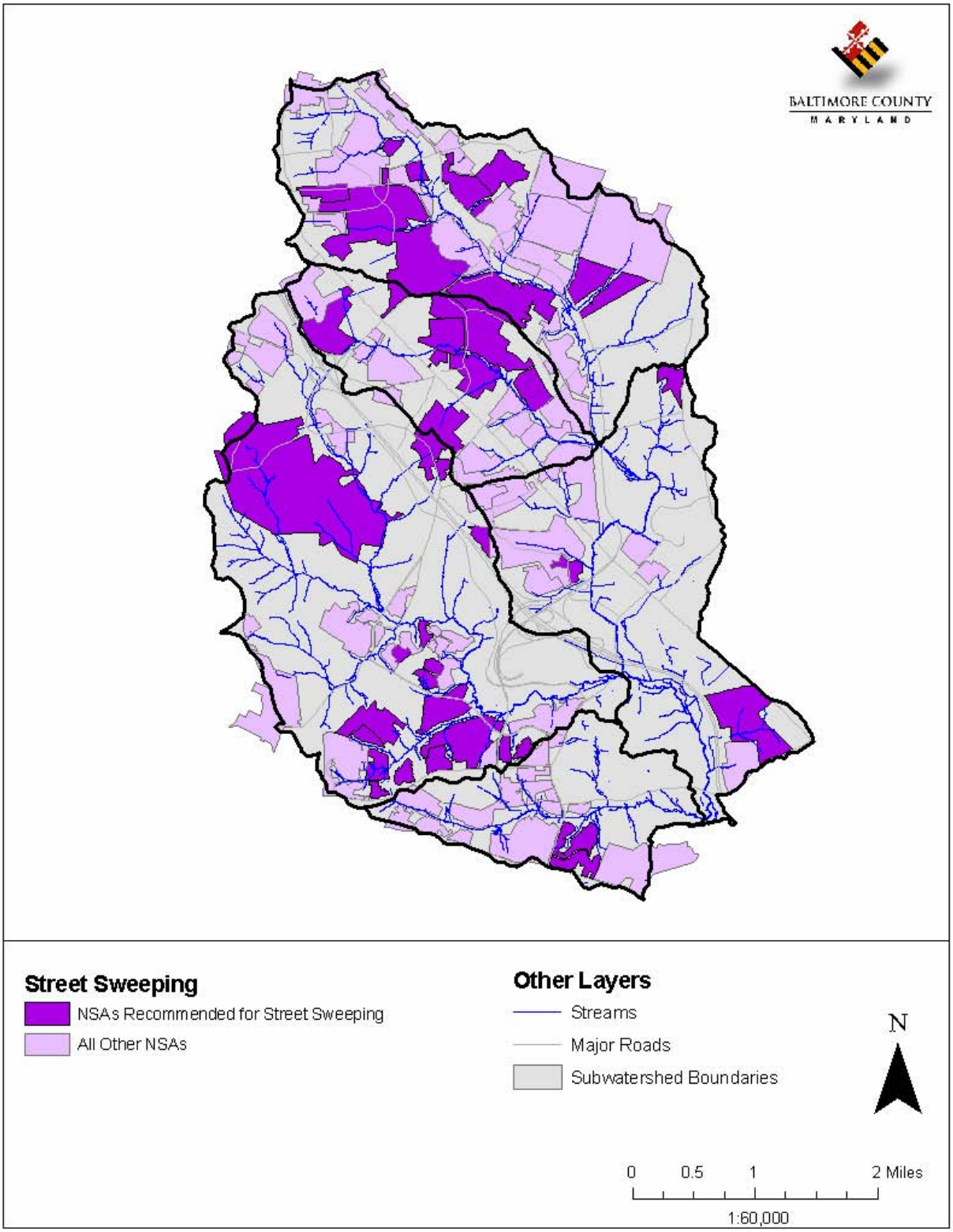

Figure 4-12: Upper Gwynns Falls SWAP Neighborhoods Recommended for Street Sweeping

4.2.3.7 Neighborhood Trash Management

Trash is a concern of citizens in the Upper Gwynns Falls watershed. The watershed survey revealed that some subwatersheds may benefit from trash management initiatives such as community cleanups, trash management awareness, and working with the Department of Public Works (DPW) to implement a bulk trash pick-up program.

Neighborhoods where junk or trash was observed in 25 percent of yards were recommended for trash management initiatives. Neighborhoods with less than 25 percent of yards with junk/trash but had other warning signs such as overflowing dumpsters or dumping in alleys or other common areas were also included. Table 4-8 includes a summary of the number of neighborhoods recommended for trash management initiatives and the acres of land addressed if it was implemented by subwatershed. Table 4-8 also includes a summary of the percent of the total subwatershed area addressed by initiating trash management.

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

Subwatershed	Number of Neighborhoods with Trash Management Recommended	Acres of Land Addressed by Trash Management	% of Subwatershed Addressed by Trash Management
Horsehead Branch	1	39.0	7.5%
Red Run	2	57.0	3.5%
UGF-B	0	0.0	0.0%
Roche's Run	1	50.2	6.3%
UGF-D	1	56.0	2.9%
Total	**5**	**202.2**	**3.7%**

Figure 4-13 illustrates the location of neighborhoods recommended for trash management initiatives. Out of the 79 neighborhoods assessed, 5 (6.3%) were recommended for trash management. If initiated, this could address approximately 4 percent of the total watershed area. While this may only represent a small fraction of the entire watershed, trash management has the potential to address more developed and potential problem areas on the subwatershed scale; for example, targeting neighborhoods in Horsehead Branch and Roche’s Run could potentially address 7% and 6% of these subwatershed areas, respectively.

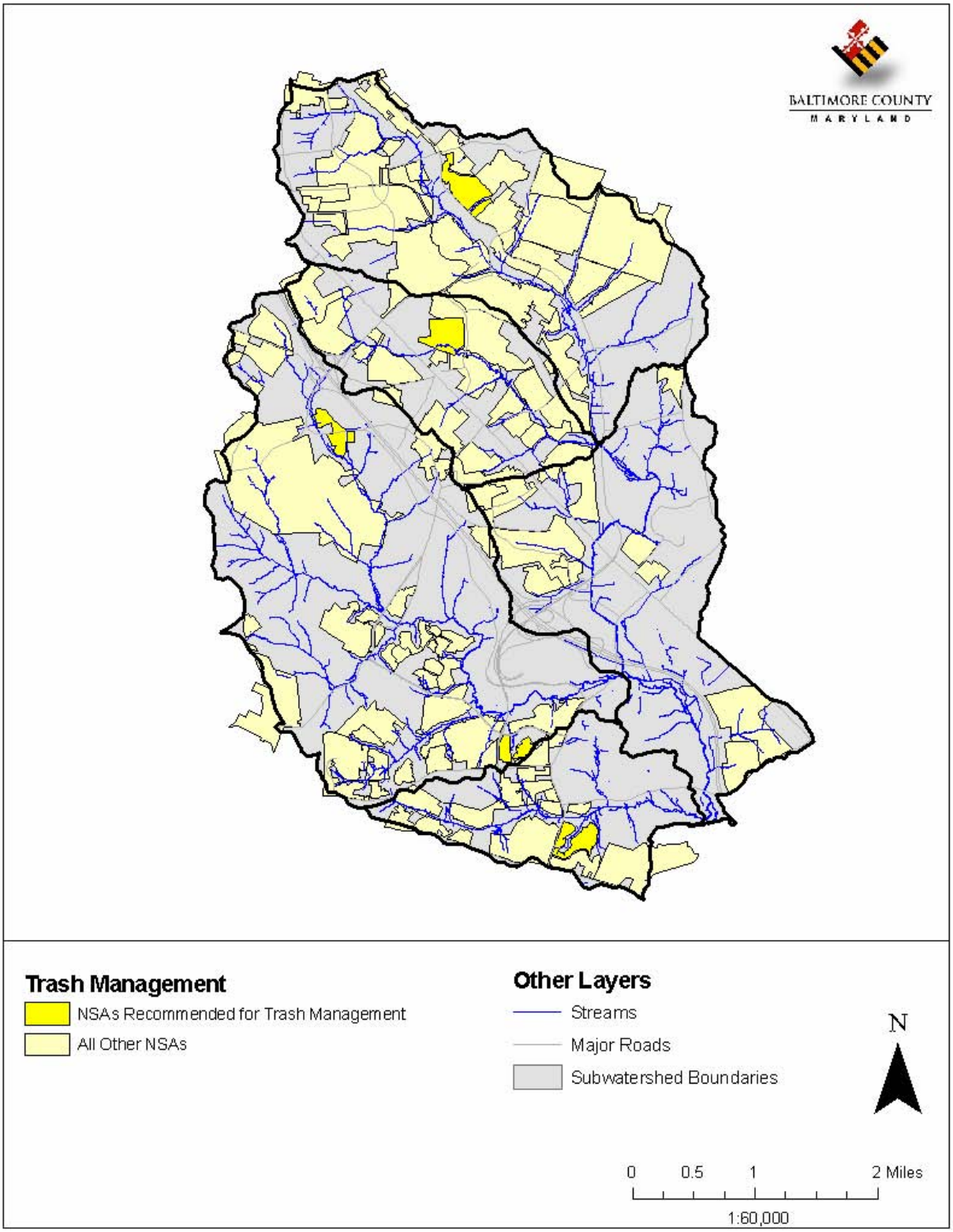

Figure 4-13: Upper Gwynns Falls SWAP Neighborhoods Recommended for Trash Management

4.3 Hotspot Site Investigation (HSI)

Stormwater hotspots are areas that have potential to generate higher concentrations of stormwater pollutants than typically found in urban runoff and/or have a higher risk of spills, leaks, or illicit discharges due to the nature of their operations (CWP 2007). These generally include commercial, industrial, municipal, or transport-related operations. Hotspots are either regulated or unregulated. Regulated hotspots are known sources of pollution that abide by applicable federal or state laws (e.g., NPDES permits). Unregulated hotspots are not regulated and the nature of their operations makes them likely to be potential pollutant sources. Stormwater pollutants generated as a result of hotspot operations depend on the specific activities but typically include nutrients, hydrocarbons, metals, chlorides, pesticides, bacteria, and trash.

Commercial hotspots include a range of businesses and activities but are grouped together in subwatersheds. Operations characteristic of commercial hotspots include waste or wash water generation, outdoor material storage, fuel handling, or auto/boat 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.

Many industrial hotspots are regulated under NPDES industrial discharge permits and include various manufacturing operations such as metal production, chemical manufacturing, and food processing. Industrial operations utilize, generate, handle, and/or store pollutants that can be washed off with stormwater, spilled, or mistakenly discharged into the storm drain. Municipal hotspots typically refer to local government operations such as solid waste, wastewater, road and vehicle maintenance, and yard waste. Like industrial operations, many municipal hotspots are subject to NPDES stormwater permits. Transport-related hotspots normally include areas of significant impervious cover and extensive private storm drain systems. Many are regulated and include uses such as airports, ports, highway construction, and trucking centers.

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

4.3.1 Assessment Protocol

Prior to conducting HSI's in the field, unique ID numbers were assigned to HSIs using the classification scheme "HSI_V_101", where "V" denotes the Upper Gwynns Falls watershed and the first number corresponds to a specific subwatershed with the following two digits assigned sequentially to each HSI as they were assessed. As previously described, subwatersheds were assigned the following unique numbers for the purposes of HSIs, ISIs, and PAAs: (1) Horsehead Branch; (2) Red Run; (3) UGF-B; (4) Roche's Run; and (5) UGF-D.

The Hot Spot Investigation primarily followed the protocols outlined in the Unified Subwatershed and Site Reconnaissance (USSR) (Wright *et. Al.* 2004). This manual is one in a series developed by the Center for Watershed Protection. Stormwater hotspots are classified into four types of operations: commercial, industrial, transport-related and all other operations which

do not meet the first three criteria. The Hot Spot Investigation is used to evaluate the potential of these types of facilities to contribute contaminated runoff to the storm drain system or directly to receiving waters.

While hotspots have unique operations, drainage systems, and pollutant-related risks, stormwater quality problems can be characterized and evaluated by operations and activities common to most hotspots. Per the USSR manual, the HSI involved an evaluation of six common operations at each potential hotspot: vehicle operations, outdoor materials, waste management, physical plant, turf/landscaping, and stormwater infrastructure. The field team investigated the property of each potential hotspot selected for an HSI to determine water quality impacts and restoration opportunities including enforcement measures, follow-up inspections, illicit discharge investigations, retrofits, or pollution prevention planning and awareness. These six categories were used to standardize the HSI process and be able to prioritize potential restoration efforts. Parameters evaluated within each operation category are described briefly below.

Vehicle Operations

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

Outdoor Materials

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

Waste Management

Every hotspot generates waste as a result of daily operations which can be potentially hazardous or a source of stormwater pollution depending on the type of waste and how it is stored. The assessment team noted the type of waste generated (e.g., hazardous, garbage, etc.) and the condition of drums, containers and 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. These activities can be a source of sediment, nutrients, paints, and solvents in stormwater runoff. For each hotspot, the condition of the building itself was evaluated. Stained, dirty, or damaged buildings were noted as potential pollution sources as well as staining or discoloration around the building which is evidence that maintenance activities (e.g., painting, power-washing, resealing, etc.) discharge to storm drains. Similarly, parking lots that were stained, dirty, breaking up, and/or impervious were recorded as potential pollution sources. Downspouts connected to impervious surfaces or the storm drain system were also recorded as pollution sources at a hotspot site. A stain leading to storm drains denoted poor cleaning practices (e.g., for construction activities).

Turf/Landscaping

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

Stormwater Infrastructure

If stormwater treatment practices were not present, this was recorded 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 were identified as potential pollution sources.

For each operation on the HSI field form, there is an observed pollution source box which was checked when there was clear evidence of pollution problems at the time of the investigation. One example was observed at a commercial shopping center while conducting an NSA in UGF B. Grease and other unknown substances were being stored in metal barrels which were actively leaking and not sealed. They were also not stored in a secondary container. This site was revisited for an HSI and marked as an observed pollution source for Outdoor Materials. Each site that was suspected to be a hotspot was visited, inspected, and an HSI assessment form was filled out. With the completed assessment and the hotspot operations evaluated, one or more of the follow-up actions listed below were recommended based on initial field observations:

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

4.3.2 Summary of Sites Investigated

A total of 34 hotspot candidates were investigated in the Upper Gwynns Falls watershed. Most of the sites (28 out of 34) were commercial or industrial establishments with three transport-related sites and three with other classifications. The hotspot candidates included as part of the Upper Gwynns Falls watershed uplands survey are listed in Table 4-9 including site ID, facility name, and subwatershed. Locations and initial hotspot status designations are shown in Figure 4-14. As shown in Table 4-9, 1 hotspot was investigated in Horsehead Branch, 3 in Red Run, 20 in UGF-B and 10 in UGF-D.

Table 4-9: Summary of Hotspot Sites Investigated in the Upper Gwynns Falls

Subwatershed	Commercial or Industrial	Transport-Related	Other	Not a Hotspot	Potential	Confirmed	Severe
Horsehead Branch	1	0	0	0	1	0	0
Red Run	2	1	0	1	1	1	0
UGF-B	16	1	3	0	10	9	1
Roche's Run	0	0	0	0	0	0	0
UGF-D	9	1	0	0	6	4	0
Total	**28**	**3**	**3**	**1**	**18**	**14**	**1**

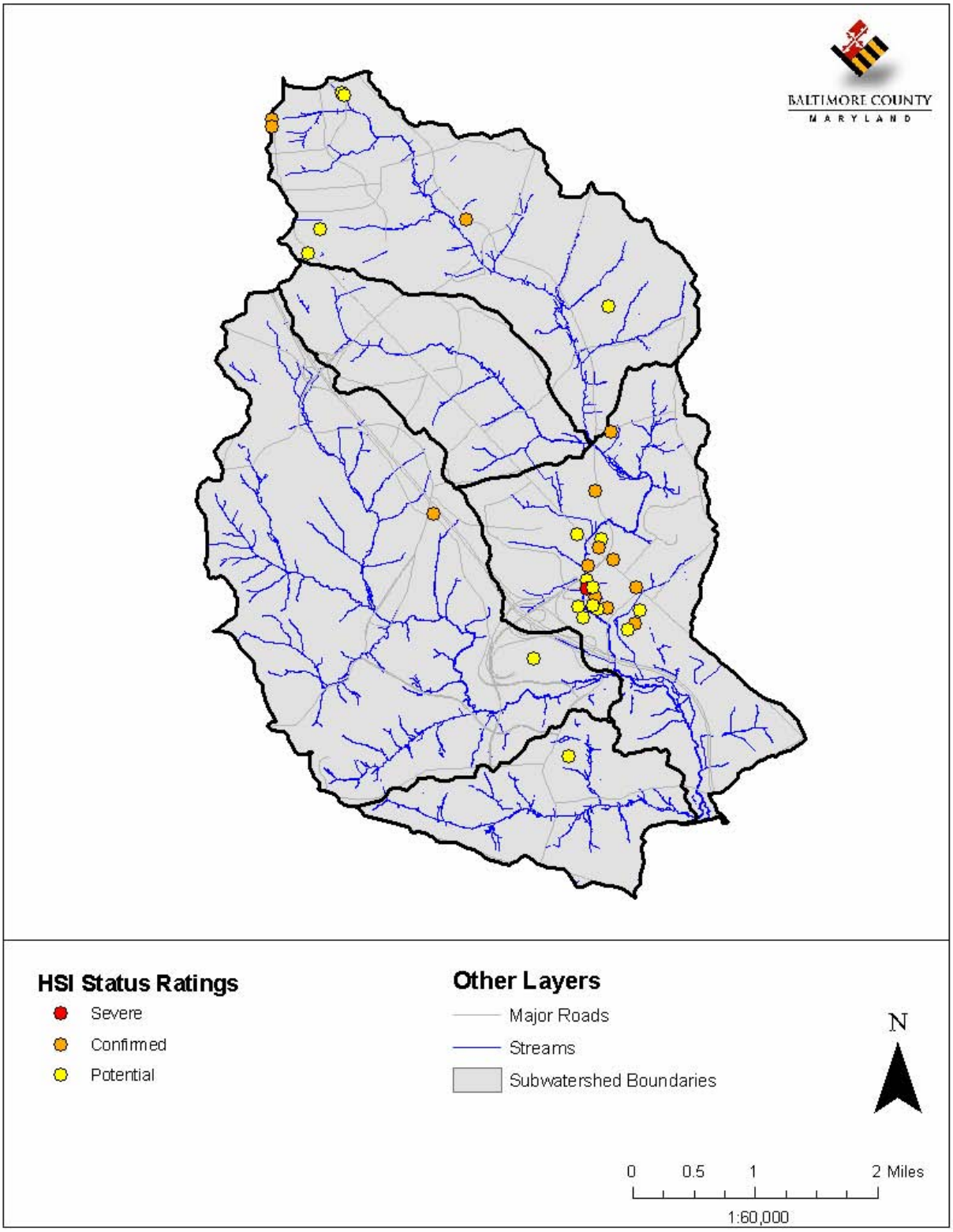

Figure 4-14: Upper Gwynns Falls SWAP Hot Spot Investigation Locations

4.3.3 General Findings

Tables of the recorded HSI results are presented in Appendices A-2 and A-3 including hotspot status, category, pollution sources, and comments regarding hotspot observations. Outdoor storage materials (i.e. loading/unloading areas and storage of materials outdoors uncovered, etc.) and vehicle operations were the most common operations contributing to hotspot stormwater pollution among this sample of hotspot candidates. Waste management was also a common pollutant source at investigated hotspots. Physical plant operations as well as turf/landscaping were marked as pollution sources for one site each respectively. A brief description of the various hotspot categories assessed and general findings are provided below. This includes a description of how the pollution potential for specific sites can be further ranked and prioritized within a specific category.

Commercial

There are several commercial areas within the watershed, each with unique operations and pollution sources. Commercial hotspots were divided into three subcategories based on characteristic operations and pollution sources: auto-related; shopping centers; and abandoned commercial buildings. Each of these is described below.

Auto-related

There are several auto-related commercial establishments throughout the Upper Gwynns Falls watershed including auto repair shops, car dealerships, sales (e.g., car parts, accessories), tire service centers, gas stations, and car washes. The typical sources of stormwater pollution from this category of hotspots include vehicle storage, outdoor materials, physical plant, and waste management operations. Vehicle operations generally include repair, fueling, washing, and storing. Any of these activities can contribute potentially hazardous pollution to the storm drain system if proper housekeeping is not performed or if impervious surfaces lack diversions or treatment for stormwater runoff. In some cases, materials such car parts are stored outdoors. If materials are uncovered and stored on an impervious surface, there is potential for any vehicle related pollutants attached to the materials to be washed off during a storm event into the stream or storm drain system (see Figure 4-15, right). It is also common for impervious surfaces (parking lots) at these types of hotspots to be stained as a result of vehicle operations or outdoor material storage which can also result in pollutants being transported by stormwater runoff. The main recommended action for these types of operations is to include in future awareness efforts explaining proper storage of outdoor materials (covered, store on pallets not directly on pavement), ensure adequate buffer or diversion methods for stream/storm drain system, and incorporate treatment of stormwater runoff where possible. Yet another problem with auto related commercial establishments, or those with any vehicle operations are uncovered gas pumps or fueling stations. As seen in the left photo of Figure 4-15 many smaller commercial sites have uncovered fuel pumps which allow rain to spread the fuel residues into the stormwater system. In the case of HSI_V_319 the rear of this site directly borders Gwynns Falls which means this fueling station is in dire need of cover.

Figure 4-15: Examples of Potential Pollution Sources at Commercial (auto-related) Hotspots (HSI_V_319 and HSI_V_506)

Shopping Centers

There are several commercial shopping center areas within the watershed, each with unique operations and pollution sources. However, waste management and outdoor storage are common sources of pollutants from commercial hotspots. Dumpsters are often located on impervious surfaces at shopping centers and if in poor condition, staining or leaks can contribute pollutants directly into the storm drain system or nearby stream. There is also potential for wind or rain to carry trash from uncovered or overflowing dumpsters to the storm drain (see Figure 4-16). Figure 4-17 shows an example of staining around a dumpster leading to the nearby storm drain system. This is another example of potential for waste management operations awareness.

Figure 4-16: Example of Overflowing Dumpster (HSI_V_308)

Figure 4-17: Pollution Source from Stained Parking Lot/Leaking Dumpster (HSI_V_202)

Abandoned Commercial Buildings

There are several abandoned commercial buildings within the watershed, each with similar pollution sources. However, waste management and outdoor storage are common sources of pollutants from abandoned commercial building hotspots. Although dumpsters are no longer located on site, illegal dumping at the site appears to be frequent. This leads to a large amount of trash and waste entering the storm drain system via inlets on site. There is also potential for wind or rain to carry trash from uncovered areas (see Figure 4-18). In addition to the trash and waste there is a large amount of sediment and organic material that can get into the storm drain system (Figure 4-19). This is another example of potential for waste management operations awareness.

Figure 4-18: Pollution Source from Illegal Dumping (HSI_V_312)

Figure 4-19: Pollution Source from Organic Material, Trash and Sediment (HSI_V_312)

Commercial areas sometimes have areas where materials are stored outside. Similar to the discussion above, if materials are uncovered and on impervious surfaces, runoff from these areas can go directly into the storm drain system along with pollutants. For example, Figure 4-20 shows a storage area in a business center where steel drums are not stored in a secondary container. The steel drums are actively leaking evidenced by the staining on the parking lot. The staining eventually ends at an inlet where the liquids enter the storm drain system. Figure 4-21 shows an outdoor commercial shopping area where pool supplies are stored uncovered. As seen in the photo, large amounts of sediment can be seen leaving the site. Also pictured is an overflowing dumpster.

Figure 4-20: Runoff from Outdoor Material Areas at Commercial Hotspots (HSI_V_202)

Figure 4-21: Potential Pollution Sources at Commercial Hotspots (HSI_V_504 and HIS_V_508))

Diversions to prevent stormwater runoff and trash from discharging directly into the storm drains are one recommended follow-up action for commercial hotpots. Another is to educate store owners about proper waste management and outdoor material storage techniques and conduct follow-up site inspections to enforce these measures. Stormwater management practices should be implemented where possible to treat runoff from the large impervious surfaces often found at commercial shopping centers. As seen on the right photo in Figure 4-21, the sediment and pollution from this outdoor storage is running directly into an inlet.

Transport-Related

Transport-related hotpots generally include large impervious areas and significant amount of vehicle operations. They can also include waste management operations. Examples of a transport-related hotspot in the Upper Gwynns Falls watershed are a medical transport facility and a bus lot. These areas can be potential sources of poor waste management. They can also be sources of potentially hazardous pollutants such as oil and grease from leaking vehicles evidenced by stained parking lot surfaces and chemicals from vehicle washing. At one fleet vehicle commercial site an area where vehicles are washed outdoors without runoff diversion is along the side of the building. Excessive staining was found in the parking lot of a Baltimore County bus lot as a result of storing fleet vehicles that leak (see Figure 4-22 for examples). These sites may be good candidates for stormwater retrofits to treat at least a portion of the runoff from impervious surfaces before reaching the storm drain network. Future awareness efforts such as proper vehicle washing techniques are also recommended.

To further prioritize HSI sites, pollution potential from transport-related hotspots can be ranked as high or low based on the following example criteria:

High pollution potential: Staining of impervious surfaces leading to storm drain inlets or stream; dumpsters in poor condition (leaking, overflowing, uncovered, next to storm drain or stream without diversion)

Low pollution potential: Proper disposal methods; good housekeeping (well maintained parking lot, waste management); stormwater management practices

Figure 4-22: Potential Pollution Sources at Transport-Related Hotspots (HSI_V_303 & HSI_V_502)

Other (Private Residence/Residential Business)

In various parts of the watershed, the assessment team observed storage of construction-related materials/equipment as well as poor waste management adjacent to forested areas and storm drain inlets (Figure 4-23). This was mostly observed in industrial business park areas. Stormwater runoff from these areas would be discharged directly to the storm drain system or forested area and potentially carrying pollutants such as metals, oil and grease, and other harmful chemicals. Storage containers in poor condition (e.g., rusting) and improperly labeled were also noted. These hotspots are recommended for follow-up inspection and future awareness effort. A community-based awareness campaign may be appropriate related to adequate stream buffer and diversion methods.

Figure 4-23: Potential Pollution Sources at Commercial Hotspots (HSI_V_304 & HSI_V_310)

To further prioritize HSI sites, pollution potential from these types of hotspots can be ranked as high or low based on the following example criteria:

High pollution potential: Potentially hazardous materials stored outside, uncovered and near streams without a buffer (e.g., construction materials, heavy machinery)

Low pollution potential: Properly stored and maintained materials (covered, secondary containment for liquid materials); safe distance from stream corridor; vegetated or forested buffer between stream and property

4.4 Institutional Site Investigation (ISI)

The USSR manual does not treat institutional sites as a separate component of the uplands survey; instead, institutions can be assessed using HSI protocols. Consistent with the Upper Back River study, 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 and because institutional areas make up nearly 5 percent of the watershed area. The ISI method was first developed and implemented for the Upper Back River study and was also used for the Upper Gwynns Falls watershed. Institutions surveyed as part of this study include the following types of community-based facilities: schools, cemeteries, faith-based facilities, community centers, municipal facilities (e.g., fire and rescue stations), and care centers (e.g., nursing homes). 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. These were shown and labeled on maps created for NSAs and on larger base maps showing the entire watershed. Institutions were surveyed as encountered in the field during NSA surveys using these maps and list of institutions as guidance. Unique ID numbers were assigned to ISIs using the classification scheme “ISI_V_123”, where “V” denotes the Upper Gwynns Falls watershed and the first number corresponds to a specific subwatershed with the following two digits assigned sequentially to each institutional site as they were assessed. As previously described, subwatersheds were assigned the following unique numbers for the purposes of HSIs, ISIs, and PAAs: (1) Horsehead Branch; (2) Red Run; (3) UGF-B; (4) Roche’s Run; and (5) UGF-D.

The property of an institutional site was visited by the assessment team to collect necessary data and take photographs. Basic information was filled out first including type of institution, address and ownership (public or private). Ownership is important because different approaches may be used to contact private versus public institutions. The ISI assessment form includes many of the pollution source categories used on the HSI form. Some of the restoration opportunities and recommended actions from the NSAs and PAAs are also incorporated into the ISI. The focus of ISIs is to identify pollutions sources, potential restoration opportunities, educate the community and provide water quality benefits. The information collected for each of the pollution source and restoration categories are briefly described below.

Tree Planting

Potential tree planting locations at an ISI site were marked on aerial photographs while examining the property. After reviewing the site, the total number of trees that could be planted at the site was estimated based on a 15- to 20-foot spacing between trees. More accurate numbers can be determined during the post-fieldwork desktop analysis after restoration opportunities have been selected and prioritized.

Exterior

The exterior category is similar to the physical plant category in the HSI assessment, 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 wash water dumping and poor erosion/sediment control, cleaning, or material storage practices for construction activities. Any observations of staining, discoloration, or mop threads around a storm drain inlet indicated a potential pollution source as a result of these activities. Building downspouts that were directly connected to the storm drain system or indirectly connected to impervious surfaces were also recorded as potential pollution sources.

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

Waste Management

Every institution generates waste as a result of daily operations but unlike hotspots, it is typically just garbage. The assessment 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 assessment 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 did not have vehicle operations but a few (including churches and care facilities) did 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. For the most part, it appeared that institutions likely only stored and washed vehicles on-site. Outdoor activities including vehicle storage, repair, fueling, and washing were also noted as potential pollution sources.

Outdoor Materials

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

Turf/Landscaping

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

Stormwater Infrastructure

Teams checked storm drains for markings and for stormwater treatment practices present. These were evaluated for potential pollution sources and restoration potential.

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

- Storm drain stenciling
- Tree planting
- Downspout disconnection
- Stormwater retrofit
- Awareness effort
- Impervious cover removal
- Stream buffer improvement
- Suggest follow-up on-site inspection
- Invasive species removal
- Water pollution prevention plan
- Trash management

4.4.2 Summary of Sites Investigated

A total of 44 institutions were assessed throughout the Upper Gwynns Falls watershed. The number and type of institutions assessed within each subwatershed is summarized in Table 4-10. Note that several faith-based institutions have schools and/or cemeteries associated with them so

they have been double counted in two, or sometimes three, categories. A table of all recorded ISI data can be found in Appendix A-4.

Table 4-10: Institutional Sites by Subwatershed

Subwatershed	Faith Based	Private School	Public School	Municipal Facility	Hospital	Cemetery	Golf Course
Horsehead Branch	3	1	0	0	0	0	0
Red Run	1	2	2	1	0	0	0
UGF-B	4	3	3	1	0	3	0
Roche's Run	2	2	3	0	1	0	0
UGF-D	6	2	2	1	0	1	0
Total	**16**	**10**	**10**	**3**	**1**	**4**	**0**

Figure 4-24 shows the distribution of the various types of institutions assessed throughout the watershed.

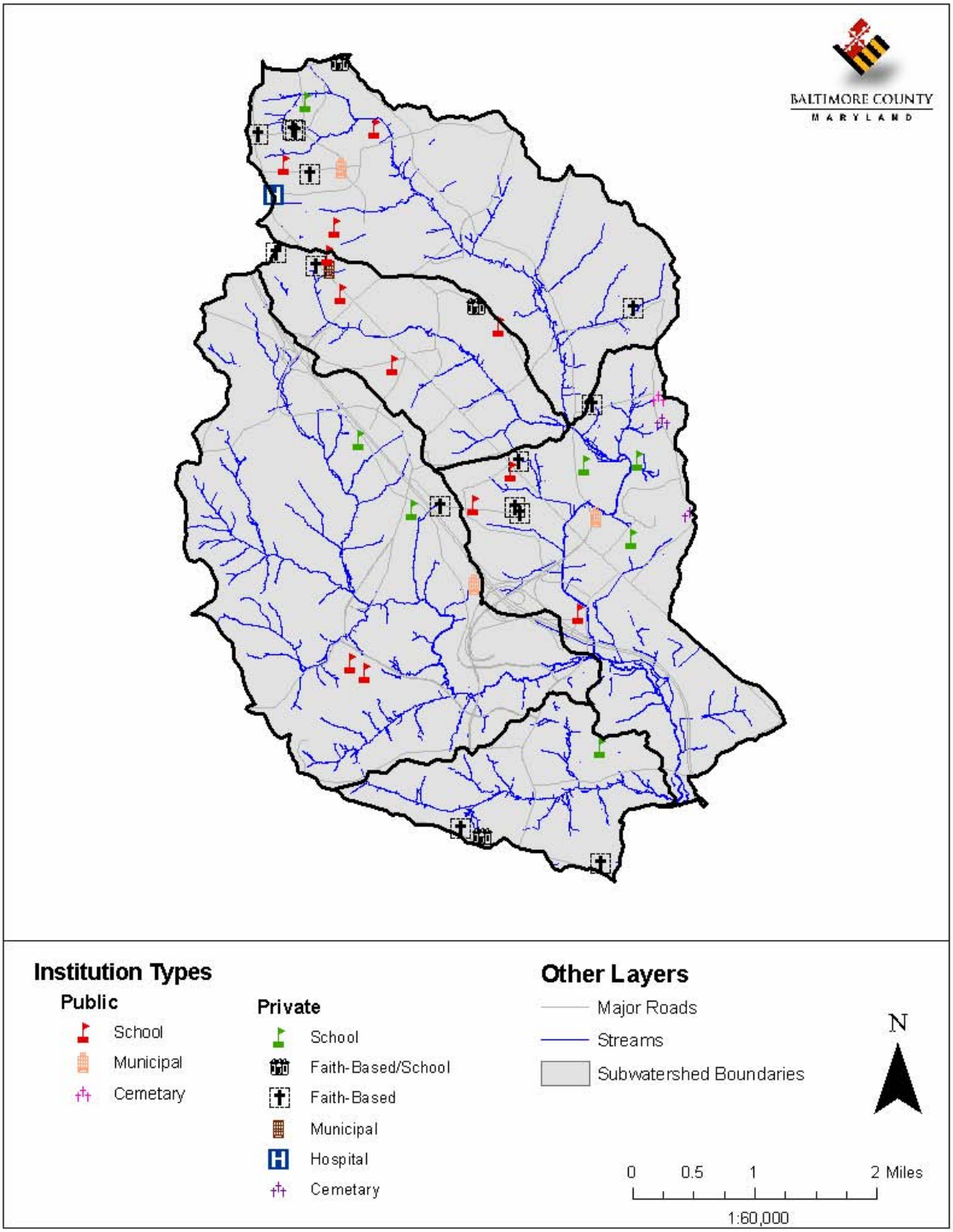

Figure 4-24: Upper Gwynns Falls SWAP Institutional Site Investigation Locations

4.4.3 General Findings

The following subsections describe the actions recommended based on the ISIs. This includes an explanation of the methodologies and criteria used to evaluate the potential for recommended actions and results expected if these actions were applied. Figures showing general locations of ISIs recommended for certain actions are included in each subsection. Appendices 4.4a and 4.4b includes a summary of ISI data collected and specific recommended actions by individual site. Specific recommended actions were grouped into overall action types. The number of the different types of recommended actions for ISIs is summarized in Table 4-11 by subwatershed.

Table 4-11: ISI Recommended Actions by Subwatershed

Subwatershed	Tree Planting	Stormwater Management	Buffer Improvement	Trash Management	Awareness Effort
Horsehead Branch	4	7	0	2	1
Red Run	4	10	0	4	3
UGF-B	8	19	4	6	7
Roche's Run	4	11	0	4	2
UGF-D	6	9	1	5	3
Total	**26**	**56**	**5**	**21**	**16**

4.4.3.1 Tree Planting

It was estimated that a total of 1,296 trees could be planted at institutions located within all of the subwatersheds comprising the Upper Gwynns Falls watershed. Trees were recommended for 26 out of the 44 institutions assessed. Tree planting sites were identified in the field and noted on assessment maps. The number of trees was estimated based on 15- to 20-foot spacing between trees. Table 4-12 represents planning level estimates which would be refined through follow-up site investigations if a site is selected for a restoration/improvement project(s). Like street trees, open space shade trees are not only an asset aesthetically but they also provide air and water quality improvement since they intercept precipitation with their leaves and can absorb precipitation and nutrients through their root systems. This infiltration of precipitation through leaves or the root systems slows flow input and provides some treatment before stormwater runoff reaches the stream system.

Table 4-12: Estimate of Tree Planting for ISIs by Subwatershed

Subwatershed	Number of Institutions with Tree Planting Potential	Number of Street Trees Recommended for Planting
Horsehead Branch	4	255
Red Run	4	150
UGF-B	8	445
Roche's Run	4	220
UGF-D	6	226
Total	**26**	**1,296**

4.4.3.2 Stormwater Retrofits

Stormwater retrofits include several aspects of the assessment. The condition of storm drains, presence and condition of stormwater treatment practices, downspout disconnection opportunities, and impervious cover removal were evaluated by the assessment team at each site. As shown in the table in Appendices 4.4a and 4.4b, a summary of the stormwater management actions that were recommended the most are storm drain marking (21 sites), stormwater retrofits (14 sites), downspout disconnection (14 sites) and impervious cover removal was also recommended (3 sites).

Storm Drain Marking

Most of the ISIs in the Upper Gwynns Falls watershed consist of curb and gutter systems including storm drain inlets that convey stormwater runoff quickly and directly to the stream system and ultimately to the Chesapeake Bay. Since there is little or no infiltration of stormwater in this type of system, there is more potential for pollutants to be carried to the stream system. Storm drain marking indicates that the inlets drain to the Chesapeake Bay; this is a way to educate the community that anything building up 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 water source and eventually the Chesapeake Bay.

Institution sites recommended for storm drain stenciling had curb and gutter systems with inlets appropriate for marking and where less than 10 percent of the existing inlets were already marked and legible. Table 4-13 includes a summary of the number of institutions recommended for storm drain marking and if they are publicly owned or privately owned.

Table 4-13: Summary of Institutions Recommended for Storm Drain Marking

Subwatershed	Storm Drain Marking for Institutions	
	Privately Owned	Publicly Owned
Horsehead Branch	3	0
Red Run	1	3
UGF-B	4	1
Roche's Run	1	4
UGF-D	2	3
Total	**11**	**11**

Stormwater Retrofits

Stormwater retrofits were recommended at 6 public institutions (6 schools) and 9 private facilities (6 faith-based, 3 schools). Stormwater retrofit opportunities included treating runoff from parking lots, inlet retrofits, and conversion of existing pervious area to wetlands. Sites where sufficient pervious area was available to treat a portion of the runoff from an impervious parking lot could implement infiltration/filtration practices such as trenches, basins, or bio-retention that incorporate vegetation and filter media through which storm water infiltrates for pollutant removal prior to groundwater recharge or entering the stream system. Table 4-14

includes a summary of the number of institutions and the acreage recommended for stormwater retrofits and if they are publicly owned or privately owned.

Table 4-14: Summary of Institutions Recommended for Stormwater Retrofits

Subwatershed	Stormwater Retrofits for Institutions			
	Privately Owned		Publicly Owned	
	Opportunities	Acres	Opportunities	Acres
Horsehead Branch	1	1	0	0
Red Run	2	2	3	3
UGF-B	5	5	2	2
Roche's Run	1	1	1	1
UGF-D	0	0	0	0
Total	**9**	**9**	**6**	**6**

Two examples of stormwater retrofit recommendations for parking lots are shown in Figure 4-25. The photo on the left is the private elementary school in UGF-B where a large pervious area is available adjacent to the impervious parking area which is not lined by curbing. This is a good opportunity to address runoff from the parking area. The photo on the right is a parking area at Northminster Presbyterian Church where runoff from the parking lot appears to be causing sediment buildup. A large pervious area adjacent to the parking lot is a good opportunity to address a large amount parking lot runoff.

Figure 4-25: Stormwater Retrofit Opportunities at ISI_V_311 (left) and ISI_V_401 (right)

Bioswale retrofits were recommended for sites with limited pervious area in strips adjacent to impervious areas less than an acre in size. Bioswales provide pollutant removal as well as infiltration through planted vegetation. Bioswales also reduce sediment and flow input into the storm drain system. Figure 4-26 shows examples of sites recommended for this type of stormwater retrofit at a church in Red Run where a bioswale could treat a small parking lot adjacent to the church (left) and in a median of the parking lot at New Town Elementary School (right).

Figure 4-26: Stormwater Retrofit Opportunities at ISI_V_203 (left) and ISI_V_204 (right)

Two schools (1 public and 1 private) have potential for wetland creation as a stormwater retrofit project. At New Town High School, a detention pond was observed next to a parking area and driveway that was grassed with some standing water (see Figure 4-27 left). This site was noted as a good opportunity to convert the existing detention pond to a wetland area which would require less maintenance while providing more water quality benefits such as filtration of stormwater pollutants and wildlife habitat. The McDonogh School, a privately owned institution, also has a detention pond suitable for a wetland creation as it had a considerable amount of standing water at the bottom of the pond (see Figure 4-27 right). Both of these sites represent an awareness opportunity for students and parents about stormwater management and water quality benefits for the Gwynns Falls.

Figure 4-27: Stormwater Retrofit Opportunity for Existing Detention Ponds at ISI_V_205 and ISI_V_104

Downspout Disconnection

As discussed previously, rooftop runoff is managed via downspouts which are considered as either connected or disconnected. Disconnection may involve redirecting connected downspouts from impervious areas or the storm drain system onto pervious areas such as yards and lawns. This requires at least 15 feet of pervious area down gradient from the downspout for infiltration

to occur. Rain barrels and rain gardens are other disconnection options that can be recommended in lieu of redirection if certain conditions exist. Rain barrels, for example, may be used to store rooftop runoff for irrigation if there is limited pervious area available for downspout redirection.

Downspout redirection is recommended for institutions where there is at least 15 feet of pervious area available down gradient from the connected downspout for redirection. Table 4-15 includes a summary of the number of institution sites where downspout disconnection was recommended and if they are publicly owned or privately owned.

Table 4-15: Summary of Institutions Recommended for Downspout Disconnection

Subwatershed	Privately Owned ISI	Publicly Owned ISI
Horsehead Branch	1	0
Red Run	0	1
UGF-B	6	1
Roche's Run	1	2
UGF-D	1	2
Total	**9**	**6**

As discussed previously, impervious surfaces prevent precipitation from naturally infiltrating into the ground. Because runoff from impervious surfaces is often accelerated and concentrated when it reaches the storm drain and stream systems, it can lead to stream erosion, habitat destruction, and water pollution. Removing unused or underutilized impervious surfaces will help increase pervious area and the watershed's capacity for infiltrating and treating stormwater runoff.

Impervious Cover Removal

Impervious cover removal was a recommended action for 3 out of the 42 institutions investigated. It was a recommended action for sites where a considerable impervious area appeared to be abandoned or underutilized such as parking lots, walking paths, and athletic courts. It also included areas where impervious cover was not absolutely necessary and appeared to be damaged (patched, breaking up) such as areas on the side or behind buildings, areas between buildings and parking lots, or areas between walkways/sidewalks. All 3 of the sites recommended for impervious cover removal are privately owned faith-based institutions. The photo in Figure 4-28 (left) shows an impervious area in the back of the faith-based institution that is breaking up and grass growing through it. This indicates that the area is not used frequently or maintained and could potentially be removed to provide greater potential for runoff infiltration.

Inlet retrofits were recommended for sites where bare soil was observed around storm drain inlets on the property. Planting native vegetation around these inlets would help stabilize soil, reduce sediment and flow input into the storm drain system, and provide some infiltration/treatment prior to runoff entering the ground and inlet. Figure 4-28 shows an example of a site recommended for this type of stormwater retrofit at Owings Mills Elementary School in UGF-B. This type of retrofit could also serve as an educational tool since it will be located directly outside of the school.

Figure 4-28: Potential Impervious Cover Removal at ISI_V_101 (left) and Inlet Retrofit Potential at ISI_V_305 (right)

4.4.3.3 Buffer Improvement

As discussed in Chapter 3.7, forested buffer areas along streams are important for improving water quality and flood mitigation since they can reduce surface runoff, stabilize stream banks (root systems), shade streams, remove pollutants such as nutrients and sediment from runoff and provide habitat for various types of terrestrial and aquatic life including fish. Several institutions have streams that run through or adjacent to the property which is a potential opportunity for improving an inadequate stream buffer by introducing native vegetation and trees. Buffer improvement was identified as a recommended action for 4 out of the 42 institutions assessed (3 public schools and 1 privately owned faith based institution). School properties typically represent a unique opportunity to combine restoration projects with awareness explanations for the children. One of the schools recommended for buffer improvement is Owings Mills Elementary School in UGF-B shown in Figure 4-29 below. Runoff from a parking area adjacent to the school is deteriorating the edge of the parking lot. The resulting waste is washing into the stream. A runoff diversion can be created at the edge of the parking lot and buffer enhancement can be planted.

Figure 4-29: Stream Buffer Improvement Opportunity at ISI_V_305

A similar situation exists at the CCBC Owings Mills building in UGF-B. The parking lot does not have curbing so runoff from the parking lot flows directly into the Gwynns Falls. Additional, runoff from the parking lot directed towards an inlet is piped to an outfall into the Gwynns falls without treatment. Pretreatment, perhaps in the form of an underground sandfilter, as well as a buffer planted with native vegetation along the Gwynns Falls have been recommended for this site.

Exotic invasive species could also affect a stream buffer as well as forested areas throughout the watershed. Exotic invasive species are any non-native species that can reproduce aggressively in a range of habitats and have a lack of natural enemies. They cause damage to native plants in the ecosystem by competing directly for resources. Exotic invasive species removal has been recommended for 1 out of 44 institutional sites.

4.4.3.4 Trash Management

Trash management is an area in need of improvement throughout various areas of the watershed including institutions. A total of 21 institution sites (10 public, 11 private) were recommended for trash management action. Waste management awareness is recommended to address leaking dumpsters, open or uncovered dumpsters where trash can leave the site, and dumpster placement near storm drain inlets or streams. For example there is no dumpster onsite at Pleasant AME Church (ISI_V_203) in Red Run. However, there is piled trash and waste dumped around a small storage shed in the back of the property. A dumpster could be placed on site to keep this type of waste from contributing pollutants to the surrounding forested area and from leaving the site with wind or rain. Dumping was also noted at multiple public schools in the watershed including both litter and trash around the dumpster and around the property. This may be addressed through various measures such as a trash campaign, waste management awareness, improving bulk trash pick-up options, and community cleanups.

4.4.3.5 Future Awareness Effort

All of these actions present an opportunity to educate the community about the connection between the storm drain system and the Gwynns Falls and how their actions can impact or improve water quality. The action of future awareness has been recommended for a total of 13 out of 44 institutional sites, 9 of which are privately owned and 4 publicly owned (8 schools, 3 faith-based, 1 cemetery and 1 municipal facility).

A water pollution prevention plan is another tool in making owners aware of how their facility impacts the subwatershed and overall system. A water pollution plan was recommended for 2 public facilities with one of those facilities being adjacent to the Gwynns Falls.

4.5 Pervious Area Assessment (PAA)

PAAs were conducted to identify and evaluate sites within the Upper Gwynns Falls watershed with potential for land reclamation, 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

Large parcels of open land throughout the watershed 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. These were shown and labeled on maps created for NSAs and on larger base maps showing the entire watershed. Upon visiting pervious areas identified in the office, a PAA was conducted if the field team verified the site as having sufficient space and potential for restoration. In some cases, sites were identified for PAAs while surveying other upland areas such as underutilized areas on institutional property and highway medians.

The USSR manual recommends assessing publicly-owned pervious areas greater than two acres and privately-owned areas greater than five acres. Because many of the subwatersheds in Upper Gwynns Falls are highly urbanized, all sites greater than approximately 1 acre were considered for PAAs. Unique ID numbers were assigned to PAAs using the classification scheme "PAA_V_100", where 'V' denotes the Upper Gwynns Falls watershed and the first number corresponds to a specific subwatershed. As previously described, subwatersheds were assigned the following unique numbers for the purposes of HSIs, ISIs, and PAAs: Horsehead Branch (1); Red Run (2); UGF-B (3); Roche's Run (4); UGF-D (5). Pervious areas were numbered sequentially in the order they were surveyed within a particular subwatershed. For example, PAAs in Horsehead would be identified as 101, 102, 103, etc.

The property of a PAA site was visited, investigated and walked by the field team to collect necessary data and take photographs. Basic information was filled out first including site accessibility, ownership, current management, and whether the site was connected to other pervious areas. The area of the site was determined in the office using GIS tax parcel information and aerial photographs. Access to the site is important when considering its restoration potential. The field team checked whether access included foot, vehicle, and/or heavy equipment. A site that can only be accessed by foot may have less potential for restoration if they require greater disturbance or costs to restore (e.g., constructing an access road). Similar to institutions, ownership is important because different approaches may be used to contact private versus public institutions. Current management describes the use of the land and includes the following: school, park, right-of-way, or vacant land.

The presence and type of connected pervious area is also relevant to the ranking of a pervious area. For example, if a site connects forested areas, reforesting the site would help to continue the forested corridor for wildlife habitat or stream buffer purposes. If a site is connected to an existing wetland area, it could be reforested to protect the wetland or revegetated to extend the wetland area. The other data categories assessed are briefly described below.

Current Vegetative Cover

The current vegetative cover was assessed including the portion of the site covered by turf, herbaceous, bare soil, trees, or shrubs. Turf management status was also recorded including turf height, mowing frequency, and condition (e.g., thick, sparse, continuous, etc.) The presence of exotic invasive species was noted including percent of site with invasive species and type.

Impacts

Impacts are assessed to indicate the amount of site preparation required to restore the pervious area. Possible impacts noted include soil compaction, erosion, trash and dumping, and poor vegetative health. Significant impacts from any of these factors will influence site preparation required, types of plants that can survive and success of an implemented project.

Reforestation Constraints

Similar to impacts, information regarding factors that may impede reforestation efforts was collected. The type of sun exposure was recorded as full sun, partial sun, or shade. The field team noted whether there was a nearby water source for supplemental water if necessary. Other constraints related to reforestation that were noted include overhead wires, underground utilities, pavement, and buildings. Private ownership was noted as a potential constraint.

Recommendations for pervious area restoration based on initial field observations included one or more of the following:

- Good candidate for natural regeneration
- May be reforested with minimal site preparation
- May be reforested with extensive site preparation
- Poor reforestation or regeneration site

4.5.2 Summary of Sites Investigated

A total of 10 pervious areas were assessed within the Upper Gwynns Falls watershed totaling 71.8 acres. The following number of PAAs were conducted according to subwatershed: One in Horsehead Branch, two in Red Run, two in Roche's Run and five in UGF-D. Parcel sizes ranged from 0.9 acres to 50 acres with eight out of ten being less than 5 acres in size. All sites surveyed were considered as open pervious cover type. Figure 4-30 shows the location and size of PAAs within the watershed.

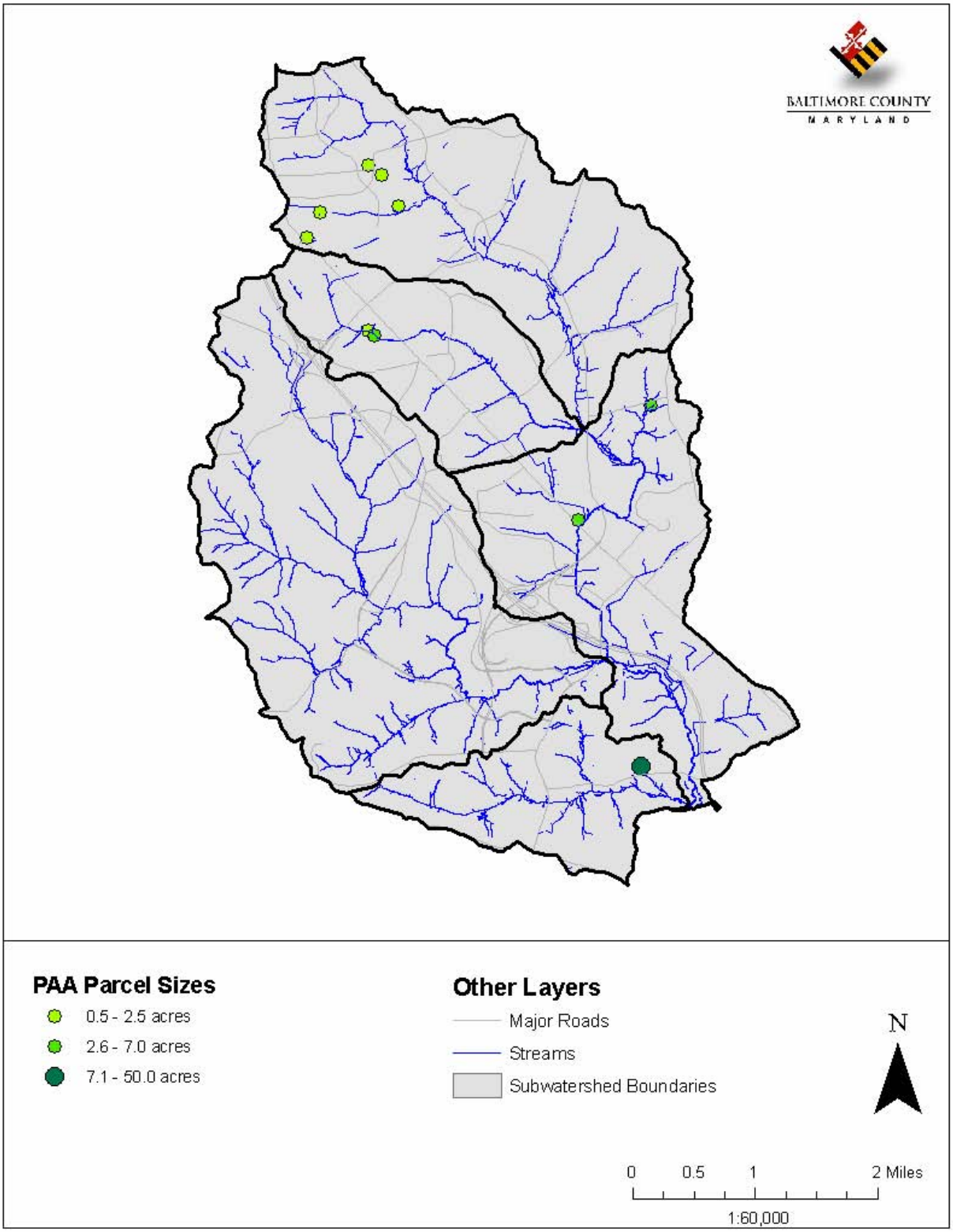

Figure 4-30: PAA Locations

4.5.3 General Findings

A summary of PAA results including parcel size, ownership, management, percent turf cover, and site preparation required for the sites assessed is provided in Table 4-16.

Table 4-16: Summary of PAA Results

Site ID	Acres	Ownership	Management	% Turf	Site Prep
PAA_V_101	50.0	Private	School	85	Minimal
PAA_V_301	6.2	Private	Vacant Land	90	Minimal
PAA_V_302	3.0	Public	Abandoned Mental Institution	90	Minimal
PAA_V_401	0.5	Private	Realty Group	75	Minimal
PAA_V_402	3.9	Public	Baltimore County	65	Minimal
PAA_V_501	0.9	Public	School	90	Minimal
PAA_V_502	1.3	Private	WG Properties	80	Minimal
PAA_V_503	2.3	Public	Vacant Land	75	Minimal
PAA_V_504	1.7	Public	Vacant Land	95	Natural
PAA_V_505	2.0	Private	Realty Group	95	Minimal

The most likely candidates for successful pervious area restoration efforts are those on public lands with minimal site preparation required. Public sites are eligible for tree planting through DNR's "Tree-mendous Maryland" program and are good opportunities for volunteer or community projects. Of the ten sites surveyed, five are under public ownership and were considered to require minimal site preparation or natural regeneration. All ten pervious area sites assessed are briefly described below.

McDonogh School (Horsehead Branch)

McDonogh School is located in Horsehead Branch and is maintained by the school. The open area is approximately 50 acres and consists of mostly turf and a stream with some trees. The area was previously used for horseback riding but due to groundhog holes creating danger to the horses it has become unsafe for riding and is no longer a utilized space. This site is recommended for reforestation with minimal site preparation. This site receives full sun exposure and is easily accessible by foot, vehicle, and heavy equipment. Reforestation of a portion of the site would require verification that it would not interfere with the future use of the site and tree planting could be a potential school project.

Figure 4-31: Photos of McDonogh School - PAA_V_101

Groff & Sons (UGF-B)

Groff & Sons is located in UGF-B. It is easily accessible by foot, vehicle, or heavy equipment. It is mostly covered by turf (90%) with some trees. This site was recommended for reforestation with minimal site preparation based on initial field observations. The site is 6.2 acres and is also a good candidate for natural regeneration. There is a nearby water source with a stream buffer. The area receives full sun. The field team observed a small amount of dumping of yard materials and 2% of invasive species of trees. The current use of the vacant land will need to be discussed with the land owner if the site is selected for potential restoration and/or natural regeneration.

Figure 4-32: Photos of Groff & Sons - PAA_V_301

Rosewood State Center (UGF-B)

Rosewood State Center is located in UGF-B by Crondall Lane. It is easily accessible by foot or vehicle. It is mostly covered by turf (90%) with some trees. This site was recommended for reforestation with minimal site preparation based on initial field observations. The site is 3.0 acres and reforestation is recommended. Reforestation of a portion of the site would require

verification that it would not interfere with the current use of the site and tree planting could be a potential community project. It is yet undecided as to the fate of this state land.

Figure 4-33: Photos of Rosewood State Center - PAA_V_302

Chartley Town Apartments (Roche's Run)

Chartley Town Apartments has a grass area neighboring PAA_V_402 which includes a concrete channel and stream that would be ideal for reforestation with minimal site preparation and stream buffer improvement. The area is only 0.5 acres but it is directly adjacent to a Baltimore County owned parcel in PAA_V_402. If reforestation and buffer improvement work were to be implemented for PAA_V_402 it would be beneficial to the downstream area and could easily be worked on at the same time. The area is 80 percent turf cover with partial sun exposure and easy access by foot, vehicle, and heavy equipment. Some invasive species are present and should also be removed. Because this site is located directly next to PAA_V_402, Baltimore County may be able to work with Chartley Town Apartments for permission to reforest and enhance the stream buffer around the concrete channel.

Figure 4-34: Photo of Chartley Town Apartments - PAA_V_401

Baltimore County Hathaway Park (Roche's Run)

Hathaway Park is located in Roche's Run and is easily accessible by foot, vehicle, or heavy equipment due to a driveway in an easement between adjacent houses (see Figure 4-35). There are low hanging overhead wires that may need to be taken into consideration if heavy equipment is needed on the site. The site is mostly covered by turf (65%) with some birch maple and pine trees, some of which are in poor health. This site is recommended for reforestation and stream buffer enhancement with minimal site preparation based on initial field observations. The site is approximately 3.9 acres with a stream as a nearby water source. The site receives partial sun light. The field team observed trash dumping and a minimal amount of invasive species that should be removed. The current use of this park land will need to be further investigated. With the exception of a small playground, it did not appear as though there are any sports fields located here or any reason why reforestation would not be pleasing to the citizens who make use of this land. The concrete channel and the asphalt path are small constraints and the land must be checked for underground utilities including possible sanitary sewer lines.

Figure 4-35: Photos of Hathaway Park - PAA_V_402

Glyndon Elementary School (UGF-D)

A PAA was conducted for the front lawn area of Glyndon Elementary School, which is approximately 0.92 acres in UGF-D. The median is 95 percent turf cover with full sun exposure and easy access by foot, vehicle, and heavy equipment. This site was recommended for reforestation with minimal site preparation. Because this site is in front of a public school this would be a good candidate for a school program. A possible school program could cover environmental improvements, watershed information and explanations of best management practices with community organizations. This would be a good opportunity for community involvement and awareness.

Figure 4-36: Photo of Glyndon Elementary School - PAA_V_501

605 Main Street (UGF-D)

605 Main Street is located in UGF-D. It is easily accessible by foot or vehicle. It encompasses approximately 1.3 acres and is mostly covered by turf (80%) with some trees and 5% bare soil. This site was recommended for reforestation with minimal site preparation based on initial field observations. There is a nearby water source and the area receives full sun. The current use of the vacant land will need to be discussed with the land owner if the site is selected for restoration.

Figure 4-37: Photos of 605 Main Street - PAA_V_502

Gwynnwest Road Grass Lot (UGF-D)

The Gwynnwest Road grass lot is located in UGF-D. It is publicly owned land that is easily accessible by foot, vehicle and also has heavy equipment access. It encompasses approximately 2.3 acres and is covered mostly by turf (75%) with many trees (20%) and some shrubs (5%). The majority of the trees are of Ash, Saw Tooth Oak and Sweet Gum varieties. The lot has thick turf which is kept at three inches and was seeing being mowed during the assessment. There are signs up around the lot that read "No Baseball or Softball Playing". It appears that this vacant use is not being used for any recreation and it would be a good location for potential reforestation with the partial sunlight it receives. Underground utilities may be a possible constraint and their location must be verified.

Figure 4-38: Photos of Gwynnwest Rd. Grass Lot - PAA_V_503

Glynlee Court Grass Lot (UGF-D)

The Glynlee Court grass lot is located in UGF-D. It is publicly owned land that is easily accessible by foot and vehicle. It encompasses approximately 1.7 acres and is covered mostly by turf (95%) with a few trees (4%) and some shrubs (1%). The lot has clumpy/bunchy turf which receives frequent mowing. There were noticeable amounts of lawn clippings being dumped on this lot. The area receives full sun but there were no nearby sources of water. This vacant lot is a good candidate for natural regeneration.

Figure 4-39: Photos of Glynlee Ct. Grass Lot - PAA_V_504

Chartley Shopping Center (UGF-D)

The Chartley Shopping center property is located in UGF-D. It is privately owned land that is easily accessible by foot, vehicle and heavy equipment access is available. The property encompasses approximately 14.9 acres total which includes the shopping center facilities and grass lots. The grass lot to the east of the shopping facility is roughly 2.0 acres and this is the specific area which was assessed as a pervious area. The area is covered mostly by turf (95%) with a few trees (3%) and some bare soil (2%). Continuous cover of one inch high grass turf covers the site and some storm drains are present. This area could be a candidate for reforestation with minimal site preparation but it might be more beneficial to perform a storm water management retrofit in the area. Transforming the grass lot to a forested area or a retrofitted storm water management facility would benefit the area and increase aesthetics for nearby apartment complexes.

Figure 4-40: Photos of Chartley Shopping Center - PAA_V_505

CHAPTER 5

RESTORATION OPTIONS

5.1 Introduction

This chapter presents an overview of the key management practice recommendations for the Upper Gwynns Falls watershed. These practices are geared toward restoring degraded resources in urban/suburban watersheds. The chapter is divided into five sections: Municipal Capital Programs, Municipal Management Programs, Volunteer Restoration Programs, Business and Institutional Initiatives, and Citizen Awareness Activities. These groups were separated based on the scale for implementation and the controlling organization. The municipal programs are county wide and implemented individually or collaboratively by multiple county agencies. Comparatively, the volunteer and many of the awareness programs are at a community or neighborhood scale and oversight is by a non-government organization. Business and institutional efforts are at a site-specific scale and implementation is most effective when oversight is with the property owner.

5.2 Municipal Capital Programs

5.2.1 Stormwater Management

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

5.2.1.1 Detention Pond Conversion

Dry detention ponds are typically designed for flood control and have little pollutant removal capacity. These facilities have the greatest potential for conversion to a facility type with greater pollutant removal efficiency. Current stormwater facilities are designed to capture and retain stormwater runoff and allow enough detention time for sediments and pollutants to settle out, while also providing flood control if necessary.

5.2.1.2 Stormwater Retrofits

The developed nature of the watershed provides limited potential for implementing new stormwater storage projects other than converting existing stormwater ponds. Where space exists between an outfall and the stream channel, retrofits such as floodplain wetlands and energy dissipation devices are considered. Floodplain wetlands can provide treatment of storm flows prior to entering the stream channel. Energy dissipation devices can reduce stream power, and thus erosive forces of storm flows, prior to entering the stream channel.

Curb and gutter systems consist of numerous inlets, pipes, and outfalls. While the curb and gutter system removes stormwater quickly from roadways, it delivers increased runoff volumes and untreated pollutants to receiving water bodies. One way to address these potential water quality issues is to install proprietary Best Management Practices (BMPs) at selected storm drain inlets. Various structural BMPs are commercially available and include catch basin inserts, water quality inlets, oil/grit separators, filtering devices and hydrodynamic devices. Proprietary BMPs are designed to address specific pollutants such as floatables and solid waste, nutrients, metals, sediment and oil/grease. Most are helpful for removing a portion of pollutants for pretreatment when used in conjunction with another BMP type such as an infiltration trench or a grassed swale for filtering pollutants upstream of an inlet. While proprietary devices can be costly, they are water improvement alternatives for areas where there is inadequate space for other stormwater management options. Selection of inlets for proprietary devices is based on the county's outfall screening program and stream corridor assessments.

5.2.1.3 Parking Lot/Alley Retrofits

In areas with limited space available for installing stormwater treatment, parking lots and alleyways can sometimes present an opportunity. Alleys can be re-surfaced with pervious pavement or retrofitted with pervious grass strips down the middle or perpendicular filter strips. Parking lots sloping towards an adjacent pervious area can be retrofitted to have their runoff directed to these pervious areas rather than flowing directly to the storm drain system.

5.2.2 Stream Corridor Restoration

Stream corridor restoration practices are used to enhance the appearance, stability, and aquatic function of urban stream corridors. The practices range from simple stream repairs such as vegetative bank stabilization and localized grade control, to comprehensive repair applications such as full channel redesign and re-alignment. Stream repair practices are often combined with stormwater retrofits and riparian management practices to meet subwatershed restoration objectives.

Channel redesign follows natural channel design techniques and is utilized to stabilize eroded, degraded stream banks and to protect infrastructure such as private property, buildings and utilities. Stabilizing the stream channel improves water quality by preventing eroded soils, and the pollutants contained in them, from entering the stream. In addition, protecting infrastructure such as sewer and storm drain pipes reduces and/or eliminates water quality impacts associated with leaking sewer pipes and manholes. Where conditions allow, reconnecting the stream to its floodplain provides additional water quality benefits.

5.2.3 Reforestation Buffers & Open Space

The Community Reforestation Program (CRP) was established by DEPRM 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 10,000 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.

5.3 Municipal Management Programs

5.3.1 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 coincides with things like trash pickup days or seasonal changes such as leaf litter in the fall and more frequent lawn care activities by residents in spring and summer.

5.3.2 Inlet Cleaning

The Baltimore County storm drain system consists of approximately 388 miles of storm drainpipe, 14,400 inlets, and 3,460 outfalls. In order to keep the entire system clean of trash, debris, and sediment, the Department of Public Works maintains three storm drain cleaning vehicles and employs three crews of two men each on a daily basis to clean 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.

5.3.3 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 composed entirely of stormwater are either permitted by 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. This program allows citizens to adopt a stream, which includes tracking the health of the stream and reporting problems or potential problems they observe.

Routine outfall screenings for detection of illicit connections compliment citizen complaints 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 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.

5.3.4 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. Post construction follow-up inspections review the stream buffers, forests, tidal shoreline and stormwater facilities before a development project is released for occupancy. The following are the current regulatory programs used during the development and redevelopment plan review process and follow-up inspections.

5.3.4.1 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 provisions for expansion of the riparian buffer for steep slopes, wetlands and floodplains. Development plans must minimize road crossings, have stormwater management facilities and outfall 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 design considerations are an attempt to maintain the integrity of the riparian buffer.

5.3.4.2 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. DEPRM 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 activity requiring an application for a subdivision, grading permit or sediment control permit on areas 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.

5.3.4.3 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.

5.3.4.4 Groundwater Management

The Groundwater Management Section within DEPRM is charged with the responsibility of managing and protecting the groundwater resources of Baltimore County. The Groundwater Management section 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.

5.3.4.5 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). Baltimore County implements stormwater management as a critical companion to riparian buffers. The control of erosive flows through stormwater management augments the riparian forest buffer in the protection of natural resources.

5.3.4.6 Erosion and Sediment Control

Baltimore County has delegated authority from the Maryland Department of the Environment to enforce the State Erosion and Sediment Control Program. The main function of the Erosion and Sediment Control 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. The standard plan for erosion and sediment control is used for residential construction activity disturbing less than 30,000 square feet and for all other construction activity disturbing less than 20,000 square feet.

5.3.5 Trash and Recycling

5.3.5.1 Single Stream Recycling

Baltimore County began Single Stream Recycling in 2010. All recyclables (plastics, glass, metals, paper, and cardboard) are collected co-mingled by the curbside each week. Under this program, recycling rates increased as a result of a greater number of accepted materials, convenience of only needing one bin, and weekly pickup. Recycling saves energy, helps protect natural resources, and reduces air and water pollution.

5.3.5.2 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, DEPRM holds two one-day collection events annually, in the spring and fall, at different locations around Baltimore County.

5.3.6 Pollution Prevention: Public Lands Management

Certain county owned facilities require an NPDES Industrial Stormwater Discharge General Permit. DEPRM assists other county agencies in fulfilling the requirements of this permit. DEPRM reviews with the agency the information needed to complete a Notice of Intent form. If required, a Pollution Prevention Plan is prepared by the agency and maintained on file at the building site. DEPRM provides the agency with a template for the preparation of the pollution prevention plan and assists with the preparation of maps and geographic and monitoring data.

Certain county facilities also prepare spill prevention and response plans, which describe operational procedures to reduce spill risks and ensure that proper controls are in place when they do occur. Spill prevention plans standardize everyday procedures and rely heavily on employee training and education. The investment is a good one for most operations, since spill prevention plans reduce potential liability, fines and costs associated with spill cleanup.

Baltimore County agencies continue to reduce the amount of fertilizers, pesticides and deicing materials used on county properties. Agencies collect statistics for usage of these materials and report them in the county's annual NPDES report. Golf courses are consistently the biggest users of fertilize and pesticides. Logically, because of its responsibility to clear roads, the Department of Public Works – Bureau of Highways remains the biggest user of deicing materials.

5.4 Volunteer Restoration Programs

5.4.1 Stream Watch Program

The Stream Watch Program is intended to develop citizen stewardship through participation of citizen volunteers in the program who actively assume the role of caring for segments of the stream network by observing changes in the system, by 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 by Stream Watch participants.

5.4.2 Downspout Disconnection

In addition to road runoff, rooftops also contribute stormwater directly into streams. Many downspouts are connected directly to the stormdrain system through underground pipes, others are funneled toward driveways and sidewalks, which then are connected to the street. By

redirecting downspouts to a pervious area, this additional runoff is allowed to filter across pervious areas such as gardens and lawns. The use of rain barrels for the collection and reuse of the runoff is a highly sustainable practice, and is effective even if there is limited space on the property. Additional treatment can be achieved by directing the runoff into a raingarden instead of lawn. Raingardens are simply gardens that are comprised of native perennials and shrubs that are compatible with wet soils. A downhill area that naturally collects rain is an ideal location for a rain garden.

5.4.3 Street Trees

Street trees improve air quality, catch precipitation with their leaves and absorb precipitation and nutrients through their root systems. Street trees can be planted where there is suitable distance between the sidewalk and road. Real estate values frequently are higher when a neighborhood is beautified with trees.

5.4.4 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 generally the highest priority in terms of improving the infiltration and recharge functions, however other techniques such as soil aeration, amendments, and establishing native plantings or meadows also serve a higher function than turf grass. Priority sites have little evidence of soil compaction, invasive plants, and trash/dumping, and can be reforested with minimal site preparation.

5.4.5 Stream Clean Ups

Stream cleanups are a simple practice used to enhance the appearance of the stream corridor by removing unsightly trash, litter, and debris. Cleanups are commonly conducted by volunteers and continue to be one of the most effective outlets for generating community awareness and involvement in watershed activities.

5.4.6 Pet Waste Stations

Pet waste is one of the contributors of bacteria to streams. 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.

5.4.7 Storm Drain Marking

Most of the developed areas in urban/ suburban watersheds have curb and gutter systems, including storm drain inlets that convey stormwater runoff quickly to the stream system, and ultimately to the Chesapeake Bay. Since there is little or no infiltration of stormwater in a curb and gutter system, there is a direct discharge of pollutants to the stream system. Citizens can walk through their neighborhood and adhere markers directly on top of the storm drain inlets.

This may help remind their neighbors of the direct connection with their local streams and the Chesapeake Bay.

5.5 Business and Institutional Initiatives

5.5.1 Impervious Cover Removal

Unused or unmaintained impervious surfaces with the potential for removal were identified at several institutions, mostly on school properties. At sites where parking lots may be larger than necessary, portions of the impervious cover could be removed and reforested or converted to bio-retention areas for treating stormwater runoff from the remaining impervious surfaces.

5.5.2 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 filtering of runoff, while still allowing for the same amount of parking spaces.

5.5.3 Open Space Planting

An increasing number of public and private schools show interest in adopting conservation landscaping principles. This begins primarily by removing unused turf areas on their schoolyard campuses. 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 stormwater runoff and can increase energy efficiency.

5.5.4 Pollution Prevention: Private Lands Management

Most commercial and industrial facilities require an NPDES Industrial Stormwater Discharge General Permit. This permit requires the business to inform the Maryland Department of the Environment (MDE) about activities on their property that may adversely affect stormwater runoff. The property owner is required to submit to MDE a Notice of Intent which provides general information about the location of the site and the pollution generating activities at the property. It may be required that a Pollution Prevention Plan (PPP) be prepared and maintained on file at the building site. A PPP outlines staff responsibilities in the event of an emergency resulting in potential toxic discharge to stormwater. There is also an outline of good house keeping and best management practices to prevent contaminants from leaving the site.

5.6 Citizen Awareness Activities

Residents and businesses engage in behaviors and activities that can negatively influence water quality, including over-fertilizing lawns (Figure 4-3), 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 a specific message that promotes behavior changes. 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.

5.6.1 Stormwater Runoff

A survey was conducted in 2004 regarding people's knowledge about stormwater. It concluded that even people who want to improve stormwater runoff, don't realize how they adversely impact it. Storm drain marking is a way to educate residents about the connection between the street inlets and the streams. Neighbors that read the message will understand that trash and lawn clippings that build up along the curbs and gutters will be washed away after a storm event and end up in their local stream and the bay.

5.6.2 Pet Waste/ Bacteria Awareness

DEPRM, in collaboration with other county agencies, is developing an awareness campaign for better pet waste management. Additional sites for installation of pet waste stations are to be identified.

5.6.3 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 on total nitrogen to stormwater can be achieved through careful fertilizer management, or better yet, by going organic. Homeowners should be reminded to follow the application instructions so that it is applied in the correct amount, during the right season, and 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.

5.6.4 Trash and Recycling

5.6.4.1 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 waste collection is reduced. Use of compost is an environmentally friendly way of improving soil and avoids chemical application of fertilizer.

5.6.4.2 Cleaner Greener Campaign

In the 13 county designated Commercial Revitalization Districts, a trash awareness campaign will employ billboards and labels on trash cans stating for example, “Cleaner Greener Liberty Road” as a reminder to dispose of trash properly.

5.6.4.3 Stewardship Projects

DEPRM provides assistance in planning and advertising local stewardship projects such as Project Clean Stream, hosted by the Alliance for the Chesapeake Bay.

5.6.4.4 Reuse Directory

Online and in print, this is a directory of reuse organizations for Baltimore County residents and businesses. It lists all 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. Published by the Baltimore County Bureau of Solid Waste Management.

5.6.4.5 The Re-Source Newsletter

Baltimore County's solid waste reduction, reuse, recycling, and refuse disposal newsletter with information pertaining to recycling, waste prevention, special events, and more. Published quarterly on the web.

5.6.5 Conservation Landscaping

Numerous water quality benefits are achieved from converting turf into landscaping and through increasing the urban tree canopy. DEPRM promotes the Tree-Mendous MD tree program and offers no-cost delivery of the trees to communities that make a request. DEPRM created the Growing Home campaign, which is a partnership between the county and retail nurseries to promote the planting of trees on private land. This program offers citizens a $10 coupon toward the sale of a tree that is valued at $25 or greater. The cost of the coupon is shared between the county and the local nursery.

DEPRM promotes invasive removal, turf reduction and conservation landscaping. When planning a landscape, homeowners are encouraged to use native plants, which reduce the need for watering, are adaptive to this climatic region and are more pest resistant. Incorporating these sustainable landscaping practices into a garden’s design can increase wildlife habitat and create a healthier home site.

5.6.6 MD Green School Award

Baltimore County uses *The Maryland Green School Awards Program* to provide a framework for integrating environmental learning and community involvement in local schools. DEPRM supports workshops and site-based meetings for teachers and provides local and regional resources to enhance staff development opportunities and increase the environmental awareness and interest of local school principals, teachers, and facilities managers. A requirement of each

Green School is to demonstrate Best Management Practices at their site. These may include: water conservation, energy conservation, solid waste reduction, and habitat restoration using the school grounds.

APPENDICIES:

UPLAND SURVEY DATA

Appendix 4–1 NSA Data

Neighborhood ID	PSI	ROI	Downspout Redirect	Rain Barrel	Rain Garden	Storm drain Stenciling	Bayscaping	Lot Forest Canopy Cover	Fertilizer Reduction	High Maintenance Lawns (%)
NSA_V_101	Moderate	High		X		X	X	X	X	20
NSA_V_102	High	Moderate	X	X		X	X	X	X	80
NSA_V_103	Moderate	High					X	X	X	80
NSA_V_104	High	Moderate				X		X	X	50
NSA_V_105	Moderate	Moderate				X	X	X	X	80
NSA_V_106	Moderate	Moderate				X	X	X		5
NSA_V_107	Moderate	Moderate				X	X	X	X	100
NSA_V_108	Moderate	Moderate		X		X	X	X	X	80
NSA_V_109	Moderate	Moderate		X		X	X	X		15
NSA_V_110	High	Moderate				X	X	X		10
NSA_V_201	Moderate	Moderate	X			X	X	X	X	100
NSA_V_202	High	Moderate		X		X	X	X		0
NSA_V_203	Moderate	Moderate		X		X	X	X	X	100
NSA_V_204	High	High	X	X		X	X	X	X	100
NSA_V_205	Moderate	Moderate	X	X	X	X	X	X		5
NSA_V_206	High	High	X	X	X	X	X	X	X	80
NSA_V_207	Moderate	High	X	X	X	X	X	X		10
NSA_V_208A	Moderate	High	X	X		X	X	X	X	60
NSA_V_208B	Moderate	Moderate	X	X		X	X	X	X	20
NSA_V_209	Moderate	Moderate		X	X	X	X	X		0
NSA_V_210	Moderate	Moderate	X	X		X	X	X	X	100
NSA_V_211	Moderate	Moderate	X	X		X	X	X		0
NSA_V_212	Moderate	Moderate	X	X		X	X	X	X	100
NSA_V_213	Moderate	Moderate		X		X	X	X	X	90
NSA_V_214	High	Moderate	X	X		X	X	X	X	50
NSA_V_215	High	Moderate		X	X		X			0
NSA_V_216	High	Moderate		X	X		X		X	60
NSA_V_217	Moderate	Moderate			X		X			0
NSA_V_218	Moderate	High	X	X	X	X	X	X		0
NSA_V_219	High	Moderate		X	X		X			0
NSA_V_220	Moderate	Moderate		X	X	X	X	X	X	80
NSA_V_221	Moderate	High	X	X	X	X	X	X		0
NSA_V_301	Moderate	Low		X	X		X			0
NSA_V_302	High	High	X	X		X	X	X		0
NSA_V_303	High	Moderate	X	X		X	X	X	X	50
NSA_V_304	Moderate	Moderate		X		X	X	X		0
NSA_V_305	Moderate	Moderate		X	X	X	X	X		0
NSA_V_306	Moderate	Moderate				X	X	X	X	70
NSA_V_307	Moderate	Moderate		X	X	X	X			10
NSA_V_308	High	High	X	X		X	X	X	X	100
NSA_V_309	Moderate	Moderate	X			X	X	X	X	50
NSA_V_310	Moderate	Moderate		X	X	X	X			0
NSA_V_311	Moderate	Moderate				X	X	X	X	90

Appendix 4–1 NSA Data (cont.)

Neighborhood ID	PSI	ROI	Downspout Redirect	Rain Barrel	Rain Garden	Storm drain Stenciling	Bayscaping	Lot Forest Canopy Cover	Fertilizer Reduction	High Maintenance Lawns (%)
NSA_V_401	Moderate	Moderate		X		X	X	X		10
NSA_V_402	Moderate	High		X		X	X	X		
NSA_V_403	Moderate	Moderate				X	X	X		0
NSA_V_404A	Moderate	Moderate	X	X		X	X	X	X	80
NSA_V_404B	Moderate	Low		X	X					0
NSA_V_405	Moderate	Moderate				X	X	X	X	25
NSA_V_406	Moderate	Moderate				X	X	X		
NSA_V_407	High	Moderate				X	X	X	X	50
NSA_V_408	High	Moderate				X	X	X		10
NSA_V_409	Moderate	Moderate		X	X	X	X	X		0
NSA_V_410	Moderate	Moderate		X		X	X		X	20
NSA_V_411	Moderate	Moderate	X			X		X		10
NSA_V_412	High	High	X			X	X	X	X	80
NSA_V_413	Moderate	Moderate		X		X	X	X	X	60
NSA_V_501	Moderate	Moderate	X	X		X	X	X	X	90
NSA_V_502	Moderate	High		X		X	X	X		5
NSA_V_503	Moderate	High		X		X	X	X		0
NSA_V_504	Moderate	Moderate	X	X		X	X	X	X	100
NSA_V_505	Moderate	Moderate	X	X			X			5
NSA_V_506	Moderate	Moderate				X	X	X		0
NSA_V_507	Moderate	Low				X		X	X	100
NSA_V_508	Moderate	Moderate			X	X	X	X		0
NSA_V_509	High	Moderate		X		X	X			5
NSA_V_510	Moderate	Moderate				X	X	X		0
NSA_V_511	High	High	X			X	X	X		0
NSA_V_512	Moderate	Moderate		X	X	X	X	X		0
NSA_V_513	Moderate	Moderate		X	X	X	X			0
NSA_V_514	Moderate	Moderate		X		X	X	X		10
NSA_V_515	High	High				X	X	X		10
NSA_V_516	Moderate	Moderate		X	X	X	X	X	X	60
NSA_V_517	Moderate	Moderate		X		X	X	X	X	50
NSA_V_518	Moderate	Moderate		X		X	X	X		0
NSA_V_519	Moderate	Moderate		X		X	X	X	X	50
NSA_V_520	High	Moderate		X	X	X	X		X	80
NSA_V_521	Moderate	Moderate		X	X	X	X	X	X	50
NSA_V_522	High	Moderate		X	X	X	X	X	X	80

Appendix 4–1 NSA Data (cont.)

Neighborhood ID	Trash Management	Street Trees	Open Space Trees	Street Sweeping	Total Acres	Average Impervious Cover per Lot (%)	Pond Maintenance Retrofit
NSA_V_101		100	200		131.5	29	X
NSA_V_102		0	0	X	30.8	32	
NSA_V_103	X	0	30	X	39.0	55	X
NSA_V_104		0	0		14.6	33	X
NSA_V_105		0	50		97.2	25	
NSA_V_106		0	0		28.6	35	
NSA_V_107		0	50		14.5	25	
NSA_V_108		35	100		95.2	35	
NSA_V_109		100	160		48.7	30	
NSA_V_110		0	20		21.2	32	
NSA_V_201		0	0		67.6	29	X
NSA_V_202	X	0	80	X	23.4	35	
NSA_V_203		0	30		15.0	44	
NSA_V_204		40	40	X	148.9	52	X
NSA_V_205		0	150	X	60.0	65	
NSA_V_206		0	100		96.2	31	X
NSA_V_207		40	40	X	59.7	40	X
NSA_V_208A		20	40	X	32.5	42	X
NSA_V_208B		30	30		17.2	50	X
NSA_V_209		30	0	X	72	33	
NSA_V_210		0	60		37.2	45	
NSA_V_211		20	20		7.8	46	
NSA_V_212		0	0		11.6	65	
NSA_V_213		0	40		34.4	44	
NSA_V_214		0	20		70.0	53	X
NSA_V_215		0	0		143.7	5	
NSA_V_216		100	300	X	606.2	5	
NSA_V_217	X	0	0		33.6	25	
NSA_V_218		20	10	X	14.4	30	X
NSA_V_219		30	40		64.3	5	
NSA_V_220		0	30		45.6	21	
NSA_V_221		40	20		20.2	19	X
NSA_V_301		0	0		50.4	10	
NSA_V_302		100	100	X	133.0	50	X
NSA_V_303		10	30		33.5	31	
NSA_V_304		30	20	X	16.8	45	
NSA_V_305		100	0		148.8	10	
NSA_V_306		0	30		33.7	35	
NSA_V_307		0	0		85.2	10	
NSA_V_308		60	40	X	89.3	40	
NSA_V_309		30	40		31.0	50	
NSA_V_310		20	0	X	18.5	25	
NSA_V_311		0	10		25.5	20	

Appendix 4–1 NSA Data (cont.)

Neighborhood ID	Trash Management	Street Trees	Open Space Trees	Street Sweeping	Total Acres	Average Impervious Cover per Lot (%)	Pond Maintenance Retrofit
NSA_V_401		0	40		34.4	49	X
NSA_V_402		100	80	X	104.0	31	X
NSA_V_403		30	20		28.4	18	
NSA_V_404A		40	20		11.0	25	
NSA_V_404B		0	0		86.0	10	
NSA_V_405		40	20		17.1	27	
NSA_V_406		0	20	X	41.0	40	X
NSA_V_407		0	60	X	71.6	38	X
NSA_V_408	X	0	35	X	50.2	35	
NSA_V_409		100	50	X	123.7	30	
NSA_V_410		100	20		58.1	33	
NSA_V_411		10	25		17.2	32	X
NSA_V_412		0	90	X	74.0	50	X
NSA_V_413		0	40		81.2	35	X
NSA_V_501		30	45		69.5	28	
NSA_V_502		100	15	X	149.1	23	X
NSA_V_503		100	100	X	162.1	19	X
NSA_V_504		0	120		79.7	42	
NSA_V_505		100	40	X	188.0	18	
NSA_V_506		20	40		19.0	23	X
NSA_V_507		0	20		9.6	32	
NSA_V_508		0	30	X	29.1	17	
NSA_V_509		100	40		143.6	18	X
NSA_V_510		0	30		25.2	23	
NSA_V_511		0	0	X	27.8	57	X
NSA_V_512		0	40		62.9	23	
NSA_V_513		0	0		65.8	10	
NSA_V_514		25	20		37.0	27	X
NSA_V_515	X	10	60	X	56.0	40	X
NSA_V_516		0	30	X	51.0	23	
NSA_V_517		100	50		121.1	28	
NSA_V_518		0	20		26.0	60	X
NSA_V_519		30	0		1312	19	X
NSA_V_520		0	0		114.0	8	
NSA_V_521		0	300		252	14	
NSA_V_522		50	40	X	90.0	24	

Appendix 4–2 HSI Data – Category and Status

Hotspot ID	HSI Category			HSI Status			
	Commercial or Industrial	Transport-Related	Other	Not a Hotspot	Potential	Confirmed	Severe
HSI_V_101	X				X		
HSI_V_201	X				X		
HSI_V_202	X					X	
HSI_V_203		X		X			
HSI_V_301	X					X	
HSI_V_302	X					X	
HSI_V_303		X				X	
HSI_V_304	X					X	
HSI_V_305			X		X		
HSI_V_306	X				X		
HSI_V_307	X				X		
HSI_V_308	X					X	
HSI_V_309	X				X		
HSI_V_310	X					X	
HSI_V_311	X				X		
HSI_V_312			X			X	
HSI_V_313	X					X	
HSI_V_314	X				X		
HSI_V_315	X				X		
HSI_V_316			X		X		
HSI_V_317	X						X
HSI_V_318	X				X		
HSI_V_319	X					X	
HSI_V_320	X				X		
HSI_V_501	X					X	
HSI_V_502		X			X		
HSI_V_503	X				X		
HSI_V_504	X					X	
HSI_V_505	X					X	
HSI_V_506	X					X	
HSI_V_507	X				X		
HSI_V_508	X				X		
HSI_V_509	X				X		
HSI_V_510	X				X		
Total	**28**	**3**	**3**	**1**	**18**	**14**	**1**

Appendix 4–3 HSI Data – Observed Pollution Sources

Hotspot ID	Vehicle Operations	Outdoor Storage Materials	Waste Management	Physical Plant	Turf / Landscaping
HSI_V_101					X
HSI_V_201*					
HSI_V_202		X	X		
HSI_V_203			X		
HSI_V_301		X			
HSI_V_302		X	X		
HSI_V_303	X				
HSI_V_304	X	X			
HSI_V_305*					
HSI_V_306*					
HSI_V_307*					
HSI_V_308		X			
HSI_V_309*					
HSI_V_310	X	X	X		
HSI_V_311*					
HSI_V_312			X	X	
HSI_V_313	X				
HSI_V_314*					
HSI_V_315			X		
HSI_V_316*					
HSI_V_317		X	X	X	
HSI_V_318			X		
HSI_V_319		X			
HSI_V_320*					
HSI_V_501	X	X			
HSI_V_502	X				
HSI_V_503*					
HSI_V_504		X			
HSI_V_505		X			
HSI_V_506	X	X			
HSI_V_507*					
HSI_V_508			X		
HSI_V_509*					
HSI_V_510			X		
Total	**7**	**12**	**10**	**2**	**1**

*** No visible pollution sources were observed at these sites**

Appendix 4–4 ISI Data – Retrofit Recommendations

Institution ID	Type	Public or Private	NMP	Tree Planting	Stormwater Retrofit	Storm Drain Marking	Downspout Disconnection	Impervious Cover Removal	Stream Buffer Improvement
ISI_V_101	Faith-Based	Private		1				1	
ISI_V_102	Faith-Based	Private		1		1		1	
ISI_V_103	Faith-Based	Private		1		1			
ISI_V_104	School	Private		1	1	1	1		
Total Horsehead Branch			**0**	**4**	**1**	**3**	**1**	**2**	**0**
ISI_V_201	School	Private		1					
ISI_V_202	School	Private		1	1	1			
ISI_V_203	Faith-Based	Private			1				
ISI_V_204	School	Public		1	1	1			
ISI_V_205	School	Public		1	1	1			
ISI_V_206	Municipal Facility	Public			1	1	1		
Total Red Run			**0**	**4**	**5**	**4**	**1**	**0**	**0**
*ISI_V_301	Cemetery	Public							
ISI_V_302	Cemetery	Private		1					
ISI_V_303	School	Private	1	1		1			
ISI_V_304	Faith-Based	Private	1	1	1	1	1		
ISI_V_305	School	Public		1	1		1		1
ISI_V_306	Faith-Based	Private		1	1		1		
ISI_V_307	Faith-Based	Private			1		1		
ISI_V_308	Faith-Based	Private			1		1		
ISI_V_309	School	Public			1				1
ISI_V_310	Cemetery	Private					1		
ISI_V_311	School	Private	1	1	1	1	1		
ISI_V_312	School	Public		1		1			1
ISI_V_313	School	Private		1		1			
ISI_V_314	Municipal Facility	Public							
Total UGF-B			**3**	**8**	**7**	**5**	**7**	**0**	**3**
ISI_V_401	Faith-Based	Private		1	1		1		
ISI_V_402	Hospital	Private							

Appendix 4-4 ISI Data – Retrofit Recommendations (cont.)

Institution ID	Type	Public or Private	NMP	Tree Planting	Stormwater Retrofit	Storm Drain Marking	Downspout Disconnection	Impervious Cover Removal	Stream Buffer Improvement
ISI_V_403	School	Public		1		1			
ISI_V_404	School	Public		1		1			
ISI_V_405	School	Public			1	1	1		
ISI_V_406	Faith-Based/School	Private		1				1	
ISI_V_407	Municipal Facility	Private				1			
ISI_V_408	School	Public				1	1		
Total Roche's Run			**0**	**4**	**2**	**5**	**3**	**1**	**0**
ISI_V_501	Faith-Based	Private		1					
ISI_V_502	Faith-Based	Private		1					
ISI_V_503	School	Public		1		1			
ISI_V_504	School	Public		1		1	1		
ISI_V_505	School	Public					1		
ISI_V_506	School	Private				1			
*ISI_V_507	Faith-Based/School	Private							
ISI_V_508	Faith-Based	Private		1					
ISI_V_509	Faith-Based	Private					1		
ISI_V_510	Faith-Based	Private		1		1			1
ISI_V_511	Municipal Facility	Public				1			
ISI_V_512	Faith-Based	Private				1			
Total UGF-D			**0**	**6**	**0**	**5**	**3**	**0**	**1**
TOTAL WATERSHED			**3**	**26**	**15**	**23**	**15**	**3**	**4**

*** ISI_V_301 and ISI_V_507 had no retrofits recommended**

Appendix 4–4 ISI Data – Retrofit Recommendations (cont.)

Institution ID	Invasive Species Removal	Trash Management	Future Awareness Effort	Follow Up On Site Visit	Water Pollution Prevention Plan	Other
ISI_V_101						
ISI_V_102		1				
ISI_V_103		1				
ISI_V_104			1			Move diesel fuel under cover
Total Horsehead Branch	**0**	**2**	**1**	**0**	**0**	**1**
ISI_V_201						
ISI_V_202		1	1	1		
ISI_V_203		1		1		
ISI_V_204		1	1			
ISI_V_205		1	1			Install trash cans onsite for litter
ISI_V_206						Follow up to see if SWM treatment is provided
Total Red Run	**0**	**4**	**3**	**2**	**0**	**2**
*ISI_V_301						
ISI_V_302						
ISI_V_303			1			
ISI_V_304			1			
ISI_V_305		1	1	1		
ISI_V_306			1	1		
ISI_V_307						
ISI_V_308		1				
ISI_V_309	1	1		1	1	
ISI_V_310			1			
ISI_V_311		1	1	1		
ISI_V_312		1				
ISI_V_313		1		1		
ISI_V_314						
Total UGF-B	**1**	**6**	**6**	**5**	**1**	**0**
ISI_V_401						
ISI_V_402		1				
ISI_V_403		1				

Appendix 4–4 ISI Data – Retrofit Recommendations (cont.)

Institution ID	Invasive Species Removal	Trash Management	Future Awareness Effort	Follow Up On Site Visit	Water Pollution Prevention Plan	Other
ISI_V_404		1				Fix parking lot
ISI_V_405		1				
ISI_V_406						
ISI_V_407			1			
ISI_V_408			1			
Total Roche's Run	**0**	**4**	**2**	**0**	**0**	**1**
ISI_V_501						
ISI_V_502		1	1			Fix parking lot and wash building
ISI_V_503						
ISI_V_504		1				
ISI_V_505		1				
ISI_V_506		1				
*ISI_V_507						
ISI_V_508		1				
ISI_V_509						Extend downspouts to grass, The church is about to rebuild / new construction
ISI_V_510						Install rain gardens on upper east side
ISI_V_511					1	remove trash/garbage from around storage shed
ISI_V_512					**1**	Fix Driveway
Total UGF-D	**0**	**5**	**1**	**0**	**2**	**5**
TOTAL WATERSHED	**1**	**21**	**13**	**7**	**3**	**9**

*** ISI_V_301 and ISI_V_507 had no retrofits recommended**

APPENDIX F:

Gwynns Falls Watershed Quality Management Plan

Gwynns Falls Water Quality Management Plan

Chapters 1 through 7

Prepared for: **Baltimore City Department of Public Works**
Bureau of Water & Wastewater
Water Quality Management Section

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October 2004

TABLE OF CONTENTS

Executive Summary……E-1

CHAPTER 1

1.1 Study Objective & Site Description …… 1
1.2 Project Description …… 1
1.3 Watershed Characterization …… 2
1.4 Watershed Management Plan Organization …… 30

CHAPTER 2

2.1 Watershed Simulation …… 31
2.2 SWMM Model Development …… 33
2.3 SWMM Model Calibration …… 51
2.4 SWMM Flow Modeling Results …… 65
2.5 Water Quality Results …… 68
2.6 Erosion Ratio Analysis …… 73
2.7 SWMM Modeling Discussion …… 80

CHAPTER 3

3.1 Cruised Research Assessment …… 84
3.2 Corps Reaches …… 102
3.3 Preparation of Database and Mapping ……103
3.4 Stream characterization …… 108

CHAPTER 4

4.1 Introduction …… 109
4.2 Methodology …… 110
4.3 Results ……112
4.4 Recommendations ……115

CHAPTER 5

5.1 Existing Facilities and Outfalls ……119
5.2 Stormwater Management Facility Survey ……121
5.3 Storm Drain outfall Survey…… 130
5.4 Watershed Summary …… 141

CHAPTER 6

6.1 Identification of Water Quality Problems …….. 143
6.2 Water Quality Summary ……..…… 234

CHAPTER 7

7.1 Introduction …….. 239
7.2 Development of Watershed and Subwatershed Goals ……..…… 239
7.3 Identification of Potential Project Sites …….. 242
7.4 Prioritizing Capital Projects …….. 253
7.5 Recommended Management Measures ……..… 259
7.6 Joint City-Council Projects …….. 260
7.7 Watershed Management Plan Summary …….. 261

LIST OF APPENDICES

Appendix A-1: Watershed Characterization
- Baltimore City NPDES Permits

Appendix A-2A: SWMM Modeling
- Gwynns Falls Catchments by Subshed
- Catchment Identifiers by Subshed
- SWMM Modeling Layout
- Catchment Characteristics
- Stream Network Characteristics
- Storm Drain Characteristics

Appendix A-2B
- Landuse by Subwatershed – Existing, Ultimate, Difference
- DCIA – Existing, Ultimate, Figures
- DCIA – Existing, Ultimate, Tables

Appendix A-2C
- Pollutant Loading by Subshed – Total Loads, Existing
- Pollutant Loading by Subshed – Baseflow Loads, Existing
- Pollutant Loading by Subshed – Total Loads, Ultimate
- Pollutant Loading by Subshed – Baseflow Loads, Ultimate
- Pollutant Loads by Landuse by Subshed – Existing
- Pollutant Loads by Landuse by Subshed – Ultimate
- Annual Loading Plots by Node
- Loading Characteristics by Land Use
- Loading Characteristics by Node – Existing & Ultimate Development, Difference between two simulations

Appendix A-2D
- Pollutant Loading by Subshed – with sewage leaks, Existing Condition
- Pollutant Loading by Catchment - with sewage leaks, Existing Condition

- Annual Loads due to Sewage by Catchment

Appendix A-2E

- Discharge versus Percent of Time by Subshed
- Discharge Duration versus Cumulative Percent of Time by Subshed
- Log Pearson III Flood Frequency Analysis by Subshed

Appendix A-2F

- EMC's for Metals by Subwatershed

Appendix A-2G

- Erosion Ration Analysis – Pre-Colonial Condition by Catchment
- Erosion Ration Analysis – Pre-Colonial Condition versus Existing Conditions by Catchment
- Erosion Ration Analysis – Pre-Colonial Condition versus Ultimate Development Conditions by Catchment

Appendix A-3: Stream Assessment

- Stream Reach Assessment, Subwatershed Mapping

Appendix A-4: Forest Assessment

- Level IV Rapid Field Assessment Data Sheets
- Forest Assessment Mapping by Subwatershed
- Forest Assessment Results by Subwatershed

Appendix A-5: Stormwater Management Assessment

- Baltimore City SWM Facilities
- Baltimore County SWM Facilities
- Baltimore County SWM Facilities - Changes from Database
- Baltimore City Storm Drain Outfalls
- Baltimore County Storm Drain Outfalls
- Baltimore County Storm Drain Outfalls - Changes from Database
- Baltimore City SWM Facilities - Results
- Baltimore County SWM Facilities - Results
- Baltimore City Storm Drain Outfalls – Results Grouped By Subwatershed
- Baltimore County Storm Drain Outfalls - Results Grouped By Subwatershed
- Baltimore County Storm Drain Outfalls - Results Grouped By Project Type

Appendix A-6: Watershed Assessment

- Data CD and Access Databases

Appendix A-7: Proposed Projects

- Proposed Project Mapping
- Proposed Project Descriptions

EXECUTIVE SUMMARY

Study Objectives & Site Description 3
Study Tasks 4
Watershed Characterization 4
Baltimore City Subwatersheds 4
Baltimore City and Baltimore County Subwatersheds 5
Baltimore County Subwatersheds 5
Water Quality Modeling 8
Subwatershed and Catchments 8
Directly Connected Impervious Area 8
Flow Modeling Results 9
Frequency Analysis 9
Water Quality Modeling Results 10
Sewage Analysis 17
Stream Stability Assessment 18
Corps Reach Assessment 18
Cruised Reach Assessment 19
Stream Stability Results 19
Stream Summary 21
Forest Assessment 23
Baltimore County Rapid Field Assessment 24
Baltimore City Forest Assessment 24
Results 24
Stormwater Mangement Assessment 25
Stormwater Management Facilities 25
Storm Drain Outfalls 26
Results 27
Restoration Goals & Management Measures 29
Group 1 – Sensitive Subwatersheds 29
Group 2 – Impacted Subwatersheds 30
Group 3 – Urbanized Subwatersheds 31
Group 4 – Highly Urbanized Subwatersheds 31
Water Quality Enhancement Projects 32
Water Quality Ranking 32
Priority Projects 33
Project Summary 34
Acknowledgements 38

List of Figures

Figure E.1: Subwatershed map 3
Figure E.2: Metal loadings (darkest subwatersheds have highest pollutant loading) ... 11
Figure E.3: Nutrient loading (darkest subwatersheds have highest pollutant loading) . 12
Figure E.4: Overall pollutant loading (darkest subwatersheds have highest pollutant loading) 12

Figure E.5: Sewage leaks found within the Gwynns Falls 18
Figure E.6: Rosgen stream classification 20
Figure E.7: Unstable streams (Red stream reaches have 50% or more unstable banks) 22
Figure E.8: Forest cover in the Gwynns Falls watershed 23
Figure E.9: Typical stormwater management facilities within the Gwynns Falls..... 26
Figure E.10: Stormdrain outfalls in need of structural repair, energy dissipation and stream stabilization. 26
Figure E.11: Proposed stormwater management facility and outfall projects 28
Figure E.12: Sensitive subwatersheds 30
Figure E.13: Impacted subwatersheds 30
Figure E.14: Urbanized subwatersheds 31
Figure E.15: Highly urbanized subwatersheds 32
Figure E.16: Proposed Priority Projects 35

List of Tables

Table E.1: Comparison between Existing and Ultimate land use for entire watershed .. 6
Table E.2: Subwatershed land use summary 7
Table E.3: Directly Connected Impervious Area by subwatershed..... 9
Table E.4: Percent increase in Log Pearson III discharges between existing and ultimate development 10
Table E.5: Annual pollutant loadings by subwatershed 13
Table E.6: Annual pollutant loadings by subwatershed 13
Table E.7: Annual pollutant loadings by subwatershed 14
Table E.8: Annual pollutant loadings by subwatershed 14
Table E.9: Annual pollutant loadings by subwatershed 15
Table E.10: Annual pollutant loadings by subwatershed 15
Table E.11: Annual pollutant loadings by subwatershed 16
Table E.12: Top three pollutant loads by subshed for each constitutient, existing conditions 17
Table E.13: Reduction in Pollutant Loading by Contaminant due to the repair of chronic sewage leaks. 18
Table E.14: Stream assessment summary..... 21
Table E.15: Baltimore County forest patch assessment results 24
Table E.16: Baltimore City forest patch assessment results 25
Table E.17: Classification of Gwynns Falls Subwatersheds..... 29
Table E.18: Water quality enhancement project ranking scheme 33
Table E.19: Summary of proposed projects within the Gwynns Falls Watershed 34
Table E.20: Percent removal efficiency for select BMP's 36
Table E.21: Pollutant reductions for stream restoration projects 36
Table E.22: Percent pollutant reduction for proposed projects..... 36
Table E.23: Pollutant loading reductions due to the installation of structural BMPs 37
Table E.24: Overall pollutant loading reduction in the Gwynns Falls..... 37
Table E.25: Pollutant load reductions due to the repair of continuous sewer leaks..... 37

EXECUTIVE SUMMARY

STUDY OBJECTIVES & SITE DESCRIPTION

In partial fulfillment of the federally mandated National Pollutant Discharge Elimination System Permit (NPDES) – Municipal Stormwater Discharge Permit (99-DP-3317) for Baltimore County and (MC-BC-1999-013) for Baltimore City, and to provide watershed restoration framework for both jurisdictions, Parsons Brinckerhoff (PB), with support from Coastal Resources Inc. and Greenman-Pedesen Inc., has prepared the Gwynns Falls Watershed Water Quality Management Plan. This management plan represents a cooperative effort between Baltimore County and Baltimore City in addressing regional water quality issues and improving the health of the Cheaspeake Bay.

The 66 square mile Gwynns Falls watershed is located in western Baltimore County and the west side of Baltimore City (Figure E.1) The watershed begins at the headwaters in Glyndon, MD and ends at the Middle Branch of the Patapsco River in Baltimore City. This study was conducted by dividing the watershed into eleven (11) sub-watersheds: Red Run, Horsehead Branch, Scotts Level, Powder Mill Run, Dead Run, Gwynns Run North, Gwynns Run South, Maidens Choice, Upper Gwynns Falls, Middle Gwynns Falls and Lower Gwynns Falls. The Gwynns Falls Watershed Management Plan was prepared to meet the following objectives:

1. Identify and evaluate non-point source stormwater pollution,
2. Assess geomorphic condition of stream network and evaluate state of degradation,
3. Assess and determine management measures for the reduction of nonpoint source pollution and reestablishment of stream stability and
4. Provide a watershed restoration framework and capital improvement planning tool for Baltimore County Department of Environment Protection and Resource Management (DEPRM) and Baltimore City Department of Public Works (DPW).

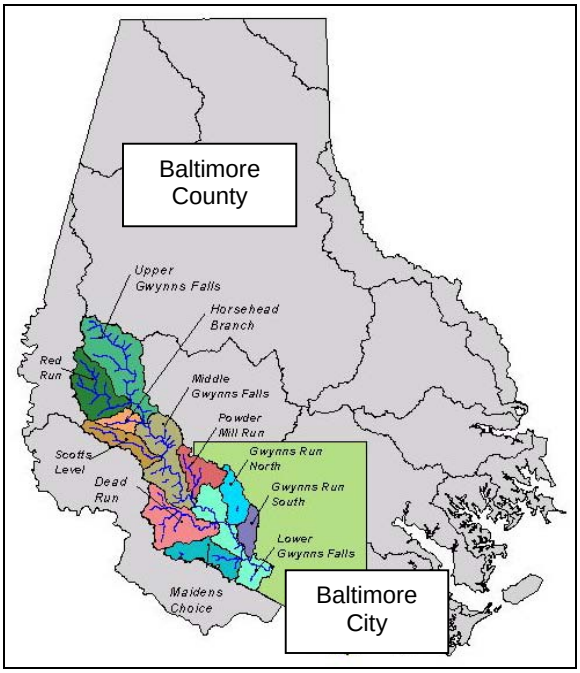


Figure E.1: Subwatershed map

STUDY TASKS

The following tasks were performed by the PB team to meet the study objectives.

I. ***Watershed Characterization***: PB assembled available GIS mapping from Baltimore City and County and identified the principle watershed characteristics.
II. ***SWMM Modeling***: Hydrologic and non-point source pollutant modeling was conducted using the EPA Stormwater Management Model (SWMM). The Gwynns Falls watershed was divided into 505 catchments with an average catchment size of 83 acres. The model simulation ran from 1980 through 2002, a 23-year period.
III. ***Stream Stability Assessment***: A rapid cruised reach assessment was conducted for all Baltimore City streams and Baltimore County streams not previously assessed by the Army Corps of Engineers. Information was collected on channel morphology, channel disturbances and habitat. A verification of the Army Corps of Engineers field data and photo documentation was provided for the Corps reaches in Baltimore County.
IV. ***Forest Assessment***: A "Level IV – Rapid Field Assessment" using the methodology and field data sheets from the report *A Geographic Information System Analysis of Forest Cover in the Gwynns Falls Watershed* prepared for Baltimore County DEPRM was conducted on 34 forest patches within the Gywnns Falls watershed. A GIS based forest assessment was also conducted in Baltimore City.
V. ***Stormwater Management Facility & Outfall Assessment***: PB assessed the condition of 39 SWM facilities and 73 major storm drain outfalls in the County and City. Based on the findings, PB recommended 81 sites in the County and City for water quality retrofit and improvement.
VI. ***Watershed Evaluation & Restoration Opportunities:*** Following the comprehensive watershed assessment, PB defined management and restoration goals for each subwatershed. PB identified more than 120 water quality improvement projects.
VII. ***Prioritization:*** PB developed a comprehensive ranking system incorporating environmental benefits and cost and ranked the improvement projects identified. Based on this ranking system, PB prioritized these projects and provided recommendations for implementation.

WATERSHED CHARACTERIZATION

The Gwynns Falls is an urbanized watershed. The lower City portion of the watershed has some of the oldest development and the upper County portion of the watershed has some of the newest development. Although many portions of the watershed are already completely built out, development continues in the central and upper portions of the watershed. Table E.1 summarizes the specific land use changes that occur between the existing land use condition and the ultimate development or full build out condition for the entire Gwynns Falls watershed. E.2 summarizes the existing and ultimate land use breakdown by subwatershed.

Baltimore City Subwatersheds

The Gwynns Run North and South and Lower Gwynns Falls subwatersheds lie wholly or mostly within Baltimore City, and are characterized by high imperviousness associated with dense residential (i.e. rowhouses), commercial and industrial development. Gwynns Run is completely built out and there is no significant change between the existing and ultimate development conditions. Gwynns Run was divided into two subwatersheds, Gwynns Run North and Gwynns Run South, because Gwynns Run North discharges directly into the Lower Gywnns Falls instead of flowing into Gwynns Run South. The Gwynns Run and Lower Gwynns Falls subwatersheds have been subject to significantly more SSO events than the other

subwatersheds. Continuous sewage leaks were evident during the stream stability assessment. Leakin Park and Gwynns Falls Park, located along the Lower Gwynns Falls mainstem near the confluence with Dead Run, represent the only significant forested areas in the Baltimore City section of the watershed. Nearly all of the development in the lower three subwatersheds predates stormwater management regulations. Limited infill development is expected in these watersheds for the ultimate conditions, but parkland will remain forested even under ultimate build-out conditions.

Baltimore City and Baltimore County Subwatersheds

Powder Mill Run, Dead Run and Maidens Choice all straddle the City-County boundary. The Maidens Choice subwatershed lies predominantly within Baltimore City and consists of a mix of residential, commercial and industrial areas. The subwatershed is highly urbanized and has a high percentage of imperviousness. Large portions of the watershed were developed prior to current stormwater management regulations.

The Powder Mill Run subwatershed is located half in Baltimore City and half in Baltimore County. It contains a mix of commercial, institutional, industrial and medium-to-high density residential land. A large percentage of the development was constructed prior to formal stormwater management regulations. Several large stormwater management facilities have recently been constructed as a result of development and redevelopment within the Seton Industrial Park.

The Dead Run subwatershed lies mostly within Baltimore County, and features a mixture of commercial, institutional, industrial and residential land uses, along with the US-40, I-70 and Security Boulevard interchanges of the Baltimore Beltway (I-695). The newer developments in the Dead Run headwaters feature stormwater management ponds, but development in a large portion of this subwatershed predates stormwater management regulations.

Limited infill development is expected in these subwatersheds under ultimate conditions.

Water quality data shows that constant sewage leaks and SSO events are also a problem in the Dead Run subwatershed.

Baltimore County Subwatersheds

The Scotts Level Run subwatershed was almost entirely converted to medium-density residential development before the advent of stormwater management, though some woodland remains. The Middle Gwynns Falls subwatershed contains a majority of medium density residential development, woodland and major transportation corridors such as the Beltway and the I-795/Baltimore Metro route. The subwatershed generally lacks stormwater management.

The Upper Gwynns Falls watershed and portions of Red Run and Horsehead Branch have been designated as growth areas by Baltimore County, thus a large percentage of the remaining woodland and agricultural areas of these subwatersheds is expected to be converted to residential, commercial and industrial development. The Horsehead Branch and Red Run subwatersheds contain a mixture of commercial, low to medium density residential, agricultural, and wooded land uses and are the least-developed tributaries to the Gwynns Falls. The Soldier's Delight Natural Environment Area in the Red Run subwatershed represents the largest contiguous wooded area in the Baltimore County section of the Gwynns Falls watershed. The Upper Gwynns Falls watershed still retains significant woodland and farmland, but the upper portion of this subwatershed has been largely converted to commercial, industrial and

residential development. The highest concentration and density of development occurs along the Reisterstown Road corridor, with the lowest density occurring east of the Upper Gwynns Falls mainstem. Stormwater management ponds serve the newest developments in the upper three subwatersheds, however, these developments comprise less than half of the current total development in the upper subwatersheds.

Table E.1: Comparison between Existing and Ultimate land use for entire watershed

Land Use Category	% of Watershed		% Change from Existing
	Existing	Ultimate	
Low Density	5.2%	7.2%	2.0%
Medium Density	28.5%	34.1%	5.6%
High Density	18.2%	25.3%	7.1%
Commercial	9.2%	8.6%	-0.6%
Industrial	6.3%	3.4%	-2.9%
Institutional	7.5%	9.8%	2.3%
Barren	0.5%	0.0%	-0.5%
Open	4.4%	3.2%	-1.1%
Agricultural	3.4%	0.5%	-2.9%
Forest	16.7%	7.7%	-9.1%
Lake	0.1%	0.1%	0.0%

Table E.2: Subwatershed land use summary

Subshed	Condition	Percentage of Subshed										
		Low Density	Medium Density	High Density	Commer-cial	Industrial	Institutional	Barren	Open	Agricultural	Forest	Lake
Upper Gwynns Falls	Existing	11.2%	24.8%	12.5%	9.5%	7.5%	7.1%	0.7%	1.8%	7.4%	17.6%	0.0%
	Ultimate	15.1%	38.8%	18.1%	7.2%	12.8%	1.2%	0.0%	1.2%	1.2%	4.4%	0.0%
Red Run	Existing	16.0%	6.8%	11.7%	6.2%	5.4%	0.5%	1.9%	2.4%	11.0%	37.8%	0.3%
	Ultimate	22.5%	11.5%	23.6%	10.8%	11.6%	0.0%	0.0%	2.1%	2.0%	15.7%	0.3%
Horsehead Branch	Existing	1.2%	34.5%	8.0%	2.5%	0.0%	4.1%	0.0%	1.9%	20.7%	27.0%	0.0%
	Ultimate	14.3%	58.2%	17.3%	7.8%	0.0%	0.0%	0.0%	0.0%	0.0%	2.4%	0.0%
Scotts Level Branch	Existing	1.6%	60.0%	11.2%	7.2%	0.3%	5.5%	0.2%	1.0%	0.0%	13.0%	0.0%
	Ultimate	0.6%	67.6%	22.9%	5.6%	0.2%	0.0%	0.0%	0.1%	0.0%	2.9%	0.0%
Middle Gwynns Falls	Existing	5.3%	46.4%	9.3%	5.3%	3.3%	5.4%	0.4%	5.9%	0.7%	18.0%	0.0%
	Ultimate	9.4%	52.4%	21.8%	3.3%	2.9%	1.5%	0.0%	2.6%	0.0%	6.2%	0.0%
Powder Mill Run	Existing	0.7%	42.9%	15.1%	15.4%	7.3%	9.5%	0.0%	1.4%	0.0%	7.8%	0.0%
	Ultimate	0.7%	42.8%	19.9%	14.6%	9.5%	7.1%	0.0%	1.4%	0.0%	4.1%	0.0%
Gwynns Run North	Existing	0.0%	23.6%	38.7%	8.2%	9.8%	10.9%	0.0%	4.5%	0.0%	3.0%	1.4%
	Ultimate	0.0%	23.6%	38.7%	8.2%	9.8%	10.9%	0.0%	4.5%	0.0%	3.0%	1.4%
Gwynns Run South	Existing	0.0%	0.2%	58.7%	9.5%	15.3%	8.8%	0.0%	6.9%	0.0%	0.6%	0.0%
	Ultimate	0.0%	0.2%	58.7%	9.5%	15.3%	8.8%	0.0%	6.9%	0.0%	0.6%	0.0%
Dead Run	Existing	2.8%	24.3%	20.0%	18.1%	10.7%	4.3%	0.5%	4.5%	0.1%	14.6%	0.0%
	Ultimate	0.0%	27.7%	29.9%	15.0%	15.3%	0.6%	0.0%	2.2%	0.0%	9.3%	0.0%
Maidens Choice	Existing	0.7%	26.0%	28.9%	12.3%	5.2%	11.8%	0.0%	10.6%	0.0%	4.6%	0.0%
	Ultimate	0.0%	26.7%	33.4%	11.1%	6.0%	10.5%	0.0%	9.3%	0.0%	2.9%	0.0%
Lower Gwynns Falls	Existing	0.2%	23.2%	23.2%	5.6%	15.1%	7.0%	0.2%	7.4%	0.0%	18.0%	0.0%
	Ultimate	0.2%	23.1%	23.6%	5.8%	15.1%	7.0%	0.2%	7.4%	0.0%	17.7%	0.0%

WATER QUALITY MODELING

A water quality model using EPA SWMM was conducted to develop an understanding of the hydrologic characteristics of the Gwynns Falls Watershed and to estimate non-point source pollutant loadings. Rainfall-runoff modeling was performed for a 23-year period (Water Years 1980 through 2002) that represents a typical range of rainfall for Baltimore County. Modeling was performed of both existing and ultimate land use conditions and the results were used in this study to develop watershed management recommendations.

Subwatershed and Catchments

The Gwynns Falls watershed is divided into 11 subwatersheds, corresponding to the eight major tributaries plus upper, middle, and lower segments of the Gwynns Falls mainstem. At the request of Baltimore City, the 11 subwatersheds were to be divided into smaller modeling units called catchments, averaging approximately 90 acres each. The smaller modeling scale was required so that the pollutant loads from different types of land use, such as residential and commercial lands, could be quantified.

Directly Connected Impervious Area

The amount of Directly Connected Impervious Area (DCIA) is a key parameter that controls the amount of runoff generated. Precipitation that falls onto directly connected impervious area is assumed to immediately runoff and not to infiltrate. DCIA is related to the type of land use in a catchment. Heavily developed areas with storm sewers and many paved streets and roads possess large areas of imperviousness directly connected to streams. Residential areas, which have large areas covered by houses, can possess relatively low DCIA if roof drainage is not directly connected to storm sewers or street drainage. Rural, agricultural areas and forests have very little DCIA except for rock channels near streams. It is important to note that the DCIA refers to impervious areas that are directly connected to the watershed's drainage network. The total impervious area in the watershed can be significantly higher than the DCIA. Water falling on the DCIA is assumed to contribute almost instantaneously to the stormwater runoff. Table E.3 shows the DCIA for existing and ultimate land use conditions by subwatershed. Its important to note how much the DCIA increases between the existing and ultimate development condition.

Table E.3: Directly Connected Impervious Area by subwatershed

Subshed Name	% Directly Connected Impervious Area		
	Existing	Ultimate	Change
Upper Gwynns Falls	26.2%	31.9%	5.8%
Red Run	18.1%	31.3%	13.2%
Horsehead Branch	14.6%	25.9%	11.3%
Scotts Level Branch	23.7%	27.2%	3.5%
Middle Gwynns Falls	21.8%	25.4%	3.6%
Powder Mill Run	33.8%	36.2%	2.4%
Dead Run	36.2%	40.7%	4.5%
Gwynns Run North	36.2%	36.2%	0.0%
Gwynns Run South	44.2%	44.2%	0.0%
Maidens Choice	32.9%	34.2%	1.2%
Lower Gwynns Falls	31.6%	31.8%	0.2%
Entire Watershed	28.1%	32.5%	4.5%

Flow Modeling Results

Frequency Analysis

The SWMM model was used to perform flood frequency analyses for each of the subwatersheds. The frequency analysis was conducted for the 2-, 5-, 10-, 25- 50- and 100-year return periods. The return period is related to the probability that a discharge of that magnitude will occur in a given year.

A frequency analysis was conducted for the existing and ultimate development condition. The model enables us to determine the increase in discharge caused by the increase in imperviousness for each of the subwatersheds. Because individual stormwater management facilities were not modeled in SWMM, the actual increases in stream flows will be less than that shown in Table E.4. Table E.4 shows the percent increase in discharges between existing and ultimate development conditions.

Table E.4: Percent increase in Log Pearson III discharges between existing and ultimate development

Subshed	Return Period (yrs) Percent Increase					
	2	5	10	25	50	100
Upper Gwynns Falls	19.7%	22.3%	24.1%	26.5%	28.2%	29.9%
Red Run	29.3%	32.7%	35.3%	38.7%	41.2%	43.6%
Horsehead Branch	28.6%	32.2%	35.2%	39.2%	42.1%	44.9%
Scotts Level Run	9.5%	10.8%	11.9%	13.2%	14.2%	15.2%
Middle Gwynns Falls	16.0%	18.3%	20.0%	22.2%	23.8%	25.3%
Powder Mill Run	4.4%	5.1%	5.6%	6.2%	6.7%	7.2%
Dead Run	6.6%	7.7%	8.4%	9.3%	9.9%	10.5%
Gwynns Run North	0.0%	0.0%	-0.1%	-0.1%	-0.1%	-0.1%
Gwynns Run South	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Maidens Choice	2.1%	2.3%	2.4%	2.6%	2.7%	2.9%
Lower Gwynns Falls	8.3%	9.9%	11.0%	12.4%	13.4%	14.4%

Water Quality Modeling Results

Water quality modeling was conducted for the 12 pollutants listed below:

- Total suspended solids (TSS)
- Total phosphorus (TP)
- Orthophosphorus (OP)
- Total Kjeldahl Nitrogen (TKN)
- Nitrate/Nitrite (NO_3N)
- Biological oxygen demand (BOD)
- Chemical oxygen demand (COD)
- Copper (Cu)
- Zinc (Zn)
- Cadmium (Cd)
- Lead (Pb)
- Fecal Coliform (Fcol)

Figures E.2 through E.4 summarize the pollutant loading by subwatershed within the Gwynns Falls. Figure E.2 is a composite of the metal loadings (Cu, Zn, Cd, & Pb), E.3 is a composite of the nutrient loadings (TKN, NO_3N, TP & OP) and E.4 is an overall pollutant composite.

Top Metal Loadings:

- Gwynns Run South
- Dead Run
- Gwynns Run North

Top Nutrient Loading:

- Upper Gwynns Falls
- Maidens Choice
- Lower Gwynns Falls

Overall Pollutant Loading:

- Gwynns Run South
- Gwynns Falls Upper (Due to high nutrients)
- Gwynns Run North

Total annual pollutant loads in lbs./acre/year by subwatershed are presented in Tables E.5 to E.11. Results are presented for both existing and proposed conditions.

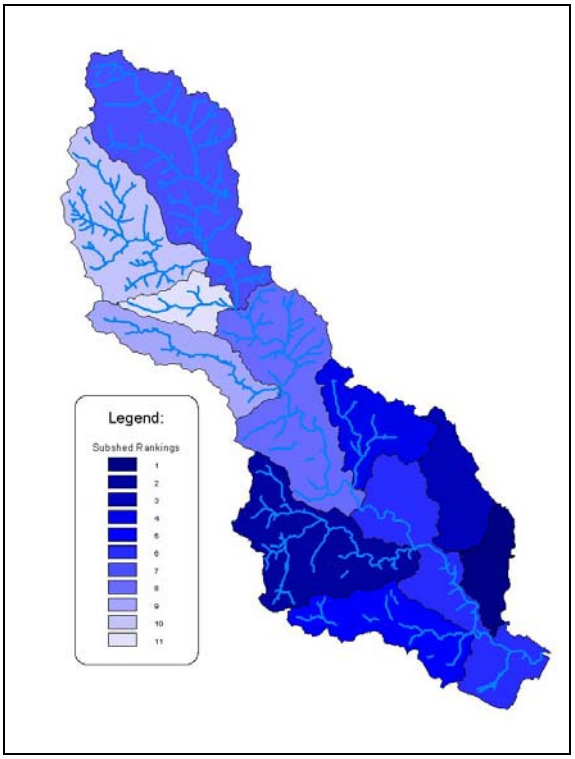


Figure E.2: Metal loadings (darkest subwatersheds have highest pollutant loading)

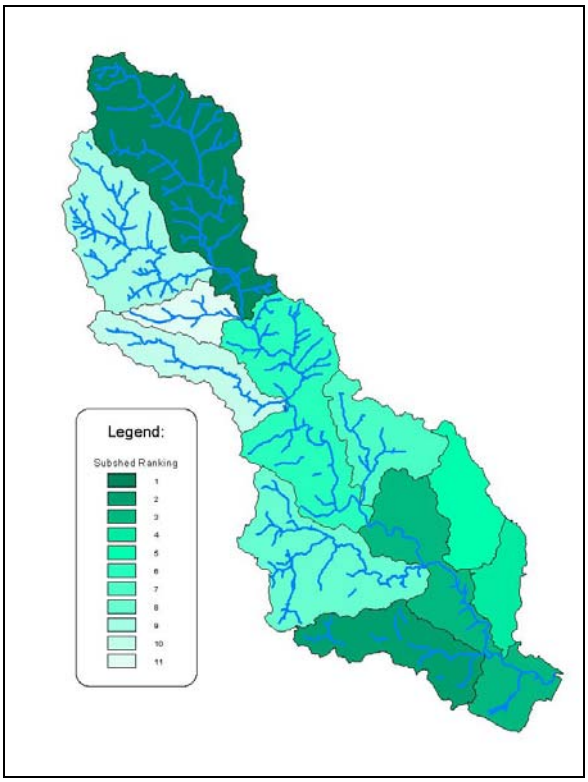


Figure E.3: Nutrient loading (darkest subwatersheds have highest pollutant loading)

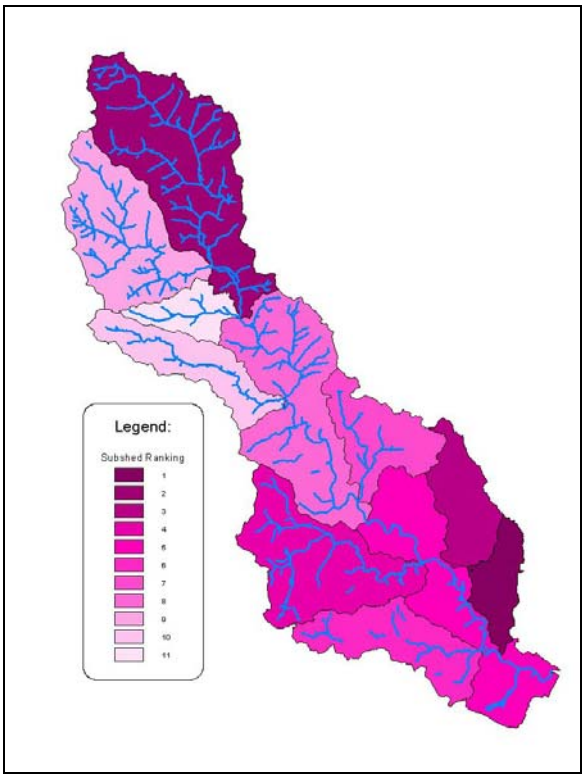


Figure E.4: Overall pollutant loading (darkest subwatersheds have highest pollutant loading)

Table E.5: Annual pollutant loadings by subwatershed

Subshed	Total Suspended Solids			Total Kjeldahl Nitrogen		
	Existing (lb/ac/yr)	Ultimate (lb/ac/yr)	% Increase	Existing (lb/ac/yr)	Ultimate (lb/ac/yr)	% Increase
Upper Gwynns Falls	51.15	54.79	7.1%	1.95	2.02	3.3%
Red Run	44.07	46.52	5.5%	1.58	1.78	12.7%
Horsehead Branch	37.26	38.05	2.1%	1.30	1.23	-5.7%
Scotts Level Run	43.76	45.89	4.9%	1.36	1.40	2.8%
Middle Gwynns Falls	50.93	52.51	3.1%	1.54	1.52	-1.9%
Powder Mill Run	46.06	46.97	2.0%	1.90	1.97	3.7%
Dead Run	46.95	44.25	-5.8%	2.07	2.14	3.0%
Gwynns Run North	49.33	49.32	0.0%	1.89	1.89	0.0%
Gwynns Run South	49.97	49.97	0.0%	2.18	2.18	0.0%
Maidens Choice	57.12	55.98	-2.0%	1.99	1.98	-0.6%
Lower Gwynns Falls	51.10	50.45	-1.3%	1.97	1.97	0.1%

Table E.6: Annual pollutant loadings by subwatershed

Subshed	Nitrate / Nitrite			Total Phosphorus		
	Existing (lb/ac/yr)	Ultimate (lb/ac/yr)	% Increase	Existing (lb/ac/yr)	Ultimate (lb/ac/yr)	% Increase
Upper Gwynns Falls	3.79	3.70	-2.2%	0.28	0.28	0.1%
Red Run	3.33	3.11	-6.9%	0.23	0.24	4.1%
Horsehead Branch	2.92	2.57	-11.8%	0.20	0.19	-4.9%
Scotts Level Run	3.01	3.04	1.0%	0.22	0.24	5.5%
Middle Gwynns Falls	3.19	3.20	0.4%	0.24	0.25	3.9%
Powder Mill Run	3.02	3.03	0.2%	0.26	0.26	2.3%
Dead Run	2.73	2.74	0.2%	0.25	0.26	4.5%
Gwynns Run North	3.01	3.01	0.0%	0.26	0.26	0.0%
Gwynns Run South	2.94	2.94	0.0%	0.27	0.27	0.0%
Maidens Choice	3.09	3.09	0.0%	0.26	0.26	0.9%
Lower Gwynns Falls	3.19	3.19	-0.1%	0.26	0.26	0.3%

Table E.7: Annual pollutant loadings by subwatershed

Subshed	Ortho Phosphorus			Biochemical Oxygen Demand		
	Existing (lb/ac/yr)	Ultimate (lb/ac/yr)	% Increase	Existing (lb/ac/yr)	Ultimate (lb/ac/yr)	% Increase
Upper Gwynns Falls	0.14	0.14	5.0%	9.38	8.74	-6.8%
Red Run	0.11	0.13	17.4%	8.06	8.18	1.6%
Horsehead Branch	0.08	0.09	9.7%	6.24	4.91	-21.3%
Scotts Level Run	0.10	0.10	6.7%	5.41	5.41	0.1%
Middle Gwynns Falls	0.11	0.11	5.5%	6.23	5.86	-5.9%
Powder Mill Run	0.13	0.13	4.2%	8.23	8.55	3.9%
Dead Run	0.13	0.14	6.8%	9.38	9.87	5.1%
Gwynns Run North	0.14	0.14	0.0%	8.14	8.14	0.0%
Gwynns Run South	0.16	0.16	0.0%	9.81	9.82	0.1%
Maidens Choice	0.13	0.13	1.8%	8.02	8.06	0.5%
Lower Gwynns Falls	0.13	0.13	0.7%	8.62	8.67	0.5%

Table E.8: Annual pollutant loadings by subwatershed

Subshed	Chemical Oxygen Demand			Fecal Coliform		
	Existing (lb/ac/yr)	Ultimate (lb/ac/yr)	% Increase	Existing (MPN/ac/yr)	Ultimate (MPN/ac/yr)	% Increase
Upper Gwynns Falls	88.02	91.06	3.4%	7.17E+04	6.73E+04	-6.2%
Red Run	71.18	81.16	14.0%	7.87E+04	7.62E+04	-3.2%
Horsehead Branch	58.65	56.42	-3.8%	5.22E+04	5.20E+04	-0.4%
Scotts Level Run	61.07	64.91	6.3%	6.12E+04	6.55E+04	7.1%
Middle Gwynns Falls	66.10	68.68	3.9%	6.56E+04	6.85E+04	4.5%
Powder Mill Run	84.10	88.05	4.7%	6.58E+04	6.74E+04	2.5%
Dead Run	90.06	96.08	6.7%	7.79E+04	8.11E+04	4.0%
Gwynns Run North	86.24	86.24	0.0%	7.54E+04	7.54E+04	0.0%
Gwynns Run South	100.62	100.62	0.0%	9.14E+04	9.14E+04	0.0%
Maidens Choice	84.14	85.31	1.4%	7.30E+04	7.47E+04	2.4%
Lower Gwynns Falls	84.36	84.93	0.7%	7.45E+04	7.53E+04	1.1%

Table E.9: Annual pollutant loadings by subwatershed

Subshed	Cadmium			Copper		
	Existing (lb/ac/yr)	Ultimate (lb/ac/yr)	% Increase	Existing (lb/ac/yr)	Ultimate (lb/ac/yr)	% Increase
Upper Gwynns Falls	0.008	0.010	26.5%	0.052	0.064	22.1%
Red Run	0.004	0.007	72.5%	0.036	0.059	63.3%
Horsehead Branch	0.005	0.007	55.6%	0.027	0.042	58.5%
Scotts Level Run	0.008	0.009	12.5%	0.041	0.050	20.9%
Middle Gwynns Falls	0.008	0.009	14.9%	0.043	0.052	21.0%
Powder Mill Run	0.010	0.011	4.4%	0.060	0.065	8.9%
Dead Run	0.010	0.011	11.5%	0.067	0.077	15.0%
Gwynns Run North	0.010	0.010	0.0%	0.072	0.072	-0.1%
Gwynns Run South	0.011	0.011	0.0%	0.092	0.092	0.0%
Maidens Choice	0.009	0.010	3.2%	0.066	0.070	5.3%
Lower Gwynns Falls	0.009	0.009	1.0%	0.063	0.064	1.5%

Table E.10: Annual pollutant loadings by subwatershed

Subshed	Zinc			Lead		
	Existing (lb/ac/yr)	Ultimate (lb/ac/yr)	% Increase	Existing (lb/ac/yr)	Ultimate (lb/ac/yr)	% Increase
Upper Gwynns Falls	0.079	0.089	12.2%	0.004	0.005	10.3%
Red Run	0.056	0.074	32.9%	0.003	0.004	32.0%
Horsehead Branch	0.046	0.057	25.3%	0.002	0.003	27.3%
Scotts Level Run	0.064	0.067	5.4%	0.003	0.003	3.2%
Middle Gwynns Falls	0.068	0.070	2.9%	0.003	0.003	-0.8%
Powder Mill Run	0.085	0.088	3.8%	0.004	0.005	4.2%
Dead Run	0.087	0.092	5.8%	0.005	0.005	5.6%
Gwynns Run North	0.084	0.084	0.0%	0.004	0.004	0.0%
Gwynns Run South	0.094	0.094	0.0%	0.005	0.005	0.0%
Maidens Choice	0.085	0.085	0.7%	0.004	0.004	0.6%
Lower Gwynns Falls	0.084	0.084	0.5%	0.005	0.005	0.5%

Table E.11: Annual pollutant loadings by subwatershed

Subshed	Total Nitrogen		
	Existing (lb/ac/yr)	Ultimate (lb/ac/yr)	% Increase
Upper Gwynns Falls	5.74	5.72	-0.3%
Red Run	4.91	4.88	-0.6%
Horsehead Branch	4.22	3.80	-9.9%
Scotts Level Run	4.37	4.44	1.6%
Middle Gwynns Falls	4.73	4.72	-0.3%
Powder Mill Run	4.92	4.99	1.5%
Dead Run	4.81	4.88	1.4%
Gwynns Run North	4.90	4.90	0.0%
Gwynns Run South	5.12	5.12	0.0%
Maidens Choice	5.08	5.07	-0.3%
Lower Gwynns Falls	5.16	5.16	0.0%

Table E.12 summarizes the top three subwatersheds with the highest annual pollutant load. The subwatershed with the lowest pollutant load is highlighted in yellow. As expected, the predominantly urban watersheds produced the highest loading per category. Gwynns Run South was ranked the highest pollutant load for 9 of the 12 constituents. Gwynns Run South is highly urbanized and almost entirely storm drain controlled. Upper Gwynns Falls ranked high in three categories including nitrate/nitrites (Rank #1), total phosphorus (Rank #1) and orthophosphorus (Rank #2). Red Run ranked high in fecal coliforms (Rank #2) and nitrate/nitrites (Rank #2). In contrast, Horsehead Branch was the cleanest subwatershed, ranking the lowest out of all subwatersheds for 9 of the 12 constituents. Over 47% of the existing watershed was comprised of agricultural or forested lands.

Although Gwynns Run South's land use composition did not change between the existing and ultimate development land use conditions, it did remain on the top of seven of the pollutant lists. Dead Run's ultimate development land use surpassed Gwynns Run South for biological oxygen demand (BOD) and Zinc (Zn). Horsehead Branch still remained the cleanest subwatershed for the ultimate condition land use, however, for the ultimate development conditions it was the lowest ranked subwatershed for all 12 constituents.

Table E.12: Top three pollutant loads by subshed for each constitutient, existing conditions

TSS	TKN	NO_3N	TP
1. Maidens Choice 2. Upper Gwynns 3. Lower Gywnns	1. Gwynns Run S 2. Dead Run 3. Lower Gwynns 3. Upper Gwynns 3. Maidens Choice	1. Upper Gwynns 2. Red Run 3. Lower Gwynns 3. Middle Gwynns	1. Upper Gwynns 2. Gwynns Run S 3. Lower Gwynns 3. Gwynns Run N 3. Maidens Choice 3. Powder Mill
Min = Horsehead	Min = Horsehead	Min = Dead Run	Min = Horsehead
OP	**BOD**	**COD**	**FCOL**
1. Gwynns Run S 2. Upper Gwynns 3. Gywnns Run N	1. Gwynns Run S 2. Dead Run 3. Upper Gwynns	1. Gwynns Run S 2. Dead Run 3. Upper Gwynns	1. Gwynns Run S 2. Red Run 3. Dead Run
Min = Horsehead	Min = Scotts Level	Min = Horsehead	Min = Horsehead
CD	**CU**	**ZN**	**PB**
1. Gwynns Run S 2. Gwynns Run N 2. Powder Mill	1. Gwynns Run S 2. Gwynns Run N 3. Dead Run	1. Gwynns Run S 2. Dead Run 3. Maidens Choice 3. Powder Mill	1. Gwynns Run S 2. Dead Run 3. Lower Gwynns
Min = Red Run	Min = Horsehead	Min = Horsehead	Min = Horsehead

Sewage Analysis

Sewage discharge into the Gwynns Falls is a major concern. The discharges provide safety risks to the public and wildlife. Many sections of the stream, particularly within Baltimore City are posted due to contaminated streamflow. Sewage in the stream system is easily identified by the general public.

Continuous sewer leaks are common occurrences in Baltimore City. The City's baseflow monitoring data and the stream assessment confirms this. The pollutant loading for Baltimore City's baseflow monitoring is much greater than for similar land uses in Baltimore County. Baltimore City has requested PB to quantify the loads that come from continuous sewer leaks and the reduction of loads if these leaks are repaired.

The original SWMM model for the existing and ultimate development comparison assumed that chronic sewage leaks would be repaired in the future. In order to determine the impact of repairing the City's chronic sewage leaks, the SWMM model was rerun and baseflow loads were adjusted to account for the high sewage discharges that are occurring in Baltimore City. Because SWMM can only model a single baseflow load, an area weighted average value between Baltimore County and City was used to determine the initial baseflow contaminant loading. This process will overestimate the pollutant loadings due to sewage in the County and underestimate the pollutant loads due to sewage in the City. By looking at the impacts of

reducing the continuous sewage leaks in the overall watershed, these variances will be minimized. Figure E.5 shows examples of continuous sewage leaks found in the Gwynns Falls. These locations were reported to the City and County for repair. Table E.13 summarizes the reduction of pollutant loadings due to the repair of chronic sewer leaks.

Figure E.5: Sewage leaks found within the Gwynns Falls

Table E.13: Reduction in Pollutant Loading by Contaminant due to the repair of chronic sewage leaks.

Location	TKN	TP	BOD	COD	Fecal Coliform
Watershed Outlet	11%	8%	8%	9%	52%

STREAM STABILITY ASSESSMENT

The goal of the stream stability assessment was to document the geomorphic and riparian vegetative condition of the streams within the watershed and identify sites for possible protection, enhancement and restoration in order to improve the overall health and quality of the Gwynns Falls Watershed system. The study was divided into two primary components: Corps Reach Assessment and Cruised Reach Assessment.

Corps Reach Assessment

The U.S. Army Corps of Engineers, under a separate study, had assessment 41 miles of stream in Baltimore County. Baltimore County's Department of Environmental Protection had performed a quality review of the data and requested that PB walk these segments of stream verifying the existing data for use in the current watershed analysis. In addition, PB looked for restoration opportunities and photodocumented each of the stream reaches. Items examined by PB include:

- Rosgen Classification
- Habitat
- Bank Erosion
- Bed Stability
- Bank Stability

Cruised Reach Assessment

Cruised reach assessments were conducted on over 70 miles of Baltimore County and 22 miles of Baltimore City first, second and third order stream reaches that were not previously assessed by the U.S. Army Corps of Engineers. Cruising is defined as a team of two stream surveyors walking the entire length of each reach and performing rapid field assessments. Measurements using a stretched tape and surveyors rod were performed to assess bankfull width and depth. Detailed cross sections were not taken at each reach. A representative riffle section of the reach was selected for assessment. This section was photographed for future reference. The rapid assessment collected four major categories of stream information:

- Channel Morphology
- Channel Disturbances
- Channel Habitat
- Restoration Opportunities

Stream Stability Results

Five stream characterization categories were used to describe the streams within the Gwynns Falls: flow regime, entrenchment, channel slope, Rosgen stream classification and altered stream status.

Flow Regime: Streamflow exhibits a strong influence on channel morphology, aquatic habitat and riparian vegetation. Different restoration approaches are used on ephemeral and perennial channels.

Entrenchment describes the relationship of a river to its valley and landform features. The entrenchment ratio describes the vertical containment of a stream. It has been defined by Rosgen to be the ratio of the width of the floodprone area to the surface width of the bankfull channel. The entrenchment ratio was computed for each stream reach and then divided into three categories: slight entrenchment, moderate entrenchment and entrenched. Many urban streams do not have adequate access to their floodplain and are entrenched or vertically contained. Providing adequate floodplain access reduces shear stress, channel velocities and ultimately reduces the amount of bank erosion and channel degradation within a stream reach.

Channel Slope: The water surface slope is a major determinant of river channel morphology and of its related sediment, hydraulic and biological function. An average channel slope range was estimated for each stream reach. The channel slope is one of the characteristics that must be considered when assessing a stream's restoration potential.

Rosgen Stream Classification: One of the most widely used stream classification systems used by engineers and environmental specialists was developed by David Rosgen (1996). The classification system allows users to describe a stream's characteristics based on geomorphic measurements. The measurements are used to categorize the stream type. The cruised reaches were visually assessed and classified using Rosgen's methodology. The entrenchment ratio, width to depth ratio and sinuosity were used in stream type selection. The majority of the watershed's streams can be classified as B, E or G stream types. Figure E.6 shows the distribution of Rosgen stream types throughout the watershed.

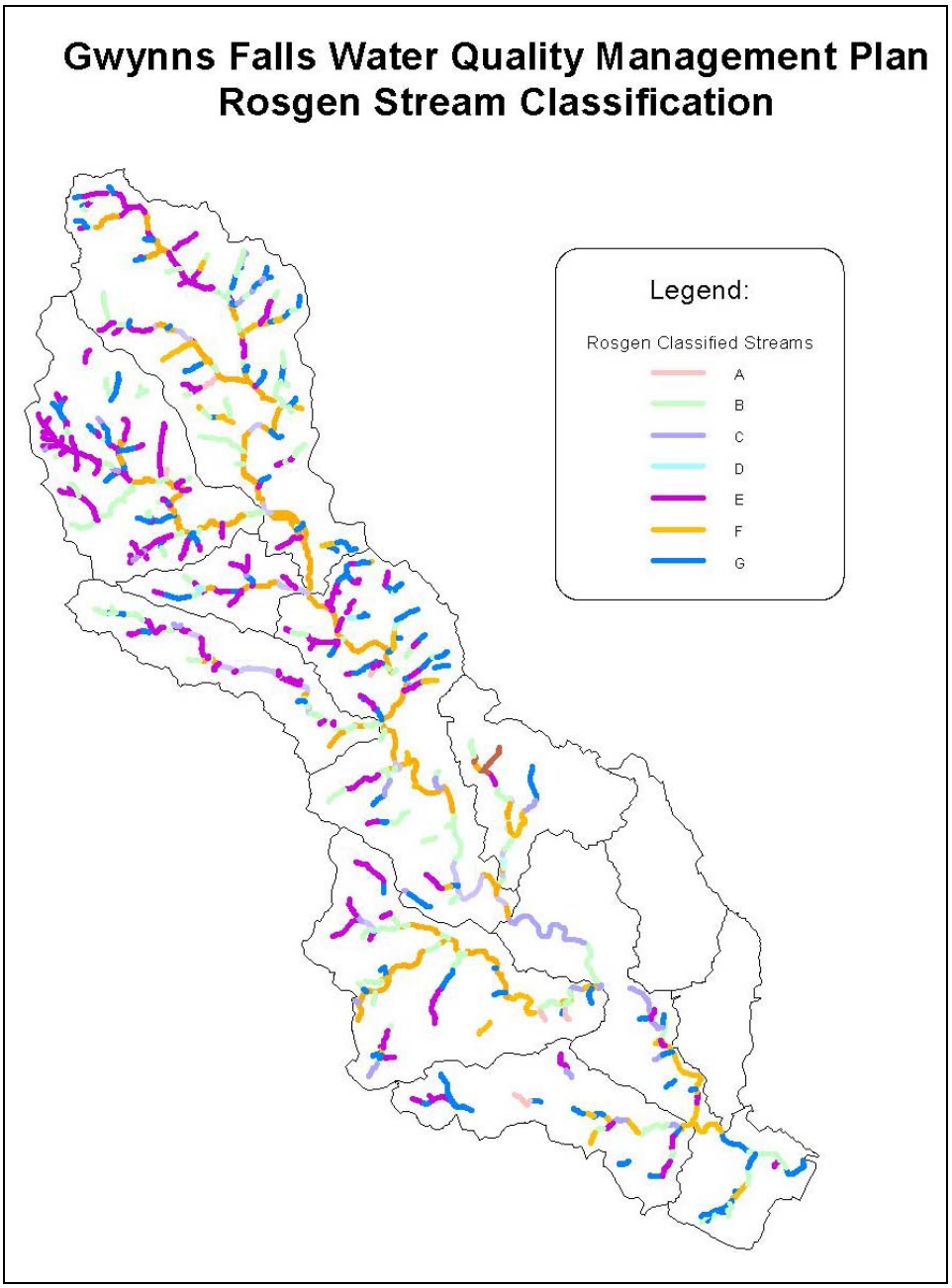


Figure E.6: Rosgen stream classification

Altered Channels: Due to the large amount of urbanization that has already occurred within the Gwynns Falls watershed, many stream channels have been altered from their natural state.

Table E.14 shows a summary of the stream assessment characteristics of the cruised reaches of the Gwynns Falls watershed.

Table E.14: Stream assessment summary

Flow Regime	Percent Cruised Reaches in Gwynns Falls Watershed
Ephemeral, flow only in response to precipitation	11%
Intermittent, flow exists seasonally or sporadically	14%
Perennial, flow exists year round	75%
Entrenchment	
Slight to No Entrenchment > 2.2	39%
Moderate Entrenchment (1.41 - 2.2)	33%
Entrenched (1.0 - 1.4)	28%
Channel Slope	
Low gradient, less than 2% slope	53%
Moderate gradient, 2 to 4% slope	43%
Steep gradient, greater than 4% slope	4%
Rosgen Stream Classification	
A - steep, entrenched, cascading streams	1%
B - moderately entrenched, riffle dominanted channel	24%
C - low gradient, meandering stream	7%
D - braided channel	1%
E - low gradient, meandering, very efficient & stable	32%
F - entrenched, meandering, overwidened channel	10%
G - entrenched "gully" type streams	25%
Altered Stream Channels	
Straighted	22%
Manmade lining such as concrete or gabion riprap	7%
Relocated channel (due to farming, buildings, roads, etc.)	6%
Piped	13%

Stream Summary

The results of the cruised reach assessment were combined with the data collected by the previous Army Corps of Engineers study. The current analysis verified and updated the Corps data collected within Baltimore County. Detailed stream assessment results appear in Chapter 3 for the overall watershed and are summarized below. Chapter 6 details the stream assessment results for each individual subwatershed.

Typical stream channel characteristics within the Gwynns Falls Watershed:

- Perennial
- Bankfull width is typically between 5-15 feet
- 25% of the streams are classified as Rosgen G stream types (gullies) and an additional 10% more Rosgen F stream types which are overwidened and entrenched
- Over 30% of the stream channel banks are classified as unstable (Figure E.7)
- More than 50% of the streams are moderately or severely entrenched
- Almost half of the stream reaches have been altered due to urbanization

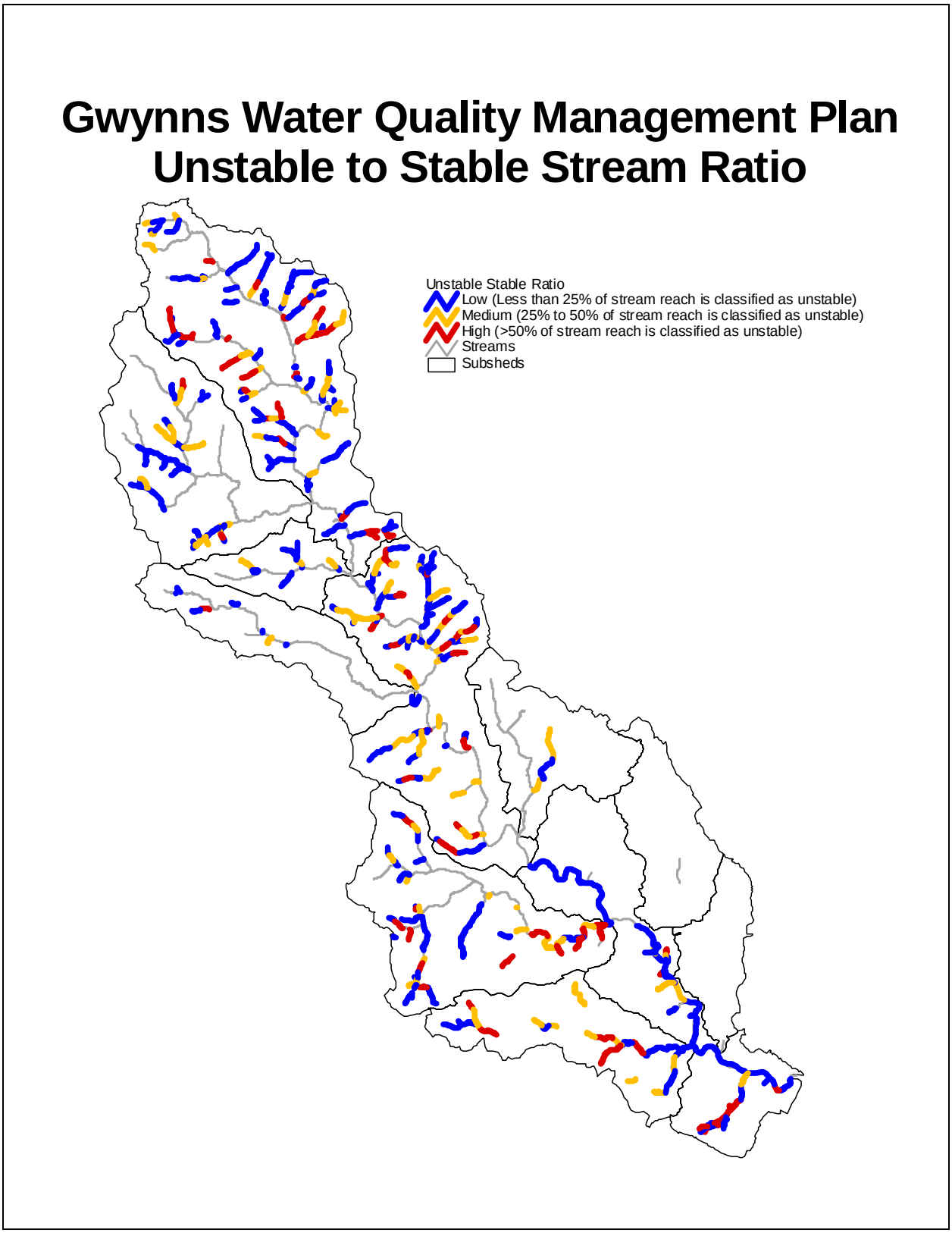


Figure E.7: Unstable streams (Red stream reaches have 50% or more unstable banks)

Typical stream buffer characteristics:

- Over half of the stream reaches have greater than 50% canopy cover
- 77% of the riparian buffers consist of deciduous overstory with brush understory
- Over half of the streams have greater than 50 feet of riparian buffer width on each side of the stream channel

FOREST ASSESSMENT

A forest patch assessment was conducted as part of the Gwynn's Falls Watershed Management Plan Study to investigate potential reforestation/conservation opportunities. Forested areas in the upland areas provides habitat and natural filtration of stormwater. Forested buffers improve the stability of the stream channel in addition to providing necessary habitat and connectivity. The primary goal of the GIS studies were to target forest parcels in low order tributaries with the greatest potential for restoration, enhancement and conservation.

17% of the Gwynns Falls is currently forested. Figure E.8 shows the areas of forested lands remaining within the Gwynns.

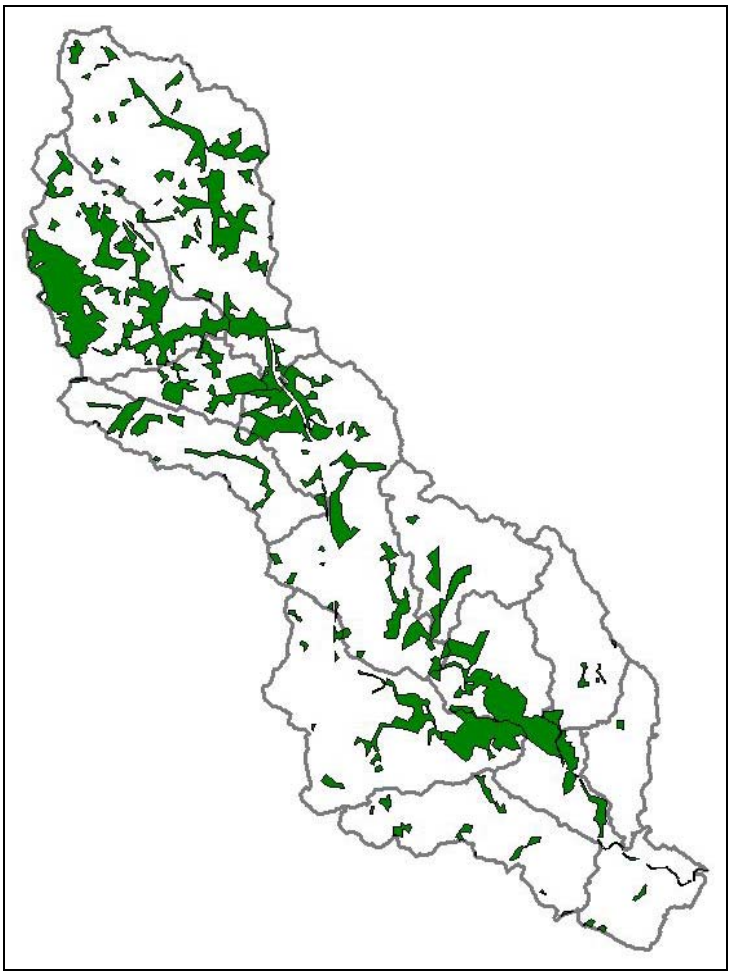


Figure E.8: Forest cover in the Gwynns Falls watershed

Baltimore County Rapid Field Assessment

29 small forested patches on primarily unforested, low order tributaries were assessed using Baltimore County's "Level IV" rapid assessment protocol. The patches ranged in size from 0.5 acres to 160 acres with an average patch size of 20.6 acres. The assessment provides an indication of forest patch quality and habitat suitability based on easily observed physical characteristics. Additionally, the assessment provides verification of the location and extent of stream and forest resources, as well as verification of adjacent land uses.

Baltimore City Forest Assessment

Five forest patch assessments were performed within Baltimore City using the same protocol as for those in the County. At Baltimore City DPW's request, investigators also documented riparian forest gaps, identified opportunities to divert runoff into forest areas, and recommended materials and supplies for reforestation of targeted patches.

Results

Table E.15 shows the recommended forest enhancement sites in Baltimore County. Dead Run and Middle Gwynns have the three highest scoring forest patches.

Table E.15: Baltimore County forest patch assessment results

FOREST PATCH ID	SCORE	SUB-WATERSHED	ACRES	JURISDICTION
168-23	499	DEAD RUN	7.1	COUNTY
72-178	485	MID GWYNNS	32.9	COUNTY
72-147	469	MID GWYNNS	113.8	COUNTY
72-80	457	UPPER GWYNNS	20.9	COUNTY
72-129	455	MID GWYNNS	4.2	COUNTY
168-29	451	DEAD RUN	2.6	COUNTY
72-10	451	UPPER GWYNNS	10.0	COUNTY
168-35	448	DEAD RUN	18.2	COUNTY
72-135	433	MID GWYNNS	1.1	COUNTY
72-49	433	UPPER GWYNNS	17.3	COUNTY
72-74	425	UPPER GWYNNS	160.2	COUNTY
72-11	420	UPPER GWYNNS	5.9	COUNTY
72-83	420	UPPER GWYNNS	3.9	COUNTY
168-11	419	DEAD RUN	2.5	COUNTY
72-187	417	MID GWYNNS	2.5	COUNTY
72-29	416	UPPER GWYNNS	7.1	COUNTY
72-48	412	UPPER GWYNNS	0.5	COUNTY
72-89	388	UPPER GWYNNS	67.1	COUNTY
72-62	383	UPPER GWYNNS	7.6	COUNTY
72-127	372	MID GWYNNS	7.3	COUNTY
86-54	371	RED RUN	1.1	COUNTY
72-45	348	UPPER GWYNNS	2.8	COUNTY
72-130	313	MID GWYNNS	2.2	COUNTY
72-78	276	UPPER GWYNNS	7.9	COUNTY
168-30	252	DEAD RUN	2.0	COUNTY
161-4	192	MAIDENS CHOICE	1.5	COUNTY
72-141	150	MID GWYNNS	64.7	COUNTY
86-24	0	RED RUN	10.7	COUNTY
86-29	0	RED RUN	11.4	COUNTY

Table E.16 shows the recommended forest enhancement sites in Baltimore City. Maidens Choice and the Lower Gwynns Falls are the highest ranking City parcels. The Lower Gwynns

sites have additional enhancement opportunities to provide water quality treatment by instituting curb cuts or removing the curb in that area completely. Plantings near the southwestern end of patch 72-220 would help the woody plant succession that is beginning in this area.

Table E.16: Baltimore City forest patch assessment results

FOREST PATCH ID	SCORE	SUB-WATERSHED	ACRES	JURISDICTION
161-30	482	MAIDENS CHOICE	18.0	CITY
161-15	417	MAIDENS CHOICE	33.4	CITY
72-220	385	LOWER GWYNNS	6.9	CITY
72-195	384	LOWER GWYNNS	39.0	CITY
161-29	368	MAIDENS CHOICE	14.1	CITY

Each of the potential sites will require detailed investigation to determine the owner of the property and whether the current owner is willing to sell their parcels or allow conservation easements to be placed on the property. Property acquisition costs will determine the feasibility of enhancing these forested sections.

STORMWATER MANGEMENT ASSESSMENT

Much of the Gwynns Falls Watershed was developed prior to formal stormwater management policies, particularly those areas in Baltimore City and inside the Baltimore Beltway (I-695) in Baltimore County. Among existing facilities, the majority are designed for quantity control without water quality improvement features.

The goals of the stormwater management assessment were to:

1) Identify select existing stormwater management facilities that have the potential for conversion and water quality enhancement
2) Identify structural deficiencies and downstream channel instabilities in the selected existing stormwater management facilities
3) Identify opportunities for BMP creation at existing storm drain outfalls
4) Identify structural deficiencies at select storm drain outfalls.

Stormwater Management Facilities

48 stormwater management (SWM) facilities were selected by Baltimore City and Baltimore County for evaluation. Figure E.9 shows typical SWM facilities.

Figure E.9: Typical stormwater management facilities within the Gwynns Falls

Storm Drain Outfalls

Urban storm drain outfalls are often sources of channel instabilities and water quality problems. 82 storm drain outfalls in the Gwynns Falls watershed were selected for evaluation to improve the stream stability in the area downstream of the outfall and the water quality in the main stream. The outfalls were selected based on the following criteria:

- 36" diameter or larger pipe
- Must have at least 50 feet between the outfall and the stream channel

Figure E.10 shows typical outfalls in need of retrofit.

Figure E.10: Stormdrain outfalls in need of structural repair, energy dissipation and stream stabilization.

Results

Stormwater management (SWM) facilities are important because they slow down and treat surface runoff before it enters the stream network. Urbanization increases the amount of impervious area and increases the runoff from storm events. This was shown in the frequency analysis conducted as part of the water quality modeling. Converting standard detention SWM facilities to extended detention facilities provides water quality treatment as well as reducing the peak discharges that enter the stream channel. Lower discharges and velocities reduce stream power and consequently channel erosion.

Thirteen sites were rated as high priority retrofits within the Gwynns Falls watershed. Three of these sites were in Baltimore County and the remainder in Baltimore City. Eleven storm drains (9 City and 2 County) and two stormwater facility retrofits (1 City and 1 County) were rated as high. Refer to Chapter 7 for detailed project recommendations. Chapter 6 details the results of the remaining sites evaluated and the recommendations for SWM facility and outfall retrofits for Baltimore City and County. Figure E.11 shows the locations of the proposed outfall and facility retrofits. Typical stormwater management facility retrofits include conversion to extended detention, addition of forebays or other pretreatment options and the creation of shallow marshes. Typical storm drain outfall retrofits include energy dissipation devices, creation of shallow floodplain marshes, creation of bioretention facilities, channel daylighting and downstream stabilization.

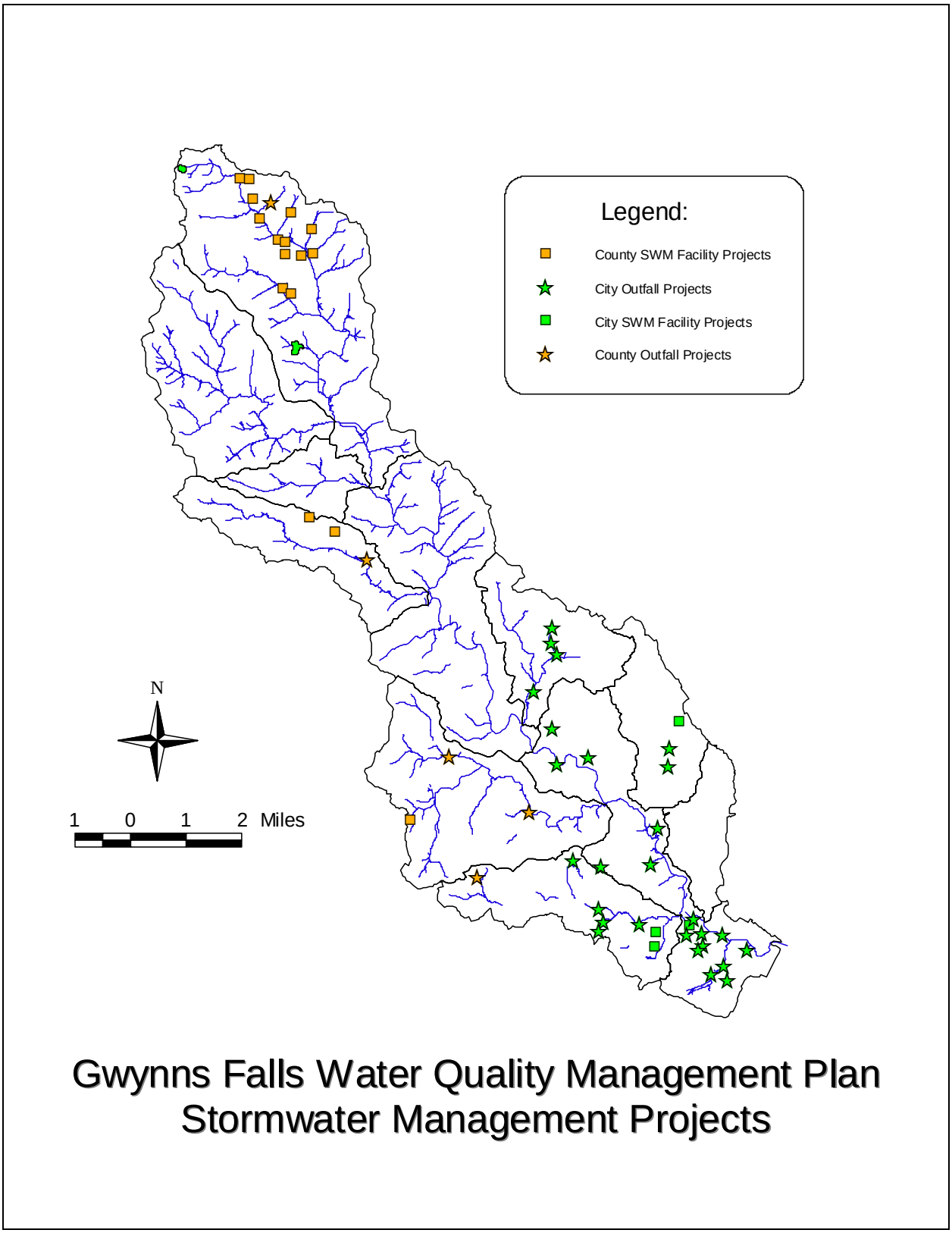


Figure E.11: Proposed stormwater management facility and outfall projects

RESTORATION GOALS & MANAGEMENT MEASURES

The Gwynns Falls subwatersheds were divided into four major groups based on the amount of development (imperviousness), stream channel stability and stormwater management potential, in each subwatershed. These grouping were used to define the subwatershed goals and objectives. Table E.17 shows the breakdown among the watersheds.

Table E.17: Classification of Gwynns Falls Subwatersheds

Group 1 – Sensitive (% Impervious)	Group 2 – Impacted (% Impervious)	Group 3 –Urbanized (% Impervious)	Group 4 – Highly Urbanized (% Impervious)
Red Run (18%)	Upper Gwynns Falls (26%)	Powder Mill (34%)	Gwynns Run North (36%)
Horsehead Branch (15%)	Scotts Level (24%)	Dead Run (36%)	Gwynns Run South (44%)
	Middle Gwynns Falls (22%)	Maidens Choice (33%)	
		Lower Gwynns Falls (32%)	

Group 1 – Sensitive Subwatersheds

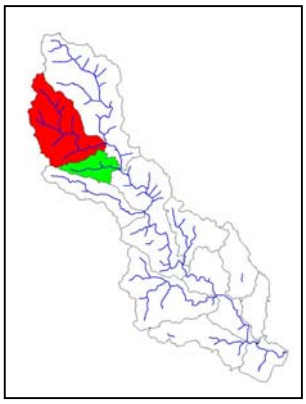
The Sensitive subwatersheds are the least developed subwatersheds within the Gwynns Falls. Both Red Run and Horsehead Branch have less than 20 percent impervious area. The majority of the development in these watersheds has taken place with some stormwater management in place. More than 25% of existing land use of these subwatersheds are comprised of forested areas.

The current land use zoning was used to evaluate the impacts of the ultimate development condition on each of the subwatersheds. Both subwatersheds are expected to experience significant increases in impervious area when comparing existing conditions versus ultimate development. In fact, these subwatersheds experience the largest increase in imperviousness out of any of the Gwynns Falls subwatersheds. Red Run's imperviousness will increase from 18% to 31% while Horsehead Branch's imperviousness will increase from 15% to 26%. These subwatersheds are just beginning to see the impacts of development on their stream networks. The future of these stream networks will depend largely on future land use conditions.

Both of the subwatersheds in this category have a large percentage of existing forested land. Protecting forested buffers will be critical in maintaining the quality of the streams within each subwatersheds.

Consequently, the primary goals for these two subwatersheds will focus on land management measures to protect the quality of the stream network during this future development period.

Some existing streams in this subwatershed are trout streams and high water quality must be maintained. The primary goals for the Group 1, Sensitive subwatersheds are:



- Land management strategies
  - Focus on stream buffer preservation
  - Forest preservation and enhancement
  - Continue to pursue opportunities to provide water quality treatment
  - Apply current stormwater management regulations to the highest standard possible. Waivers and variances should not be considered without evaluating the cumulative effect of the waiver/variance on the watershed.

Figure E.12: Sensitive subwatersheds

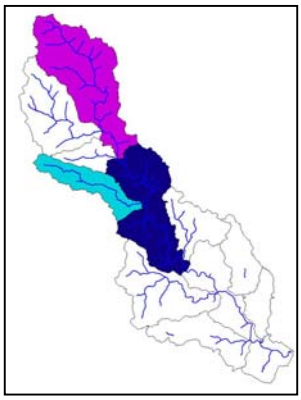
Land management strategies are critical to maintaining the health of Group 1 streams. Future zoning and land use changes will have a significant effect on the future stability and habitat of the streams within these subwatersheds. Figure E.12 shows the location of the sensitive subwatersheds within the Gwynns Falls. Red Run is shaded red and Horsehead Branch is shaded green.

Group 2 – Impacted Subwatersheds

The Impacted subwatersheds are already feeling the effects of urbanization and are between 22 and 26% imperviousness. The streams are affected by urbanization but have the potential for recovery with habitat oriented stream improvements.

Large portions of the subwatersheds were developed with stormwater management, however, the majority of these occurred before water quality requirements. All stormwater management facilities should be evaluated for potential expansion and/or conversion to extended detention. Baltimore County DEPRM selected over 23 stormwater management ponds within these three subwatersheds for evaluation.

Many of the streams within these subwatersheds have nearly vertical stream banks and poor ecological habitat. Because a significant amount of development has already occurred in these subwatersheds, the focus switches from land management (as in Group 1 – Sensitive streams) to retrofit opportunities. Retrofit opportunities considered in these watersheds should enhance stream stability and improve the habitat quality of the existing stream network. Figure E.13 shows the impacted subwatersheds. Upper Gwynns Falls is colored purple, Middle Gwynns Falls is navy blue and Scotts Level is turquoise.



The primary goals for the Group 2, Impaired subwatersheds are:

- Stream channel improvements with habitat enhancement focus
- Identify stormwater management retrofit opportunities

Figure E.13: Impacted subwatersheds

- Continue to enforce current stormwater management regulations

Group 3 – Urbanized Subwatersheds

The Urbanized subwatersheds contain between 30 and 36% impervious area and experience significant stream channel instabilities and habitat impairment. Although the percentage of impervious development within these subwatersheds is high, there are a significant number of open stream channels. ***This key difference between the Urbanized subwatersheds and the Highly Urbanized subwatersheds is that the Urbanized subwatersheds still have a significant stream network while the Highly Urbanized subwatersheds are primarily piped.***

Many of the Urbanized subwatersheds were developed prior to mandatory stormwater management regulations, both quantity and quality control. BMP creation and/or expansion are considered high priorities in these subwatersheds.

The high amount of urbanization has caused widespread stream stability issues within these subwatersheds. Land use and space constraints are common problems in the these urbanized areas. Because many of the subwatersheds in this category are completely built out, water quality enhancement efforts should be focused on redevelopment projects. Figure E.19 shows the urbanized subwatersheds. Powder Mill is orange, Dead Run is red, Maidens Choice is blue and the Lower Gwynns Falls is shaded green in Figure E.14.

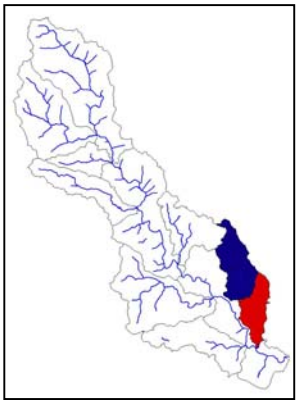
The primary goals for the Group 3, Urbanized subwatersheds are:

- Design stream channel improvements with a focus on geomorphic adjustment to achieve stream stability
- Identify new opportunities for stormwater management BMPs
- Proactive relocation and/or protection of non-leaking sewer/utility lines and manholes in stream channel
- Seek opportunities for water quality improvement in evaluating redevelopment projects

Figure E.14: Urbanized subwatersheds

Group 4 – Highly Urbanized Subwatersheds

The Highly Urbanized subwatersheds contain 36% or more imperviousness. The primary difference between the Urbanized (Group 3) and Highly Urbanized (Group 4) categories is that Group 3 subwatersheds have a significant amount of open stream channel and that Group 4 subwatersheds have primarily piped channels. Once contaminants enter the stormdrain system, they are transported straight into the mainstem of the Gwynns Falls. Figure E.20 shows the highly urbanized subwatersheds. Gwynns Run North is shown in navy blue and Gwynns Run South is shown in red in Figure E.15.



The primary goals for the Group 4, Highly Urbanized subwatersheds are:

- Focus on prevention and reduction of pollutant loads before they enter the stormdrain system
- Focus on installing *structural* BMP devices at proper locations in the storm drain systems
- Identification and correction of existing sewage leaks from sewer lines and manholes
- Continue to look for opportunities to create SWM facilities where space is available

Figure E.15: Highly urbanized subwatersheds

WATER QUALITY ENHANCEMENT PROJECTS

Potential projects were identified using the results of the field assessments and the management goals for each subwatershed established above. Because of the complexity of data collected during this study, a two-tiered approach was developed to aid in project identification:

1) Stream based assessment – incorporates the results of the cruised reach and Corps reach assessments
2) Source based assessment – incorporates the results of the stormwater management facility and outfall assessment, Forest assessment and SWMM modeling assessment.

WATER QUALITY RANKING

Ranking is performed for potential restoration and stabilization projects in order to determine recommended City and County actions. A well defined and balanced ranking system allows direct comparison of competing projects. This mitigates for inherent subjectivity.

Five criteria were used to form a ranking of water quality enhancement projects. Details of the criteria are explained below and in Table E.18.

1. Water Quality Benefit – This represents an assessment of a project's benefit to reducing pollutant and sediment loads and improving water quality within the watershed.

2. Habitat enhancement – This criteria looks specifically at improvements to habitat within the watershed and the stream channel itself.

3. Land availability & Construction Access – This category rates the ability for a project to be constructed and includes both land availability and construction access.

4. Public Acceptance and educational opportunities – This category rates the public's willingness to support a project, its benefit to community aesthetics and potential for public education.

5. Reduction of Risk to Public Safety or Infrastructure – This includes the threat of localized flooding, culvert failure and unstable stream banks along improved properties.

Table E.18: Water quality enhancement project ranking scheme

Ranking Category	Numeric Ranking			
	0	1	2	3
1) Water Quality Benefit	None	Low	Moderate	High
2) Habitat Enhancement	None	Low	Moderate	High
3) Land Availability & Construction Access	Private land w/ no access	Private land w/ good access	Public land w/ fair access	Public land w/ good access
4) Public Acceptance & Educational Opportunity	Strong objections & no educational opportunity	Some objections & minimal educational opportunity	Some desire & good educational opportunity	Strong desire & strong educational opportunity
5) Reduction of Risk to Public Safety or Infrastructure	No Impact	Low	Moderate	High

Priority Projects

The priority projects were chosen using the prioritization scheme described above. Projects were broken into three size categories based on total cost for comparison purposes. Projects were broken into three categories:

- Large (Present worth of project is > $300,000)
- Medium ($100,000< Present worth of project<= $300,000)
- Small (Present worth of project <= $100,000)

Projects were ranked in two steps. First, the projects were sorted by project score and then based on the project's annual cost. In order to provide a uniform cost benefit comparison, the project score was divided by the annual project cost (in thousands). The cost benefit analysis did not assign a cost associated with each benefit, however, it allowed for a reasonable cost comparison among proposed projects. When two projects had the same project score and annual cost, they were ranked as a tie.

PROJECT SUMMARY

The data collection and analysis conducted as part of this comprehensive effort have led to the identification of 120 proposed capital projects at a cost of approximately $30 million. Table E.19 summarizes the variety of projects that have been recommended as part of this water quality plan. These projects include over 10 miles of stream restoration, 8 miles of riparian buffer enhancements and 67 stormwater retrofits. The proposed stream restoration and riparian enhancement projects restore 25% of the watersheds most unstable streams. Stabilizing these streams reduces sediment loads within the watershed by approximately 26%. Figure E.16 shows the location of the priority projects throughout the watershed.

Table E.19: Summary of proposed projects within the Gwynns Falls Watershed

Project Type	Number of Proposed Projects
SWM Facility Retrofit	29
SWM Facility Maintenance	1
SWM Storm Drain Outfall Retrofit	37
New BMP Creation	17
Floodplain Wetland Creation	12
Forest Enhancement	4
Riparian Buffer Enhancement	25
Stream Restoration & Stabilization	42
Sediment Reduction due to Proposed Projects	26%
Utility Protection and/or Relocation	1
Debris Removal	3

To estimate the pollutant reductions that would be achieved by constructing these projects, average pollutant loading reductions for BMP and stream restoration projects based on past Baltimore County monitoring projects were used. The values in table E.20 show the pollutant removal efficiency of many types of BMP's. Table E.21 shows the average pollutant reduction in pounds per linear foot of stream restoration.

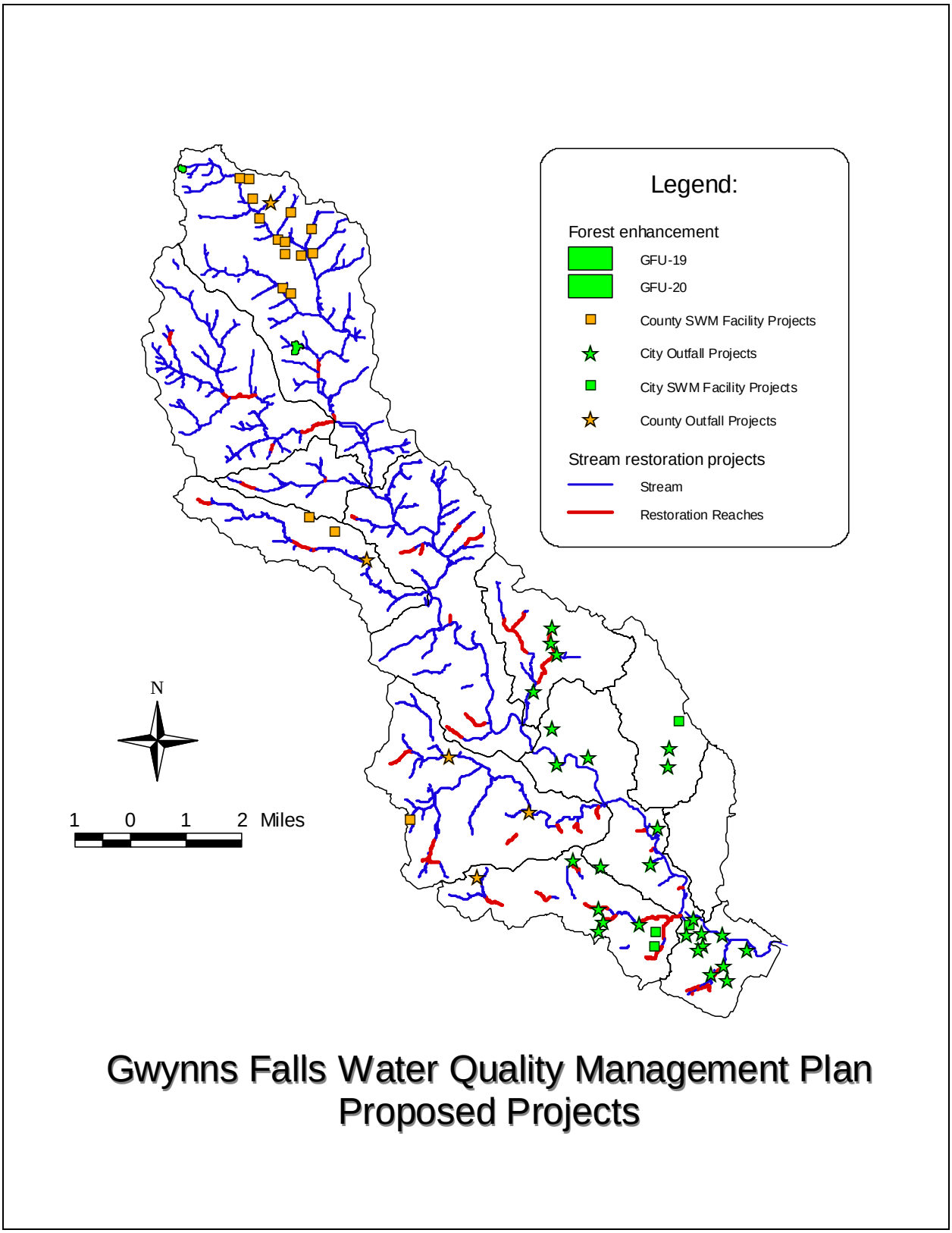


Figure E.16: Proposed Priority Projects

Table E.20: Percent removal efficiency for select BMP's

Facility Type	TSS	TP	TN	Pb	Zn
Detention Facility	10%	10%	5%	43%	26%
Extended Detention Facility	60%	20%	30%	43%	26%
Wet Ponds/Shallow Marshes	80%	50%	50%	73%	51%
Infiltration Practices	90%	70%	50%	71%	80%
Filtration Practices	85%	60%		-	-
Stormceptors	80%	35%	35%	40%	40%

Table E.21: Pollutant reductions for stream restoration projects

Stream Reductions	TSS	TP	TN	Pb	Zn
Lbs of reduction per linear foot	2.55	0.0035	0.024	0.00007	0.0007

Table E.22 shows the estimated percent reduction in annual pollutant loading by subwatershed.

Table E.22: Percent pollutant reduction for proposed projects

Subwatershed	Miles of stream restored	TSS	TP	TN	Pb	Zn
Upper Gwynns Falls	0.8	15%	4%	1%	7%	3%
Red Run	0.6	3%	1%	0%	2%	1%
Horsehead Branch	0.0	10%	3%	1%	19%	5%
Scotts Level	1.5	30%	9%	3%	17%	7%
Middle Gwynns Falls	0.9	10%	3%	1%	9%	3%
Powder Mill	0.9	17%	5%	2%	10%	4%
Gwynns Run North	0.0	1%	1%	0%	6%	1%
Gwynns Run South	0.0	-	-	-	-	-
Dead Run	1.6	19%	6%	3%	37%	8%
Maiden Choice	2.0	20%	7%	3%	21%	6%
Lower Gywnns Falls	1.6	12%	4%	2%	21%	5%
Overall reduction in Gwynns Falls Pollutant Loading		**13.5%**	**4.0%**	**1.5%**	**15.1%**	**4.0%**

Because no stream or stormwater retrofit projects are recommended for Gwynns Run South, there is no pollutant load reduction associated with this watershed. In highly urbanized subwatersheds like Gwynns Run North and South, there is often limited space available for the construction of new stormwater management facilities and other restoration measures. Treating runoff before it enters the storm drain system is critical. One potential treatment option is through the use of structural BMP devices such as Stormceptors®, ,Baysavers® and other filtration devices. These devices capture the “first flush” of flow entering a storm drain and separate the sediments and oils from the discharge. Regular maintenance of these facilities is necessary to keep these systems working efficiently. These structures should also be considered when performing any maintenance in an urbanized area and during redevelopment projects. The reductions that can be obtained from these types of technology are summarized

in table E.23. It is assumed that these devices will treat a percentage of the runoff generated from each of the subwatersheds. Since Powder Mill, Dead Run and Maidens Choice have the potential for water quality projects such as stormwater management retrofits and stream restoration, the structural BMP's can be used to supplement the water quality treatment network. In Gwynns Run North and South, the structural BMP's will be the primary source of water quality treatment.

The last line of table E.23 shows the potential reduction in pollutant loading for the entire Gwynns Falls watershed. By installing these devices in the highly urbanized subwatersheds which are typically high pollutant generators, a significant reduction in overall watershed loading can be obtained.

Table E.23: Pollutant loading reductions due to the installation of structural BMPs

Subwatershed	% of watershed runoff treated	Cost per acre of treatment	TSS	TP	TN	Pb	Zn
Powder Mill	15	$7,200	12%	5%	5%	6%	6%
Gwynns Run North	75	$8,200	60%	26%	26%	30%	30%
Gwynns Run South	75	$7,200	60%	26%	26%	30%	30%
Dead Run	20	$8,800	16%	7%	7%	8%	8%
Maiden Choice	15	$6,800	60%	26%	26%	30%	30%
Lower Gywnns Falls	50	$6,400	40%	18%	18%	20%	20%
Overall reduction in Gwynns Falls Pollutant Loading			**18.1%**	**7.7%**	**7.5%**	**9.8%**	**9.6%**

Table E.24 shows the overall pollutant reduction that can be achieved by the construction of the non-structural projects and the installation of the structural BMP devices in the urban areas.

Table E.24: Overall pollutant loading reduction in the Gwynns Falls

Subwatershed	TSS	TP	TN	Pb	Zn
Reduction due to proposed projects	**13.5%**	**4.0%**	**1.5%**	**15.1%**	**4.0%**
Reduction due to structural BMPs	**18.2%**	**7.7%**	**7.4%**	**39.5%**	**37.7%**
Total reduction for the Gwynns Falls	**31.8%**	**11.8%**	**8.9%**	**54.6%**	**41.7%**

One additional area that will provide significant water quality benefit to the watershed is to clean-up the continuous sewage leaks that are occurring within the watershed. Although these leaks occur throughout the watershed, the largest concentrations can be found in Dead Run, Maidens Choice and the Lower Gywnns Falls subwatersheds. Table E.30 summarizes the pollutant load reductions that can be achieved as the City and County continue to address these problems.

Table E.25: Pollutant load reductions due to the repair of continuous sewer leaks

Location	TKN	TP	BOD	COD	Fecal Coliform
Watershed Outlet	11%	8%	8%	9%	52%

With the completion of the Gwynns Falls Water Quality Management Plan, the City and County now have a comprehensive water quality plan that will allow them to make the most efficient use of the limited funds available. The plan serves as a framework and provides multiple tools for the agencies to select the best project based on cost, subwatershed area or overall pollutant reductions. By combining capital projects with community education and outreach, the City and County can work towards achieving their water quality goals.

ACKNOWLEDGEMENTS

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A study of this magnitude requires a team of many individuals. Ms. Kelly Brennan, P.E. was the overall project manager for Parsons Brinckerhoff. Mr. Chin Lien, P.E. served as the project's technical advisor. They were assisted by Mr. Gene Bosley, Mr. Greg Fox, Ms. Krista Greer and Mr. Joel Gladfelter. Mr. Chuck Weinkam of Coastal Resources, Inc. directed the stream stability and forest assessments. He was assisted by Ricardo Gonzalez, David Durmowicz, Cliff Garrett, David Smith and Christine Smith of Coastal Resources and Rachel Shea, P.E., Ms. Jennifer Sampson, P.E., Eric Karch, Doug Streaker, Krista Bethune, Greg Keenan, Mike Mitchell and J. Harne of GPI.

CHAPTER 3: STREAM ASSESSMENT

The field assessments of this watershed study were divided into three distinct categories: stream assessment, forest assessment and stormwater assessment. This chapter will describe the data collected in the stream assessment of the Gwynns Falls Watershed. The goal of the assessment was to document the geomorphic and riparian vegetative condition of the streams within the watershed and identify sites for possible protection, enhancement and restoration in order to improve the overall health and quality of the Gwynns Falls Watershed system.

The stream assessment was divided into three primary parts. Each part will be discussed in detail in this chapter.

- Cruised Reach Assessment (70% of stream channels)
- Corps Reach Assessment (30% of stream channels)
- Database Creation and Mapping

Field crews of two team members were used to assess both the cruised and corps reaches. The field crew consisted of one senior staff member who served as the team leader and one junior staff member. Team leader training and calibration was done prior to beginning the overall field work. Supervisory staff worked with the team leaders to ensure continuity in data collection. Appendix 3 contains mapping of the stream reaches by subwatershed.

Eldon Gemmill, Baltimore County DEPRM, performed a joint field assessment with several of the field crews to ensure that the data collection was consistent with the scope and County standards.

3.1 CRUISED REACH ASSESSMENT

Cruised reach assessments were conducted on over 70 miles of Baltimore County and 22 miles of Baltimore City first, second and third order stream reaches that were not previously assessed by the U.S. Army Corps of Engineers. Cruising is defined as a team of two stream surveyors walking the entire length of each reach and performing rapid field assessments. Measurements using a stretched tape and surveyors rod were performed to assess bankfull width and depth. Detailed cross sections were not taken at each reach. A representative riffle section of the reach was selected for assessment. This section was photographed for future reference. The items included in the rapid assessment were divided into four major categories:

- Channel Morphology
- Channel Disturbances
- Channel Habitat
- Restoration Opportunities

The methodology and data collection parameters for each category are defined below.

Prior to beginning field work, all streams were divided into reaches of approximately 750 feet. Reach breaks were adjusted in the field if stream type and characteristics changed significantly. Final cruised reach assessment yielded an average stream reach of 804 feet.

Channel Morphology

Flow Regime

Streamflow exhibits a strong influence on channel morphology, aquatic habitat and riparian vegetation. Flow regime categories were based on the Level III Rosgen Methodologies. Table 3.1 lists the categories used in this field assessment.

Table 3.1: Flow regime categories for the Gwynns Falls cruised reaches

Code	Flow Regime Category	Percent in Gwynns Falls Watershed
E	Ephemeral stream channel, flow only in response to precipitation	10.8%
S	Subterranean stream channel, flows parrallel to and near the surface for various seasons	0.1%
I	Intermittant stream channel, flow which exists seasonally or sporadicly	14.3%
P	Perennial stream channel, flow which exists year round	74.8%

Stream Size

Bankfull width is often used to assess stream size because of the many hydrologic and geomorphic interpretations that can be derived from width measurements. Stream size can be used to provide prospective for interpreting hydraulic processes, sediment transport and biological processes. Table 3.2 lists the stream size categories based on Rosgen Level III classification that were determined from the measurement of bankful width for each stream reach. Table 3.2 also lists the percent of each stream size assessed in this study.

Table 3.2: Stream size classification for the Gwynns Falls cruised reaches

Code	Stream Size	Percent Cruised Reaches in Gwynns Falls Watershed
S-1	Bankfull Width less than 1 foot	0%
S-2	Bankfull Width from 1 to 5 feet	15%
S-3	Bankfull Width from 5 to 15 feet	65%
S-4	Bankfull Width from 15 to 30 feet	8%
S-5	Bankfull Width from 30 to 50 feet	6%
S-6	Bankfull Width from 50 to 75 feet	3%
S-7	Bankfull Width from 75 to 100 feet	2%
S-8	Bankfull Width from 100 to 150 feet	1%
S-9	Bankfull Width from 150 to 250 feet	0%
S-10	Bankfull Width from 250 to 350 feet	0%
S-11	Bankfull Width from 350 to 500 feet	0%
S-12	Bankfull Width from 500 to 1000 feet	0%
S-13	Bankfull Width > 1000 feet	0%

Entrenchment Ratio Range

Entrenchment describes the relationship of a river to its valley and landform features. The entrenchment ratio describes the vertical containment of a stream. It has been defined by Rosgen to be the ratio of the width of the floodprone area to the surface width of the bankfull

channel. The entrenchment ratio was computed for each stream reach and then divided into three categories: slight entrenchment, moderate entrenchment and entrenched. Table 3.3 shows the entrenchment characteristics of the Gwynns Falls Watershed.

Table 3.3: Entrenchment ratio ranges for the Gwynns Falls cruised reaches

Category	Percent Cruised Reaches in Gwynns Falls Watershed
Slight to No Entrenchment (> 2.2)	39%
Moderate Entrenchment (1.41 - 2.2)	33%
Entrenched (1.0 - 1.4)	28%

Sinuosity Range

Channel sinuousity is the ratio of stream channel length to down-valley distance. It is also defined as the ratio of valley slope to channel slope. Sinuosity is a primary indicator of Rosgen stream type and also provides an indication of how the stream slope has adjusted in comparison with the valley slope. The actual sinuosity was not field measured for each cruised reach, however, the sinuosity range was determined from the aerial photogrammetry and visually verified in the field. Table 3.4 shows the classification categories used in this analysis.

Table 3.4: Sinuosity range for the Gwynns Falls watershed cruised reaches

Code	Category	Percent Cruised Reaches in Gwynns Falls Watershed
Low	Sinuosity Ratio of 1.0 to 1.2	64%
Moderate	Sinuosity Ratio of 1.2 to 1.5	32%
High	Sinuosity Ratio of greater than 1.5	4%

Depositional Features

Depositional patterns are easily observed features that are beneficial in interpreting stream condition. Depositional patterns can be used to illustrate the effects of past land management on sediment supply and storage and the effects on channel form and stability. Table 3.5 lists the depositional features used to assess the cruised reaches in this study.

Table 3.5: Depositional features of the Gwynns Falls cruised reaches

Code	Category	Percent Cruised Reaches in Gwynns Falls Watershed
B-1	Point Bars	18%
B-2	Point Bars with Few Mid Channel Bars	5%
B-3	Many Mid Channel Bars	0%
B-4	Side Bars	22%
B-5	Diagonal Bars	0%
B-6	Main Branching with Many Mid Bars and Islands	1%
B-7	Mixed Side Bar and Mid Channel Bars exceeding 2-3 times the width	1%
B-8	Delta Bars	0%
NONE	NONE	54%

Channel Substrate

Channel bed and bank materials influence the cross sectional form, plan view and longitudinal profile of rivers. They also determine the extent of sediment transport and resistance to hydraulic stress. It is also important for addressing the biological function and stability of rivers.

Table 3.6 shows the channel substrate categories used in the cruised reach assessment. In addition to noting a primary channel substrate, bimodal channel substrates were considered and documented. Approximately 12% of the watershed exhibited bimodal substrate characteristics. The channel substrate was visually estimated as the field crew cruised the reach. There were no physical samples taken. The channel subpavement was not assessed.

Table 3.6: Channel substrate for the Gwynns Falls cruised reaches

Category	Percent Cruised Reaches in Gwynns Falls Watershed
Boulder	4%
Cobble	42%
Gravel	31%
Sand	13%
Silt and Silt/Clay	11%

Stream Classification Type (Rosgen)

The cruised reaches were visually assessed and classified according to Rosgen's stream classification system. The entrenchment ratio, width to depth ratio and sinuosity were used in stream type selection. The majority of the watershed's streams can be classified as B, E or G stream types. Table 3.7 shows the breakdown of stream types within the Gywnns Falls Watershed. Figure 3.1 shows the Rosgen stream classification for both the cruised and corps reaches.

Table 3.7: Rosgen stream classification for Gwynns Falls cruised reaches

Rosgen Classification	Percent Cruised Reaches in Gwynns Falls Watershed
A	1%
B	24%
C	7%
D	1%
E	32%
F	10%
G	25%

Channel Slope Range

The water surface slope is a major determinant of river channel morphology and of its related sediment, hydraulic and biological function. An average slope range was estimated for each stream reach. Detailed profile measurements were not taken for each reach. Table 3.8 shows the slope ranges used in the Cruised Reach assessment.

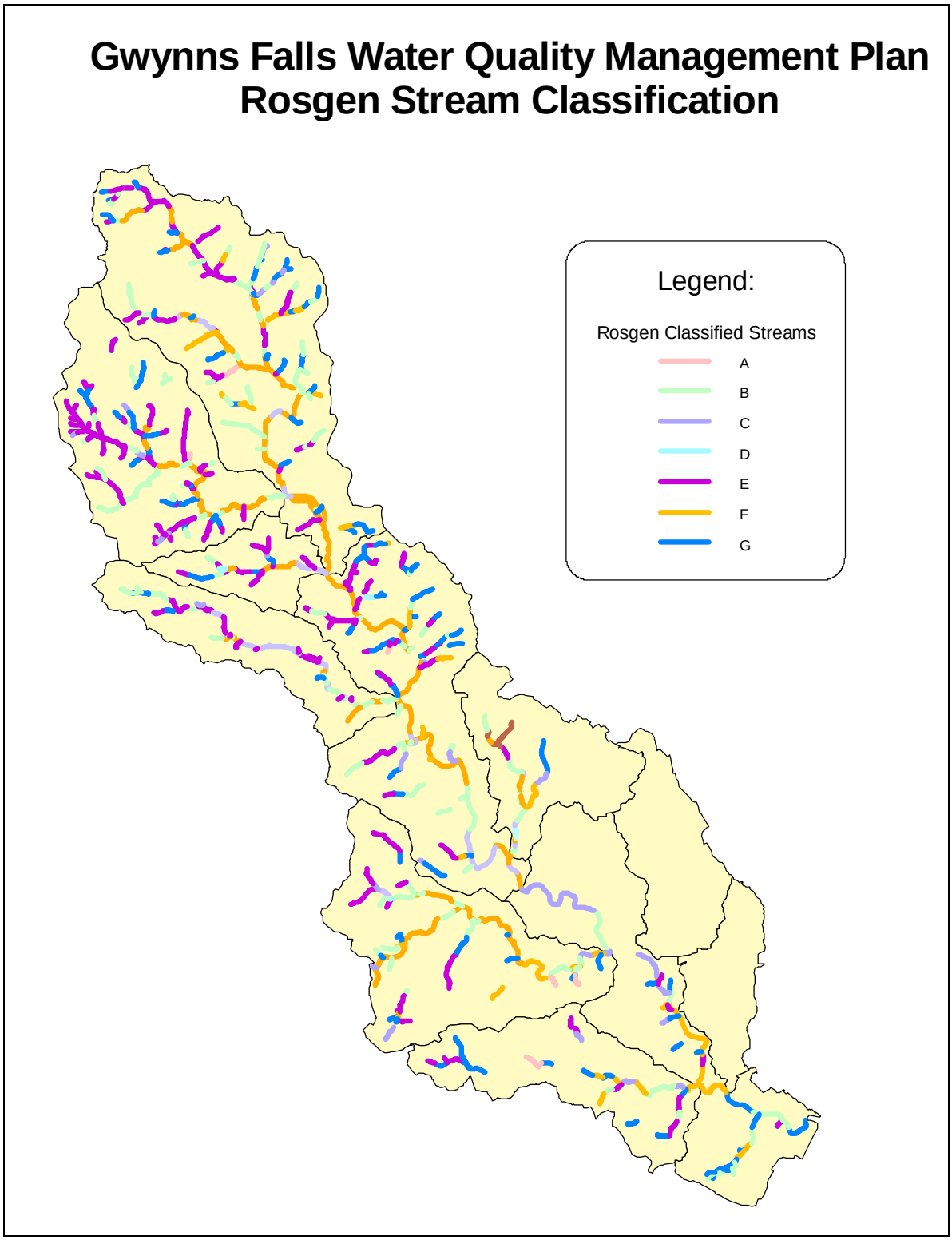

Figure 3.1: Rosgen Stream Classification

Table 3.8: Channel slope ranges for the Gwynns Falls cruised reaches.

Category	Percent Cruised Reaches in Gwynns Falls Watershed
Channel Slope < 2%	53%
2% < Channel Slope < 4%	43%
Channel Slope > 4%	4%

Width to Depth Ratio Range

The width to depth ratio is defined as the ratio of the bankfull surface width to the mean depth of the bankfull channel. The width to depth ratio is key to understanding the distribution of available energy within a channel and the ability of various discharges within the channel to move sediment. Of Rosgen's Level II parameters, the width to depth ratio is the most sensitive and positive indicator of trends in channel instability.

For channels with high width to depth ratios, the distribution of energy in the channel is such that stress is placed within the near bank region. As the width to depth ratio increases, the hydraulic stress against the banks also increase and bank erosion is accelerated. The accelerated bank erosion is usually the result of high velocity gradients and high boundary stress.

The actual width to depth ratio was computed using the field measured bankfull width and average bankfull depth. Table 3.9 summarizes the results of the width to depth ratio analyses. The categories for the width to depth ratio were taken from the Rosgen classification system. Cutoff values of 12 and 40 are used to distinguish between the various Rosgen stream types.

Table 3.9: Width to Depth ratios for the Gwynns Falls cruised reaches

Category	Percent Cruised Reaches in Gwynns Falls Watershed
Width/Depth Ratio < 12	71%
40 > Width/Depth Ratio > 12	27%
Width/Depth Ratio >40	2%

Meander Pattern

Channel meander patterns provide a plan view of lateral channel adjustments, meander width ratios and lateral containment characteristics for all of the stream types. The meander patterns provide insight into how the stream channel adjusts its slope in relation to the stream valley. Table 3.10 show the Rosgen meander classification and the percent that each meander pattern occurred within the cruised reaches of the watershed.

Table 3.10: Meander patterns of the Gwynns Falls cruised reaches

Rosgen Code	Category	Percent Cruised Reaches in Gwynns Falls Watershed
M-1	Regular Meanders	67%
M-2	Tortuous Meanders	1%
M-3	Irregular Meanders	31%
M-4	Truncated Meanders	1%
M-5	Unconfined Meander Scrolls	0%
M-6	Confined Meander Scrolls	0%
M-7	Distorted Meander Loops	0%
M-8	Irregular Meanders with Oxbows and Oxbow Cutoffs	0%

Bank Failure Assessment

The bank failure assessment is based on a combination of field measured parameters:

- Length of bank instability
- Average height of bank instability
- Ratio of Unstable to Stable Bank
- Bank Height versus Bankfull Depth (low, medium or high erosion potential)
- Bank Angle
- Denisty of Roots
- Particle Size

Average Bank Height versus Bankfull Depth

Bank Erosion Potential based on average bank height versus bankfull depth shows that 22% of the stream reaches have low or very low erosion potential and 69% of the stream reaches have high, very high or extreme erosion potentials. Low erosion potential ratios were between 1.0 and 1.19, medium erosion potential ratios were between 1.2 and 1.59, and high erosion potential ratios were greater than 1.6. Table 3.11 shows the percentage breakdown for the Gwynns Falls watershed.

Bank Angle

The bank angle data was rated for erosion potential as follows: low potential was assigned to banks sloping away from the stream, medium potential was assigned to nearly vertical banks and high potential was assigned to undercut banks, sloping in towards the stream. Sixty-nine percent of the streams had medium erosion potential and 8% have high erosion potential. Refer to table 3.11.

Root Density

Root density was another factor considered in the bank failure analyses. Low erosion potential was given to banks with dense roots throughout the entire bank, medium potential was given to

banks with dense roots in the upper half of the banks and high erosion potential was given to banks with minimal root density. Refer to table 3.11.

Streambank Substrate

Streambank substrate was the fourth component of the bank failure analysis. Low erosion potential was given to banks composed of cobbles, boulders or bedrock. Medium erosion potential was given to sand banks and high erosion potential was given to silt and clay banks. Sixty six percent of the streambanks consist of silty or clayey material.

Unstable to Stable Stream Ratio (or percentage)

The final factor in the bank erosion analysis was the ratio of unstable stream length to total stream length. Low erosion potential was given to reaches with an unstable to stable length ratio of less than 25 percent. Medium erosion potential was given to reaches with an unstable to stable ratio between 25 and 50 percent. High erosion potential was given to any reaches that had more than 50% unstable to stable lengths. More than 25% of the Gwynns Falls Reaches are more than 50 percent unstable. Figure 3.2 shows the unstable to stable ratios for the cruised reach assessment.

Table 3.11: Erosion potential of the Gwynns Falls cruised reaches

Erosion Potential	Avg Bank Ht /Bankfull Depth	Bank Angle	Density of Roots	Particle Size	Ratio of Unstable to Stable Banks
Low	23%	23%	23%	6%	40%
Medium	9%	69%	65%	29%	35%
High	69%	8%	12%	66%	25%

Channel Stability – Vertical and Lateral

Each stream reach was assessed for its vertical and lateral channel stability. Table 3.12 was used to assist the field crews with the classification of aggrading or degrading. Watershed wide, 63% of the cruised stream reaches assessed were vertically stable. However, over 49% of the cruised stream reaches assessed were laterally unstable.

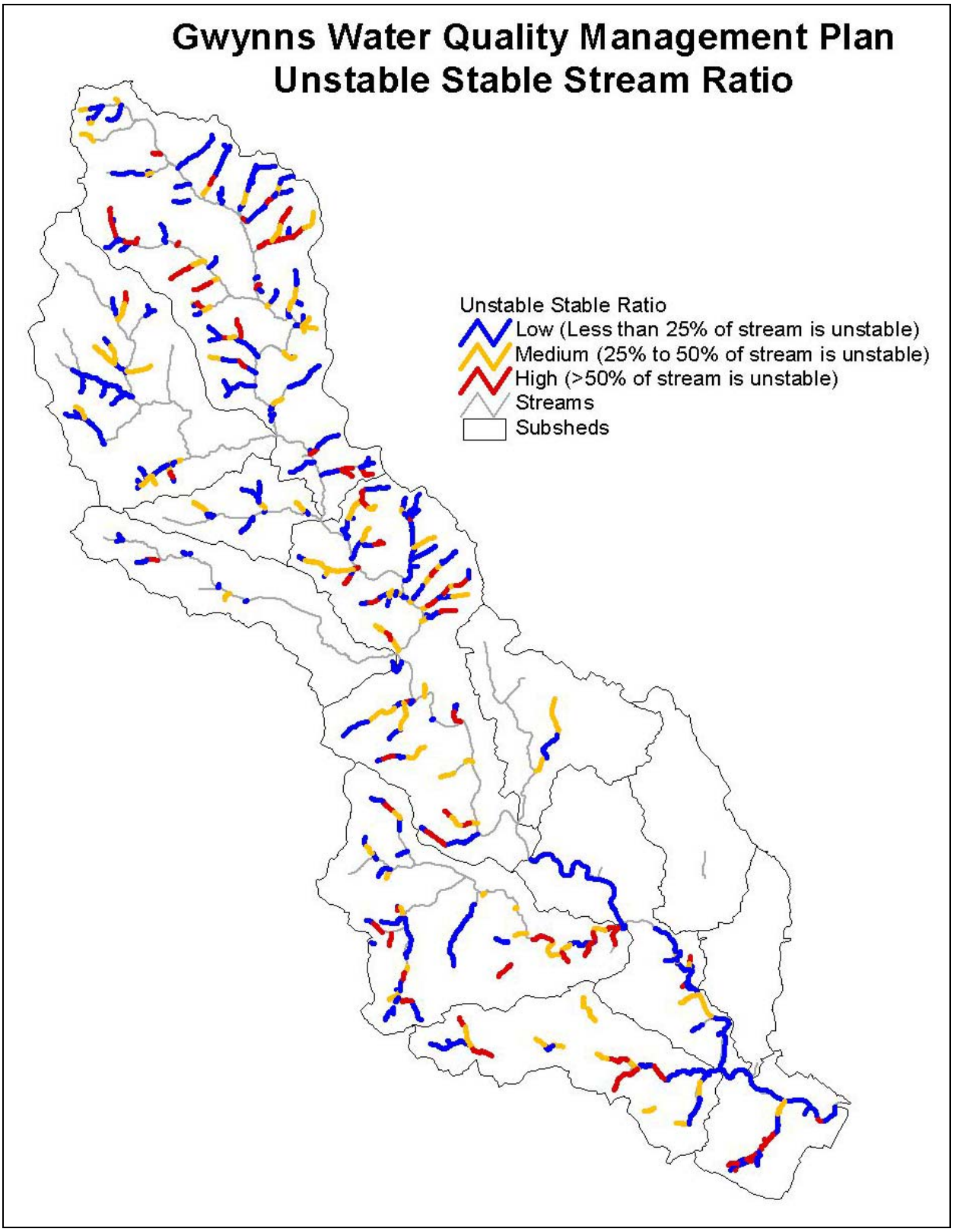

Figure 3.2: Unstable to Stable Stream Ratio

Table 3.12: Field Indicators to assess vertical and lateral stream stability.

Field Indicators for Stream Degradation or Aggradation		
Observed Condition	**Degrading**	**Aggrading**
Channel Form:		
Straightened Channel	X	
Active Head Cuts	X	
Active Meander Development		X
Channel Avulsions		X
Loss of Channel Bars	X	
Channel Bars Developing		X
Mass Wasting of Banks	X	
Vertical or Steepened Banks	X	
Tributary Stream Hanging or Steepened	X	
Hydraulic Conditions:		
Decrease in Energy Slope		X
Increse in Energy Slope	X	
Stage Control Downstream		X
Stage Control Upstream	X	
Dam or Reservior Upstream	X	
Hydrologic Conditions:		
Logging/Land Clearing		X
Watershed Urbanizing	X	
Clearwater Diversion		X
Drought Period		X
Wet Period	X	
Sediment:		
Reduction in Supply	X	
Increase in Supply		X
Alluvial Fan Downstream	X	
Alluvial Fan Upstream		X
Vegetation:		
Vegetation High Relative to Flow Line	X	
Trees Leaning into Channel	X	

Geologic Controls

Any geologic controls (bedrock) found in a reach were noted in the data collection forms. Approximately 14% of the watershed's reaches had bedrock controls.

Channel Evolution Stage (Schumm, et al 1984))

The incised channel evolution model (Schumm et al, 1984) was used to classify each of the cruised stream reaches. The intent of the channel evolution model is to determine if the reach is in a stable, incising, widening or stabilizing state. The five stages are defined as follows:

- **Stage I**: Well developed baseflow and bankfull change; consistent floodplain features easily identified; *one terrace* apparent above active floodplain; predictable pattern and

stream bed morphology; floodplain covered by diverse vegetation; stream banks less than 45 degree angle.

- **Stage II**: Headcuts; exposed cultural features; sediment deposits absent or sparse; exposed bedrock; streambank slopes > 45 degree angle.
- **Stage III**: Streambank sloughing sloughed material eroding; streambank slopes 60 degrees, vertical or concave.
- **Stage IV**: Streambank aggrading; sloughed material not eroded; soughed material colonized by vegetation; baseflow, bankfull and floodplain channel developing; predictable, sinuous pattern developing; streambank slopes less than or equal to 45 degrees.
- **Stage V**: Well developed baseflow and bankfull channel; consistent floodplain features easily identified; *two terraces* apparent above active floodplain; predictable pattern and streambed morphology; streambank angle less than 45 degrees.

Table 3.13 defines the channel evolution stages and occurrence within the Gwynns Falls Watershed. Only 21 percent of the stream reaches within the watershed were defined as stable. Twenty three percent of the stream reaches are in the process of stabilizing. The remaining 57% are in the process of widening and incising. Figure 3.3 shows the stable, aggrading and degrading streams within the entire watershed. Stages I and V were assumed to be stable, Stage II and III were assumed to be degrading and Stage IV was assumed to be aggrading.

Table 3.13: Channel Evolution Stage (Schumm et al) for the Gwynns Falls Cruised Reaches

Channel Evolution Stage	Percent Cruised Reaches in Gwynns Falls Watershed
I	16%
II	20%
III	37%
IV	23%
V	5%

Channel Disturbances

Bank Instabilities

Localized bank instabilities were recorded in each reach. The length and average height of unstable bank were measured in each reach. Separate values were recorded for the left and right bank. Bank instabilities that threatened private structures were also recorded. Table 3.11 describes some of the bank instability data collected.

Additional information on bank instabilities can be found throughout the channel morphology and habitat section of the cruised reach assessment. Figure 3.4 shows one example of the bank instabilities data, it contains a plot of the bank angle of the cruised reaches.

Altered Channels

Due to the large amount of urbanization that has already occurred within the Gwynns Falls watershed, many stream channels have been altered from their natural state. The field forms

required the field crew to assess whether each of the stream reaches was impacted by the following:

- Channel Straightening and Widening
- Manmade Lining – includes concrete, riprap and gabion lined channels
- Relocation
- Piped

Table 3.14 summarizes the altered channel data.

Table 3.14: Altered channels in the Gywwns Falls watershed.

Altered Channels	Percent Cruised Reaches in Gwynns Falls Watershed
Straightened	22%
Manmade lining	7%
Relocated	6%
Piped	13%

Figure 3.3: Stream stability analysis

Figure 3.4: Bank angles of cruised reaches

Debris Blockages

Debris blockages occurred on many of the stream reaches throughout the cruised reach assessment. The severity of the debris blockage was determined based on Rosgen's debris blockage description as describe in table 3.15.

Table 3.15: Debris blockages in the Gwynns Falls Cruised Reaches

Rosgen Code	Description	Percent Cruised Reaches in Gwynns Falls Watershed
D1	None	28.6%
D2	Infrequent	36.5%
D3	Moderate	22.9%
D4	Numerous	11.1%
D5	Extensive	0%
D6	Dominating	0.7%
D7	Beaver Dams - Few	0.2%
D8	Beaver Dams - Frequent	0%
D9	Beaver Dams - Abandoned	0%
D10	Human Influences	0%

Utilities

Sewage leaks were a major problem throughout the Gwynns Falls watershed, but particularly in Baltimore City. During the utility assessment, any reaches with the following items were noted:

- Exposed Crossings
- Leaking Utility
- Exposed manholes in or near the channel

Figure 3.5 shows a map of utility conflicts within the cruised reach assessments. A large portion of these problems occur within the southern portion of the watershed in Baltimore City.

Channel Habitat

Fish Blockages

Stream reaches with fish blockages were noted during the field assessment. Forty-eight (48) percent of the cruised reaches have some type of fish blockage. Figure 3.6 shows the extent of fish blockages on the cruised reaches throughout the watershed. Each fish blockage was classified as having one of four causes as shown in Table 3.16.

Table 3.16: Fish blockage causes on cruised reaches

Causes of Fish Blockages	Percent Cruised Reaches in Gwynns Falls Watershed
Debris Blockages	42%
High Velocities	2%
Excessive Height	28%
Shallow Depth of Flow	28%

Vegetation

Riparian cover on both the left and right overbanks of the stream was assessed. The width, composition and density of each riparian zone was collected. Density was classified as low, medium or high. Table 3.17 shows the percentage of each vegetation category that was found at the cruised reaches.

Table 3.17: Vegetation cover in the Gwynns Falls cruised reaches

Vegetation	Percent Cruised Reaches in Gwynns Falls Watershed
Bare	1%
Forbs only	<1%
Annual grass with forbs	11%
Brush	2%
Deciduous overstory	3%
Deciduous overstory with brush understory	77%
Wetland vegetation	6%

In addition to the adjacent riparian zone, the canopy cover immediately over the stream was assessed. Canopy cover was broken into five categories: less than 10% cover, 10 to 25% cover, 25 to 50% cover, 50 to 75% cover, and greater than 75% cover. Table 3.18 shows the results of the canopy cover analysis. More than 50% of the assessed cruised reaches have greater than 50% canopy cover.

Table 3.18: Canopy cover in the Gwynns Falls cruised reaches

Canopy Cover	Percent Cruised Reaches in Gwynns Falls Watershed
0 to 10%	11%
10 to 25%	13%
25 to 50%	19%
50 to 75%	31%
75 to 100%	26%

Figure 3.5: Utility conflicts in cruised reaches

Figure 3.6: Fish blockages in the cruised reach assessment

Restoration Opportunities

It was determined that the first screening for potential restoration sites would occur during the stream assessments. As the field crews collected the data above, they were also looking at the sites in terms of potential restoration projects. Types of the potential restoration opportunities are listed below. Restoration projects that did not fit into the categories below were noted in the comments section of the form. Restoration opportunities are summarized in Chapters 6 and 7 of this report.

- Channel Restoration
- Bank Stabilization
- Buffer Enhancement
- Supplemental Planting
- Utility Conflict Resolution
- Floodplain Access Enhancement
- Habitat Enhancement
- BMP
- Grade Control

3.2 CORPS REACHES

The U.S. Army Corps of Engineers, under a separate study, had assessment 41 miles of stream in Baltimore County. Baltimore County's Department of Environmental Protection had performed a quality review of the data and requested that PB walk these segments of stream verifying the existing data for use in the current watershed analysis. In addition, PB looked for restoration opportunities and photodocumented each of the stream reaches. Items examined by PB include:

- Rosgen Classification
- Habitat
- Bank Erosion
- Bed Stability
- Bank Stability

The Corps study provided qualitative data that was field verified by the PB field crews. It was impossible to compare the Cruised data and Corps data directly because the Cruised data contained much more detailed information about each reach. In addition, the cruised reaches were broken into smaller segments so there was less variability in reach characteristics. However, the Corps study did provide important comparative data that was used in the watershed evaluation and project selection processes. For example, the Corps rated bank erosion as good, fair, bad and very bad. The very bad segments of the Corps reaches were matched and compared with the cruised reaches that had the most significant bank erosion. The database contains special check boxes to note if any changes were made to the original Corps data.

Chapter 6 summarizes the Corps data collected in each individual subwatershed. Refer to that section for additional information on the Corps data.

3.3 PREPARATION OF DATABASE AND MAPPING

Cruised Reach Identification Criteria

A vast amount of data was collected in the stream stability assessment. To organize the data for storage and retrieval, a combined database and Geographic Information System was prepared using ArcView and Microsoft Access. The database and GIS are organized by individual reaches. Unique identification numbers were assigned to each reach in the initial watershed characterization.

Reaches are identified by a unique four category alphanumeric system that describes the position of the reach within the subwatershed. The first two (left most) letters represent the subwatershed in which the reach is found, for example all reach identifications for streams in the Red Run watershed begin with RR. The next two digits in the ID refer to the sequence in which the tributary enters into the mainstem. By convention the mainstem of a subwatershed is always tributary 00, the first tributary to enter the mainstem from the left side (working from upstream to downstream) is labeled tributary 01 and the first stream entering from the right is labeled 02. This numbering is continued odd numbering on the left and even numbering on the right, all the way down the mainstem until its confluence with another subwatershed mainstem. The next two numbers in the identification sequence refer to the sub-tributary and are assigned according to where a sub-tributary enters into a tributary. The first sub-tributary into a tributary would be assigned 01, subsequent sub-tributaries are labeled 02, 03, etc. Sub-tributary designations are assigned in a clockwise manner, beginning with the lowermost sub-tributary entering the tributary from the right and ending with the lowermost sub-tributary entering the tributary from the left (plan view looking from upstream to downstream). Finally, a reach number is assigned to each reach segment from upstream to downstream. The reach number is a two digit number 01 through 99 that identifies a discreet length of stream that has been assessed.

Corps Reach Identification Criteria

Corps reach identification was taken directly from mapping provided by Baltimore County. Only paper copies of the mapping were available. Therefore, reach breaks were determined by comparing the color coding on maps provided by DEPRM and assigning the appropriate naming convention. Corps reaches were not renamed for this study.

Access Database & Mapping

An Access Database was developed in Microsoft Access 2000. The database allows the user to select reaches by subwatershed. The database form has five tabs that separate the data obtained in the major categories listed below. The tabs are shown below:

- Bank Stability
- Channel Disturbances
- Channel Morphology
- Vegetation
- Restoration Opportunities

Figure 3.7 shows a sample of the Access database form. Note that because the data was entered using handheld field computers, many of the entries are listed in “logical” terms. For example, a “true” value would appear for the category *Riprap lined* if the channel had been lined with riprap. If no riprap appeared in the channel, the field would show a “false.” This logic was used for many of the fields used in data collection in order to speed up the data collection process. The logical attributes allow the user to easily flag all of the stream reaches with a particular characteristic, for example, all streams with riprap lining could be color coded red while all natural channels could be color coded blue.

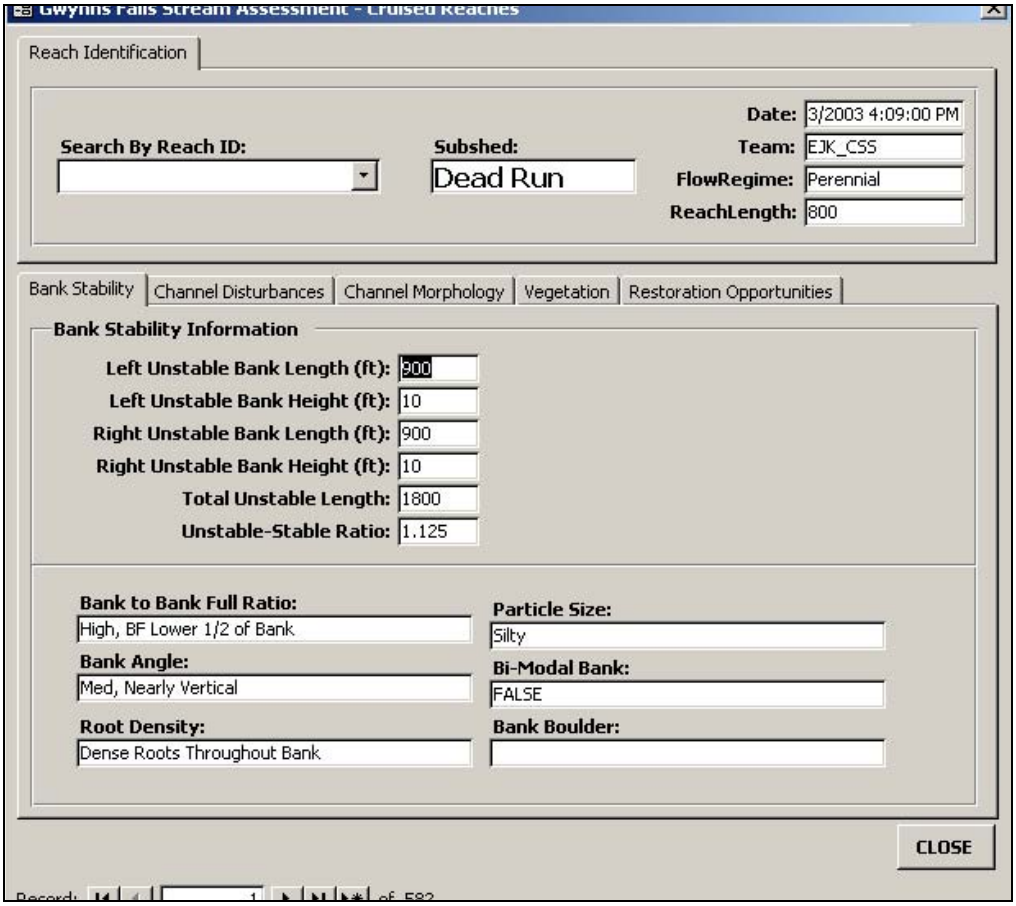

Figure 3.7: Sample database form (bank stability tab)

Bank Stability

This card contains information regarding bank stability. It records the length and average height of unstable right and left banks. The unstable-stable stream bank ratio is developed by comparing the amount of unstable bank with the total bank length for the entire reach. In addition, this card provides information on channel entrenchment, bank angle, root density and bank particle size.

Channel Disturbances

This card contains information regarding all natural and man-made disturbances in the reach including debris blockages, fish passage problems, utility crossing information, threatened private structures and channel modifications. This section also records any culvert information on this reach. It does not include information on all of the outfalls that drain into the reach, however, it includes the culvert dimensions for up to two culverts if there are any roadway crossings that require culverts. Figure 3.8 shows the channel disturbances tab in the Access database.

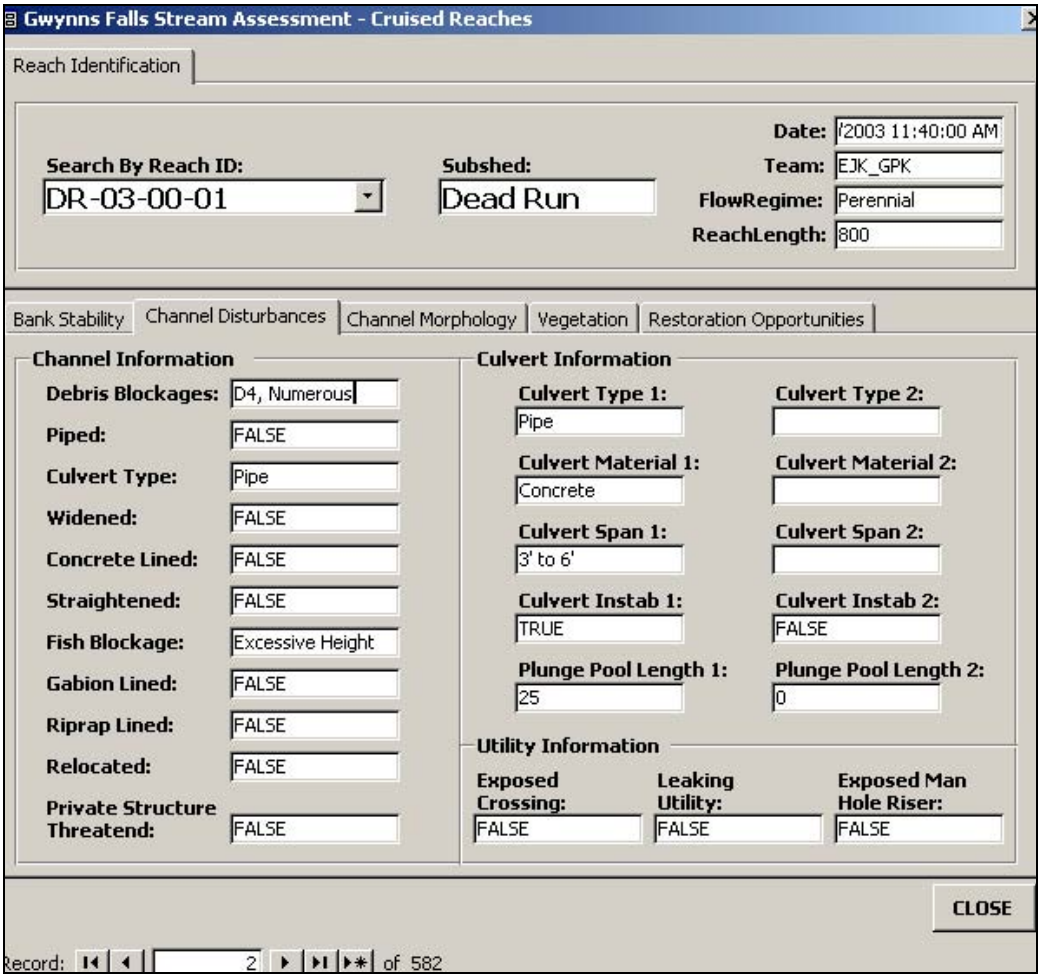

Figure 3.8: Sample database form (channel disturbances tab)

Channel Morphology

This sections contains the detailed geomorphic information that was collected during the field review such as bankfull width, bankfull depth, width to depth ratio, sinuousity, channel slope, depositional features, meander pattern, and channel evolution stage. Figure 3.9 shows the channel morphology tab in the Access database.

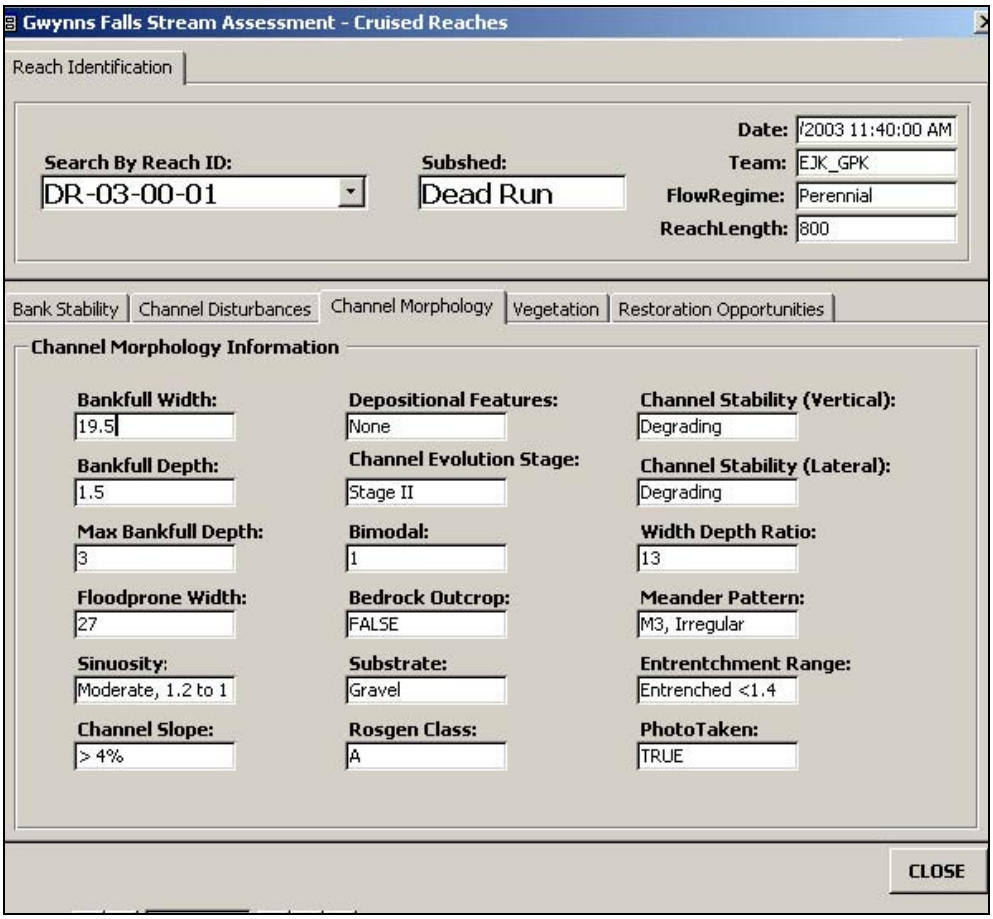

Figure 3.9: Sample database form (channel morphology tab)

Vegetation

This section contains information on the percent canopy cover over the stream reach. It also provides information on the width, composition and density of the riparian buffer. Figure 3.10 shows the vegetation tab in the Access database.

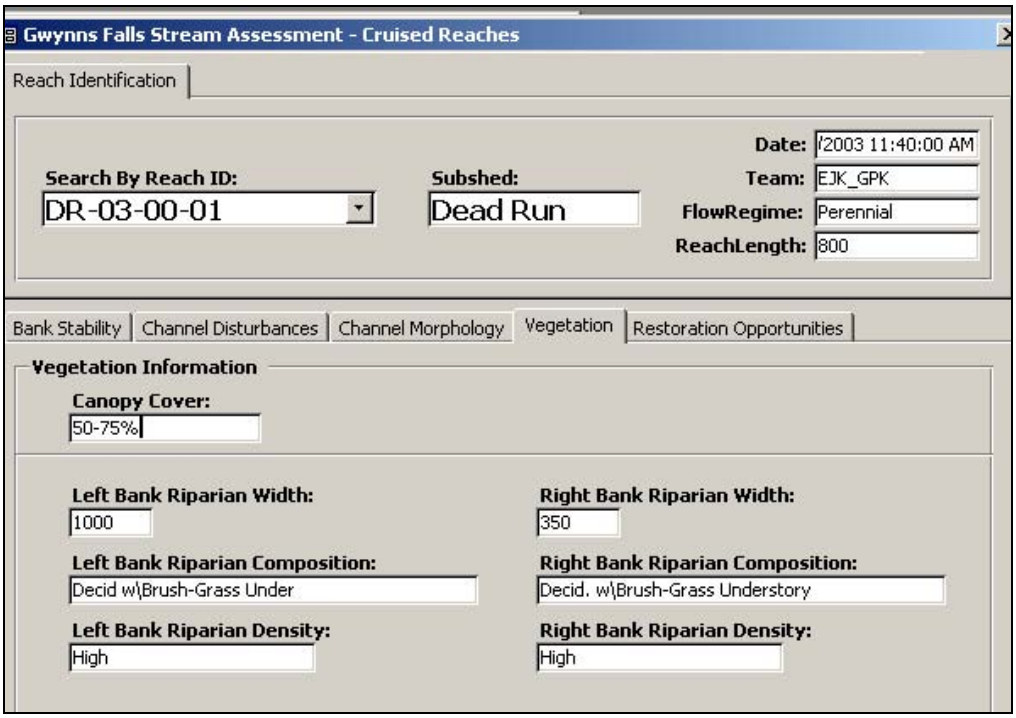

Figure 3.10: Sample database form (Vegetation tab)

Restoration Opportunities

Finally, the restoration opportunities tab gives the first glimpse of potential restoration projects for this watershed study. It is designed to give the user a better understanding of the types of restoration projects that could be undertaken in an individual reach. Figure 3.11 shows the restoration opportunities tab.

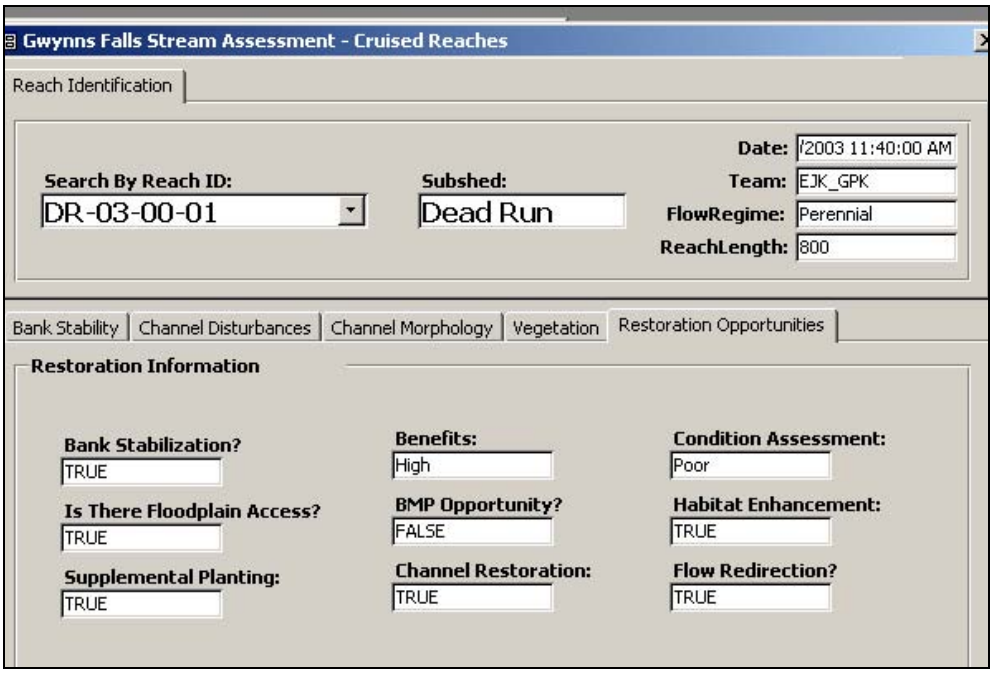

Figure 3.11: Sample database form (Restoration Opportunities tab)

Data Reporter

In addition, there is a data reporter that allows for easy reporting of the various categories on a subwatershed level. The user can easily select the report and specific subwatersheds to include in the report. Figure 3.11 shows a sample of the data reporting form.

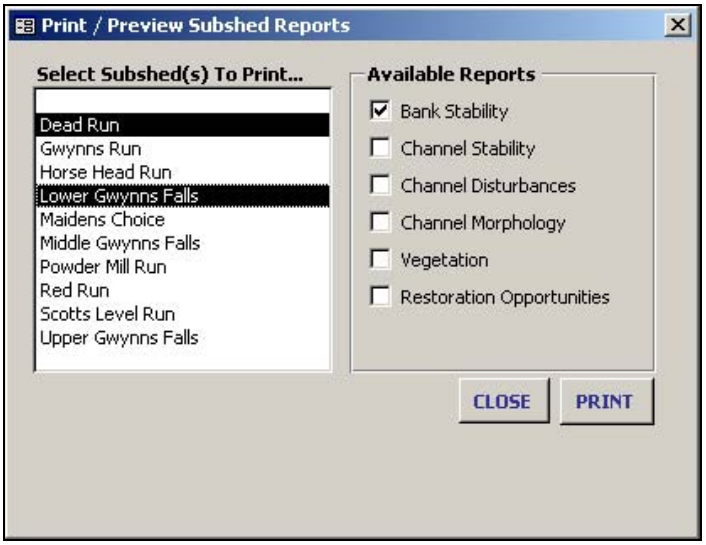

Figure 3.12: Data reporter from Access database.

GIS Mapping

All of the Access database information was joined with the stream reach shapefile in ArcView. This will allow the GIS user to click on any stream within the watershed and view all of the data collected for that stream reach. The ArcView GIS mapping can then be color coded to show different characteristics about that stream reach. Figures 3.1 through 3.5 show some of the analysis maps used in this section of the report. More detailed analysis will be completed in the Chapter 6, Watershed Assessment chapter.

Appendix 6 will contain a maps of all of the stream reach ids within each subwatershed. Each base map contains the subwatershed boundary, stream network and road network. Due to the large size of some subwatersheds, the subwatershed may have been broken down into several parts in order to easily view the reach identification information.

3.4 STREAM CHARACTERIZATION

Detailed results of the stream assessment will be included in Chapter 6 – Watershed Assessment. This section will analyze the stream assessment data collected in this chapter on a subwatershed basis. This chapter will also include recommendations for detailed restoration projects.

CHAPTER 4: FOREST ASSESSMENT

4.0 INTRODUCTION

Maintaining and improving the quality of the forested portions of the Gwynns Falls watershed is critical for the protection of habitat, stream stability and water quality. There are several challenges that must be overcome in order to protect the forested resources within the Gwynns Falls.

1. Historic land use practices
2. Fragmentation of existing forested areas
3. Invasive species
4. Limited land availability

The first two challenges are historic land use practices and the forest fragmentation that has resulted from these practices. Much of the development in the Gwynns Falls watershed occurred prior to the introduction of regulatory programs intended to protect natural resources. Because of this, the resulting landscape is a patchwork of unevenly distributed forest stands interspersed with other land uses. Fragmenting the forest increases the edge between the forest patch and its surrounding landscape and reduces the size of its undisturbed interior area. Greater diversity in native vegetative and wildlife species, structure, and habitats are usually present in this interior area. Fragmentation alters the structure, composition and function of the forest.

Invasive species are another challenge. Fragmentation increases the problem with invasive species because trees at the edge of the forest stand are more susceptible to wind, air pollution and increased temperatures, resulting in a drier microclimate (Saunders et al. 1991). Invasive species that are being cultivated in nearby landscaped communities may out-compete native species in forests with increased edge and disturbance (Binelli 2001). While invasive species may be controlled, they represent a long term maintenance and management problem because of recolonization from readily available seed sources.

The final challenge is the limited availability of land for reforestation. Land within the watershed that could be used for reforestation often goes for premium rates because it is located within urban land. Intense development throughout the Gwynns Falls has limited the amount of land available for reforestation. The goal of this study is to identify the best opportunities for enhancement within the Gwynns Falls.

Although there are many challenges to enhancing the forested areas within the Gwynns Falls, the benefits of providing a more forested watershed are clear. An enhanced forest system will provide greater biodiversity, improved stream stability and water quality treatment of urban runoff prior to reaching the stream channel.

4.1 METHODOLOGY

A forest patch assessment was conducted as part of the Gwynn's Falls Watershed Management Plan Study to investigate potential reforestation/conservation opportunities. The forest assessment that was completed for the Gwynns Falls study was based on the fourth phase of a previous analysis conducted by Baltimore County, *A GIS Analysis of Forest Cover in the Gwynns Falls Watershed (1999)*. The 1999 Baltimore County GIS study in the Gwynns Falls was based on the assessment methodology used in a 1996 Baltimore County study called *A GIS-based Methodology for Establishing a Greenway Corridor System in a Fragmented Forest Landscape (1996)*. The methodology of the 1996 study was designed to use a GIS based analysis to verify the location and extent of forest and stream resources, and to prioritize sites for conservation. The studies (1996 and 1999) utilize a three phased desktop based GIS system to identify, analyze, assess, and prioritize forest patches and deforested low order tributaries for conservation and restoration. The primary goal of the GIS studies are to target forest parcels in low order tributaries with the greatest potential for restoration, enhancement, and conservation.

Baltimore County Rapid Field Assessment

29 small forested patches on unforested, low order tributaries were assessed using Baltimore County's "Level IV" rapid assessment protocol. The patches ranged in size from 0.5 acres to 160 acres with an average patch size of 20.6 acres. The assessment provides an indication of forest patch quality and habitat suitability based on easily observed physical characteristics. Additionally, the assessment provides verification of the location and extent of stream and forest resources, as well as verification of adjacent land uses. A complete description of the methodology, including general recommendations, discussions, and insights on forest function, can be found in Section 6.2 – Field Methodology Level Four – Rapid Field Assessment of the Baltimore County study (Baltimore County 1996).

The field crew reviewed the protocols in the 1996 Baltimore County study and began preparing field mapping. Field maps displaying roads, buildings, streams and forest patches were generated using GIS layers provided by Baltimore County.

The assessment protocol scores the forest patch on six general attributes and twenty-four specific resource parameters. The maximum possible conservation score is 717. The site attributes and specific resource parameter headings are identified in Table 4.1.

Table 4.1: Site attributes and specific resource parameters assessed in the field at each selected forest patch

Site Attributes	Resources Parameters
General Site Characteristics	Maximum Conservation Score **33**
	Habitat heterogeneity
Forest Composition	Maximum Conservation Score **82**
	Forest cover, food, and nest site value
	Number of dominant/co-dominant native canopy species
	Species richness of indigenous trees, shrubs, and vines
	Evenness of species diversity
Forest Structure	Maximum Conservation Score **90**
	Crown closure
	Size class of canopy species
	Stand stratification
	Tree size-class distribution
Forest/Wildlife Habitat	Maximum Conservation Score **127**
	Standing dead trees
	Trees with excavated cavities
	Downed logs and coarse woody debris
	Humus layer
	Leaf mold
Disturbances	Maximum Conservation Score **165**
	Types of disturbance
	Intensity of disturbances
	Periods of disturbances discernable in the field
	Presence of exotic invasive species
	Distribution of exotic invasive species
	Extent of exotic invasives into edges
Riparian Corridor	Maximum Conservation Score **220**
	Water availability
	Does parcel contain headwaters, seeps, or springs
	Presence /condition of riparian corridor
	Streambank soil erosion

Teams of two to three people walking slowly through the entire forest patch and recording observations on the field data sheets completed the assessments. Larger sites were cruised in transects perpendicular to the hydrologic gradient. Transects were spaced to maximize coverage and to ensure a thorough assessment of all forest and stream features. (Refer to Appendix A-4 for all forest patch data sheets).

Following the completion of the field assessments, the scores for each patch were summed. The patch data were entered into a table and ranked from highest to lowest according to score.

Baltimore City Forest Assessment

Five forest patch assessments were performed within Baltimore City using the same protocol as for those in the County. At Baltimore City DPW's request, investigators also documented riparian forest gaps, identified opportunities to divert runoff into forest areas, and recommended materials and supplies for reforestation of targeted patches.

4.3 RESULTS

Recommendations regarding restoration and conservation opportunities are presented below. A total of thirty-four (34) forest patches in six subwatersheds were assessed (See Figures in Appendix 4-B). Twenty-nine (29) forest patches were located in Baltimore County and the remaining five (5) were in the City. Table 4.2 shows the results of the forest patch assessments.

The average conservation score was 393 out of a possible maximum of 717. The scores ranged between 499 and 150 with a median score of 417. In general the patch scores were very close (in the 400 range). A small number of patches scored significantly lower because their connection to stream resources were either poor or severed and/or there was a significant invasive species presence. These two site attributes account for 54% of the total score.

Two patches (86-24 and 86-29) in the County were not scored because their condition had been altered to the point that the assessment was not deemed applicable. Patch 86-24 appears to have been cleared for BGE power lines and a substation. A narrow strip (50 to 75' wide) south of the power line is still in tact. A 100 to 150 foot reforestation buffer to the south of the power lines is planted with mostly Cherry trees and is under stress from deer browsing. Patch 86-29 has also been disturbed. This patch appears to have been cleared during the Red Run Road enhancements and construction of the new Postal facility and the Care First building. The remaining mature trees consist of two narrow strips (one to two trees wide). The rest of the area is characterized by successional regrowth.

Forest Patch scores are summarized in Table 4.2 and a complete summary of the resource parameter data is included in Appendix A-4.

Table 4.2: Forest patch score results, sorted by sub-watershed

FOREST PATCH ID	SCORE[1]	TRIB ID	SUB-WATERSHED	AREA (FT)	ACRE	TAX MAP NO.[2]	JURISDICTION
168-23	499	T-7	DEAD RUN	309442	7.1	95	COUNTY
168-29	451	T-7	DEAD RUN	114375	2.6	95	COUNTY
168-35	448	T-6	DEAD RUN	793873	18.2	94	COUNTY
168-11	419	T-7	DEAD RUN	107663	2.5	95	COUNTY
168-30	252	T-7	DEAD RUN	87438	2.0	95	COUNTY
72-220	385	T-58	LOWER GWYNNS	300825	6.9	N/A	CITY
72-195	384	T-53	LOWER GWYNNS	1699145	39.0	N/A	CITY
161-30	482	T-3	MAIDENS CHOICE	784646	18.0	N/A	CITY
161-15	417	T-3	MAIDENS CHOICE	1454381	33.4	N/A	CITY
161-29	368	T-3	MAIDENS CHOICE	612497	14.1	N/A	CITY
161-4	192	T-1	MAIDENS CHOICE	67300	1.5	101	COUNTY
72-178	485	T-51	MID GWYNNS	1434919	32.9	88	COUNTY
72-147	469	T-43	MID GWYNNS	4958425	113.8	78	COUNTY
72-129	455	T-39	MID GWYNNS	181674	4.2	78	COUNTY
72-135	433	T-39	MID GWYNNS	47083	1.1	78	COUNTY
72-187	417	T-52	MID GWYNNS	107666	2.5	88	COUNTY
72-127	372	T-38	MID GWYNNS	316220	7.3	78	COUNTY
72-130	313	T-39	MID GWYNNS	94198	2.2	78	COUNTY
72-141	150	T-40	MID GWYNNS	2819001	64.7	78	COUNTY
86-54	371	T-15	RED RUN	47078	1.1	67	COUNTY
86-24	N/A	T-4	RED RUN	464187	10.7	57	COUNTY
86-29	N/A	T-5	RED RUN	497843	11.4	58	COUNTY
72-80	457	T-23	UPPER GWYNNS	908301	20.9	58	COUNTY
72-10	451	T-1	UPPER GWYNNS	437321	10.0	48	COUNTY
72-49	433	T-16	UPPER GWYNNS	753493	17.3	58	COUNTY
72-74	425	T-18	UPPER GWYNNS	6976594	160.2	58	COUNTY
72-11	420	T-1	UPPER GWYNNS	255650	5.9	48	COUNTY
72-83	420	T-20	UPPER GWYNNS	168197	3.9	58	COUNTY
72-29	416	T-23	UPPER GWYNNS	309437	7.1	58	COUNTY
72-48	412	T-16	UPPER GWYNNS	20172	0.5	58	COUNTY
72-89	388	T-27	UPPER GWYNNS	2923717	67.1	58	COUNTY
72-62	383	T-16	UPPER GWYNNS	329661	7.6	58	COUNTY
72-45	348	T-16	UPPER GWYNNS	121083	2.8	58	COUNTY
72-78	276	T-23	UPPER GWYNNS	343093	7.9	58	COUNTY

1. N\A patch not scored.
2. N\A Tax Map number not available.

Subwatershed Forest Patch Assessment Results

Upper Gwynns Falls

The majority of the forest patches assessed (12) were located within the Upper Gwynns Falls subwatershed. The patch sizes ranged between 0.5 and 160 acres with a mean patch size of 26 acres. The median was eight acres. The

average score was 430.5 out of a possible maximum of 717. The range of scores was between 457 and 276, with a median score of 418.

Mid Gwynns Falls

Eight forest patches were assessed in the Middle Gwynns Falls subwatershed. The patch sizes ranged between one and 114 acres with a mean patch size of 29 acres. The median patch size was six acres. The average score was 389 out of a possible maximum of 717, and the range of scores was between 485 and 150. The median score was 42.

Red Run

Three forest patches were identified for assessment in the Red Run subwatershed, however, data were collected for only one. Two patches (86-24 and 86-29) in the county were not scored because their condition had been altered to the point that the assessment was not deemed applicable. The patch sizes ranged between 1.1 and 11.4 acres with a mean patch size of 7.7 acres. The median was 10.7 acres. The score for the only patch assessed was 371 out of a possible maximum of 717.

Dead Run

Five forest patches were assessed in the Dead Run subwatershed. The patch sizes ranged between two and 18 acres with a mean patch size of 6.5 acres. The median size was 6.5 acres. The average score was 413 out of a possible maximum of 717, and the range of scores was between 499 and 252. The median score was 448.

Maidens Choice County

Only one forest patch was assessed in the County portion of the Maidens Choice subwatershed. The patch size was 1.5 acres. The score was 192 out of a possible maximum of 717.

Maidens Choice City

Three forest patches were assessed in the City portion of the Maidens Choice subwatershed. The patch sizes ranged between 14 and 33 acres with a mean patch size of 22 acres. The median was 18 acres. The average score was 409 out of a possible maximum of 717, and the range of scores was between 437 and 373. The median score was 417. Using the Baltimore City assessment criteria, none of the three forest patches had opportunities for diverting runoff into the forest areas. Forest gaps were present only at site 161-29. However, these gaps were small canopy gaps that were already beginning to close from natural forest succession.

Lower Gwynns Falls City

There were only two forest patches assessed in the Lower Gwynns Falls subwatershed. The patch sizes were seven and 39 acres with a mean patch size

of 23 acres. The median was 23 acres. The average score was 384.5 out of a possible maximum of 717, and the range of scores was between 385 and 384. The median score was 384.5. Applying the Baltimore City criteria, both sites had some opportunity for diverting runoff into the forest patch by providing curb cuts. Site 72-195 is located on a golf course. One side of the forest patch extends along California Boulevard. A curb extends much of the length of the road in this area. At site 72-220, the forest patch occurs adjacent to a small community park. An asphalt parking lot and access road extends along one side of the forest patch. Most of this paved area is separated from the forest patch by a curb. No significant forest gaps occur at site 72-195. However, a large gap was present at site 72-220 at the southwestern end of the forest patch.

4.4 RECOMMENDATIONS

Baltimore County Rapid Field Assessment

Based on the results of the Level IV forest assessment, all subwatersheds, with the exception of Red Run, had at least one site that scored above 400 out of a possible 717. All three Red Run sites had recently been disturbed, and two of the sites could not properly be assessed. Red Run appears to have one of the highest percentages of existing forest cover of the assessed subwatersheds, but appears to be developing rapidly.

The watershed median score was 417. Four out of five of the assessed sites in Dead Run scored higher than the median score, whereas, about 50% of the sites in the Mid Gwynns Falls and Upper Gwynns Falls subwatersheds scored above the median.

The goal of the study is to identify opportunities to enlarge or enhance existing forest patches on lower order tributaries of Gwynns Falls subwatersheds. To maximize the benefit to those subwatersheds, restoration should be directed to the highest quality sites; i.e., those sites that scored the highest in the forest assessment. Other factors may contribute to the decisions to provide restoration services at a given site. These may include the availability of undeveloped land adjacent to the forest patches, cost, the ability to incorporate the reforestation project into other watershed restoration projects at a given site, and the degree of connectedness of the assessed site to other high quality forest patches within the subwatershed. Therefore, these other criteria should be factored into the decision making when choosing reforestation projects rather than simply accepting the highest-ranking sites as having the best potential for reforestation.

More broad-based recommendations include, but are not limited to, establishing greenways ranging from narrow urban trails to winding river corridors to very wide, landscape level linkages designed to connect open spaces for ecological, cultural and recreational purposes. Additionally, incorporating stepping stones, that help facilitate movement of some plants and animals from one ecosystem fragment to another, can improve habitat and diversity. (Franklin 1993). Some

other typical ways to enhance biodiversity and maintain and/or restore the ecosystem's ecological processes within targeted forest patches include:

- Leaving stumps, leaves, snags and logs on-site to enhance the ecosystem's natural structure, maintain the nutrient cycle, and provide habitat for wildlife and other organisms;
- Controlling invasive plants and animals which may eliminate native species;
- Re-instating hydroperiods, i.e., flooding in drained wetlands;
- Mimicking successional stages of nearby similar ecosystems;
- Promoting and educating about the need for retaining leaves, twigs, branches and logs on site to store and cycle nutrients; and
- Finding ways to aid the hydrological cycle by improving infiltration (Binelli 2001).

Baltimore City Forest Assessment

Baltimore City forest assessment sites occurred within two subwatersheds of the Gwynns Falls watershed, Maiden's Choice and Lower Gwynns Falls. All five sites scored relatively high using the Baltimore County forest assessment methodology, and are recommended for conservation and reforestation. This is particularly important because they represent some of the last remaining forested habitat within the City portion of the watershed.

Applying the Baltimore City assessment criteria, only one site (161-15) within the Maiden's Choice subwatershed had closed sections of roadway where the potential for curb cuts could be assessed. However, because of the grade of the roadway and the limited floodplain width between the road and the tributary stream, curb cuts would not be practical. There were also no good opportunities for reforestation on the three Maiden's Choice sites, as site 161-15 was completely developed outside of the forest patch and sites 161-29 and 161-30 were adjacent to a large cemetery.

Within the two Lower Gwynns Falls subwatershed sites, adjacent roadways or parking lots had closed sections. At both sites (72-195 and 72-220), it appears that the curb could either be removed or that periodic cuts could be placed in the curb to allow sheet flow of stormwater runoff into these forest patches. The large forest gap present at the southwestern end of Site 72-220 is experiencing early woody plant succession. This could be augmented by plantings. Common trees and shrubs within the surrounding floodplain forest include white oak, willow oak, tulip poplar, red maple, pin oak, sycamore, black cherry, silver maple, and silky dogwood. Planting with these species, and perhaps other shrubs such as southern arrow-wood and spicebush, could speed up the natural succession process. In addition, any non-native, invasive species beginning to take hold within the gap, could be removed prior to installing the new woody plant material.

Recommended Forest Enhancement Projects

Table 4.3 shows the recommended forest enhancement sites in Baltimore County. Dead Run and the Middle Gwynns has the top three highest scoring forest patches.

Table 4.3: Baltimore County forest patch assessment results

FOREST PATCH ID	SCORE	SUB-WATERSHED	ACRES	JURISDICTION
168-23	499	DEAD RUN	7.1	COUNTY
72-178	485	MID GWYNNS	32.9	COUNTY
72-147	469	MID GWYNNS	113.8	COUNTY
72-80	457	UPPER GWYNNS	20.9	COUNTY
72-129	455	MID GWYNNS	4.2	COUNTY
168-29	451	DEAD RUN	2.6	COUNTY
72-10	451	UPPER GWYNNS	10.0	COUNTY
168-35	448	DEAD RUN	18.2	COUNTY
72-135	433	MID GWYNNS	1.1	COUNTY
72-49	433	UPPER GWYNNS	17.3	COUNTY
72-74	425	UPPER GWYNNS	160.2	COUNTY
72-11	420	UPPER GWYNNS	5.9	COUNTY
72-83	420	UPPER GWYNNS	3.9	COUNTY
168-11	419	DEAD RUN	2.5	COUNTY
72-187	417	MID GWYNNS	2.5	COUNTY
72-29	416	UPPER GWYNNS	7.1	COUNTY
72-48	412	UPPER GWYNNS	0.5	COUNTY
72-89	388	UPPER GWYNNS	67.1	COUNTY
72-62	383	UPPER GWYNNS	7.6	COUNTY
72-127	372	MID GWYNNS	7.3	COUNTY
86-54	371	RED RUN	1.1	COUNTY
72-45	348	UPPER GWYNNS	2.8	COUNTY
72-130	313	MID GWYNNS	2.2	COUNTY
72-78	276	UPPER GWYNNS	7.9	COUNTY
168-30	252	DEAD RUN	2.0	COUNTY
161-4	192	MAIDENS CHOICE	1.5	COUNTY
72-141	150	MID GWYNNS	64.7	COUNTY
86-24	0	RED RUN	10.7	COUNTY
86-29	0	RED RUN	11.4	COUNTY

Table 4.4 shows the recommended forest enhancement sites in Baltimore City. Maidens Choice and the Lower Gwynns Falls. The Lower Gwynns sites have additional enhancement opportunities to provide water quality treatment by instituting curb cuts or removing the curb in that area completely. Plantings near the southwestern end of patch 72-220 would help the woody plant succession that is beginning in this area.

Table 4.4: Baltimore City forest patch assessment results

FOREST PATCH ID	SCORE	SUB-WATERSHED	ACRES	JURISDICTION
161-30	482	MAIDENS CHOICE	18.0	CITY
161-15	417	MAIDENS CHOICE	33.4	CITY
72-220	385	LOWER GWYNNS	6.9	CITY
72-195	384	LOWER GWYNNS	39.0	CITY
161-29	368	MAIDENS CHOICE	14.1	CITY

Each of the potential sites will require detailed investigation to determine the owner of the property and whether the current owner is willing to sell their parcels or allow conservation easements to be placed on the property. Property acquisition costs will determine the feasibility of enhancing these forested sections. Only the top two parcels are considered in the overall Gwynns Falls water quality project ranking due to the unknowns associated with the project costs. Refer to Chapter 7 for more detail on the forest enhancement projects recommended in this study.

4.5 REFERENCES

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7.0 WATERSHED RESTORATION AND MANAGEMENT

7.1 INTRODUCTION

The data collected in the previous watershed assessments is combined into a comprehensive planning tool to be used by Baltimore City and County agencies. This chapter discusses watershed goals, potential project sites, recommended capital projects and recommended management measures.

7.2 DEVELOPMENT OF WATERSHED AND SUBWATERSHED GOALS

7.2.1 Subwatershed Goals and Objectives

The Gwynns Falls subwatershed were divided into three major groups based on the amount of development (imperviousness), stream channel stability and stormwater management potential, in each subwatershed. These grouping were used to define the subwatershed goals and objectives. Table 7.1 shows the breakdown among the watershed.

Table 7.1: Classification of Gwynns Falls Subwatersheds

Group 1 – Sensitive (% Impervious)	Group 2 – Impacted (% Impervious)	Group 3 – Urbanized (% Impervious)	Group 4 – Highly Urbanized (% Impervious)
Red Run (18%)	Upper Gwynns Falls (26%)	Powder Mill (34%)	Gwynns Run North (36%)
Horsehead Branch (15%)	Scotts Level (24%)	Dead Run (36%)	Gwynns Run South (44%)
	Middle Gwynns Falls (22%)	Maidens Choice (33%)	
		Lower Gwynns Falls (32%)	

Group 1 – Sensitive Subwatersheds

The sensitive subwatersheds are the least developed subwatersheds within the Gwynns Falls. Both Red Run and Horsehead Branch have less than 20 percent impervious area. The majority of the development in these watersheds has taken place with some stormwater management in place. More than 25% of existing land use of these subwatersheds are comprised of forested areas.

The current land use zoning was used to evaluate the impacts of the ultimate development condition on each of the subwatersheds. Both subwatersheds are expected to experience significant increases in impervious area in the watershed when comparing existing conditions versus ultimate development. In fact, these subwatersheds experience the largest increase in imperviousness out of any of the Gwynns Falls subwatersheds. Red Run's imperviousness will increase from 18% to

31% while Horsehead Branch's imperviousness will increase from 15% to 26%. These subwatersheds are just beginning to see the impacts of development on their stream networks. The future of these stream networks will depend largely on future land use conditions.

The majority of streams in the sensitive subwatersheds are in good condition, but are beginning to feel the effects of urbanization. Land use changes can have a significant affect on the stability of these streams. Although some of the streams may already be impaired the damage is still reversible. A proactive approach to watershed management should be taken in these areas. For example, by improving the stormwater management water quality and quantity treatment within the subwatershed, we may be able to prevent these streams from progressing into the impacted or urbanized stream categories. When restorations are necessary, natural channel design principles should be used when possible.

Both of the subwatersheds in this category have a large percentage of existing forested land. Protecting forested buffers will be critical in maintaining the quality of the streams within each subwatersheds.

Consequently, the primary goals for these two subwatersheds will focus on land management measures to protect the quality of the stream network during this future development period. Some existing streams in this subwatershed are trout streams and high water quality must be maintained. The primary goals for the Group 1, Sensitive Subwatersheds are:

- Land management strategies
    - Focus on stream buffer preservation
    - Forest preservation and enhancement
    - Continue to pursue opportunities to provide water quality treatment
    - Apply current stormwater management regulations to the highest standard possible. Waivers and variances should not be considered without evaluating the cumulative effect of the waiver/variance on the watershed.

Land management strategies are critical to maintaining the health of Group 1 streams. Future zoning and land use changes will have a significant affect on the future stability and habitat of the streams within these subwatersheds.

Group 2 – Impacted Subwatersheds

The Impacted subwatersheds are already feeling the effects of urbanization and are between 22 and 26% imperviousness. The streams are affected by urbanization but have the potential for recovery with habitat oriented stream improvements.

Large portions of the subwatershed were developed with stormwater management, however, the majority of these occurred before water quality requirements. All stormwater management facilities should be evaluated for potential expansion and/or conversion to extended detention. Baltimore County DEPRM selected over 23 stormwater management ponds within these three subwatersheds for evaluation.

Many of the streams within these subwatersheds have nearly vertical stream banks and poor ecological habitat. Because a significant amount of development has already occurred in these subwatersheds, the focus switches from land management (as in Group 1 – Sensitive streams) to retrofit opportunities. Retrofit opportunities considered in these watersheds should enhance stream stability and improve the habitat quality of the existing stream network.

The primary goals for the Group 2, Impaired Subwatersheds are:

- Stream channel improvements with habitat enhancement focus
- Identify stormwater management retrofit opportunities
- Continue to enforce current stormwater management regulations

Group 3 – Urbanized Subwatersheds

The Urbanized subwatersheds contain between 30 and 36% impervious area and experience significant stream channel instabilities and habitat impairment. Although the percentage of impervious development within these subwatersheds is high, there are a significant number of open stream channels. ***This key difference between the Urbanized Subwatersheds and the Highly Urbanized Subwatersheds is that the Urbanized Subwatersheds still have a significant stream network while the Highly Urbanized Subwatersheds are primarily piped.***

Many of the Urbanized Subwatersheds were developed prior to mandatory stormwater management regulations, both quantity and quality control. BMP creation and/or expansion are considered high priorities in these subwatersheds.

The high amount of urbanization has caused widespread stream stability issues within these subwatersheds. Land use and space constraints are common problems in the these urbanized areas. Because many of the subwatersheds in this category are completely built out, water quality enhancement efforts should be focused on redevelopment projects.

The primary goals for the Group 3, Urbanized Subwatersheds are:

- Design stream channel improvements with a focus on geomorphic adjustment to achieve stream stability
- Identify new opportunities for stormwater management BMPs
- Proactive relocation and/or protection of non-leaking sewer/utility lines and manholes in stream channel
- Identification and correction of existing sewage leaks from sewer lines and manholes
- Seek opportunities for water quality improvement in evaluating redevelopment projects

Group 4 – Highly Urbanized Subwatersheds

The Highly Urbanized subwatersheds contain 36% or more imperviousness. The primary difference between the urbanized and highly urbanized categories is that Group 3 subwatersheds have a significant amount of open stream channel and that Group 4 subwatersheds have primarily piped channels. Once contaminants enter the stormdrain system, they are transported straight into the mainstem of the Gwynns Falls.

The primary goals for the Group 4, Highly Urbanized Subwatersheds are:

- Focus on prevention and reduction of pollutant loads before they enter the stormdrain system
- Focus on installing *structural* BMP devices at proper locations in the storm drain systems
- Focus on incorporating stormwater management and water quality improvements into the watersheds during redevelopment projects
- Identification and correction of existing sewage leaks from sewer lines and manholes
- Continue to look for opportunities to create SWM facilities where space is available

7.3 IDENTIFICATION OF POTENTIAL PROJECT SITES

7.3.0 Introduction

Potential projects were identified using the results of the field assessments and the management goals for each subwatershed established above. Because of the complexity of data collected during this study, a two-tiered approach was developed to aid in project identification:

1) Stream based assessment – incorporates the results of the cruised reach and Corps reach assessments
2) Source based assessment – incorporates the results of the stormwater management facility and outfall assessment, Forest assessment and SWMM modeling assessment.

7.3.1 Methodology

7.3.1.1 Stream Based Assessment

The stream based assessment is divided into two separate categories:

1) Cruised reach assessment
2) Corps reach assessment

Because of the differences in data collection methods, the cruised reaches and the Corps reaches will be analyzed separately. The methods used to assess each type of data are explained below:

7.3.1.1.1 Cruised reaches

Large volumes of data were collected during the field phase of cruised stream assessment. Although all of the data collected is important for the characterization of the subwatershed, four primary categories were used to identify potential projects. These categories were used to identify potential problem reaches. The problem reaches were then plotted on mapping to determine groups of potential reaches that could be combined into a single project.

This section only analyzes the results of the cruised reach assessment and does not attempt to characterize the other watershed assessments completed during this study.

The four primary categories established from the cruised stream assessment are:

- Physical Characteristics
- Manmade influences
- Vegetation
- Threats to private and public structures

An overall reach score was developed for each of the four categories above. A high number of points indicates channel instability and the need for management measures and a low score indicates that the stream is relatively stable under the current land use conditions. The scoring for each of the categories is described below.

Physical Characteristics:

During the stream assessment a variety of physical characteristics were collected during the field assessment. Many of these characteristics evaluated the stability of the stream channel. Thus, the results of the following parameters were used to compute the total eroded area of reach per unit length.

- Left unstable bank length
- Left unstable bank height
- Right unstable bank length
- Right unstable bank height
- Reach length

The eroded area per stream reach is determined by the following equation:

$$EA_{reach} = UL_{right} \times UH_{right} + UL_{left} \times UH_{left}$$

where:

EA_{reach} = eroded area per reach, sf

UL_{right} = unstable length, right side of channel, ft

UL_{left} = unstable length, left side of channel, ft

UH_{right} = unstable height, right side of channel, ft

UH_{left} = unstable height, left side of channel, ft

If the total eroded area per reach is divided by the total reach length, the total eroded area per foot is obtained. Comparing the eroded area per foot allows for the comparison of eroded bank for reaches of different lengths.

- Eroded area/reach length < 0 – classified as “no erosion”
- Eroded area/reach length 0 ≤ 2 – classified as “minor erosion”
- Eroded area/reach length 2 ≤ 4 – classified as “moderate erosion”
- Eroded area/reach length 4 ≤ 20 – classified as “severe erosion”

No erosion was assigned 0 points, minor erosion assigned 1 point, moderate erosion assigned 2 points, and severe erosion assigned 3 points. There was a maximum of three points assigned for the physical characteristics category.

<u>Manmade influences:</u>

The Manmade influences category was used to categorize the manmade impacts to each cruised channel reach. While many of the streams within the Gwynns Falls have been impacted in some manner, this section is meant to highlight the stream reaches that have had significant manmade impacts.

This section is divided into four primary categories: channel modifications, debris blockages, fish blockages and utility conflicts.

Channel modifications: Channel modifications may or may not be a stream stability problem. Some stream reaches within the Gwynns may have been straightened and/or riprap lined but are now stable. They may not be aesthetically pleasing or have quality habitat, but they are not adversely affecting the water quality of the stream. If any of the following fields have a “true” statement, then add ‘0.25’ pts. Maximum number of pts per reach is ‘0.5’. If all categories are false, add ‘0’ pts.

- Straightned
- Widened
- ConcreteLined
- RiprapLined
- GabionLined
- Relocated
- Piped

Debris blockages: The amount and frequency of debris blockages was noted during the stream assessment survey. 88% of the debris blockages within the Gwynns Falls were classified as minor or infrequent. These blockages will be moved during high flow events. Approximately one percent of the blockages were classified as dominating. Dominating blockages have the potential to impact the flow patterns of higher discharges and thus were flagged.

If field "DebrisBlockages" = "D6, Dominating" then add '0.5' pt.

For all other categories, add '0' pts.

Utility conflicts: Utility conflicts are also an important manmade concern. Exposed utility lines and manholes in the channel were noted during field inspections. These structures are particularly sensitive to channel migration and degradation. Exposed utility lines have a greater potential to be damaged due to inadequate support and debris. Repairing exposed manholes or utility lines within the channel is a proactive way to prevent future water quality impacts. Leaking utilities allow pollutants to discharge directly to the streams during both baseflow and stormflow events, directly affecting water quality. Utility leaks were given a higher ranking than unleaking, exposed utility lines and manholes. Reaches with obvious signs of leaking utilities (particularly sewage leaks) were flagged so that the leaks in those areas can be repaired.

If the fields "ExposedCrossing" or "ExposedMHRiser" have a "true" statement, then add '1' pt. Maximum number of pts equals '2'. If both categories are false, add '0' pts.

If the field "LeakingUtility" is "true", then add '2' pts.

Fish blockages: During the cruised reach assessment, fish blockages were noted for each reach when found. In some cases (shallow depth of flow), the fish blockage may only occur during lower baseflow periods but allow fish to travel upstream during winter/spring baseflows and during small storm events. In other cases, such as at a roadway culvert, channel downcutting and scour may cause excessive height problems that prevent fish passage through the reach. Fish blockages were not documented for the Corps reaches, only in the cruised reach assessment. Excessive height blockages were given the highest point ranking. Shallow depth of flow was given a lower ranking because it is likely that the fish would be able to pass through the reach during certain times of the year.

If the field "FishBlockages" equals:

- "Excessive height" = add '0.5' pts
- "Shallow depth" or "High Velocity Q" = add '0.25' pts
- "None" or "Debris Blockage" = add '0' pts

Vegetation:

Reaches with inadequate riparian buffers were identified using the vegetation category. This score was based on three primary indicators: vegetative composition, density and width.

Part 1: Composition – The composition of the riparian buffer is an important factor is stream stability. Due to the highly urban nature of the watershed, some stream reaches run through the backyards of private residences. While public drainage ways often exist, local residents often use this property as their own without regard to stream stability. Where riparian buffers do exist, the goal of the assessment was to rank the quality of the buffer. Deciduous overstories with brush understories were given the highest quality rating while bare soil was given the lowest quality rating. Points were added by composition type to help signify which reaches were in need of the greatest vegetative improvement. A high vegetation score indicates the need for improvements in the riparian buffer.

If "bare", add '2' pts

If "brush" or "grass with forbs" or "forbs only", add '1' pt

If "deciduous overstory", add '0.5' pts

If "decidous overstory with brush understory" or "wetland", add '0' pts

Part 2: Width – In addition to the composition of the riparian buffer, the width of the buffer plays an important role in stream stability. Ideally, we would like to see a wide riparian buffer (greater than 100 feet). In general, points were added to this score as the riparian width becomes smaller. This is only true for vegetated buffers. If the buffer composition is classified as bare, more points are added as the bare buffer width becomes wider.

If "bare", add '1' pt if greater than 20 feet, add '2' pts if greater than 50 feet and '3' pts if greater than 100 feet.

If "brush" or "grass with forbs" or "forbs only" or "deciduous overstory" or "decidous overstory with brush understory", add '1.5' pts if less than 50 feet, '1' pt if less between 50 and 100 feet and '0.5' pts if less than 100 feet.

Part 3: Density

Riparian buffer density is essential to the health of the stream buffer. A low density buffer has a minimal amount of vegetation and affords an opportunity for riparian buffer improvement and receives two points. A medium density buffer has a significant amount of vegetation, but less than the ideal density. Because there is still room for some vegetative enhancement, the medium density buffers receive a score of 1. A high density buffer that does not need any maintenance, is given a score of zero. The density results for the left and right bank are averaged and then points assigned for low, medium and high density rankings.

If “low”, add 2 pts

If “medium”, add 1 pt

If “high”, add 0 pts.

Vegetative scores are summed into a composite vegetation score. The scores within the Gwynns Falls cruised reaches ranged from a low of 0 to a high of 11. The higher the score, the greater the need of vegetative enhancement.

Threat to Public & Private Structures:

This category was designed to flag immediate threats to public and private structures such as buildings, parking lots, storage sheds, fences, roads, railroad tracks, etc. This category was not used to identify structures that may become a problem in the future, those will be addressed by the stream stability rankings, but rather those problems which need to be addressed in the present.

If “true”, add 2 pts

If “fasle”, add 0 pts

7.3.1.1.2 Corps Reach Assessment

The Corps reach assessment (Baltimore County) did not include the same amount of detailed information as the cruised reach assessments did. However, the Corps data does provided important information of its own. The Corps’ bank erosion category was used to identify sources of channel instability and bank erosion.

Corps reaches identified as having “very bad”, “bad” and “fair” bank erosion were flagged on the watershed mapping. The “fair” Corps erosion rating corresponds to minor erosion category of the cruised reach assessment. The “bad” category corresponded with moderate erosion estimates and the “very bad” category corresponds with the severe erosion estimates in the cruised reaches. This information was plotted on the composite mapping (Section 7.3.1.3) and used to determine potential project locations. This information was very useful, particularly when looking at the downstream impacts of unvegetated areas and upstream tributaries with channel instabilities.

7.3.1.2 Source Based Assessments

The source based assessment encompasses all of the assessment tools in the Gwynns Falls study besides the cruised stream assessment. The assessment tools included in this analysis are:

- Stormwater management facility and outfall assessment
- SWMM modeling
- Forest assessment

The results of each assessment tool are plotted on a subwatershed map to evaluate the combined impacts of development within the subwatershed.

Stormwater Management Facility and Outfall Assessments

The results of the Stormwater Management Facility and Outfall Assessments were also overlaid on the subwatershed mapping. Each outfall and facility had been previously ranked in the stormwater management assessment. These rankings had been based on land use, available area, immediate downstream channel condition and several other factors.

The results of the stormwater management assessment were combined with the other assessments to determine the final stormwater management rating. The new ranking was based on land use, available area, immediate downstream channel condition and access of the SWM facility or outfall combined with the results of the stream stability and habitat assessment. Stormwater management facilities and outfalls that were initially given low priority ratings were increased to medium or high priority ratings if the downstream channel conditions showed poor downstream stability or water quality problems. Likewise, stormwater management facility conversions to extended detention were given higher priorities to protect sensitive habitat or highly degraded downstream conditions.

SWMM Modeling

The results of the SWMM modeling were used to identify the subwatersheds with the largest pollutant loadings within the Gwynns Falls subwatershed. Priority was given to projects that help reduce the pollutant loadings in the subwatershed. The greater the water quality benefit of the project, the higher the ultimate project ranking. Project ranking is discussed in more detail in Section 7.4.1 of this report.

Forest Assessment

The results of the forest assessment were also used to identify potential projects in each subwatershed. All forest patch enhancements that scored above the watershed average were recommended for enhancement, particularly when they occurred on public lands. Because the forest patch assessment did not cover all of the forested areas within each subwatershed, the orthophotogrammetry was used to identify other gaps in the forested buffer.

7.3.1.3 Composite Mapping Analysis

The results of the stream based and source based analyses were plotted on subwatershed maps. This provided a clearer picture of the problems that were occurring in each subwatershed. Groups of problem reaches, facilities, buffers, etc. were combined to create potential projects. The photographs taken of these areas were used to verify that the potential project was necessary. Because the photographs were taken at an average reach location, some photographs did not show the severity of erosion that was estimated during the cruised reach assessment. In these cases, field visits were conducted to either confirm the erosion or make

additional project recommendations. In addition, complex, multifaceted projects were also visited to confirm the project approach for each location. When projects were particularly large, these field visits were used to identify phases of the project that could be completed in not all of the capital funds were available at once. When phased projects are recommended, the project should proceed from upstream to downstream.

7.3.2 Project Identification

The results of the above analyses were combined to identify potential project sites. Field visits were made to the largest potential project sites in each subwatershed. When water quality problems were identified from field and office visits, BMP solutions were brainstormed and project descriptions were developed for the BMP's having the most merit, available land, proximity to the problem and likelihood for success. Projects were identified based on the type of deterioration present. Problems identified include excessive scour and downcutting of channels, uncontrolled and untreated runoff entering streams, lack of riparian buffer, lack of instream habitat and utility conflicts.

The BMP's identified include:

- Stabilization of outfalls and streambanks
- Installation of ponds to treat water quality and quantity
- Retrofit of existing ponds to extended detention to provide additional quality and quantity treatment
- Retrofit of existing outfalls to provide stream stability and water quality/quantity treatment when space permits
- Removal of concrete channels
- Riparian buffer enhancement and supplemental planting
- Cleaning and maintenance of existing streams and ponds

Potential Project summary sheets were developed for each project identified. These summaries contain:

- Project name and number
- Subwatershed
- ADC Map Location
- Catchment No.
- Property ownership
- Nearest street/road
- Stream reach ID
- Project type

- Project description
- Project photos
- Project cost

The proposed project descriptions for all proposed projects appear in Appendix 7-A of this report. Photographs are included to provide a visual picture of the problems associated at each site. Additional photographs may be found in the stream assessment and stormwater management facility and outfall assessment folders found on the data CD in Appendix 8.

7.3.3 Cost Estimates

Cost estimates were developed for each project. Standard unit costs were developed for individual project components. Unit costs are based on experience with stream restoration and stormwater quality retrofit projects conducted in Maryland. Because procurement costs differ between the City and the County, separate costs were used to estimate projects in each jurisdiction. The City's estimated costs for stream restoration projects and land acquisition are typically higher than the County's and this was accounted for in Table 7.2 Baltimore County DEPRM's stream restoration database was also used to compute stream restoration related costs based upon project size.

Particularly in Baltimore City, there are numerous stream reaches with exposed or leaking utility lines and manholes. The existence of these problems are noted in each project sheet, however, it is assumed that leaking utility lines will be repaired prior to the project's implementation and thus their costs are not included in the cost estimate. Costs for pro-active relocation and/or protection of manholes and utility lines were included as part of the project costs estimates.

Table 7.2: Project cost estimates

Project Cost Description	Basis of Cost Estimate	Unit	Unit Cost (City)	Unit Cost (County)
Stream Restoration & Stabilization				
Stream restoration – small project (< 200 linear feet)	Length of reach (excluding land acquisition)	LF	$700	$500
Stream restoration – medium project (200 – 1,500 linear feet)	Length of reach (excluding land acquisition)	LF	$500	$300
Stream restoration – major project (> 1,500 linear feet)	Length of reach (excluding land acquisition)	LF	$350	$200
Stream stabilization with bioengineering techniques	Length of unstable reach (excluding land acquisition)	LF	$100	$80
Floodplain wetland creation (Small)	Excluding land acquisition	Each	$25,000	$25,000
Riparian buffer improvements (assume 100' width of new creation)	Length of reach (excluding land acquisition)	LF	$95	$75
Riparian buffer improvements – New forest creation	Area of improvement (excluding land acquisition)	Acre	$15,000	$15,000
Riparian buffer improvements -forest patch enhancement	Area of improvement (excluding land acquisition)	Acre	$10,000	$10,000
Stormwater Management				
SWM pond/ wetland creation - large	Cost excludes maintenance and land acquisition	Each	$375,000	$300,000
SWM pond/ wetland creation - small	Cost excludes maintenance and land acquisition	Each	$250,000	$200,000
SWM pond conversion to Extended Detention (large pond, > 80 acres drainage area)	Cost excludes maintenance, land acquisition and/or access easement	Each	$225,000	$180,000

SWM pond conversion to Extended Detention (medium pond, 20 - 80 acres drainage area)	Cost excludes maintenance, land acquisition and/or access easement	Each	$187,500	$150,000
SWM pond conversion to Extended Detention (small pond, <20 acres drainage area)	Cost excludes maintenance, land acquisition and/or access easement	Each	$150,000	$120,000
Outfall retrofit – large	Cost excludes maintenance, land acquisition and/or access easement	Each	$100,000	$100,000
Outfall retrofit – medium	Cost excludes maintenance, land acquisition and/or access easement	Each	$50,000	$50,000
Outfall retrofit - small	Cost excludes maintenance, land acquisition and/or access easement	Each	$25,000	$25,000
Right of Way and Land Acquisition				
Land acquisition: riparian buffer	100 feet of each side of reach	Acre	$50,000	$30,000
Land acquisition: stream restoration	50 feet of each side of reach	Acre	$50,000	$30,000
Land acquisition: new SWM pond/wetland	Dependent upon drainage area to pond.	Acre	$62,500	$50,000
Riparian Buffer Enhancement/Stream Stabilization Easement	Cost to establish permanent easement along stream	Acre	$10,000	$5,000
Right of Way easement	Cost to negotiate easement and right of entry	LS	$10,000	$5,000
Maintenance Costs				
Debris Removal: moderate debris	Annual cost per year	LS	$1,000	$1,000
Debris Removal: heavy debris	Annual cost per year	LS	$2,000	$2,000

Maintenance: SWM pond	Annual cost per year	LS	$3,000	$3,000
Maintenance: stream restoration (includes monitoring)	Annual cost per year	LS	$4,000	$4,000
Other Costs				
Sewer/Manhole relocation	Excludes right of way easement	Each	$31,250	$25,000
Storm Ceptor – small		Each		
Storm Ceptor – large		Each		
Vernal pool creation	Excludes right of way easement	SF	$3.00	$2.00

7.4 PRIORITIZING CAPITAL PROJECTS

7.4.0 Introduction

Water Quality Improvement Projects are ranked and prioritized in this section to aid Baltimore City and County in formulating their capital improvement program. Rankings were developed for several categories of project attributes. This helps to provide an objective comparison of project attributes. The project rankings were combined with project costs to provide a means of comparing project benefits with project costs. Financial costs for project benefits were not assigned, only relative benefits and costs were compared. A final prioritization of projects was made based on the benefits to cost comparison subject to consideration of overriding subwatershed goals and watershed wide quality needs.

7.4.1 Water Quality Improvement Project Ranking

7.4.1.1 Ranking

Ranking is performed of potential restoration and stabilization projects in order to determine recommended City and County actions. Rankings are inherently subjective. The value of the rankings is that they allow direct comparison of competing projects.

An initial ranking of water quality enhancement projects was prepared based on four different criteria. The criteria were selected to look at the water quality benefit, land availability and construction access, public acceptance and reduction of risk to public safety and infrastructure. The criteria are explained in more detail below and in table 7.3.

1. Water Quality Benefit – This represents an assessment of a project's benefit to reducing pollutant and sediment loads and improving water quality within the watershed. A score of zero represents no benefit while a score of three represents a high benefit. Projects that stabilize over 1,000 linear feet of stream or improve/create over 500 feet of riparian buffer are given the highest priority and thus a score of 3. Stormwater management facility and outfall

retrofits ranked with a high and medium priority also receive a score of 3. Smaller projects that do not have as widespread an impact within the subwatershed and stormwater management facility and outfall retrofits with a low priority were given a score of 2. Local projects such as outfalls and drainage channel retrofits were given a score of 1 unless they included water quality retrofits.

2. Habitat enhancement – This criteria looks specifically at improvements to habitat within the watershed and the stream channel itself. Projects that are specifically designed for habitat enhancement are given a ranking of 3. Projects that include habitat enhancement features and forest patch enhancements are given a ranking of 2. Projects that improve a debris or fish blockage are ranked 1. Projects that have no habitat enhancement receive a score of 0.
3. Land availability & Construction Access – This category rates the ability for a project to be constructed and includes both land availability and construction access. For land availability, private land without access is given a zero while public land with good roadway access is given a 3.
4. Public Acceptance and educational opportunities – This category rates the public's willingness to support a project, its benefit to community aesthetics and potential for public education. A project with many public objections will receive a score of zero while a score of 3 represents a very visible project with strong public support and education opportunities.
5. Reduction of Risk to Public Safety or Infrastructure – This includes the threat of localized flooding, culvert failure and unstable stream banks along improved properties. A score of zero indicates no reduction of the risk of failure or that no risk exists and a score of three represents a high reduction in the risk of failure.

Table 7.3: Water quality enhancement project ranking scheme

Ranking Category	Numeric Ranking			
	0	1	2	3
1) Water Quality Benefit	None	Low	Moderate	High
2) Habitat Enhancement	None	Low	Moderate	High
3) Land Availability & Construction Access	Private land w/ no access	Private land w/ good access	Public land w/ fair access	Public land w/ good access
4) Public Acceptance & Educational Opportunity	Strong objections & no educational opportunity	Some objections & minimal educational opportunity	Some desire & good educational opportunity	Strong desire & strong educational opportunity
5) Reduction of Risk to Public Safety or Infrastructure	No Impact	Low	Moderate	High

7.4.2 Prioritization

The water quality enhancement scheme was used to prioritize projects within the watershed as a whole and within each individual subwatershed. Projects were ranked based on their water quality enhancement benefit and their overall project score. The overall project score is a summation of the four ranking categories above.

Appendix 7 shows detailed project descriptions and summary tables. Table 7.A.1 shows the breakdown of recommended projects by subwatershed. Table 7.A.2 shows projects sorted by Annual Cost. Table 7.A.3 shows detailed costs per project including maintenance and land acquisition.

7.4.3 Priority Projects

The priority projects were chosen using the prioritization scheme described above. Projects were broken into three size categories for comparison purposes. This allowed for the comparison of projects of similar size. Projects were broken into three categories:

- Large (Present worth of project is > $300,000)
- Medium ($100,000< Present worth of project<= $300,000)

- Small (Present worth of project <= $100,000)

Projects will be ranked in two separate ways. First, the projects will be sorted by project score and then based on the project's annual cost. If two projects have the same project score, the project with the lower annual cost will be given the higher project rank. If the projects have the same project score and annual cost, they will be ranked as a tie. Appendix table 7.B.4 shows the project ranks based on project size. Appendix table 7.B.5 shows the projects by size by subwatershed.

The second method of project ranking will be the cost benefit ratio. In order to provide a uniform cost benefit comparison, the project score is divided by the annual project cost (in thousands). This does not assign a cost associated with each benefit, however, it allows for a reasonable cost comparison among proposed projects. If two projects have the same project score and annual cost, they were ranked as a tie. Appendix table 7.B.6 shows the projects by size by cost benefit ratio.

7.4.3.1 Large Projects

Large projects are defined as those with total project cost (in today's dollars) greater than $300,000. Each project was ranked within the entire watershed as a whole. This multi-tiered ranking allows the user to target projects within a specific subwatershed or allows them to choose the highest ranked projects in the entire watershed. Appendix table 7.B.4 ranks the large priority projects by project score and project cost. Each project is then assigned an overall watershed rank for its size category.

The top 3 large projects based on project score and annual cost:

Baltimore City: MC-07 ($410,000), GFL-01 ($930,000), & DR-06 ($790,771)

Baltimore County: RR-01 ($368,900), PM-01 ($701,300) & MC-02 ($403,300)

The top 3 large projects based on cost benefit ratio:

Baltimore City: MC-11 ($316,250), PM-03 ($305,500), & MC-07 ($410,000)

Baltimore County: RR-01 ($368,900), MC-02 ($403,300) & RR-04 ($394,971)

7.4.3.2 Medium Projects

Medium projects are defined as those with total project cost (in today's dollars) between $100,000 and $300,000. This is the largest project category. 45 projects are characterized as medium sized projects. Each project was ranked within the entire watershed as a whole. This multi-tiered ranking allows the user to target projects within a specific subwatershed or allows them to choose the highest ranked projects in the entire watershed. Appendix table 7.B.4 ranks the medium priority projects by project score and project cost. Each project is then assigned an overall watershed rank for its size category.

The top 3 medium projects based on project score and annual cost:

Baltimore City: GRN-03 ($238,271), MC-09 ($238,271) & MC-12 ($298,000)

Baltimore County: GFU-20B ($150,000), GFM-09 ($155,000) & GFM-01 ($195,771).

The top 3 medium projects based on cost benefit ratio:

Baltimore City: MC-08 ($114,000), DR-04 ($131,250) & GRN-03 ($238,271)

Baltimore County: GFU-20B ($150,000), GFM-09 ($155,000) & RR-02 ($148,900).

7.4.3.3 Small Projects

Small projects are defined as those with total project cost (in today's dollars) less than $100,000. The majority of these projects are less than $50,000 and provide an opportunity to use involve the community in riparian plantings and site clean ups. Each project was ranked within the entire watershed as a whole. This multi-tiered ranking allows the user to target projects within a specific subwatershed or allows them to choose the highest ranked projects in the entire watershed. Appendix table 7.B.4 ranks the small priority projects by project score and project cost. Each project is then assigned an overall watershed rank for its size category.

The top 3 small projects based on project score and annual cost:

Baltimore City: GFL-03 ($50,000), GFL-22 ($62,500), & PM-05 ($92,000)

Baltimore County: GFM-02 ($43,250), GFM-04 ($90,000), & HB-03 ($37,000).

The top 3 medium projects based on cost benefit ratio:

Baltimore City: GFL-02 ($25,000), GFL-06 ($25,000), & GFL-12 ($25,000)

Baltimore County: HB-01 ($10,000), GFU-15 ($15,050) & HB-03 ($37,000).

7.4.3.4 Projects by Subwatershed

In addition to ranking the project by size within the entire Gwynns Falls watershed. The projects were also sorted into individual subwatersheds. Appendix Table 7.B.5 shows the projects ranked by subwatershed. Every other subwatershed is highlighted to help differentiate between the individual subwatersheds.

7.4.4.5 Potential Grant Opportunities

Projects with total costs greater than $400,000 are good candidates for Baltimore City and Baltimore County to apply state and federal grant money. Table 7.4 lists projects that have the potential for utilizing grant money towards design and construction. Potential grant sources include, but are not limited to:

- Maryland Department of Natural Resources – Shore Erosion Control grants
- Maryland Department of the Environment – Non-point source pollutant
- Maryland Department of the Environment – Stormwater Pollution Control Program
- Maryland Department of the Environment – Small Creeks & Estuaries Restoration Program
- EPA Section 319(h) funds
- Chesapeake Bay Small Watershed Grants (Community Legacy Grants)

Table 7.4: Potential projects for grant consideration

Project ID	Total Present Worth Cost of Project	Total Annual Cost of Project A/P Capital Recovery	Project Score	Rank
Large Projects (>$300,000 Present Worth Cost)				
Baltimore County				
RR-01	$ 368,900	$ 27,100	14	1
PM-01	$ 701,261	$ 51,600	14	11
MC-02	$ 403,300	$ 29,700	12	2
GFU-20 A	$ 600,000	$ 44,100	10.5	13
RR-04	$ 394,971	$ 29,100	10	6
DR-02	$ 386,542	$ 28,400	9.5	7
GFM-07	$ 554,521	$ 40,800	8.5	17
GFU-17	$ 779,700	$ 57,400	8.5	32
SL-03	$ 655,000	$ 48,200	8	27
SL-01	$ 775,000	$ 57,000	8	33
DR-03	$ 883,371	$ 65,000	8	36
DR-01	$ 1,247,671	$ 91,800	8	37
PM-02	$ 526,171	$ 38,700	7.5	21
GFU-19 A	$ 1,260,000	$ 92,700	7.5	38
GFU-19 B	$ 315,000	$ 23,200	6	12
Baltimore City				
MC-07	$ 410,000	$ 30,200	11	5
GFL-21	$ 930,000	$ 68,400	11	29
DR-06	$ 790,771	$ 58,200	10.5	24
GFL-09	$ 478,271	$ 35,200	10	10
DR-07	$ 1,040,771	$ 76,600	10	34
GFL-04	$ 550,000	$ 40,500	9.5	14
MC-04	$ 625,000	$ 46,000	9.5	18
MC-03	$ 634,000	$ 46,700	9.5	19
MC-11	$ 316,250	$ 23,300	9	3
PM-03	$ 305,500	$ 22,500	8.5	4
GRN-02	$ 465,771	$ 34,300	8	15
PM-08	$ 478,271	$ 35,200	8	16
MC-15	$ 641,250	$ 47,200	8	25
MC-16	$ 645,000	$ 47,500	8	26
MC-18	$ 670,000	$ 49,300	8	28
GFL-01	$ 315,771	$ 23,200	7.5	8
PM-07	$ 353,271	$ 26,000	7.5	9
GFL-13	$ 540,771	$ 39,800	7.5	23
DR-05	$ 665,771	$ 49,000	7.5	30
MC-05	$ 681,250	$ 50,100	7.5	31
MC-06	$ 796,000	$ 58,600	7.5	35
PM-04	$ 1,481,361	$ 109,000	7.5	39
GFL-20	$ 1,860,000	$ 136,900	7	40
DR-09	$ 415,771	$ 30,600	6	20
MC-10	$ 425,771	$ 31,300	6	22

7.5 RECOMMENDED MANAGEMENT MEASURES

It is recommended that the City and County undertake the following management measures:

Regulations:

- Follow current MDE Stormwater Design Manual, Volumes I & II. Minimize the number of waivers allowed, particularly in the Sensitive, Group I subwatersheds.
- Look for water quality treatment measures that will not cause increases in stream temperatures, particularly in Class III Trout streams in the Upper Gwynns Falls and Red Run subwatersheds.
- Follow current Baltimore County DEPRM regulations regarding forested buffers for wetlands, streams and floodplains. Minimize the number of waivers or exceptions permitted, particularly in the Sensitive, Group I subwatersheds. Focus on incorporating water quality treatment in redevelopment projects in urbanized areas.
- Follow current Baltimore City DPW regulations regarding forested buffers for wetlands, streams and floodplains. Focus on innovative methodologies for incorporating stormwater management and water quality treatment into redevelopment projects.
- Follow current erosion and sediment control guidelines, particularly for new construction. Maintain inspection program to insure that existing guidelines are being enforced.

Community education:

- Educate community on importance of stream buffers and what they can do to prevent stream bank erosion on their property
- Provide community demonstration projects where possible to show the community about the environmental benefits of various water quality projects. In addition, inform the community members about what they can do to improve the water quality of their local streams.
- Educate community on the importance of keeping their streets and neighborhoods clean. Make the connection that the debris that enters the storm drain systems will eventually enter the stream network and the Bay.
- Work with community watershed associations to improve riparian buffers and water quality within their local neighborhoods.

Stormwater Management Retrofits:

- Where possible, investigate conversion of all standard detention ponds to extended detention facilities.

- Investigate new opportunities for BMP creation at existing storm drain outfall locations.
- In highly urbanized settings, consider the use of structural devices such as StormCeptors to help trap sediment and pollutants prior to being discharged into the stream/storm drain network.
- During redevelopment in highly urbanized areas, consider encouraging the installation of sand filters or other filtration devices to trap sediment and other pollutants prior to being discharged into the storm drain network.

7.6 JOINT CITY-COUNTY PROJECTS:

The inter-jurisdictional nature of this watershed study lends itself to several joint Baltimore City and Baltimore County projects. While all projects conducted in the Gwynns Falls watershed will help to improve downstream water quality, some particularly visible projects include:

- *Powder Mill* – This subwatershed provides a unique opportunity for a joint City-County project. Powder Mill has two main tributaries, one that is primarily in the City and one primarily in the County. The benefits of these two water quality improvements should be visible at the confluence of these two sections. Projects to be included in this joint effort could include:
    - PM-01 & PM-02 in Baltimore County
    - PM-03 through PM-07 in Baltimore City
- *Dead Run* – Dead Run is another subwatershed that falls partially within Baltimore City and partially within Baltimore County. Multiple stream restoration and BMP creation projects are recommended throughout this subwatershed. Partnering could occur by both agencies efforts to focus multiple projects within this subwatersheds. Also, water quality sampling shows evidence of continuous sewage leaks within this subwatershed. Both DEPRM and DPW should work to repair leaking sewer lines.
- *Maidens Choice* – Maidens Choice is similar to Dead Run in that a portion of the watershed is within Baltimore County and a portion within Baltimore City. A large number of projects within the watershed are located within Baltimore City, however, there are two stabilization projects located within County limits. Water quality sampling shows evidence of continuous sewage leaks within this subwatershed. Both DEPRM and DPW should work to repair leaking sewer lines.
- *General Water Quality Treatment in Heavily Impervious Areas* – Both municipalities should focus on applying water quality treatment for redevelopment projects, particularly in heavily urbanized areas. One potential option to consider is the use of StormCeptors or similar devices to trap pollutants and sediments once they reach the storm drain system. Baltimore City and County could sponsor a joint initiative to install StormCeptors or similar

devices within one of the joint urban subwatersheds such as Powder Mill, Dead Run or Maidens Choice.

7.7 WATERSHED MANAGEMENT PLAN BENEFITS & SUMMARY

The data collection and analysis conducted as part of this comprehensive effort have led to the identification of 120 proposed capital projects at a cost of approximately $31 million. Table 7.5 summarizes the variety of projects that have been recommended as part of this water quality plan. These projects include over 10 miles of stream restoration, 8 miles of riparian buffer enhancements and 67 stormwater retrofits. The proposed stream restoration and riparian enhancement projects restore 25% of the watersheds most unstable streams. Stabilizing these streams reduces sediment loads within the watershed by approximately 26%.

Table 7.5: Summary of proposed projects within the Gwynns Falls Watershed

Project Type	Number of Proposed Projects
SWM Facility Retrofit	29
SWM Facility Maintenance	1
SWM Storm Drain Outfall Retrofit	37
New BMP Creation	17
Floodplain Wetland Creation	12
Forest Enhancement	4
Riparian Buffer Enhancement	25
Stream Restoration & Stabilization	42
Sediment Reduction due to Proposed Projects	26%
Utility Protection and/or Relocation	1
Debris Removal	3

Each of these projects provides water quality benefits as well as ecological enhancement benefits to the watershed. One way to evaluate the water quality benefits provided is to determine the pollutant reductions that will occur when the project is complete. Baltimore County provided average pollutant loading reductions for BMP and stream restoration projects based on past monitoring projects. The values in table 7.6 show the pollutant removal efficiency of many types of BMP's. Table 7.7 shows the average pollutant reduction in pounds per linear foot of stream restoration. To determine actual pollutant reductions for the various project types, water quality monitoring before and after the project construction should be conducted. Monitoring of this type will help improve the pollutant removal efficiency estimates for future projects.

Table 7.6: Percent removal efficiency for select BMP's

Facility Type	TSS	TP	TN	Pb	Zn
Detention Facility	10%	10%	5%	43%	26%
Extended Detention Facility	60%	20%	30%	43%	26%
Wet Ponds/Shallow Marshes	80%	50%	50%	73%	51%
Infiltration Practices	90%	70%	50%	71%	80%
Filtration Practices	85%	60%		-	-
Stormceptors	80%	35%	35%	40%	40%

Table 7.7: Pollutant reductions for stream restoration projects

Stream Reductions	TSS	TP	TN	Pb	Zn
Lbs of reduction per linear foot	2.55	0.0035	0.024	0.00007	0.0007

The implementation of current stormwater management regulations will also reduce ultimate development pollutant loading within the Gwynns Falls watershed. Table 7.8 shows the reduction in average annual pollutant loadings due to the implementation of current stormwater management regulations.

The total expected load to each project site is estimate and then average pollutant removal percentages are used to estimate the reduction due to the project construction. Applying the values in tables 7.6 and 7.7 to the proposed project list, table 7.8 shows the estimated percent reduction in annual pollutant loading. Because no stream or stormwater retrofit projects are recommended for Gwynns Run South, there is no pollutant load reduction associated with this watershed.

Table 7.8: Percent pollutant reduction for proposed projects

Subwatershed	Miles of stream restored	TSS	TP	TN	Pb	Zn
Upper Gwynns Falls	0.8	15%	4%	1%	7%	3%
Red Run	0.6	3%	1%	0%	2%	1%
Horsehead Branch	0.0	10%	3%	1%	19%	5%
Scotts Level	1.5	30%	9%	3%	17%	7%
Middle Gwynns Falls	0.9	10%	3%	1%	9%	3%
Powder Mill	0.9	17%	5%	2%	10%	4%
Gwynns Run North	0.0	1%	1%	0%	6%	1%
Gwynns Run South	0.0	-	-	-	-	-
Dead Run	1.6	19%	6%	3%	37%	8%
Maiden Choice	2.0	20%	7%	3%	21%	6%
Lower Gywnns Falls	1.6	12%	4%	2%	21%	5%
Overall reduction in Gwynns Falls Pollutant Loading		**13.5%**	**4.0%**	**1.5%**	**15.1%**	**4.0%**

In highly urbanized subwatersheds like Gwynns Run North and South, there is often limited space available for the construction of new stormwater management facilities and other restoration measures. Treating runoff before it enters the storm drain system is critical. One potential option to do this is through the use of structural BMP devices such as Stormceptors®, ,Baysavers® and other filtration devices. These devices capture the "first flush" of flow entering a storm drain and separate the sediments and oils from the discharge. Regular maintenance of these facilities is necessary to keep these systems working efficiently. These structures should be considered when performing any maintenance in an urbanized area and during redevelopment projects. These structures can efficiently remove sediments and metals from the storm drain system and prevent their ultimate discharge into the Gwynns Falls. The reductions that can be obtained from this type of technology are summarized in table 7.9. It is assumed that these devices will treat a percentage of the runoff generated from each of the subwatersheds. Since Powder Mill, Dead Run and Maidens Choice have the potential for water quality projects such as stormwater management retrofits and stream restoration, the structural BMP's can be used to supplement the water quality treatment network. In Gwynns Run North and South, the structural BMP's will be the primary source of water quality treatment.

The last line of table 7.9 shows the potential reduction in pollutant loading for the entire Gwynns Falls watershed. By installing these devices in the highly urbanized subwatersheds which are typically high pollutant generators, a significant reduction in overall watershed loading can be obtained.

Table 7.9: Pollutant loading reductions due to the installation of structural BMPs

Subwatershed	% of watershed runoff treated	Cost per acre of treatment	TSS	TP	TN	Pb	Zn
Powder Mill	15	$7,200	17%	5%	2%	10%	4%
Gwynns Run North	75	$8,200	1%	1%	0%	6%	1%
Gwynns Run South	75	$7,200	-	-	-	-	-
Dead Run	20	$8,800	19%	6%	3%	37%	8%
Maiden Choice	15	$6,800	20%	7%	3%	21%	6%
Lower Gywnns Falls	50	$6,400	12%	4%	2%	21%	5%
Overall reduction in Gwynns Falls Pollutant Loading			**18.2%**	**7.7%**	**7.4%**	**39.5%**	**37.7%**

Table 7.10 shows the overall pollutant reduction that can be achieved by the construction of the non-structural projects and the installation of the structural BMP devices in the urban areas.

Table 7.10: Overall pollutant loading reduction in the Gwynns Falls

Subwatershed	TSS	TP	TN	Pb	Zn
Reduction due to current stormwater management regulations					
Reduction due to proposed projects	**13.5%**	**4.0%**	**1.5%**	**15.1%**	**4.0%**
Reduction due to structural BMPs	**18.2%**	**7.7%**	**7.4%**	**39.5%**	**37.7%**
Total reduction for the Gwynns Falls	**31.8%**	**11.8%**	**8.9%**	**54.6%**	**41.7%**

One additional area that will provide significant water quality benefit to the watershed is to clean up the continuous sewage leaks that are occurring within the watershed. Although these leaks occur throughout the watershed, the largest concentrations can be found in Dead Run, Maidens Choice and the Lower Gywnns Falls subwatersheds. Table 7.11 summarizes the pollutant load reductions that can be achieved as the City continues to address these problems.

Table 7.11: Pollutant load reductions due to the repair of continuous sewer leaks

Location	TKN	TP	BOD	COD	Fecal Coliform
Watershed Outlet	11%	8%	8%	9%	52%

With the completion of the Gwynns Falls Water Quality Management Plan, the City and County now have a comprehensive water quality plan that will allow them to make the most efficient use of the limited funds available. The plan serves as a framework and provides multiple tools for the agencies to select the best project based on cost, subwatershed area or overall pollutant reductions. By combining capital projects with community education and outreach, the City and County can work towards achieving their water quality goals.

APPENDIX G:

TMDLs of Fecal Bacteria For the Non-Tidal Gwynns Falls Basin

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

Decision Rationale
Total Maximum Daily Loads of Fecal Bacteria For the Non-Tidal Gwynns Falls Basin Baltimore City and Baltimore County, Maryland

John Armstead for

Jon M. Capacasa, Director
Water Protection Division

Date: 12/4/2007

Decision Rationale

Total Maximum Daily Loads of Fecal Bacteria
For the Non-Tidal Gwynns Falls Basin
Baltimore City and Baltimore County, Maryland

I. Introduction

The Clean Water Act (CWA) requires a Total Maximum Daily Load (TMDL) be developed for those waterbodies identified as impaired by the state where technology-based and other controls will not provide for attainment of water quality standards. A TMDL is a determination of the amount of a pollutant from point, nonpoint, and natural background sources, including a margin of safety (MOS), that may be discharged to a water quality-limited waterbody.

This document sets forth the U.S. Environmental Protection Agency's (EPA) rationale for approving the TMDLs for fecal bacteria in the Gwynns Falls Watershed. The TMDLs were established to address water quality impairments caused by bacteria as identified in Maryland's 2002 Section 303(d) List of impaired waters. The Maryland Department of the Environment (MDE), submitted[1] the *Total Maximum Daily Loads of Fecal Bacteria for the Non-Tidal Gwynns Falls Basin in Baltimore City and Baltimore County, Maryland*, dated September 2006 (TMDL Report), to EPA for final review, which was received on September 26, 2006. The Gwynns Falls Non-Tidal Watershed (02-13-09-05) was first identified on Maryland's 1996 Section 303(d) List as impaired by nutrients and sediments. Bacteria (fecal coliform) and impacts to biological communities were added to the 2002 Section 303(d) List. The TMDLs described in this document were developed to address fecal bacteria non-tidal water quality impairments.

EPA's rationale is based on the TMDL Report and information contained in the computer files provided to EPA by MDE. EPA's review determined that the TMDLs meet the following seven regulatory requirements pursuant to 40 CFR Part 130.

1. The TMDL is designed to implement applicable water quality standards.
2. The TMDL includes a total allowable load as well as individual wasteload allocations (WLAs) and load allocations (LAs).
3. The TMDL considers the impacts of background pollutant contributions.
4. The TMDL considers critical environmental conditions.
5. The TMDL considers seasonal environmental variations.
6. The TMDL includes a MOS.
7. The TMDL has been subject to public participation.

In addition, these TMDLs considered reasonable assurance that the TMDL allocation assigned to nonpoint sources can be reasonably met.

---

[1]By letter dated August 10, 2006.

II. Summary

Gwynns Falls Watershed is located in Baltimore City and Baltimore County; both watershed locations are Phase I National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permit jurisdictions. MDE provided adequate land use and instream bacteria data in the TMDL report and allocated the TMDL loads to specific sources. The TMDL shown in Table 1 requires up to 100 percent reduction from existing or baseline conditions.

Table 1. Gwynns Falls Watershed Non-Tidal TMDL Summary

Subwatershed	Baseline	TMDL	WLA-PS[2]	WLA-MS4[3]	WLA-CSO[4]	LA[5]
	Billions MPN[1]/day *E. coli*					
GWN0160	2,539.6	172.5	0	110.0	0	62.6
GWN0115sub	314.8	103.4	0	69.6	0	33.8
GWN0026sub	17,990.7	629.9	0	551.3	0	78.6
GWN0015sub	90,620.3	11.5	0	10.5	0	1.0
TOTAL	111,465.5	917.4	0	741.4	0.0	176.0

[1]MPN = Most Probable Number
[2]WLA-PS = Wasteload Allocation for non MS4 systems (municipal or industrial)
[3]WLA-MS4 = Wasteload Allocation for MS4 systems
[4] WLA-CSO = Wasteload Allocation for Combined Sewer Overflow
[5] LA = Load Allocation

The TMDL is a written plan and analysis established to ensure that a waterbody will attain and maintain water quality standards. The TMDL is a scientifically-based strategy which considers current and foreseeable conditions, the best available data, and accounts for uncertainty with the inclusion of a "MOS" value. For this TMDL, the MOS was incorporated as conservative assumptions used in the TMDL analysis. The loading capacity of the stream was estimated based upon a reduced (more stringent) water quality criterion concentration. The *E.coli* water quality criterion concentration was reduced by 5%, from 126 *E. coli* MPN/100 ml to 119.7 *E. coli* MPN/100 ml.

III. Background

The Gwynns Falls Watershed comprises approximately 61 square miles (41,710 acres) within Baltimore City and Baltimore County, Maryland. The headwaters of Gwynns Falls begin in Glyndon, Maryland. The mainstem of Gwynns Falls flows southeast until its confluence with the Middle Branch of the Potapsco River near downtown Baltimore.

The Gwynns Falls Basin lies within the Piedmont and Atlantic Coastal Plain Provinces of Central Maryland. The Gwynns Falls Watershed lies predominantly in the Baile and Lehigh soil series. Baile soils are deep, poorly drained soils (with high available moisture capacity and water table that is seasonally at or near the surface). Lehigh soils are somewhat poorly drained to moderately well-drained, rather shallow soils.

The 2002 Maryland Department of Planning (MDP) land use/land cover data shows that the watershed is primarily a residential and commercial region. The land use percentage distribution for Gwynns Falls Basin is shown in Table 2.

Table 2. Land Use Area and Percentages in Gwynns Falls Basin (TMDL Report, Table 2.1.1)

Land Type	Acreage	Percentage
Forest	7,068	16.9%
Residential	23,860	57.2%
Commercial	9,367	22.5%
Crops	921	2.2%
Pasture	333	0.8%
Water	161	0.4%
Totals	**41,710**	**100%**

MDE estimated the total population in the Gwynns Falls Watershed to be 315,828 people, based on a weighted average from the Geographic Information System (GIS) 2000 Census Block and the 2002 MDP land use cover that includes the Gwynns Falls Watershed.

IV. Computational Procedure

The length of Gwynns Falls within Maryland is non-tidal or free flowing. MDE developed the method described below to determine non-tidal TMDLs.

General

In addition to the TMDL Report provided during the public notice period, MDE provided EPA with computer files in Microsoft Excel® for review. MDE's procedure uses a variation of the load-duration curve method which is also used by several states and by EPA. MDE uses stream flow data from U.S. Geological Survey (USGS) gages and sampling data to determine the bacteria load reductions necessary to meet water quality standards. MDE then uses bacteria source tracking (BST) results to allocate the TMDL loads to various sources (i.e., domestic animals, human sources, livestock, and wildlife).

The load-duration curve method uses sampling data combined with a long-term stream flow record, frequently from a USGS gaging station, to provide insight into the flow condition under which exceedances of the water quality standard occur. Exceedances that occur under low-flow conditions are generally attributed to loads delivered directly to the stream such as straight pipes, sanitary sewer overflows, livestock with access to the stream, and wildlife. Exceedances that occur

under high-flow conditions are typically attributed to loads that are delivered to the stream in stormwater runoff.

The flow-duration curve is converted to a load-duration curve by multiplying the flow by the bacteria count and the appropriate unit conversion factor (100 ml to cubic feet).

Frequently, the target load, shown in the load-duration curve, is based on the single-sample maximum value from the state's water quality standards. The required load reduction at all flows is equal to the difference between the target load and a line parallel to the target load line which passes through the highest sample value. However, MDE's water quality standards do not contain a single-sample maximum number and, therefore, modified the above procedure.

Gwynns Falls Basin Computational Method

In order for EPA to conduct a thorough review of MDE's method, MDE provided EPA with Microsoft Excel® files and, therefore, the following description of MDE's computational method refers to information not necessarily contained in the TMDL Report.

MDE conducted bacteria monitoring at four stations throughout Gwynns Falls. There is one USGS gaging station, located within the Gwynns Falls Watershed, which was used to estimate surface flow in Gwynns Falls.

The analysis to define daily flow duration intervals (flow regions, strata) includes the bacteria monitoring data. Bacteria (*enterococci* or *E. coli*) monitoring data are "placed" within the regions (stratum) based on the daily flow duration percentile of the date of sampling. An example plot of the Gwynns Falls *E. coli* monitoring data is shown in the TMDL Report, Appendix B.

The representative geometric mean for the station is equal to 0.25 times the $\log_{10}$ high-flow geometric mean plus 0.75 times the $\log_{10}$ low-flow geometric mean changed back into a geometric mean. The high-flow, low-flow, and representative geometric mean are shown in Table 3 below. Note that geometric means in the table exceed the 126 MPN/100 ml criterion for *E. coli*.

Table 3. Existing/Baseline Conditions (TMDL Report, Table 2.3.3)
Annual Steady State Geometric Mean by Stratum per Subwatershed

Station	Flow Stratum	Samples (#)	*E. coli* Minimum Concentration (MPN/100ml)	*E. coli* Maximum Concentration (MPN/100ml)	Annual Steady State Geometric Mean (MPN/100ml)	Annual Weighted Geometric Mean (MPN/100ml)
GWN0015	High	7	15,530	86,600	40,086	32,470
	Low	19	5,800	77,000	30,267	
GWN0026	High	6	280	38,700	3,633	753
	Low	17	60	4,350	446	
GWN0115	High	7	320	16,700	1,009	321
	Low	19	20	5,790	219	
GWN0160	High	6	110	23,800	1,611	508
	Low	17	60	2,050	345	

Table 4. Existing Seasonal Period Steady State Geometric Mean
By Stratum per Subwatershed (TMDL Report, Table 2.3.4)

Station	Flow Stratum	Samples (#)	*E. coli* Minimum Concentration (MPN/100ml)	*E. coli* Maximum Concentration (MPN/100ml)	Seasonal Steady State Geometric Mean (MPN/100ml)	Seasonal Weighted Geometric Mean (MPN/100ml)
GWN0015	High	3	43,500	86,600	62,529	40,716
	Low	9	5,800	77,000	35,290	
GWN0026	High	3	280	38,700	1,498	528
	Low	9	60	2,600	373	
GWN0115	High	3	620	16,700	1,954	842
	Low	9	310	5,790	636	
GWN0160	High	3	820	23,800	3,102	1,062
	Low	9	360	2,050	743	

The seasonal period (Table 4) uses only data from May 1st through September 30th, a critical period for the recreational use.

Using the average flow for the high-flow and low-flow regimes, and the high-flow and low-flow regime bacteria concentrations, the baseline loads were estimated as explained in Section 4.3 and shown in Table 4.3.1 of the TMDL Report and below.

Table 5. Baseline Load Calculations (TMDL Report, Table 4.3.1)

Station		GWN0160	GWN0115sub	GWN0026sub	GWN0015sub
Area (mi^2)		19.2	13.4	24.8	4.0
High Flow	Daily Average Flow (cfs)	74.9	52.3	96.7	15.5
	E. coli Concentration (MPN/100ml)	1611.3	302.3	8109.8	740277.0
	Bias Correction Factor	3.2	2.9	3.6	1.2
Low Flow	Daily Average Flow (cfs)	14.0	9.8	18.1	2.9
	E. coli Concentration (MPN/100ml)	345.4	65.2	1271.1	156243.6
	Bias Correction Factor	1.6	2.6	1.7	1.2
Baseline Load (Billion *E. coli* MPN/day)		2539.6	314.8	17990.7	90620.3

In order to analyze the flow record for periods that might produce higher overall geometric means and loads (critical conditions) and to account for seasonality, each day of the flow record was assigned to either the high-flow or low-flow regime. MDE used a rolling one-year period to find a year with the most high-flow days and a year with the most low-flow days, and examined each year's swimming season to find the one with the most high-flow days and most low-flow days.

Table 6. Critical Time Periods (TMDL Report, Table 4.4.1)

Hydrological Condition		Averaging Period	Water Quality Data Used	Fraction High-Flow	Fraction Low-Flow	Condition Period
Annual	Average	365 Days	All	0.25	0.75	Long-term Average
	Wet	365 Days	All	0.56	0.44	Jan. 1997-Jan. 1998
	Dry	365	All	0.06	0.94	May 1994-May 1995
Seasonal	Wet	May 1st-Sept. 30th	May 1st-Sept. 30th	0.46	0.54	May 1996-Sept. 1996
	Dry	May 1st-Sept. 30th	May 1st-Sept. 30th	0.00	1.00	May 1993-Sept. 1993

Bacteria source tracking (BST) was used to identify the relative contribution of the various sources to the instream water samples. The TMDL Report, Appendix C, is the Salisbury University, Department of Biological Sciences and Environmental Health Services, BST report, *Identifying Sources of Fecal Pollution in the Gwynns Falls Watershed, Maryland. Enterococci* isolates were obtained from known sources, which included human, dog, cow, beaver, deer, coyote, rabbit, fox, and goose. For purposes of the TMDL, the sources were separated into domestic animals, human, livestock, and wildlife. A fifth classification of "unknown" results from the analysis when the source could not be identified. The source percentage for each sample is shown in the TMDL Report, Appendix C, Table C-8, Percentage of Sources per Station per Date.

Table 7. Distribution of Fecal Bacteria Source Loads in the Gwynns Falls Basin for the Annual Condition (TMDL Report, Table 2.4.3)

STATION	Flow Stratum	% Domestic Animals	% Human	% Livestock	% Wildlife	% Unknown
GWN0015	High Flow	10	73	0	4	13
	Low Flow	21	66	0	2	11
	Weighted	18	68	0	2	12
GWN0026	High Flow	14	66	0	12	8
	Low Flow	27	47	0	10	16
	Weighted	24	52	0	10	14
GWN0115	High Flow	11	48	0	16	25
	Low Flow	14	44	0	31	11
	Weighted	14	45	0	27	14
GWN0160	High Flow	10	65	0	15	10
	Low Flow	8	59	0	21	12
	Weighted	8	60	0	20	12

Table 8. Distribution of Fecal Bacteria Source Loads in the Gwynns Falls Basin for the Seasonal Period May 1 - September 30 (TMDL Report, Table 2.4.4)

STATION	Flow Stratum	% Domestic Animals	% Human	% Livestock	% Wildlife	% Unknown
GWN0015	High Flow	10	61	0	4	25
	Low Flow	17	65	0	2	16
	Weighted	16	63	0	3	18
GWN0026	High Flow	3	55	0	26	16
	Low Flow	23	43	0	16	18
	Weighted	18	45	0	19	18
GWN0115	High Flow	2	45	0	14	39
	Low Flow	9	53	0	27	11
	Weighted	7	51	0	24	18
GWN0160	High Flow	12	54	0	22	12
	Low Flow	7	60	0	22	11
	Weighted	8	58	0	22	12

The target reduction for each condition is the reduction necessary in the geometric mean from Table 3 to meet the criterion. In determining the initial reduction scenario, two additional factors were considered: risk and practicability.

Bacteria from human sources are presumed to present a larger risk to humans than bacteria from other sources, and bacteria from wildlife presents the lowest risk to humans. TMDL Report, Section 4.7, Practicable Reduction Targets, page 38, identified the assumed risk factors shown in Table 9, below. Table 10, Maximum Practicable Reduction Targets, shown below, identifies the practicable reductions and the rationale for selecting them.

Table 9. Relative Risk Factors

	Human	Domestic Animal	Livestock	Wildlife
Relative Risk to Humans	5	3	3	1

Table 10. Maximum Practicable Reduction Targets (TMDL Report, Table 4.7.2)

Max Practicable Reduction per Source	Human	Domestic Animals	Livestock	Wildlife
	95%	75%	75%	0%
Rationale	(1) Direct source inputs. (2) Human pathogens more prevalent in humans than animals. (3) 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 presents a public health risk that is orders of magnitude less than that associated with human waste.[4]

1. EPA. 1984. Health Effects Criteria for Fresh Recreational Waters. EPA-600/1-84-004. U.S. Environmental Protection Agency, Washington, DC.
2. EPA. 1999. Preliminary Data Summary of Urban Storm Water Best Management Practices. EPA-821-R-99-012. U.S. Environmental Protection Agency, Washington, DC.
3. EPA. 2004. Agricultural BMP Descriptions as Defined for The Chesapeake Bay Program Watershed Model. Nutrient Subcommittee Agricultural Nutrient Reduction Workshop.
4. Environmental Indicators and Shellfish Safety. 1994. Edited by Cameron, R., Mackeney and Merle D. Pierson, Chapman & Hall.

The required reductions were determined by analyzing each of the critical time periods (Table 6) individually for each subwatershed, together with the results of the BST analysis, to minimize the final risk. First, the reductions were not allowed to exceed the practicable reductions in the above table. The water quality criterion for *E. coli* could not be achieved (Table 11).

Table 11. Practical Reductions Results (TMDL Report, Table 4.7.3)

Station	Applied Reductions				WQS Achievable
	Domestic %	Human %	Livestock %	Wildlife %	
GWN0160	75.0%	95.0%	75.0%	0.0%	No
GWN0115sub	75.0%	95.0%	75.0%	0.0%	No
GWN0026sub	75.0%	95.0%	75.0%	0.0%	No
GWN0015sub	75.0%	95.0%	75.0%	0.0%	No

Next, the analysis was performed allowing greater reductions for each fecal bacteria source until the water quality criterion for *E. coli* was achieved (Table 12).

Table 12. Required Reductions to Achieve Water Quality Criterion up to 100% Reductions (TMDL Report, Table 4.7.4)

Station	Domestic %	Human %	Livestock %	Wildlife %	Target Reduction
GWN0160	98.0%	98.0%	0.0%	76.5%	93.2%
GWN0115sub	96.0%	98.0%	0.0%	2.3%	67.2%
GWN0026sub	98.0%	98.0%	0.0%	85.5%	96.5%
GWN0015sub	99.9989%	99.9998%	0.0%	99.6%	99.987%

The TMDL load is then divided into WLA-MS4, CSO, and LA portions. MDE developed allocation rules summarized in Table 13 below. The "unknown" BST source category is deleted and the other categories increased.

Table 13. Source Contributions for TMDL Allocations (TMDL Report, Table 4.8.1)

Allocation Category	LA	WLA		
		WWTP	MS4	CSOs
Human			X	
Domestic			X	
Livestock				
Wildlife	X		X	

The load reduction scenario results in a load allocation that will achieve water quality standards. The state reserves the right to revise these allocations provided such allocations are consistent with the achievement of water quality standards.

Because the entire Gwynns Falls Watershed is covered by an MS4 permit, the final human load is allocated entirely to WLA-MS4. Domestic pets are also allocated entirely to WLA-MS4. There are no livestock contributions in the Gwynns Falls watershed. Wildlife is distributed between LA and WLA-MS4, based on a ratio of the amount of urban land compared to pasture and forest land in the watershed.

Baltimore County and Baltimore City have developed long term control plans (LTCPs) which require elimination of all CSOs by March 2020 and January 2016, respectively; therefore a zero allocation will be assigned to WLA-CSOs.

V. Discussion of Regulatory Conditions

EPA finds that Maryland has provided sufficient information to meet all of the seven basic requirements for establishing bacteria TMDLs for Gwynns Falls. Therefore, EPA approves the

TMDLs for the Gwynns Falls Watershed. EPA's approval is outlined according to the regulatory requirements listed below.

1. The TMDLs are designed to implement the applicable water quality standards.

The Maryland water quality standards Surface Water Use Designation for this watershed include Use III (Non-tidal Cold Water) for Gwynns Falls and tributaries above Reiterstown Road, Use IV (Recreational Trout Waters) for Dead Run and tributaries, and Use I – (Water Contact Recreation and Protection of Nontidal Warmwater Aquatic Life) for all remaining waters (COMAR 26.08.02.08R(3)(e) &(4)(e)).

The standard for bacteria used in this study is as follows (COMAR 26.08.02.03-3):

Table 14. Water Quality Criteria

Indicator	**Steady State Geometric Mean Indicator Density**
Freshwater	
E. coli	126 MPN/100ml

The standards do not specify either a minimum number of samples required for the geometric mean or time frame such as the commonly used 30-day period. However, the *2006 List of Impaired Surface Waters [303(d) List] and Integrated Assessment of Water Quality In Maryland*, dated April 2006, Section B.3.2.1.3.1, Recreational Waters, contains MDE's interpretation of how bacteria data will be used for assessing waters for general recreational use. A steady state geometric mean will be calculated with available data where there are at least five representative sampling events. The data shall be from samples collected during steady state conditions and during the beach season (Memorial Day through Labor Day) to be representative of the critical condition. Furthermore, according to Section B.3.2.1.3.2, Beaches, "(t)he single sample maximum criteria applies only to beaches and is to be used for closure decisions based on short-term exceedances of the geometric mean portion of the standard." Since warm temperatures can occur early in May and last until the end of September or early October, a longer seasonal period than the official beach season (Memorial Day through Labor Day) was used for the water quality assessment, as a conservative assumption in the analysis.

In 1986, EPA published "Ambient Water Quality Criteria for Bacteria" whereby three indicator organisms, fecal coliform, *E. coli* and *Enterococci*, were assessed to determine their correlation with swimming-associated illnesses. Fecal coliform are a subgroup of total coliform bacteria and *E. coli* are a subgroup of fecal coliform. *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 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), leading EPA to propose that States use *E. coli* or *Enterococci* as pathogen indicators. Maryland has adopted the EPA recommended bacterial indicators, *E. coli* and Enterococcus. Although the criteria numbers are different, the risk to the recreational bathers at the criteria levels are the same.

EPA finds that the TMDLs for bacteria will ensure that the designated use and water quality criteria for Gwynns Falls are met and maintained.

2. The TMDLs include a total allowable load as well as individual wasteload allocations and load allocations.

The TMDL is expressed as MPN per day and is based on meeting the instream long-term geometric mean of *E. coli* bacteria. EPA's regulations at 40 CFR §130.2(i), also define "total maximum daily load (TMDL)" as the "sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background." As the total loads provided by Maryland equal the sum of the individual WLAs for point sources and the land-based LAs for nonpoint sources set forth below, the TMDLs for fecal bacteria for Gwynns Falls are consistent with §130.2(i).

The WLAs are assigned to MS4 systems. Because the entire Gwynns Falls Watershed is covered by an MS4 permit, the final human load is allocated entirely to WLA-MS4. Domestic pets are also allocated entirely to WLA-MS4. There are no livestock contributions in the Gwynns Falls watershed. Wildlife is distributed between LA and WLA-MS4, based on a ratio of the amount of urban land compared to pasture and forest land in the watershed.

Baltimore County and Baltimore City have developed long term control plans (LTCPs) which require elimination of all CSOs (see Table 1) by March 2020 and January 2016, respectively; therefore a zero allocation will be assigned to WLA-CSOs.

Table 15. Locations of Combined Sewer Overflows in Gwynns Falls Watershed (TMDL Report, Table 2.4.2)

Treatment Plant	NPDES ID	CSO/SSO Structure ID	Type	Latitude	Longitude	Receiving Water
Back River WWTP	MD0021555	79	SSO	39.277	-76.663	Gwynns Falls
		81	SSO	39.277	-76.662	Gwynns Falls
		55	SSO	39.345	-76.672	Gwynns Run
		56	SSO	39.339	-76.671	Gwynns Run
		57	SSO	39.340	-76.671	Gwynns Run
		60	SSO	39.325	-76.674	Gwynns Run
		63	SSO	39.323	-76.666	Gwynns Run
		103	SSO	39.327	-76.675	Gwynns Run
		106	SSO	39.306	-76.664	Gwynns Run
		107	SSO	39.307	-76.663	Gwynns Run
		126	SSO	39.332	-76.675	Gwynns Run
		127	SSO	39.331	-76.675	Gwynns Run
		128	SSO	39.333	-76.676	Gwynns Run
		130	SSO	39.328	-76.664	Gwynns Run
		131	SSO	39.340	-76.670	Gwynns Run
Patapsco WWTP	MD0021601	10P	CSO	39.326	-76.695	Gwynns Falls
		11P	CSO	39.323	-76.700	Gwynns Falls
		13P	CSO	39.319	-76.704	Gwynns Falls
		18P	CSO	39.329	-76.686	Gwynns Falls
		19P	CSO	39.327	-76.688	Gwynns Falls
		21P	CSO	39.308	-76.680	Gwynns Falls
		31P	CSO	39.326	-76.692	Gwynns Falls
		16P	SSO	39.295	-76.709	Dead Run
		17P	SSO	39.297	-76.702	Dead Run
		84	SSO	39.267	-76.632	Gwynns Falls
		12P	SSO	39.320	-76.700	Gwynns Falls
		22P	SSO	39.306	-76.679	Gwynns Falls
		25P	SSO	39.325	-76.700	Gwynns Falls
		26P	SSO	39.324	-76.701	Gwynns Falls
		27P	SSO	39.325	-76.687	Gwynns Falls
		6	SSO	39.274	-76.666	Maidens Choice Run
		23P	SSO	39.286	-76.713	Maidens Choice Run
		24P	SSO	39.279	-76.709	Maidens Choice Run
		32P	SSO	39.274	-76.675	Maidens Choice Run
		28P	SSO	39.342	-76.694	Powder Mill
		29P	SSO	39.342	-76.692	Powder Mill
		30P	SSO	39.342	-76.692	Powder Mill
		33P	SSO	39.343	-76.702	Powder Mill

EPA realizes that the bacteria allocations shown in Table 1 is one allocation scenario designed to meet instream water quality standards. As implementation of the established TMDLs proceed or more detailed information becomes available, Maryland may find other combinations of dividing the TMDL loads between WLA-PS and LA allocations are feasible and/or cost effective. Any subsequent changes, however, must ensure that the instream water quality standards are met.

Based on the foregoing, EPA has determined that the Gwynns Falls TMDLs for fecal bacteria are consistent with the regulations and requirements of 40 CFR Section 130.

3. The TMDLs consider the impacts of background pollutant contributions.

Maryland's Gwynns Falls Watershed is comprised of four subwatersheds. While the monitoring data used in developing the TMDL is from instream sampling which integrates the effects of all loads, the effects of the upstream subwatersheds are considered on the downstream subwatersheds. A decay factor and estimated time of travel was used to estimate the effect of the upstream subwatersheds on the downstream subwatersheds.

4. The TMDLs consider critical environmental conditions.

EPA regulations at 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 Gwynns Falls' water quality is protected at all times.

MDE's water quality standards do not specify a time period for which the geometric mean is calculated. For the designated recreational use, the critical period for exposure is the summer months during the swimming season. To identify critical periods resulting from flow and rainfall conditions, MDE developed a procedure to examine the 10-year (October 1, 1996 to January 17, 2006) flow record for critical high and low-flow periods of one year and for seasonal (May 1 to September 30) conditions. MDE's 2006 Section 303(d) listing methodology identifies the swimming period as Memorial Day to Labor Day, however, MDE used May through September because May and September may be warm and swimming may occur. The corresponding critical period dates are shown in the TMDL Report (Table 4.4.1.) and Table 6 of this document.

5. The TMDLs consider seasonal environmental variations.

Seasonal variations involve changes in stream flow as a result of hydrologic and climatological patterns. In the continental United States, seasonally high flow normally occurs during the colder period of winter and in early spring from snow melt and spring rain, while low flow typically occurs during warmer summer and early fall drought periods[2]. MDE's statistical method analyzed flows in Gwynns Falls by dividing them into high and low-flow regimes and calculated geometric mean bacteria concentrations for each regime in order to evaluate seasonal differences.

---

[2]Technical Guidance Manual for Developing Total Maximum Daily Loads, Book 2, Part 1, Section 2.33, (EPA 823-B-97-002, 1997)

6. The TMDLs include a margin 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 water bodies. 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.[3] One approach is to reserve a portion of the loading capacity as a separate term in the TMDL. The second approach is to incorporate the MOS as conservative assumptions used in the TMDL analysis.

For this TMDL, the MOS was incorporated as conservative assumptions used in the TMDL analysis. The loading capacity of the stream was estimated based upon a reduced (more stringent) water quality criterion concentration. The *E.coli* water quality criterion concentration was reduced by 5%, from 126 *E. coli* MPN/100 ml to 119.7 *E. coli* MPN/100 ml.

7. The TMDLs have been subject to public participation.

MDE conducted a public review of the proposed TMDL of Fecal Bacteria for Gwynns Falls. The public comment period was open from August 4, 2006 through September 5, 2006. MDE received one set of written comments.

VI. Discussion of Reasonable Assurance

In addition to the seven outlined elements above, there is a reasonable assurance that the TMDLs can be met. According to 40 CFR §122.44(d)(1)(vii)(B), the effluent limitations for an NPDES permit must be consistent with the assumptions and requirements of any available WLA for the discharge which is prepared by the state and approved by EPA. Therefore, any WLAs will be implemented through the NPDES permit process. Based on the point source permitting information, Baltimore County and Baltimore City are Phase I NPDES MS4 permit jurisdictions. CSOs are not given a WLA within the TMDLs for Gwynns Falls.

In Gwynns Falls Watershed, MDE's analysis indicates that required reductions to meet the water quality criteria are extremely large and are not feasible by implementing cost-effective and reasonable best management practices (BMP) to nonpoint sources. Therefore, MDE intends to implement an iterative approach that addresses those sources with the largest impact on water quality and human health risk, with consideration given to ease of implementation and cost.

Maryland has several well established programs that will be drawn upon, such as the NPDES permit limits that will be based on the TMDL loadings, MDE's Managing for Results work plan, and MDE procedures adopted to assure that future evaluations are conducted for all established TMDLs.

---

[3] *Guidance for Water Quality-based Decisions: The TMDL Process*, (EPA 440/4-91-001, April 1991)

MDE's implementation plan is not only based on reductions to total fecal bacteria, it is based on reductions by sources of bacteria. MDE used the results of its BST monitoring from October 2002 through October 2003 to estimate the required reduction in sources of bacteria. MDE does not propose elimination of wildlife to allow for the attainment of water quality standards, although managing the overpopulation of wildlife is an option for state and local stakeholders. MDE identifies the maximum practicable reduction (MPR) per source as:

- Human - 95 percent
- Domestic Animal - 75 percent
- Livestock - 75 percent
- Wildlife - 0 percent

The TMDLs specify LAs that will meet the water quality standards. In the practicable reduction targets scenario, no subwatersheds met water quality standards.

To further develop the TMDLs, the constraints were relaxed in all subwatersheds. The maximum allowable reduction was increased to 100% for all sources, including wildlife.

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, 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.

Finally, MDE has recently adopted 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. This follow-up monitoring will allow MDE to determine whether the second stage TMDL implementation can be implemented successfully or whether an alternate action should be pursued.

APPENDIX H:

TMDLs of Nitrogen and Phosphorus for the Baltimore Harbor

Total Maximum Daily Loads of Nitrogen and Phosphorus for the Baltimore Harbor in Anne Arundel, Baltimore, Carroll and Howard Counties and Baltimore City, Maryland

FINAL

DEPARTMENT OF THE ENVIRONMENT

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Submitted to:

Watershed Protection Division
U.S. Environmental Protection Agency, Region III
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Table of Contents

List of Figures ..... *i*

List of Table ..... *i*

List of Abbreviations ..... *ii*

EXECUTIVE SUMMARY ..... *iii*

1.0 INTRODUCTION *1*

2.0 SETTING AND WATER QUALITY DESCRIPTION *2*

2.1 General Setting and Source Assessment **2**
2.1.1 Watershed Description 2
2.1.2 Land Use 4
2.1.3 Geology 6
2.1.4 Nutrients Source Assessment 6
2.1.4.1 Point Sources: Municipal and Industrial Wastewater Treatment Plant Loads 6
2.1.4.2 Nonpoint Source Loads and Urban Stormwater Loads 8

2.2 Water Quality Characterization **9**

2.3 Water Quality Impairment **13**
2.3.1 Dissolved Oxygen Criteria 14
2.3.2 Chlorophyll *a* Criteria 14

3.0 TARGETED WATER QUALITY GOAL *15*

4.0 TOTAL MAXIMUM DAILY LOADS DEVELOPMENT AND ALLOCATION *15*

4.1 Overview **15**

4.2 Analysis Framework **15**
4.2.1 Computer Modeling Framework 15
4.2.1.1 Eutrophication Model Calibration 17
4.2.2 TMDL Analysis Framework 18
4.2.2.1 Dissolved Oxygen Analytical Framework 18
4.2.2.2 Chlorophyll *a* Analytical Framework 20

4.3 Scenario Descriptions and Results **20**
4.3.1 Baseline Conditions Scenario 20
4.3.2 Baseline Conditions Scenario Results 21
4.3.2.1 Dissolved Oxygen Assessment of the Baseline Conditions Scenario 22
4.3.2.2 Chlorophyll *a* Assessment for the Baseline Conditions Scenario 24
4.3.3 Maximum Anthropogenic Reduction from Baltimore Harbor Scenario 24
4.3.4 Maximum Anthropogenic Reduction Scenario Results 24
4.3.5 Future Conditions (TMDL) Scenario 25
4.3.6 Future Conditions (TMDL) Scenario Results 26

4.3.6.1 Dissolved Oxygen Criteria Attainment Assessment of the Future Conditions (TMDL) Scenario 28
4.3.6.2 Chlorophyll *a* Criteria Attainment Assessment of the Future Conditions (TMDL) Scenario 29

4.4 TMDL Loading Caps 30

4.5 Load Allocations Between Point Sources and Nonpoint Sources 30
4.5.1 Growing Season TMDL Allocations 30
4.5.2 Average Annual TMDL Allocations 32

4.6 Margin of Safety (MOS) 33

4.7 Summary of Total Maximum Daily Loads 35

5.0 ASSURANCE OF IMPLEMENTATION 36

REFERENCES 39

APPENDIX A: Baseline Scenario Dissolved Oxygen Criteria Attainment Assessment A1

APPENDIX B: TMDL Scenario Dissolved Oxygen Criteria Attainment Assessment B1

APPENDIX C: Potential TMDL Allocations by Source Category C1

List of Figures

Figure 1: Location Map of Baltimore Harbor Drainage Basin 3
Figure 2: Predominant Land Uses in the Watershed Draining into Baltimore Harbor..... 5
Figure 3: Proportions of Land Use in the Basins Draining into Baltimore Harbor 6
Figure 4: Percentages of Average Annual Nitrogen and Phosphorus Loads from Municipal and Industrial Point Sources, Urban Stormwater and NPS in Baltimore Harbor, 1995-1997..... 9
Figure 5: Location of Water Quality Stations in Baltimore Harbor 11
Figure 6: Time Series of Chlorophyll *a* Data at Baltimore Harbor Station WT5.1 / M16 12
Figure 7: Time Series of DO Data at Baltimore Harbor Station WT 5.1 / M16..... 13
Figure 8: Time Series of Model Calibration Results of DO in Harbor Station WT5.1 17
Figure 9: Time Series of Model Calibration Results of Chl *a* in Harbor Station WT5.1 18
Figure 10: Cumulative Frequency Distribution curve representing an approximately 10 percent allowable exceedance equally distributed between time and space (EPA, 2003) 19
Figure 11: Time Series of Model Results for the Baseline Conditions Scenario for DO in Baltimore Harbor Station WT5.1..... 21
Figure 12: Model Results for the Baseline Conditions Scenario for Chl *a* in Baltimore Harbor Station WT5.1 22
Figure 13: Maximum Anthropogenic Reduction Scenario model results for DO levels in surface and bottom waters in Baltimore Harbor at Station WT5.1 25
Figure 14: Time Series of Model Results for the TMDL Scenario for DO at Station WT5.1 27
Figure 15: Time Series of Model Results for the TMDL Scenario for Chl *a* at Station WT5.1 . 27

List of Tables

Table 1: Baltimore Harbor Subwatershed Areas Within Maryland Jurisdictions 4
Table 2: Baltimore Harbor Subwatershed Areas 4
Table 3: Average Municipal WWTP Loads, 1992-1997 7
Table 4: Average Industrial WWTP Loads, 1992-1997 7
Table 5: Average Daily Flows for Permitted Point Sources Discharging into Baltimore Harbor during the 1992-1997 Model Calibration Period 7
Table 6: Dissolved Oxygen Criteria and Time Periods for the Designated Use Subcategories ... 14
Table 7: Baseline Conditions Scenario: Percent Nonattainment of Dissolved Oxygen Criteria in the Baltimore Harbor 23
Table 8: TMDL Scenario: Percent Nonattainment of Dissolved Oxygen Criteria in the Baltimore Harbor 29
Table 9: Growing Season Allocations 32
Table 10: Average Annual Allocations 33

List of Abbreviations

BHEM	Baltimore Harbor Eutrophication Model
BMPs	Best Management Practices
BNR	Biological Nutrient Removal
CBP	Chesapeake Bay Program
CE-QUAL-ICM	Corps of Engineers Water Quality Integrated Compartment Model
CEWES	Corps of Engineers Waterways Experiment Stations
CFD	Cumulative Frequency Distribution
CH3D-WES	Curvilinear Hydrodynamics in Three Dimensions – Waterways Experiment Stations
Chl *a*	Active Chlorophyll *a*
COMAR	Code of Maryland Regulations
CTIC	Conservation Technology Information Center
CWA	Clean Water Act
DMCF	Dredged Material Containment Facility
DO	Dissolved Oxygen
ENR	Enhanced Nutrient Removal
EPA	Environmental Protection Agency
HSPF	Hydrological Simulation Program Fortran
FSA	Farm Service Agency
ISG	International Steel Group
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
mg/l / µg/l	Milligrams per Liter / Micrograms per Liter
mgd	Million Gallons per Day
MOS	Margin of Safety
MS4	Municipal Separate Stormwater Sewer System
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
PATMH	Patapsco River Mesohaline Stream Segment
PCBs	Polychlorinated Biphenyls
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
WLA	Wasteload Allocation
WQIA	Water Quality Improvement Act
WQLS	Water Quality Limited Segment
WWTP	Waste Water Treatment Plant

EXECUTIVE SUMMARY

Upon approval by the U.S. Environmental Protection Agency (EPA) this document will establish Total Maximum Daily Loads for nitrogen and phosphorus in the Patapsco River Mesohaline Stream Segment – PATMH (not including Bodkin Creek). Hereafter this stream segment will be referred to as the Baltimore Harbor or the Harbor (basin number 02130903). The Baltimore Harbor drains into the Chesapeake Bay and is part of the Patapsco/Back River Tributary Strategy Basin.

Baltimore Harbor (basin number 02130903) was identified on the State's 1996 list of water quality limited segments (WQLSs) submitted to the U.S. EPA by the Maryland Department of the Environment (MDE) as impaired by nutrients. The Baltimore Harbor has also been identified on the 303(d) list as impaired by bacteria (fecal coliform) (1998), toxics (polychlorinated biphenyls, or PCBs) (1998), metals (chromium, zinc and lead) (1998), suspended sediments (1996), and impacts to biological communities (2004). These other impairments will be addressed separately. The TMDLs described within this document were developed to address the water quality impairments associated with excess nutrient loadings.

The TMDLs for the nutrients nitrogen and phosphorus were determined using a time-variable, three-dimensional water quality eutrophication model package, which includes a watershed model (Hydrological Simulation Program Fortran (HSPF)), a hydrodynamic model (Curvilinear Hydrodynamic in Three Dimensions (CH3D)), a water quality model (Corps of Engineers-Water Quality-Integrated Compartment Model (CE-QUAL-ICM)), and a sediment flux model. Loading caps for total nitrogen and total phosphorus entering the Baltimore Harbor are established for growing season conditions and for average annual flow conditions.

To assure that critical conditions are addressed, the growing season TMDL for nitrogen is 2,145,750 lbs/growing season, and the growing season TMDL for phosphorus is 149,152 lbs/growing season. These TMDLs apply from May 1 through October 31. The allowable loads have been allocated between point and nonpoint sources. The nonpoint sources are allocated 459,912 lbs/growing season of total nitrogen, and 12,776 lbs/growing season of total phosphorus. The National Pollutant Discharge Elimination System (NPDES) point sources, including municipal wastewater treatment plant (WWTP) loads, NPDES industrial discharge loads and NPDES regulated urban stormwater loads, are allocated 1,642,014 lbs/growing season of nitrogen, and 113,212 lbs/growing season of phosphorus. A future allocation (FA) load to account for future growth and an explicit margin of safety comprises the remainder of the nitrogen and phosphorus allocations.

The average annual TMDL for nitrogen is 5,323,963 lbs/year, and the average annual TMDL for phosphorus is 324,309 lbs/year. The allowable loads have been allocated between point and nonpoint sources. The nonpoint source loads are allocated 1,246,036 lbs/year of total nitrogen and 34,654 lbs/year of total phosphorus. The point sources, including NPDES WWTP loads, NPDES industrial discharge loads and NPDES urban stormwater loads, are allocated 3,976,215 lbs/year of total nitrogen and 243,127 lbs/year of total phosphorus. A future allocation (FA) load to account for future growth and an explicit margin of safety comprises the remainder of the nitrogen and phosphorus allocations.

Several legislative and policy-derived programs will be utilized to implement these TMDLs. First, NPDES permits will reflect TMDL loadings as they are renewed. Additionally, the Chesapeake Bay Restoration Fund will be used to finance Enhanced Nutrient Removal (ENR) upgrades to WWTPs discharging into the Baltimore Harbor. Second, Maryland has several well-established programs to draw upon, including Maryland's Tributary Strategies for Nutrient Reductions, developed in accordance with the Chesapeake Bay 2000 Agreement. Third, Maryland's Water Quality Improvement Act (WQIA) of 1998 requires that nutrient management plans be implemented for all agricultural lands throughout Maryland. Finally, Maryland has adopted a watershed cycling strategy, which will ensure that future monitoring and water quality evaluations are conducted.

The water quality goal of these TMDLs is to reduce excessive algal blooms that result in high chlorophyll *a* concentrations, and maintain the dissolved oxygen concentrations at levels above the water quality criteria for the specific designated uses of the Baltimore Harbor. MDE has described the legislative and policy-derived programs that will result in significant nutrient reductions and the achievement of water quality standards for all designated uses in the Baltimore Harbor except the Deep Channel.

Based on information generated in the TMDL analysis, MDE is unable to ensure that the Deep Channel Refuge designated use water quality criterion for dissolved oxygen can be met at all times that it is applicable. The regions to which the Deep Channel Refuge designated use applies represent approximately 10% of the area of the Harbor. These regions include the main navigation channel of the Harbor, the channels into Curtis Bay, Middle Branch, and Northwest Branch and associated anchorages (COMAR 26.08.02.08). The region subject to potential non-attainment is in the main shipping channel, from the mouth of the Harbor to Fort McHenry, and represents < 5% of the area of the Harbor. The volume of water that does not meet the dissolved oxygen criteria represents approximately 3% of the total volume of the Harbor.

The reason that the designated use cannot be fully attained is due to the deepening of the natural river channel into a navigation channel that began in 1836 and continues today. In the past 170 years the dredging effort has incrementally deepened and expanded the size of the channels and their associated turning basins and anchorages. As a result, the channels and the water that flows within them, has been hydrologically modified. In a portion of the main navigation channel, from the mouth of the Harbor to Fort McHenry, it has been observed that water from the upper portion of the water column does not mix with the lower portion of the water column. This observed stratification of the water column, and the lack of mixing associated with it, occurs every spring/summer/fall. As a result, there is a limited region within the navigation channel that does not meet the dissolved oxygen criteria during the observed spring/summer/fall stratification period. Additionally, a computer model simulation was conducted that removed all anthropogenic sources of nutrients to the system and returned the watershed to a forest. Even under these conditions, the results indicated that the designated use could not be attained.

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 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 for the Patapsco River Mesohaline Stream Segment – PATMH (hereafter referred to as the Baltimore Harbor or the Harbor) are: (1) Migratory Fish Spawning and Nursery, (2) Seasonal Shallow Water Submerged Aquatic Vegetation, (3) Open Water Fish and Shellfish Habitat, (4) Deep Water Seasonal Fish and Shellfish Habitat, and (5) Deep Channel. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. Criteria differ among waters with different designated uses.

The Baltimore Harbor (basin number 02130903) was first identified on the 1996 303(d) list submitted to EPA by the Maryland Department of the Environment (MDE). It was listed as impaired by nutrients due to signs of eutrophication, expressed as high levels of chlorophyll *a* (Chl *a*) and low concentrations of dissolved oxygen (DO). Eutrophication is the over-enrichment of aquatic systems by excessive inputs of nutrients (nitrogen and/or phosphorus). The nutrients act as a fertilizer leading to excessive growth of algae. The algae die and are eventually consumed by bacteria. During the consumption process the bacteria utilize the available DO, which results in decreased DO concentrations in the water column particularly when stratification or layering prevents oxygen in the surface layers from mixing with deeper layers. Therefore, MDE uses measures of DO and Chl *a* to understand the impact of the nitrogen and phosphorus on the ecosystem. For these reasons, this document, upon EPA approval, establishes TMDLs for the nutrients nitrogen and phosphorus in the Baltimore Harbor.

The Baltimore Harbor has also been identified on the 303(d) list as impaired by bacteria (fecal coliform) (1998), toxics (polychlorinated biphenyls (PCBs) (1998), metals (chromium (Cr), zinc (Zn), and lead (Pb)) (1998), suspended sediments (1996), and impacts to biological communities (2004). To date, Cr and Zn impairments in Bear Creek and the Inner Harbor/Northwest Branch and Pb in the Inner Harbor/Northwest Branch have been addressed with water quality analyses. The remaining impairments will be addressed separately.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting and Source Assessment

2.1.1 Watershed Description

The watershed draining into the Baltimore Harbor estuary is the Patapsco River Watershed. The Patapsco River Watershed is located in the western shore region of Maryland (Figure 1), and includes the mainstem Patapsco and the tributaries of Jones Falls, Gwynns Falls, Colgate Creek, Bear Creek, Curtis Creek, Stony Creek, and Rock Creek. The Patapsco River Mesohaline (PATMH) segment, or Baltimore Harbor estuary, is located on the west side of the upper Chesapeake Bay about 160 miles from the Virginia Capes at the entrance to the Bay. The Harbor estuary is the 15-mile tidal region of the lower Patapsco River. It is the end of the Patapsco River where it joins the Chesapeake Bay. The PATMH segment includes the Baltimore Harbor estuary and the tidal segments of the Colgate Creek, Bear Creek, Curtis Creek, Stony Creek, Rock Creek and Bodkin Creek tributaries. Bodkin Creek is identified in the 303(d) list as a separate waterbody and will be addressed in the future.

Natural water depths in the Harbor are generally less than 20 feet except for the main navigation channel maintained by the U.S. Army Corps of Engineers, which is maintained at a depth of 50 feet. The tidal range in the Harbor is approximately one foot. Other than the Patapsco River, the only sizable tributaries entering the Harbor directly are Jones Falls and Gwynns Falls.

The Jones Falls, Gwynns Falls and Patapsco River discharge into the Baltimore Harbor. The South Branch and mainstem of the Patapsco River flows about 85 miles (134 km) from Parr's Spring in Carroll County to the Middle Branch. The North Branch, formed at the confluence of the East Branch and West Branch, flows into Liberty Reservoir where it is retained for drinking water purposes. A small segment of the North Branch exists below the dam and joins the South Branch near the Town of Sykesville. After flowing through Baltimore Harbor, the Patapsco River discharges into the Chesapeake Bay.

The subwatersheds draining into the Harbor are located within Baltimore City and Baltimore, Anne Arundel, Carroll, and Howard Counties. The total area of these subwatersheds is 268,671 acres (1,087 square kilometers), excluding the land area above Liberty Reservoir. Water from the subwatershed draining into Liberty Reservoir typically does not drain to the Baltimore Harbor because it is used for drinking water.

Table 1 shows the area in acres that the Patapsco River watershed (not including Liberty Reservoir watershed) occupies in each of the above counties. Table 2 shows the area in acres for each of the four major subwatersheds draining into the Baltimore Harbor estuary.

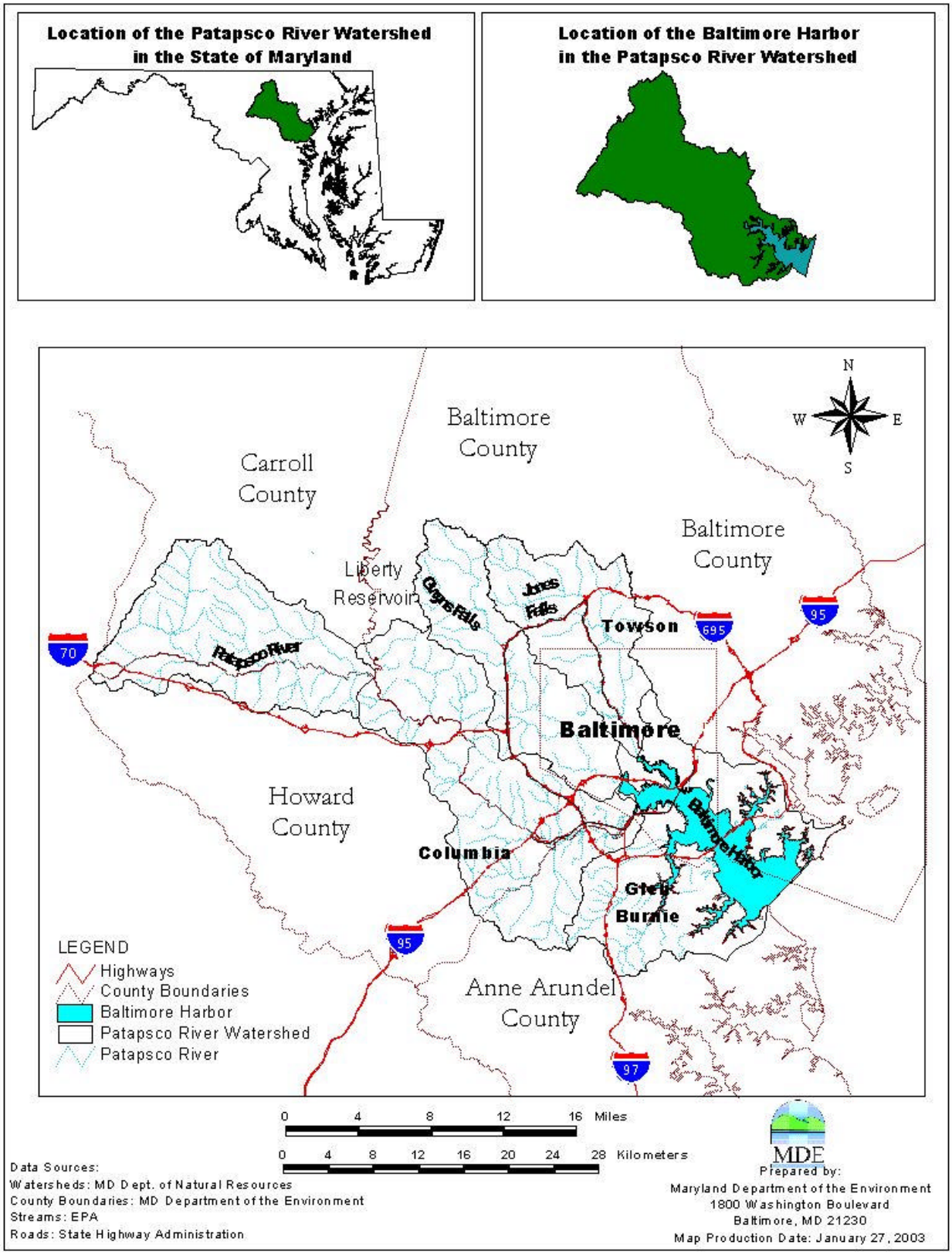


Figure 1: Location Map of Baltimore Harbor Drainage Basin

Table 1: Baltimore Harbor Subwatershed Areas Within Maryland Jurisdictions

Jurisdictions	Area (acres)
Anne Arundel County	46,223
Baltimore City	40,476
Baltimore County	100,600
Carroll County	40,182
Howard County	41,190
Total	268,671

Table 2: Baltimore Harbor Subwatershed Areas

Subwatersheds	Area (acres)
Gwynns Falls	41,701
Jones Falls	37,273
Patapsco River	130,662
Baltimore Harbor	59,035
Total	268,671

2.1.2 Land Use

The land use in the Baltimore Harbor watershed is diverse. The land cover consists of urban, suburban, rural, industrial, forest, and agricultural land uses. One of the largest forested areas in the watershed is the Patapsco Valley State Park.

The watershed draining into the Baltimore Harbor (not including the watershed draining into the Liberty Reservoir) has an area of approximately 268,671 acres (1,087.3 square kilometers). The land uses in the watershed consist of forest and other herbaceous growth (77,077 acres or 29%), mixed agriculture (41,848 acres or 15%), water (1,806 acres or 1%), and urban (147,940 acres or 55%). Land use information was derived from the 1997 Maryland Department of Planning (MDP) land cover database, the Farm Service Agency (FSA), the 1997 Agricultural Census, and information from the 1996 Conservation Technology Information Center (CTIC). See Figure 2 for the predominant land uses in the Baltimore Harbor watersheds. Figure 3 shows the relative amounts of different land uses in the watersheds draining into the Baltimore Harbor.

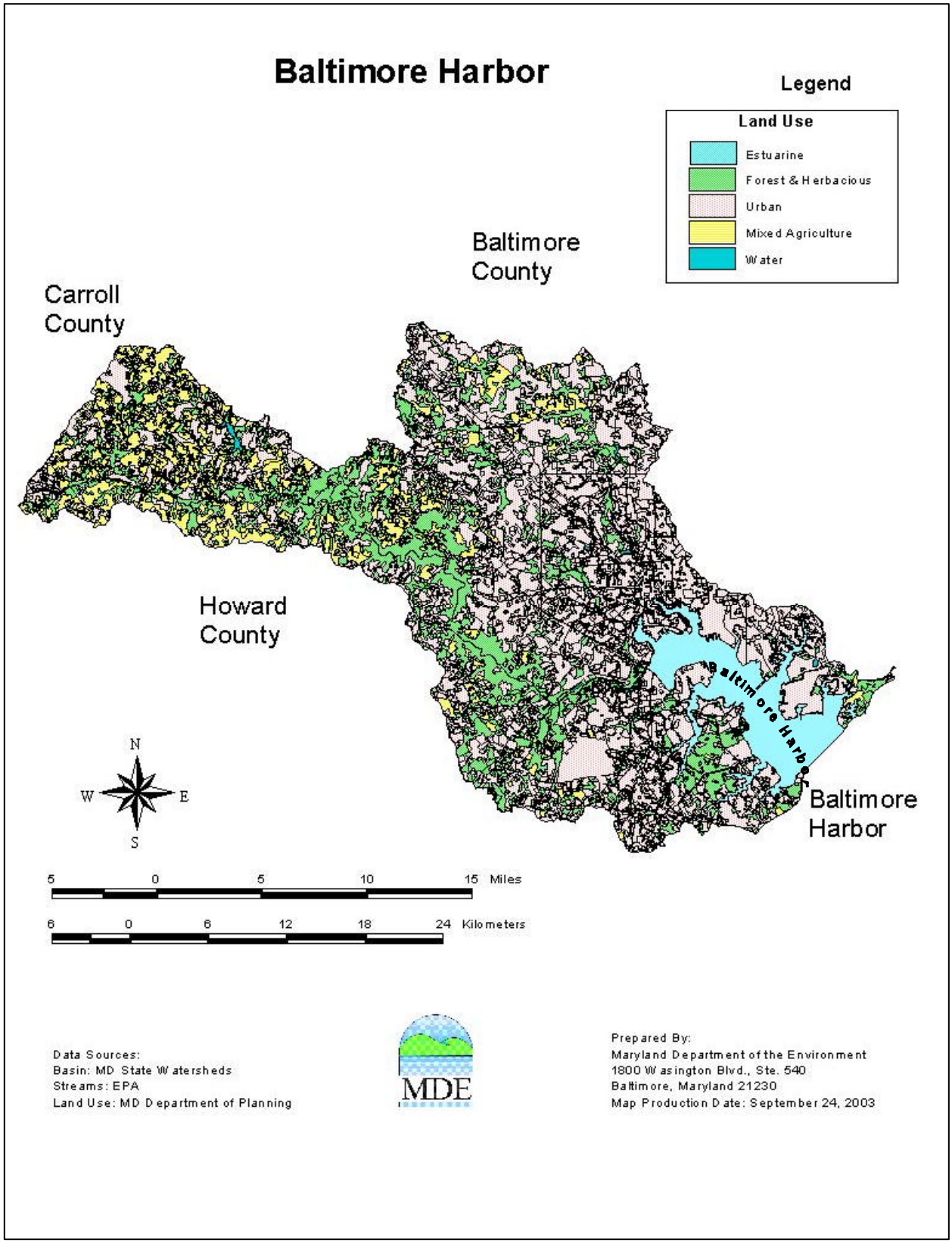


Figure 2: Predominant Land Uses in the Watershed Draining into Baltimore Harbor

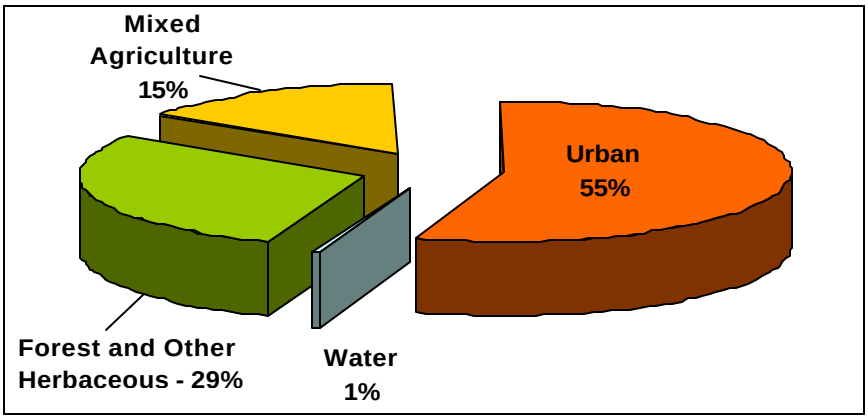


Figure 3: Proportions of Land Use in the Basins Draining into Baltimore Harbor

2.1.3 Geology

The watersheds draining into the Baltimore Harbor lie primarily within the Piedmont and, to a lesser extent, the Coastal Plain provinces of Central Maryland. The surficial geology is characterized by crystalline rocks of volcanic and sedimentary origin, consisting primarily of schist and gneiss. These formations are resistant to short-term erosion, and often determine the limits of stream bank and streambed. Crystalline formations decrease in elevation from northwest to southeast, eventually extending beneath the younger sediments of the Coastal Plain. The fall line represents the transition between the Atlantic Coastal Plain Province and the Piedmont Province. The Atlantic Coastal Plain surficial geology is characterized by thick, unconsolidated marine sediments deposited over the crystalline rock formations of the Piedmont Province (Coastal Environmental Services, 1995).

2.1.4 Nutrients Source Assessment

2.1.4.1 Point Sources: Municipal and Industrial Wastewater Treatment Plant Loads

The Patapsco Wastewater Treatment Plant (WWTP) and Cox Creek WWTP are municipal point sources that discharge directly into Baltimore Harbor. International Steel Group (ISG), Grace Davison, Erachem-Comilog, US Gypsum, and Millenium Specialty are the five industrial point sources that discharge directly into the Harbor. The combined estimated average annual loads from municipal WWTPs for 1992-1997 (the model calibration period) are 3,455,063 lbs/yr for total nitrogen (TN) and 216,099 lbs/yr for total phosphorus (TP). The combined estimated average annual loads from industrial WWTPs for 1992-1997 are 3,001,015 lbs/yr for TN and 89,376 lbs/yr for TP. Thus, the total average annual loads from all WWTPS are 6,456,078 lbs/yr for TN and 305,475 lbs/yr for TP. This information was obtained from discharge monitoring reports stored in MDE's point source database. The municipal average annual point source loads for 1992-1997 are presented in Table 3. The industrial average annual point source loads for 1992-1997 are shown in Table 4. Table 5 lists the average daily flows for all permitted point sources discharging into Baltimore Harbor during 1992-1997 in millions of gallons per day (mgd).

Table 3: Average Municipal WWTP Loads, 1992-1997

Year	TN	TP
	lbs/yr	lbs/yr
1992	2,762,146	207,976
1993	3,814,825	235,890
1994	5,132,577	220,309
1995	3,049,908	243,216
1996	3,059,893	221,403
1997	2,911,024	167,800
Average	3,455,063	216,099

Table 4: Average Industrial WWTP Loads, 1992-1997

Year	TN	TP
	lbs/yr	lbs/yr
1992	3,506,205	93,862
1993	2,846,814	88,115
1994	2,636,706	84,041
1995	2,697,273	85,333
1996	3,127,613	90,767
1997	3,191,478	94,140
Average	3,001,015	89,376

Table 5: Average Daily Flows for Permitted Point Sources Discharging into Baltimore Harbor during the 1992-1997 Model Calibration Period

Facility	Type	Average Flow (mgd)
Patapsco WWTP	Municipal	47.96
Cox Creek WWTP	Municipal	11.18
Erachem-Comilog	Industrial	0.089
Grace Davison	Industrial	2.38
US Gypsum-1	Industrial	0.001
US Gypsum-2	Industrial	0.000
ISG-1	Industrial	37.34
ISG-2	Industrial	5.66
ISG-3	Industrial	55.42
ISG-4	Industrial	3.60
ISG-5	Industrial	0.064
ISG-6	Industrial	3.94
ISG-7	Industrial	1.51
Millennium 001	Industrial	0.067
Millennium 002	Industrial	0.589

These flow and point source load estimates represent actual discharge into the Baltimore Harbor from municipal WWTPs and industrial plants from 1992-1997. It is important to note that these plants were not all discharging at their maximum flow capacities and/or nutrient permit limits during this period. For example, the Patapsco River and Cox Creek municipal WWTPs discharged an average of 3.5 million lbs/yr of TN and 0.22 million lbs/yr of TP during the 1992-1997 study period. If these plants discharged consistently at their maximum capacity flow, their loads could increase to 3.9 million lbs/yr of TN and 0.46 million lbs/yr of TP, assuming the TN concentration was the same as the actual 1992-1997 concentrations and the TP concentration equal to the current permit limit of TP = 2.0 mg/l for both plants. Similarly, industrial facilities loads could increase significantly if they discharged at maximum capacity for long periods of time.

2.1.4.2 Nonpoint Source Loads and Urban Stormwater Loads

Nonpoint source loads and urban stormwater loads entering the Baltimore Harbor were estimated using the Hydrologic Simulation Program-Fortran (HSPF). The HSPF model is used to estimate flows, suspended solids and nutrient loads from the watershed's sub-basins. Nonpoint source and urban stormwater loads are linked to a three-dimensional, time-variable hydrodynamic model and a water quality model coupled with a sediment process model designed specifically for Baltimore Harbor. The water quality model is used to determine the maximum load of nutrients that can enter the Harbor while maintaining the water quality criteria associated with its designated uses. The water quality modeling framework is shown in Section 4.2.

The Baltimore Harbor HSPF watershed model 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, like crop types and tilling practices, were estimated from MDP land use data, the 1997 Agricultural Census Data, and the Farm Service Agency (FSA) data. 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 growing season conditions. Details of the HSPF watershed model developed to estimate these urban and non-urban loads are found in the "Patapsco/Back River Watershed HSPF Model Report" (MDE, 2001).

Figure 4 presents the relative average annual amounts of nitrogen and phosphorus from nonpoint source, municipal and industrial point source, and urban stormwater delivered loadings to the Baltimore Harbor during the 1995-1997 period.

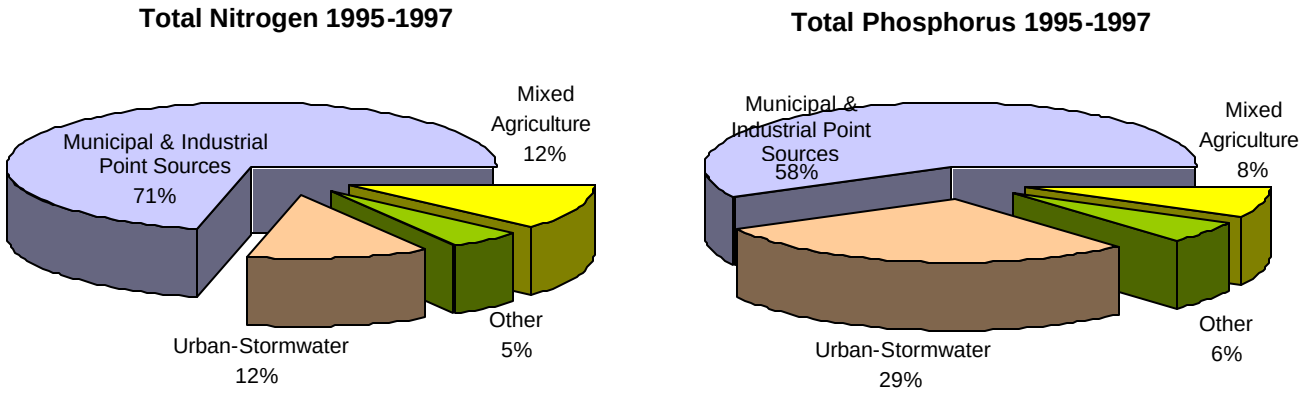


Figure 4: Percentages of Average Annual Nitrogen and Phosphorus Loads from Municipal and Industrial Point Sources, Urban Stormwater and NPS in Baltimore Harbor, 1995-1997

The calibration of the model was conducted for the 1992-1997 period. The TMDL analysis was conducted using the 1995-1997 period as a baseline, which includes dry, wet and average years. For these reasons, the delivered loads percentages in the figures represent an average for the 1995-1997 period.

In the Baltimore Harbor watershed, the estimated 1995-1997 average annual TN delivered load from nonpoint sources (NPS) is 1,364,400 lbs/yr, and the NPS TP delivered load is 37,465 lbs/yr. The estimated 1995-1997 average annual TN load for point sources, including regulated urban stormwater TN load, is 7,053,689 lbs/yr and the estimated 1995-1997 average annual point source TP load is 317,423 lbs/yr.

2.2 Water Quality Characterization

Eutrophication is the over-enrichment of aquatic systems by excessive inputs of nutrients (nitrogen and/or phosphorus). The nutrients act as a fertilizer leading to excessive growth of algae. The algae grow rapidly, die and are subsequently consumed by bacteria. The bacterial consumption of the algae results in the use of available dissolved oxygen in the water column, which produces hypoxic (low oxygen) or anoxic (no oxygen) conditions. Eutrophication has probably been more extensively studied in the Chesapeake Bay and its tributaries than in any other coastal ecosystem. Scientists have uncovered the relationships of how nutrients stimulate biological productivity in the Bay, and how eutrophication results in oxygen depletion, increased turbidity, loss of submersed vegetation, and alteration of food webs (Boesch *et al.*, 2001).

Portions of the Chesapeake Bay and its tributaries often show signs of eutrophication. The Baltimore Harbor has shown clear indications of eutrophication for several decades (Robertson, 1977; Magnien *et al.*, 1993; Boynton *et al.*, 1998). For example, extensive and persistent anoxic or hypoxic conditions were observed regularly in the bottom waters of the Baltimore Harbor.

The Chesapeake Bay Water Quality Monitoring Program has recorded measurements in the Baltimore Harbor indicating anoxic and hypoxic events occur as early as April and extend until October every year. Also, increased algal blooms have been found to occur yearly during the

warm season (Wang *et al.,* 2004). Anoxic conditions occur at the bottom of the navigation channel as well as in most tributaries, such as the Inner Harbor and the Middle Branch. Anoxic water exists in the mainstem of the Chesapeake Bay each summer. However, Wang *et al* (2004) and Liu (2002) hypothesize that the origin of low DO in the Harbor is not from the intrusion of anoxic Bay water, but rather is an internal process of the Harbor.

Wang *et al,*. (2004) indicate that the water circulation and exchange within the Baltimore Harbor region are generally regulated by local wind forces, which overwhelm the weak currents driven by river and tidal forces. Pritchard and Carpenter (1960) inferred the existence of a three-layered circulation in Baltimore Harbor based on salinity and dye distributions. This was confirmed by Boicourt and Olson (1982) with direct measurements. This unique hydrodynamic feature has to be taken into consideration because it can affect the dynamics of water quality parameters.

Data for the 1992-1997 period have been selected for the development of the eutrophication model and the subsequent nutrient TMDL analyses. There are 24 water quality stations located in the Baltimore Harbor that MDE and the Chesapeake Bay Program (CBP) surveyed during the model calibration period. The reader is referred to Figure 5 for the locations of the water quality sampling stations.

The CBP has sponsored a long-term water quality sampling station (WT5.1) in the Baltimore Harbor since 1984 to monitor its physical, chemical, and biological parameters. MDE also monitored the Baltimore Harbor intensively at the other 23 stations during the period March 1994 to May 1995 for parameters similar to those monitored by the CBP. A detailed list of all parameters measured in these surveys can be found in the report "The Development of a Water Quality Model for Baltimore Harbor, Back River and the Adjacent Upper Chesapeake Bay" (Wang *et al.,* 2004).

The time series data for dissolved oxygen (DO) and chlorophyll *a* (Chl *a*) at stations WT5.1 and M16 are presented in this report to provide a trend analysis of the two parameters associated with Maryland water quality standards. Additional time series and longitudinal data profiles from the MDE and CBP stations for various nutrient parameters are available upon request and through the MDE TMDL website as supporting documentation. The time series data files are too large to incorporate as appendices to this report.

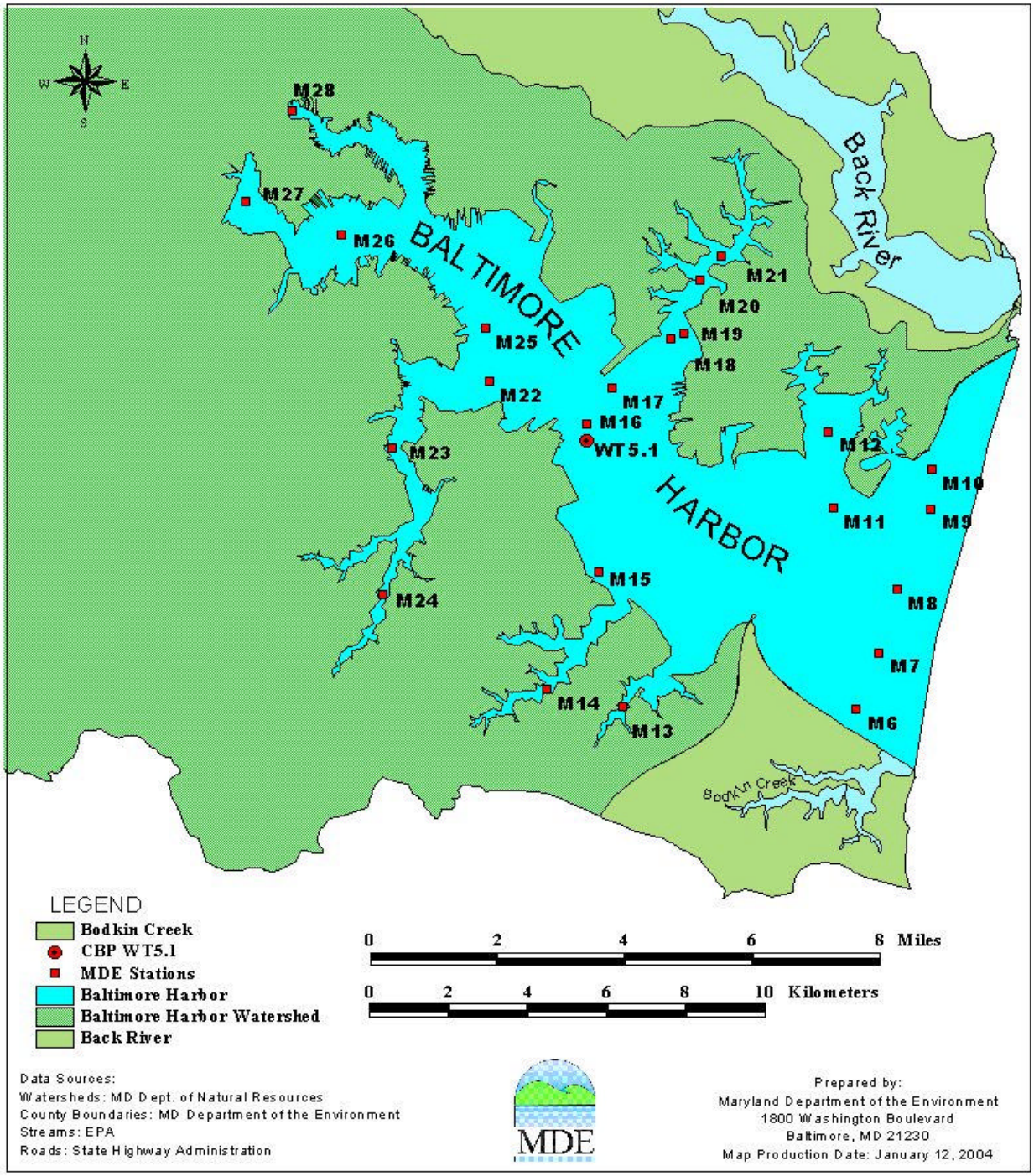


Figure 5: Location of Water Quality Stations in Baltimore Harbor

Figure 6 presents the time series of Chl *a* concentrations in the Baltimore Harbor from January 1992 to December 1997 for the CBP long-term monitoring station WT5.1 (MDE Station M16) located in the middle of the Harbor, approximately 8.8 km from the Harbor's mouth.

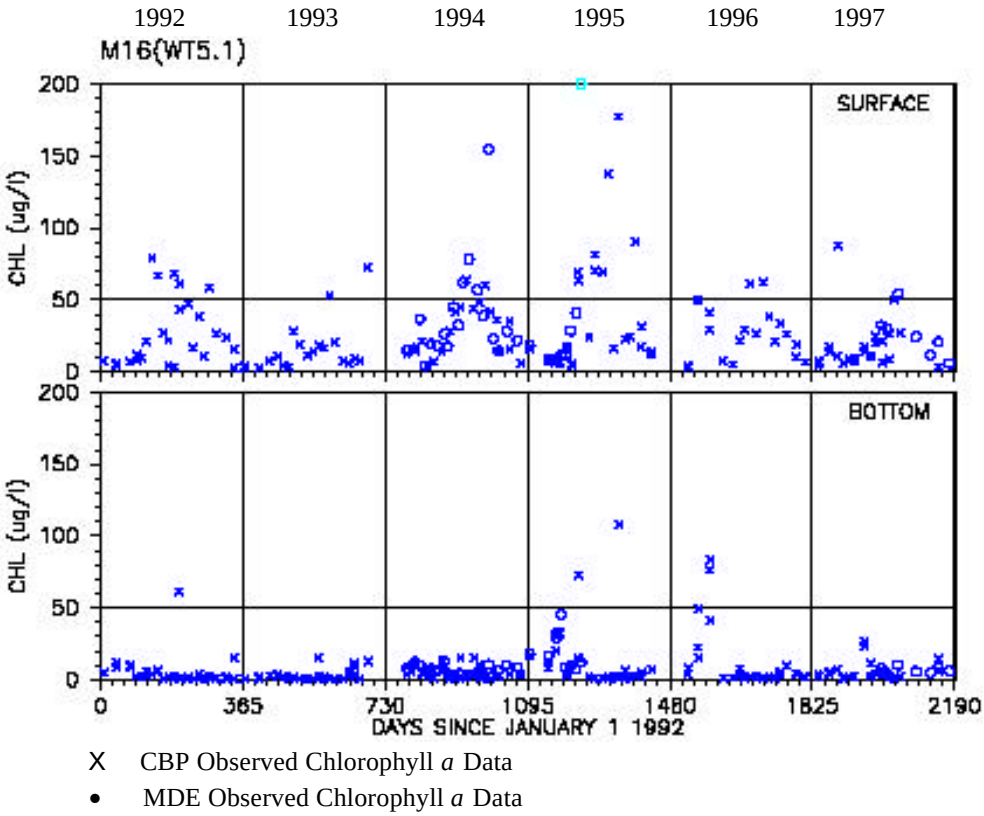
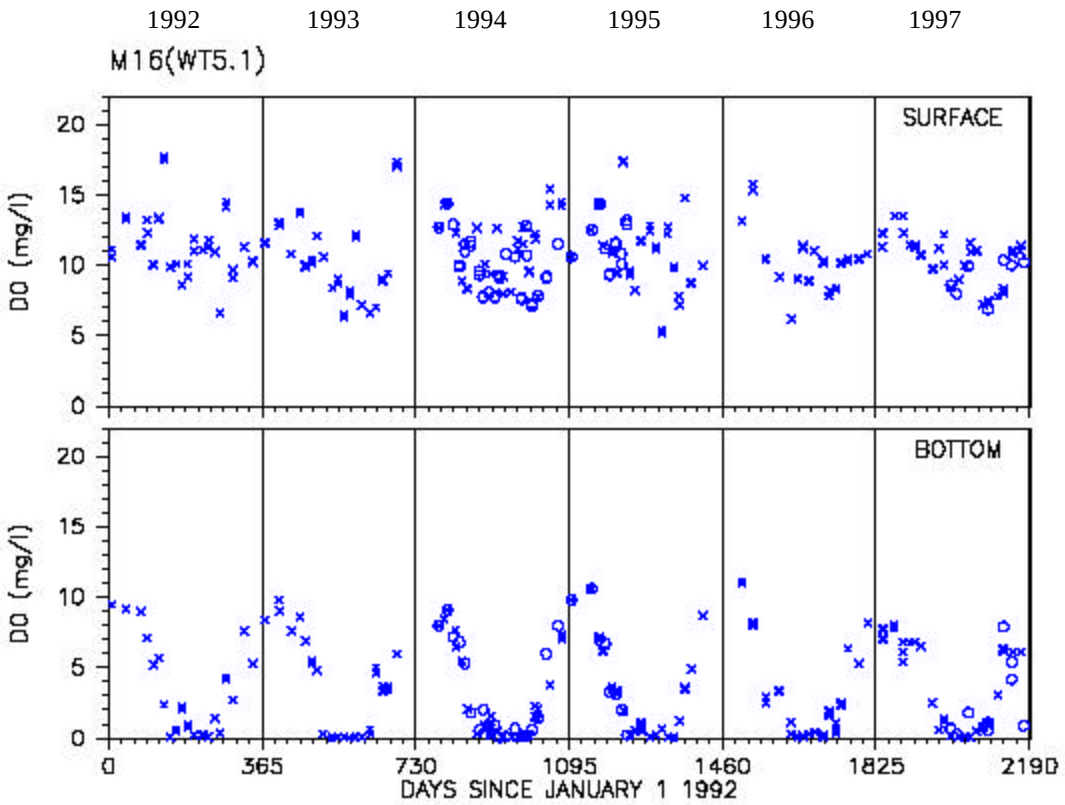


Figure 6: Time Series of Chlorophyll *a* Data at Baltimore Harbor Station WT5.1 / M16

As Figure 6 shows, surface Chl *a* concentrations include observations that are above 50 µg/l every year, with a seasonal pattern of higher values during warmer months and lower values during colder months. Concentrations rarely exceed 100 µg/l, except in the summers of 1994 and 1995 when maximum concentrations were close to 200 µg/l. Bottom Chl *a* is normally below 20 µg/l, except during the springs of 1995 and 1996 where concentrations reached 100 µg/l and 85 µg/l, respectively (probably weather-related, as several snowstorms may have resulted in unusual patterns of thermal stratification).

A time series for surface and bottom DO concentrations at station WT5.1 is depicted in Figure 7, showing that the observed surface DO levels did not fall below 5.0 mg/l. The surface DO ranged from 5.2 mg/l to 18.0 mg/l with average DO concentrations around 10 mg/l. There is some degree of seasonal variation with higher DO values during winter months and lower values during summer months, due to seasonal changes in temperature. The bottom water DO concentrations range from 0 mg/l to 11 mg/l and display a distinct seasonal pattern. Anoxic conditions can be observed at the bottom waters starting as early as April in some years and lasting until the end of summer every year. During early fall, DO levels start to increase rapidly, reaching the 5.0 mg/l level by November.



X CBP Observed DO Data

O MDE Observed DO Data

Figure 7: Time Series of DO Data at Baltimore Harbor Station WT 5.1 / M16

2.3 Water Quality Impairment

The Maryland Water Quality Standards Stream Segment Designation [Code of Maryland Regulations (COMAR) 26.08.02.08K(2)(b)] for the Patapsco River Mesohaline (PATMH) (not including Bodkin Creek) is Use II: Tidal Waters: Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting. Designated Uses present in the Baltimore Harbor Segment are: 1) Migratory Spawning and Nursery, 2) Shallow Water Submerged Aquatic Vegetation, 3) Open Water Fish and Shellfish, 4) Seasonal Deep Water Fish and Shellfish, and 5) Deep Channel. No areas in the Harbor are designated as Shellfish Harvest Use areas.

The designated uses described above and the associated criteria are the result of MDE's adoption of water quality standards developed by the Chesapeake Bay Program. MDE adopted the standards in the fall of 2005 and the Baltimore Harbor TMDL represents the second application of these standards to Maryland's estuarine waters.

2.3.1 Dissolved Oxygen Criteria

Table 6 presents descriptions of the numeric DO criteria for designated uses present in the Harbor. The DO level is based on specific numeric criteria for Use II waters set forth in the COMAR 26.08.02.03-3C(2)(8). However, due to data limitations MDE will follow EPA guidance and assess the DO attainment based on 30-day component of the Open Water Use designated use for the Migratory Fish Nursery and Spawning Use, and Seasonal Shallow Water Submerged Aquatic Vegetation designated uses. The Deep Water Use will also be assessed using a 30-day methodology, however the requisite concentration is different from the Open Water Use.

Table 6: Dissolved Oxygen Criteria and Time Periods for the Designated Use Subcategories

Designated Use II Subcategory	Period	Dissolved Oxygen Criteria
Seasonal Migratory Fish Spawning and Nursery	February 1 through May 31 inclusive	▪ Open Water criteria apply
Seasonal Shallow Water Submerged Aquatic Vegetation	April 1 through October 31 inclusive	▪ Open Water criteria apply
Open Water Fish and Shellfish	January 1 through December 31 inclusive	▪ 5.0 mg/l 30-day average
Seasonal Deep Water Fish and Shellfish	June 1 through September 30 inclusive	▪ 3.0 mg/l 30-day average*
Seasonal Deep Channel Refuge	June 1 through September 30 inclusive	▪ ≥ 1 mg/l instantaneous minimum

* Allows a restoration variance of up to 7% applied spatially or temporally in combination from June 1 through September 30

2.3.2 Chlorophyll *a* Criteria

The Chl *a* concentration goal used in this analysis are based on guidelines set forth by Thomann and Mueller (1987) and by the EPA Technical Guidance Manual for Developing Total Maximum Daily Loads, Book 2, Part 1 (1997). The Chl *a* narrative criterion (COMAR 26.08.02.03-3C(10) state: "Chlorophyll *a* - Concentrations of chlorophyll *a* in free-floating microscopic aquatic plants (algae) shall not exceed levels that result in ecologically undesirable consequences that would render tidal waters unsuitable for designated uses." The Thomann and Mueller guidelines acknowledge that "'Undesirable' levels of phytoplankton [Chl *a*] vary considerably depending on water body." MDE has determined, per Thomann and Mueller, that it is acceptable to maintain Chl *a* concentrations below a maximum of 100 µg/L, and to target, with some flexibility depending on waterbody characteristics, a 30-day rolling average of approximately 50 µg/L.

Consistent with the guidelines set forth above, MDE's interpretation of narrative criteria for Chl *a* in the Baltimore Harbor is comprised of the following water quality goals:

(1) Ensure that instantaneous concentrations remain below 100 µg/L at all times and
(2) Minimize exceedances of the 50 µg/L, 30-day rolling average, to a frequency that will not result in ecologically undesirable conditions.

The water quality impairment being addressed by this TMDL analysis consists of DO concentrations less than the numeric criteria presented in Section 2.3.1 and Chlorophyll *a* (Chl *a*) concentrations above the MDE interpretation of the narrative criteria presented in Section 2.3.2 (See Figures 6&7). The achievement of the DO and Chl *a* criteria is required for all the uses throughout the water column of the Baltimore Harbor system. In the Harbor, data are not sufficient to assess the 7-day average and instantaneous minimum DO criteria for attainment of the designated uses; thus, the calibrated model results are used to evaluate conditions.

3.0 TARGETED WATER QUALITY GOAL

The objective of the nutrient TMDLs established in this document is to ensure that DO and Chl *a* concentrations in the Baltimore Harbor meet the criteria associated with specific designated uses. Specifically, the TMDLs for nitrogen and phosphorus are intended to control excessive algal growth and increase DO concentrations in areas not currently meeting water quality criteria.

4.0 TOTAL MAXIMUM DAILY LOADS DEVELOPMENT AND ALLOCATION

4.1 Overview

The following sections describe the modeling frameworks for simulating nutrient loads, hydrology, and water quality responses. Section 4.2 summarizes the TMDL analysis framework and model calibration. Section 4.3 describes the scenarios and results that were generated using the modeling framework. Sections 4.4–4.5 describe how the nutrient TMDLs and load allocations for point sources and nonpoint sources were developed for the Baltimore Harbor. Section 4.6 explains the rationale for the margin of safety and the last section summarizes the TMDLs for the growing season and average annual conditions.

4.2 Analysis Framework

4.2.1 Computer Modeling Framework

To develop a TMDL, a linkage must be defined between the selected water quality targets or goals and the identified pollutant sources. This linkage establishes the cause-and-effect relationship between the sources of the pollutant of concern and the water quality response of the impaired water quality segment to that pollutant. For nonpoint sources, the relationship can vary seasonally due to factors such as precipitation. Once defined, the linkage yields the estimate of total loading capacity or TMDL (EPA, 1999).

MDE chose a set of time-variable models as the analysis tool to link the sources of nutrient loadings to the DO criteria and chlorophyll *a* goal. The computational framework chosen for the

Baltimore Harbor nutrients TMDLs is the three-dimensional, time-variable Baltimore Harbor Eutrophication Model (BHEM). This water quality simulation package provides a generalized framework for modeling nutrient fate and transport in surface waters (Cerco and Cole, 1995). The BHEM package includes a watershed model, a hydrodynamic model, a water quality model and a sediment flux sub-model, and represents twenty-two water quality parameters from the water column and sediment bed. For detailed information, please refer to the report "The Development of a Water Quality Model for Baltimore Harbor, Back River and the Adjacent Upper Chesapeake Bay" (Wang *et al.*, 2004).

Since many studies have shown the significant influence of the Chesapeake Bay on its tributaries, the spatial domain of the BHEM extends longitudinally from the mouth of the Susquehanna River about 90 miles seaward (south) to the mouth of the Patuxent River, which is defined as the upper Chesapeake Bay. Baltimore Harbor is located on the western shoreline of the upper Chesapeake Bay. This modeling domain is represented by BHEM model segments. A diagram of the model segmentation is presented in Wang *et al* (2004).

The water quality model, Corps of Engineers Water Quality Compartment Model (CE-QUAL-ICM), is externally coupled with the three-dimensional, time-variable hydrodynamic model, Curvilinear Hydrodynamic in Three Dimensions, (CH3D). As its name indicates, CH3D makes hydrodynamic computations on a curvilinear or boundary-fitted platform grid that allows the model to accurately represent the deep navigation channel and irregular shoreline. The CH3D simulates physical processes such as tides, wind, density effects (salinity and temperature), freshwater inflows, turbulence, and the effect of the earth's rotation. The model outputs are used to drive the water quality model (Johnson *et al.*, 1991).

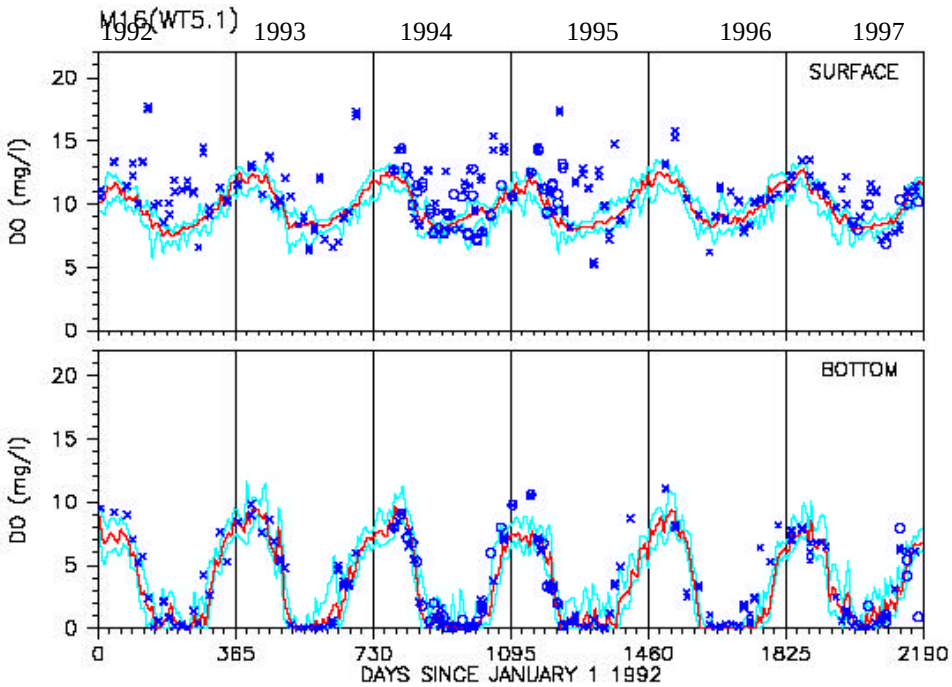
The sediment flux model developed by DiToro and Fitzpatrick (1993), and coupled with CE-QUAL-ICM for Chesapeake Bay water quality modeling efforts, is used in the present model application. The state variables, resulting fluxes, and complete model documentation can be found in Wang *et al* (2004), and also in DiToro and Fitzpatrick (1993).

The stormwater load and nonpoint source loading estimation was conducted using a HSPF watershed model, which simulates the fate and transport of pollutants over the entire hydrologic cycle. Details of this effort are described in Section 2.1.4.2. For detailed information, see "Patapsco/Back River Watershed HSPF Model Report" (MDE, 2001).

The BHEM package described above was calibrated to reproduce observed water quality characteristics for 1992-1997 conditions. The calibration of the model for these six years establishes an analytical tool that may be used to assess a range of scenarios with differing flow and nutrient loading conditions. For a detailed explanation of the calibration of the watershed model, hydrodynamic model, water quality model and sediment flux model please refer to MDE, 2001 and Wang *et al.*, (2004).

4.2.1.1 Eutrophication Model Calibration

The calibration and verification of the BHEM modeling package was reviewed and accepted by various modeling technical groups, *i.e.*, Chesapeake Bay Program Modeling Subcommittee and Baltimore Harbor Stakeholder Advisory Group. The calibration of the eutrophication model is the process of modifying the model input parameters until the model output matches the set of observed water column data in an optimal way. Observed water quality, hydrological, and loading data collected during the period 1992-1997 were used to calibrate the BHEM. Figures 8 and 9 show the results of the model calibration for chlorophyll *a* and DO at station WT5.1 in both surface and bottom water. Additional time series and longitudinal data profiles from the MDE and CBP stations for various nutrient parameters may be found in Wang *et al* (2004) and are also available upon request and through the MDE TMDL website as supporting documentation. The time series data files are too large to incorporate as appendices to this report.



X CBP Observed DO Data
O MDE Observed DO Data
Model Calibration results: Weekly Minimum and Maximum DO
Model Calibration results: Weekly Average DO

Figure 8: Time Series of Model Calibration Results of DO in Harbor Station WT5.1

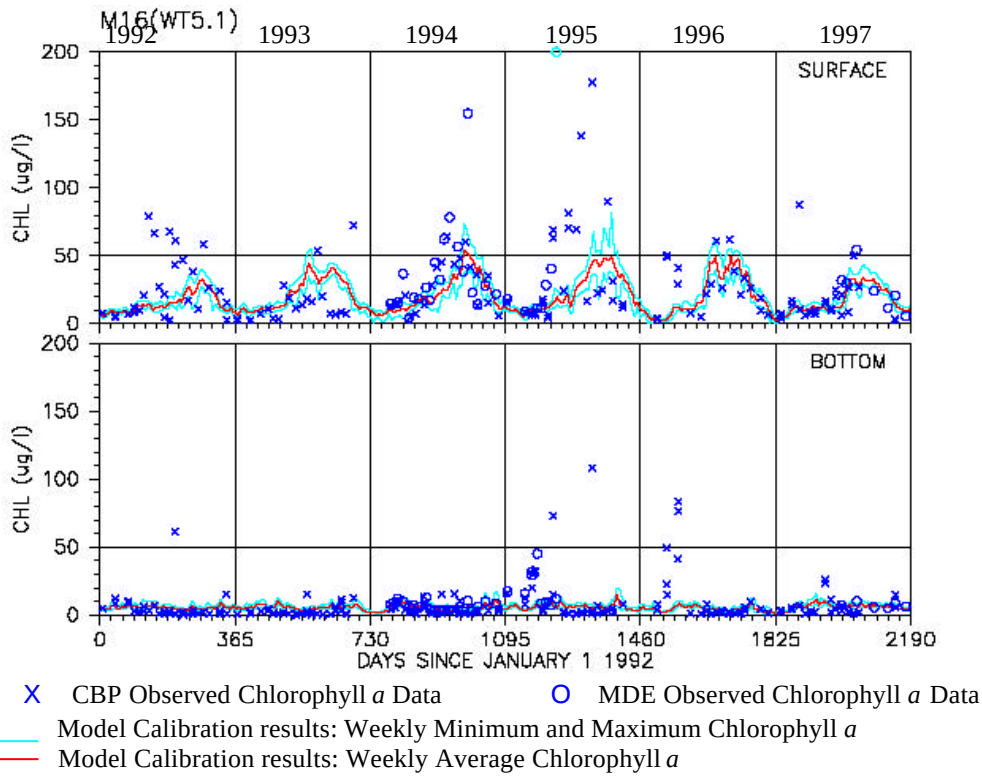


Figure 9: Time Series of Model Calibration Results of Chl *a* in Harbor Station WT5.1

4.2.2 TMDL Analysis Frame work

The nutrient TMDL analysis consists of two broad elements: an assessment of growing season loading conditions and an assessment of average annual loading conditions. Both the growing season and the average annual flow TMDL analyses investigate the critical conditions under which symptoms of eutrophication are typically most acute. During excessively dry or wet years the flux in loadings impact water quality significantly. Additionally, water quality is impacted during late summer when flows are low, the system is poorly flushed, and sunlight and temperatures are most conducive to excessive algal production. The TMDL analysis allows a comparison of current loading conditions to future conditions that project the water quality response to various simulated load reductions of the impairing substances.

4.2.2.1 Dissolved Oxygen Analytical Framework

In April 2003, the CBP published its approach to assessing the attainment of water quality criteria designed to protect the living resources of the Chesapeake Bay and its tidal tributaries, as defined by their respective designated uses. In 2005, MDE adopted the CBP DO criteria and its associated attainment methodology, utilizing DO biological reference curves to represent the spatial and temporal distribution of DO concentrations. MDE is applying this methodology using Cumulative Frequency Distributions (CFDs) for the Baltimore Harbor generated from model output, and compared against the CBP reference curves, to assess spatial and temporal DO criteria exceedances. This method quantifies the degree of criteria attainment or exceedence by incorporating the percent of area or volume of a region that meets or exceeds the DO criterion for

the specific designated uses periods. Using CFDs generated from the model data, the calibrated and verified assessment results express exceedances above the reference curve (violations of the allowable criteria limit) as percentages of the total time-volume for the area. These percentages are then used to determine whether a load reduction (TMDL) is required to meet the designated use.

The CFDs are derived from empirical, biology-based field data wherever possible. The DO criteria are intended have several duration curves that reflect *in situ* conditions: 30-day mean, 7-day mean, 1-day mean and the instantaneous minimum. However, given the limitations in directly monitoring at the temporal scales required for assessing attainment of the instantaneous minimum, 1-day mean and 7-day mean criteria, EPA indicates that the states can waive attainment assessments for these criteria until monitoring at the required temporal scales is implemented or apply statistical methods to estimate probable attainment (EPA, April 2003). For these reasons, MDE will assess the DO attainment for only the 30-day component of the Open Water Use and Deep Water Use DO criteria in the Baltimore Harbor. For the Migratory Fish Nursery and Spawning Use, EPA indicates that until more data are collected to better assess the attainment of the 7-day mean and instantaneous minimum criteria of this designated use, the Open Water DO reference curve should be applied. For the Migratory Fish Nursery and Spawning Use attainment analysis, MDE utilized the Open Water DO reference curve and model output associated with the Migratory Fish Nursery and Spawning Use period. Figure 10 below is an example of the CBP DO reference curve adopted by MDE. (For more information on monitoring, assessment of DO criteria attainment, and CBP DO reference curves, please refer to the CBP document entitled "Ambient Water Quality Criteria for the Dissolved Oxygen, Water Clarity and Chlorophyll *a* for the Chesapeake Bay and its Tidal Tributaries" (EPA, 2003).

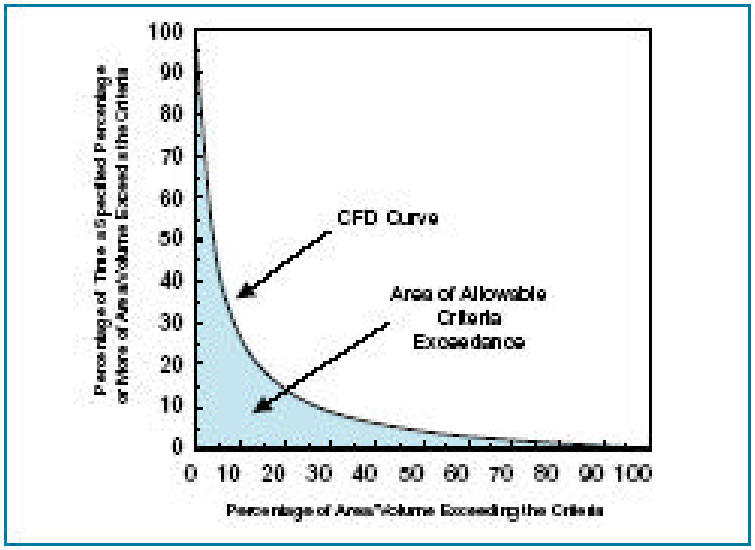


Figure 10: Cumulative Frequency Distribution curve representing an approximately 10 percent allowable exceedance equally distributed between time and space (EPA, 2003)

Additionally, the Deep Channel Designated Use area does not have a reference curve. The Deep Channel is defined as the region below the lower boundary of the pycnocline, extending down to the water/sediment interface. The Deep Channel Designated Use is applied from June 1st to

September 30th and requires an instantaneous minimum concentration of 1.0 mg/l. Two factors have prevented the development and application of a "reference curve" approach as used in the other segments of the water column. First, the Deep Channel portion of the Chesapeake Bay has not been monitored as part of the long-term benthic monitoring program and therefore lacks appropriate data for development of a reference curve. Second, the Deep Channel segment of the Chesapeake Bay is considered severely degraded and appropriate reference sites with similar characteristics and non-degraded conditions are not available.

Due to the unavailability of a reference curve to assess attainment, MDE has conducted an analysis to determine the percentage of time when the modeled DO concentration in the Deep Channel was below the 1.0 mg/l instantaneous minimum concentration required by the criteria. The assessment consisted of an evaluation of the modeled scenario DO concentrations versus the instantaneous minimum concentration.

4.2.2.2 Chlorophyll *a* Analytical Framework

Model results were compared to the quantitative implementation of the narrative Chl *a* criteria stated in Section 3.0 as: (1) ensuring that instantaneous concentrations remain below 100 µg/l at all times and (2) minimizing exceedances of the 50 µg/l, 30-day rolling average, to a frequency that will not result in ecologically undesirable conditions.

4.3 Scenario Descriptions and Results

The scenarios are grouped according to *baseline conditions, future conditions,* and a m*aximum anthropogenic reduction from Baltimore Harbor scenario.* The baseline condition is intended to provide a point of reference by which to compare future scenarios that simulate conditions of a TMDL. The future conditions scenario is associated with TMDLs, while the maximum anthropogenic reduction from Baltimore Harbor scenario is used as a bounding exercise to determine if it is possible to achieve water quality standards in the Deep Channel portion of the Harbor. The baseline and future conditions scenarios were used to estimate growing season and average annual TMDLs. The period 1995-1997 corresponds to the "baseline" period in analyses described below. The following analyses allow a comparison between current water quality conditions and future conditions that project various simulated load reductions of impairing substances.

4.3.1 Baseline Conditions Scenario

The baseline conditions scenario represents the observed conditions of the Harbor and its tributaries from 1995-1997. Simulating the system for three years accounts for various loading and hydrologic conditions, which represent possible critical conditions and seasonal variations of the system. For example, the 1995-1997 period includes an average year (1995), a wet year (1996) and a dry year (1997). The modeling approach also specifically examines conditions during summer months when the river system is poorly flushed, and sunlight and warm water temperatures are more conducive to creating the water quality problems associated with excessive nutrient enrichment.

The nonpoint nutrient loads, including urban stormwater loads, were estimated from the HSPF model of the Patapsco and Back River watersheds. The HSPF model utilized land use information and hydrology associated with the 1995-1997 period to generate loading estimates for this scenario. The HSPF model simulates stormwater and nonpoint loadings by integrating all natural and human-induced sources, including direct atmospheric deposition and loads from septic tanks. For point source loads, this scenario uses the municipal WWTP and industrial discharge monitoring data from 1995-1997. Additionally, time series and longitudinal data profiles from the MDE and CBP stations for various nutrient parameters are available upon request and through the MDE TMDL website as supporting documentation. The time series data files are too large to incorporate as appendices to this report.

4.3.2 Baseline Conditions Scenario Results

Results of DO and Chl *a* concentrations represented in the baseline scenario are summarized in Figures 11 and 12. Figure 11 displays the observed and modeled DO data while Figure 12 displays the observed and modeled Chl *a* concentrations at station WT5.1 in both surface and bottom water.

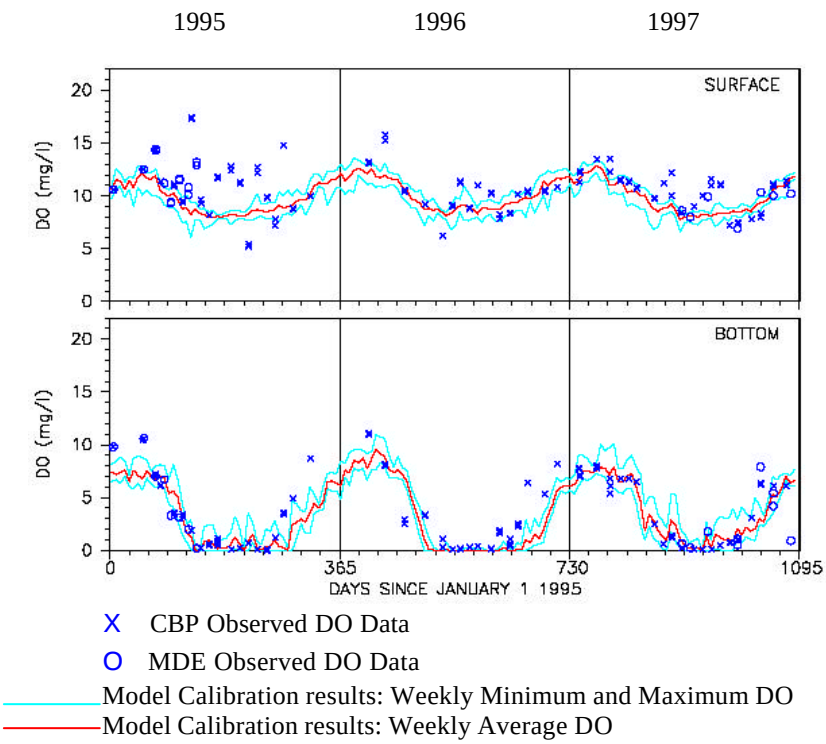
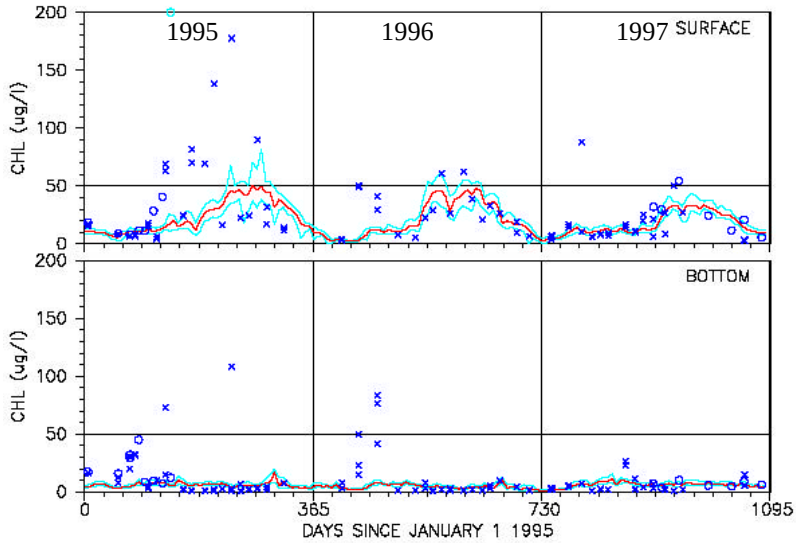


Figure 11: Time Series of Model Results for the Baseline Conditions Scenario for DO in Baltimore Harbor Station WT5.1



X CBP Chlorophyll *a* Observed data
O MDE Chlorophyll *a* Observed data
Model Calibration results: Minimum and Maximum Chlorophyll *a*
Model Calibration results: 30-day Rolling Average Chlorophyll *a*

Figure 12: Model Results for the Baseline Conditions Scenario for Chl *a* in Baltimore Harbor Station WT5.1

4.3.2.1 Dissolved Oxygen Assessment of the Baseline Conditions Scenario

For the DO assessment of the baseline conditions scenario in the Baltimore Harbor, the CBP reference curve approach for the Migratory Fish and Spawning, Open Water and Deep Water Designated Uses was used. Due to limited data in the Baltimore Harbor, the calibrated model output generated during the baseline conditions scenario was used for the attainment analysis. The attainment assessment procedure is as follows: First, using the calibrated model DO output for the baseline conditions scenario period (1995-1997), DO attainment curves are developed for the Migratory Fish and Spawning, Open Water and Deep Water Designated Uses. Second, the reference curves from the CBP are obtained. Third, MDE generated attainment curves for each of the designated use areas are compared to the corresponding CBP reference curves. The results of the comparison allow MDE to quantify the degree of criteria attainment or exceedance based on the amount of area or volume of a specific designated use region.

A summary of the attainment assessment is presented in Table 7. The baseline scenario assessment of the DO criteria attainment for the Migratory Fish Spawning and Nursery Designated Use, which applies from February 1st to May 31st, indicates that there is a period of nonattainment in time and volume that represents a 3% exceedance of the criteria (See Appendix A, Figure A4). The assessment of DO criteria attainment for the Open Water Designated Use, which applies from June 1st to September 30th indicates that there is a period of nonattainment in time and volume that represents a 3% exceedance of the criteria (See Appendix A, Figure A5). The assessment of DO criteria attainment for the Open Water Designated Use, which also applies

from October 1st to January 31st, indicates that there is a period of nonattainment in time and volume that represents a 2% exceedance of the criteria (See Appendix A, Figure A6). The assessment of the DO criteria attainment for the Deep Water Designated Use, which applies from June 1st to September 30th, indicates that there is a period of nonattainment in time and volume that represents a 23% exceedance of the criteria (See Appendix A, Figure A7).

MDE conducted an analysis of the baseline scenario to determine the percentage of time when the modeled DO concentration in the Deep Channel was below the 1.0 mg/l instantaneous minimum concentration required by the criteria. The assessment consisted of an evaluation of the modeled baseline scenario DO concentrations versus the instantaneous minimum concentration. The result of this assessment indicates that the Deep Channel exceeded the criteria 87% of the time and volume.

The Deep Channel segment of the Baltimore Harbor is considered degraded due to two related factors. The first is the dredging that occurs in the channel, allowing for the passage of ships in and out of the commercial port areas within the Harbor. The dredging has resulted in modifications of the Harbor hydrodynamic circulation patterns that effectively separate the Deep Channel portion of the water column from the remaining water column during the late spring through fall seasons. This occurs due to temperature and salinity barriers that do not allow mixing of surface waters with deep channel waters. Second, maintenance dredging and propeller wash from ship movements result in the periodic disturbance and/or removal of any biological communities that may be established during the interval between dredging events.

Table 7: Baseline Conditions Scenario: Percent Nonattainment of Dissolved Oxygen Criteria in the Baltimore Harbor

Period	Designated Use	% Nonattainment
February 1st to May 31st	Migratory Fish Spawning and Nursery	3%
June 1st to September 30th	Open Water	3%
	Deep Water	23%
	Deep Channel	87%
October 1st to January 31st	Open Water	2%
February 1st to January 31st	Open Water	0%

4.3.2.2 Chlorophyll *a* Assessment for the Baseline Conditions Scenario

The Chl *a* levels in the baseline conditions scenario output were analyzed using a 30-day rolling average as referenced in Section 2.3. The analysis shows that in both surface and bottom water, Chl *a* concentrations exceeded 50 µg/l during early spring and the summer months of 1995 (see Figure 12) and occasionally were observed to exceed 100 µg/l. Chl *a* rarely exceeded 50 µg/l during 1996 and 1997.

4.3.3 Maximum Anthropogenic Reduction from Baltimore Harbor Scenario

Based on the exceedances of the water quality criteria associated with the baseline scenario, particularly in the Deep Channel Designated Use, MDE conducted a scenario run to determine whether the act of removing anthropogenic nutrient sources, both point and nonpoint, would result in the attainment of water quality standards within the Deep Channel Designated Use region of the Baltimore Harbor. This scenario provides an estimate of the water quality response if the maximum amount of anthropogenic nutrient loading reductions were made in the Baltimore Harbor watershed. To conduct this analysis, the water quality model was run with nutrient loads from point and nonpoint sources reduced to zero. The sediment model was allowed to continue running from the initial condition set by the calibration, and the upper Bay loading conditions were based on the calibration period. With all sources of nutrients removed the model was allowed to run for six years to determine the impact on water quality.

4.3.4 Maximum Anthropogenic Reduction Scenario Results

Modeled results for the maximum anthropogenic reduction scenario of DO levels in the surface and bottom waters at station WT5.1 are summarized in Figure 13. Under this scenario, the attainment assessment results indicate that DO concentration will be < 1.0 mg/l in the Deep Channel for approximately 57.8% of the time and volume that Deep Channel criteria are in effect. Therefore, the Deep Channel criteria are not achieved in this scenario.

The results of this model scenario predict that with the removal of anthropogenic point and nonpoint sources of nutrients, the Baltimore Harbor will not fully meet the Deep Channel Designated Use water quality standard although all other standards will be met. The constant manipulation and sequential deepening of the channel over time has created a system in which the water in the Harbor channel is effectively sealed off from mixing action during the summer months due to the hydrodynamic circulation pattern. As a result, oxygen is not transferred from the upper portions of the water column into the Baltimore Harbor channel. Consequently, the oxygen that is present in the channel during the winter and spring seasons is being consumed but not replaced during the summer months. The maximum anthropogenic reduction from Baltimore Harbor scenario indicates that the hydrodynamics of the Harbor system create conditions whereby the Harbor channel becomes anoxic for periods during the summer.

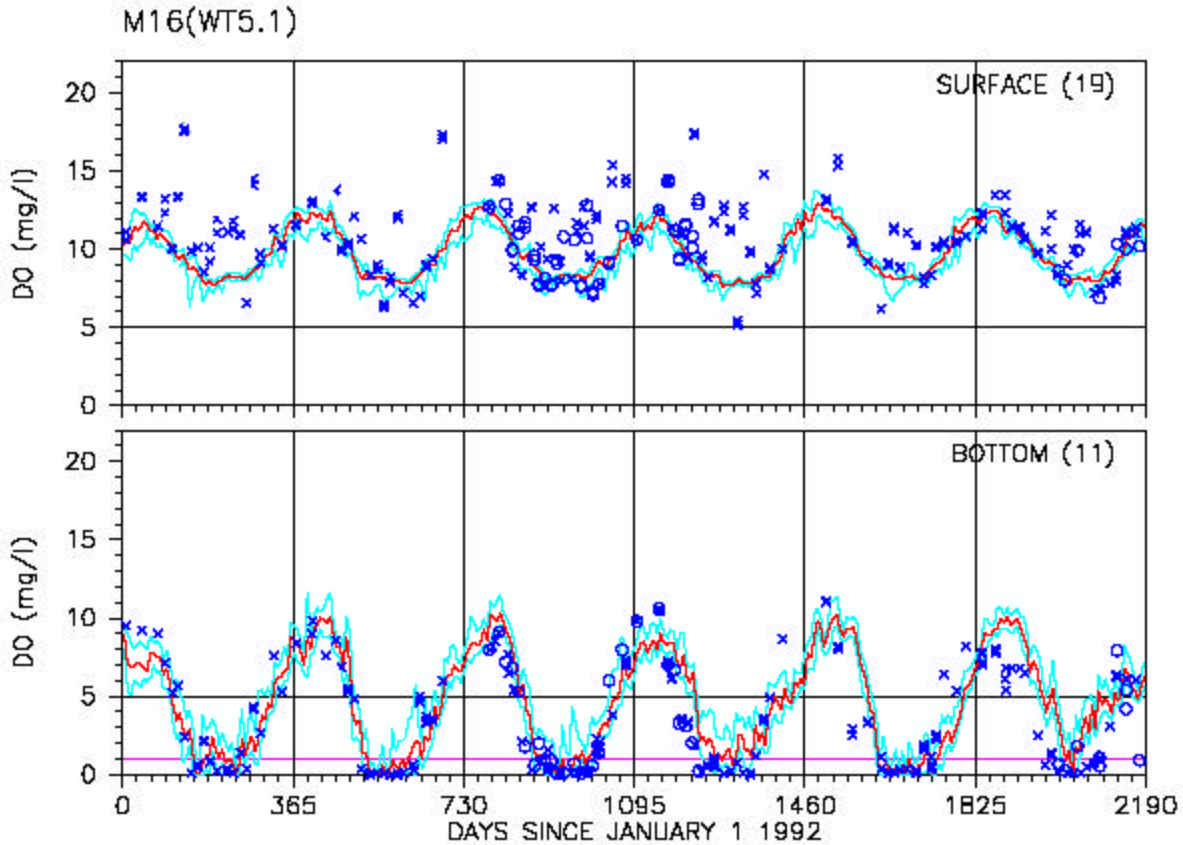


Figure 13: Maximum Anthropogenic Reduction Scenario model results for DO levels in surface and bottom waters in Baltimore Harbor at Station WT5.1

4.3.5 Future Conditions (TMDL) Scenario

This scenario provides an estimate of future conditions in the Baltimore Harbor system based on a simulation with 1) WWTP discharges set at design flow and nitrogen and phosphorus concentrations based on Maryland's Enhanced Nutrient Reduction (ENR) strategy, 2) industrial discharges based on permitted flow and concentrations of nitrogen and phosphorus reduced based on estimates of loading reductions due to technological improvements, and 3) urban stormwater and agricultural loads for all subwatersheds draining into the Baltimore Harbor reduced by 15%. Based on the results of the Maximum Anthropogenic Reduction Scenario, which indicated the Deep Channel Designated Use would not achieve water quality standards at all times with the removal of all anthropogenic nutrient sources, MDE developed this scenario to represent the current limit of technology for municipal WWTPs, and an aggressive nutrient reduction goal for industrial point sources and nonpoint sources. This scenario was used to estimate both growing season and average annual flow TMDLs.

The point source loads from the Patapsco and Cox Creek WWTPs were based on National Pollutant Discharge Elimination System (NPDES) permit flows and ENR-based concentrations of TN equal to 4 mg/l annual average (3 mg/l in May–October and 5 mg/l in November–April) and TP of 0.3 mg/l. These levels are consistent with Maryland's Tributary Strategy and ENR Policy.

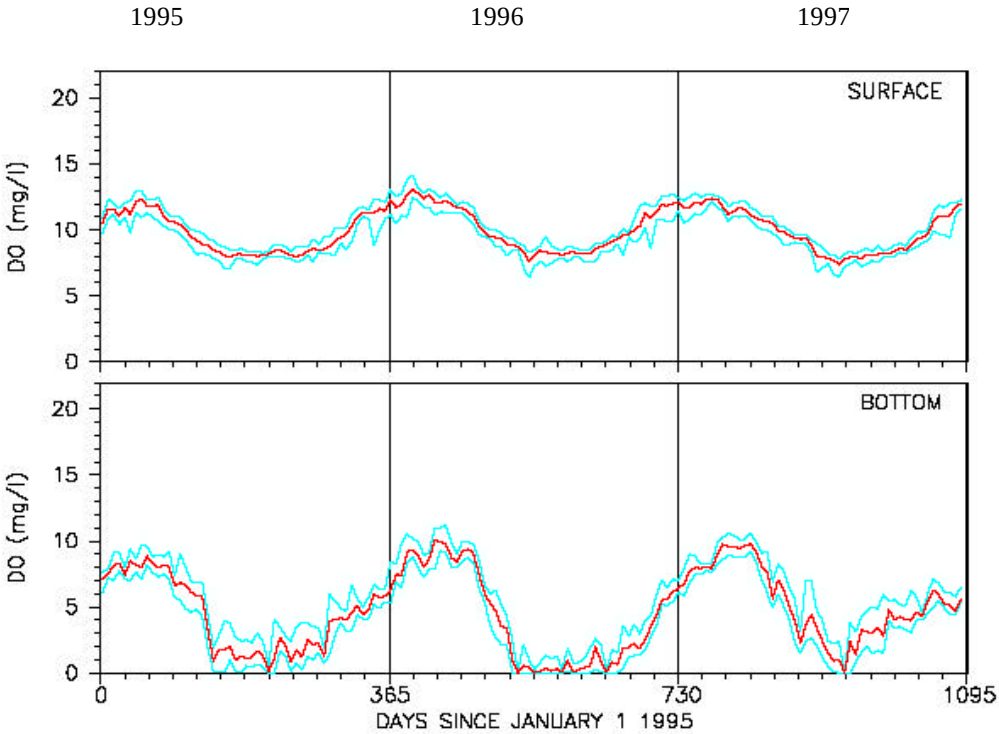
Industrial point source flows and concentrations vary for the different facilities, and their effluent loadings were based on recent performance levels, after having already achieved significant loading reductions since the initial baselines established in 1985. Their recent performance levels were then adjusted based on additional potential loading reductions.

Urban stormwater and agricultural TN and TP loads for this scenario were reduced by 15% from their baseline loads in order to reach the water quality goals for Chesapeake Bay waters. The baseline urban stormwater and agricultural loads are estimated by the HSPF watershed model as described in "Patapsco/Back River Watershed HSPF Model Report" (MDE, 2001). The loading reductions are based on the implementation of urban and agricultural Best Management Practices (BMPs) that are used to reduce pollution from these land uses. The load reduction was quantified based on nutrient removal efficiency ratings that have been developed for various BMPs. This approach is based on the assumptions made by the CBP in its Chesapeake Bay watershed modeling effort and is consistent with the method used to develop Maryland's Tributary Strategies.

The Harbor watershed land uses are comprised of approximately 55% urban, 15% agricultural, and 29% forest. An assessment of the urban and agricultural land use components indicate that the baseline load for urban land use is approximately 43% of the average annual TN load, 75% of the average annual TP load, 49% of the growing season TN load, and 78% of the growing season TP load from watershed land uses. Similarly, the baseline load for agricultural landuse is approximately 33% of the average annual TN load, 12% of the average annual TP load, 24% of the growing season TN load, and 11% of the growing season TP load from watershed land uses. Other non-urban stormwater and non-agricultural nutrient loads, including forest loads, represent the remaining contribution to the total load.

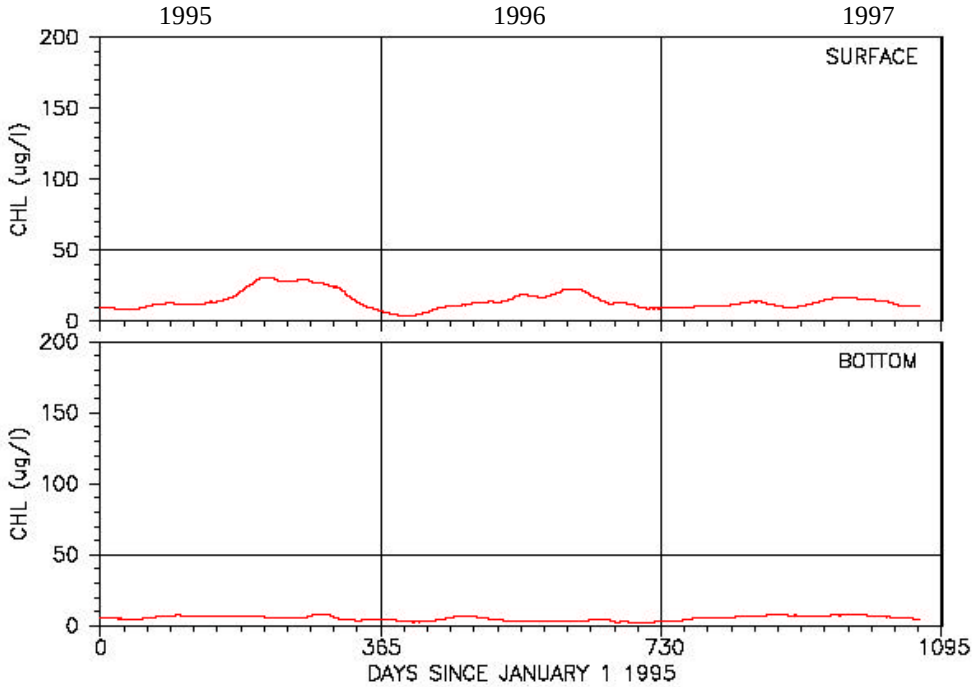
4.3.6 Future Conditions (TMDL) Scenario Results

DO and Chl *a* time series results for water quality station WT5.1 for surface and bottom waters for the TMDL scenario are summarized in Figures 14 and 15. As displayed in Figure 14, under the TMDL scenario, the minimum DO concentrations at water quality station WT5.1 are above 6.5 mg/l in the surface water. However, the bottom water DO decreases to below 1 mg/l and approaches 0 mg/l during the summer months. It can be observed that the anoxic condition starts later and ends earlier than in the baseline scenario. As displayed in Figure 15, under the TMDL scenario, Chl *a* concentrations at Water Quality Station WT5.1 remain below 50 µg/l in both the surface and bottom waters. Additional time series and longitudinal data profiles from the MDE and CBP stations for various nutrient parameters are available upon request and through the MDE TMDL website as supporting documentation. The time series data files are too large to incorporate as appendices to this report.



TMDL Scenario results: Minimum and Maximum DO
TMDL Scenario results: Weekly Average DO

Figure 14: Time Series of Model Results for the TMDL Scenario for DO at Station WT5.1



TMDL Scenario results: Moving 30-day Average Chlorophyll *a*

Figure 15: Time Series of Model Results for the TMDL Scenario for Chl *a* at Station WT5.1

4.3.6.1 Dissolved Oxygen Criteria Attainment Assessment of the Future Conditions (TMDL) Scenario

The DO attainment assessment of the TMDL scenario in the Baltimore Harbor was performed as explained in the baseline conditions scenario assessment (Section 4.3.2.1). The attainment and reference curve assessments generated for the Migratory Fish Spawning and Nursery, Open Water, and Deep Water Designated Uses are provided in Appendix B. The following is a summary of the attainment assessment analysis.

The TMDL scenario assessment of the DO criteria attainment for the Migratory Fish Spawning and Nursery Designated Use, which applies from February 1st to May 31st indicates that the attainment curve is always below the reference curve and that the designated use is met 100% of the time (See Appendix B, Figure B1). The assessment of the DO criteria attainment for the Open Water Designated Use, which applies from June 1st to September 30th and from October 1st to January 31st, indicates that there is a period of nonattainment; however, this period is not significant enough in time or volume affected to cause an exceedance of the criteria, therefore the designated use is being met (See Appendix B, Figures B2 and B3). The assessment of the DO criteria attainment for the Deep Water Designated Use, which applies from June 1st to September 30th, indicates that there is a period of nonattainment in time and volume that represents a 7% exceedance of the criteria (See Appendix B, Figure B4). The Deep Water DO criteria allows a restoration variance of up to 7% applied spatially and/or temporally from June 1 to September 30 (COMAR 26.08.02.03-3 C(8)(e)(vi)); therefore, the assessment of the DO criteria indicates that the designated use is attained. During the remaining months of the year, these areas are designated as Open Water and the criteria are met.

MDE conducted an analysis of the TMDL scenario to determine the percentage of time when the modeled DO concentration in the Deep Channel was below the 1.0 mg/l instantaneous minimum concentration required by the criteria. The assessment consisted of an evaluation of the modeled TMDL scenario DO concentrations versus the instantaneous minimum concentration. The result of this assessment indicates that the Deep Channel exceeded the criteria 78.5% of the time and volume.

During the October 1st to May 31st period the Deep Water and Deep Channel Designated Use areas are considered Open Water Designated Use. Results of the attainment assessment utilizing the reference curve approach indicate that the criteria are achieved. Table 8 presents a summary of the Baltimore Harbor DO attainment assessment for the TMDL Scenario.

Table 8: TMDL Scenario: Percent Nonattainment of Dissolved Oxygen Criteria in the Baltimore Harbor

Period	Designated Use	% Nonattainment
February 1st to May 31st	Migratory Fish Spawning and Nursery	0%
June 1st to September 30th	Open Water	0%
	Deep Water*	7%
	Deep Channel	78.5%
October 1st to January 31st	Open Water	0%

*The Deep Water designated use DO criterion allows a restoration variance of up to 7% applied spatially and/or temporally from June 1 to September 30.

4.3.6.2 Chlorophyll *a* Criteria Attainment Assessment of the Future Conditions (TMDL) Scenario

Under the TMDL scenario, Chl *a* concentrations at Water Quality Station WT5.1 remain below 50 µg/l in both the surface and bottom waters, indicating attainment of the narrative criteria for Chl *a* (see Figure 15 above).

4.4 TMDL Loading Caps

The TMDLs for nitrogen and phosphorus are presented below. The detailed calculation of TMDL loading allocations can be found in Appendix C.

For the period of May 1 through October 31, the following TMDLs apply:

Growing Season TMDLs:

NITROGEN TMDL 2,145,750 *lbs/growing* ***season***

PHOSPHORUS TMDL 149,152 *lbs/****growing season***

The average annual TMDLs for nitrogen and phosphorus are:

Average Annual TMDLs:

NITROGEN TMDL 5,323,963 ***lbs/year***

PHOSPHORUS TMDL 324,309 ***lbs/year***

4.5 Load Allocations Between Point Sources and Nonpoint Sources

This section describes one viable allocation of loads between point sources, nonpoint sources, and the margin of safety for the nitrogen and phosphorus TMDLs. A more detailed overview of potential allocations to various sources is provided in the accompanying point and nonpoint Technical Memorandums. The allocations presented are quantified for growing season (May 1st through October 31st) and average annual conditions. The State reserves the rights to revise these allocations provided the allocations are consistent with the achievement of water quality standards.

4.5.1 Growing Season TMDL Allocations

Load Allocations (LA)

- **Nonpoint Source Loads**

  The nonpoint source loads represent the loads from agricultural land, forest and other herbaceous land, and septic systems. The nitrogen and phosphorus loading reductions simulated in the TMDL scenario represent a 15% reduction from the baseline agricultural loads and an explicit margin of safety (MOS) that is approximately 5% of the reduced agricultural loads for the growing season period. The other nonpoint source loads such as

septic systems and forest loads were not reduced from baseline condition levels. See Appendix C for LA calculations.

Waste Load Allocations (WLA)

- **Stormwater Loads**

In November 2002, EPA advised States that Municipal Separate Storm Sewer System (MS4) stormwater discharges must be addressed by the wasteload allocation (WLA) (See 40 C.F.R. § 130.2(h)). Therefore, MS4 communities regulated by NPDES permits will have their loads reflected in the WLA. The urban stormwater loads of nitrogen and phosphorus simulated in the Baltimore Harbor TMDL scenario are reduced 15% from the baseline urban stormwater loads.

The TMDL, including loads from urban stormwater discharges, is now expressed as:

TMDL = WLA [NPDES point sources* + regulated stormwater point source] + LA + MOS + FA (if applicable)

*NPDES point sources include municipal and industrial wastewater treatment plants.

Phase I and Phase II MS4's stormwater permits will be considered point sources subject to WLA assignment in the TMDL. EPA recognizes that limitations in the available data and information usually preclude stormwater allocations to specific outfalls. Therefore, EPA guidance allows the urban stormwater WLA to be expressed as a gross allotment, rather than individual allocations for separate pipes, ditches, construction sites, etc.

Estimating a load contribution to a particular waterbody from the stormwater is imprecise, given the variability in sources, runoff volumes, and pollutant loads over time. Therefore, the urban stormwater WLA is based on the best loadings estimate currently available. For the Baltimore Harbor the current data allows the urban stormwater allocation to be defined separately for Baltimore City, Baltimore County, Anne Arundel County, Carroll County, and Howard County. However, it should be noted that these WLAs aggregate municipal and industrial stormwater, including the loads from highways and construction activity.

- **Municipal and Industrial Wastewater Treatment Plants Loads**

During the 1995-1997 baseline conditions period, there were seven permitted point sources discharging nutrients into the Baltimore Harbor. For the TMDLs scenario, all seven point sources were given an allocation. In addition to the seven permitted point sources considered in the baseline scenario, the Cox Creek Dredged Material Containment Facility (DMCF) is included in the TMDL scenario and given an allocation. The Cox Creek DMCF was not discharging during the 1992-1997 period, therefore was not considered in the calibration of the model and the baseline scenario.

The Patapsco and Cox Creek WWTPs maximum allowable current permit flows are used for this scenario. Concentrations were adjusted to reflect Maryland's ENR Strategy of a maximum total nitrogen concentrations of 3 mg/l from May 1st to October 31st. Total

phosphorus limits are 0.3 mg/l year round. Industrial point source flows and concentrations vary from plant to plant, and are set at levels based on the implementation of best available technologies to achieve water quality criteria in both local and Chesapeake Bay waters. These allocations are also consistent with Maryland's current Tributary Strategy. All significant point sources are addressed by this allocation and are described further in the technical memorandum entitled *"Significant Nutrient Point Sources in the Baltimore Harbor Watershed"*. The nitrogen and phosphorus allocations for growing season conditions are presented in Table 9. See Appendix C for WLA calculations.

Table 9: Growing Season Allocations

	Total Nitrogen ***(lbs/growing season)***	**Total Phosphorus** ***(lbs/growing season)***
Nonpoint Source[1]	459,912	12,776
Point Source[2]	1,642,014	113,212
FA	33,204	22,848
MOS[3]	10,620	316
Total	2,145,750	149,152

1. Does not include regulated urban stormwater loads.
2. Includes regulated urban stormwater loads.
3. Approximately 5% of the reduced agricultural loads.

4.5.2 Average Annual TMDL Allocations

Load Allocations (LA)

- **Nonpoint Source Loads**
  The average annual nonpoint source loads represent the average loads from agricultural land, forest and other herbaceous land, and septic systems. The nitrogen and phosphorus loadings simulated in the TMDL scenario represent a 15% reduction from the baseline agricultural loads and an explicit MOS that is approximately 5% of the reduced agricultural loads. Other nonpoint source loads such as septic systems and forest and other herbaceous loads were not reduced from baseline condition levels. See Appendix C for LA calculations.

Waste Load Allocations (WLA)

- **Urban Stormwater Loads**

  For the average annual TMDL, the urban stormwater loads of nitrogen and phosphorus simulated in the TMDLs scenario represent a 15% reduction in TN and TP from average annual baseline urban stormwater loads.

- **Municipal and Industrial Wastewater Treatment Plants Loads**

  The Patapsco and Cox Creek WWTPs maximum allowable current permit flows are used. The TN concentration was set to a maximum of 3 mg/l from May 1st to October 31st and 5 mg/l from November 1st to April 30th. The TP concentrations for the two plants were set at 0.3 mg/l year-round. Industrial point source flows and concentrations vary from plant to plant, and they are set at levels based on the implementation of best available technologies to achieve water quality criteria in both local and Chesapeake Bay waters. These allocations are also consistent with Maryland's current Tributary Strategy. All significant point sources are addressed by this allocation and are described further in the technical memorandum entitled *"Significant Nutrient Point Sources in the Baltimore Harbor Watershed"*. The nonpoint and point source nitrogen and phosphorus allocations for average annual load conditions are shown in Table 10. See Appendix C for WLA calculations.

Table 10: Average Annual Allocations

	Total Nitrogen *(lbs/yr)*	**Total Phosphorus *(lbs/yr)***
Nonpoint Source[1]	1,246,036	34,654
Point Source[2]	3,976,215	243,127
FA	66,410	45,690
MOS[3]	35,302	838
Total	5,323,963	324,309

1. Does not include regulated urban stormwater loads.
2. Includes regulated urban stormwater loads.
3. Approximately 5% of the reduced agricultural loads.

4.6 Margin of Safety (MOS) and Future Allocation (FA)

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 magnitude of pollutant loads from various sources due to normal variations in precipitation and process changes, 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 explicitly 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 (implicit MOS). Maryland has adopted a MOS for these TMDLs using the first approach. For both the growing season and the average annual flow TMDLs, the load allocated to the MOS is approximately 5% of the reduced agricultural loads for nitrogen and phosphorus. The MOS is not considered a part of the reduced agricultural loads; it is a separate term in the TMDL equation. That is, the sum of the MOS and the reduced agricultural loads is equal to the load reduction that was used in the model run to

determine the TMDL. These explicit nitrogen and phosphorus margins of safety are presented in Tables 9 and 10. See Appendix C for MOS calculations.

Future Allocation represents an allowance for future growth, which accounts for reasonably foreseeable increases in pollutant loads (40 CFR 130.33(b)(9)). Future growth can be included in the TMDL by reserving a separate allocation for this purpose or by allocating acceptable wasteloads and loads in a way that incorporates potential growth. In the Baltimore Harbor nutrients TMDL analysis, the first approach is used for the nitrogen and phosphorus TMDLs to address the contingency that a seasonal nitrogen limit based on 3 mg/l of nitrogen and a limit of 0.3 mg/l of phosphorus may not be practical for ENR technology at some facilities.

4.7 Summary of Total Maximum Daily Loads

The Growing Season TMDLs, applicable from May 1- October 31, for the Baltimore Harbor:

For Nitrogen:

TMDL (*lbs/growing season*)	**=**	**LA**	**+**	**WLA**	**+**	**FA**	**+**	**MOS**
2,145,750	**=**	**459,912**	**+**	**1,642,014**	**+**	**33,204**	**+**	**10,620**

For Phosphorus:

TMDL (*lbs/growing season*)	**=**	**LA**	**+**	**WLA**	**+**	**FA**	**+**	**MOS**
149,152	**=**	**12,776**	**+**	**113,212**	**+**	**22,848**	**+**	**316**

The average annual flow TMDLs for the Baltimore Harbor:

For Nitrogen:

TMDL (*lbs/year*)	**=**	**LA**	**+**	**WLA**	**+**	**FA**	**+**	**MOS**
5,323,963	**=**	**1,246,036**	**+**	**3,976,215**	**+**	**66,410**	**+**	**35,302**

For Phosphorus:

TMDL (*lbs/year*)	**=**	**LA**	**+**	**WLA**	**+**	**FA**	**+**	**MOS**
324,309	**=**	**34,654**	**+**	**243,127**	**+**	**45,690**	**+**	**838**

Where:

TMDL = Total Maximum Daily Load
LA = Load Allocation (Nonpoint Source)
WLA = Waste Load Allocation (Point Source)
MOS = Margin of Safety

Average Daily Loads:

The growing season TMDLs will result in average daily loads of approximately 11,662 lbs/day of nitrogen and 817 lbs/day of phosphorus. Similarly, the average annual flow TMDLs will result in average daily loads of approximately 14,586 lbs/day of nitrogen and 889 lbs/day of phosphorus. Since nutrients do not result in acute impacts and the impacts of a given amount of nutrients vary seasonally, these average daily loads are provided for informational purposes, since daily loads will not be a factor controlling the ability to meet the water quality standards.

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 order to achieve water quality standards. In the Baltimore Harbor, both the TMDL and maximum anthropogenic reduction analyses indicate that reductions of the nutrients nitrogen and phosphorus from all sources, including the elimination of all point and nonpoint sources, do not result in the water quality standards being met in all waters of the Harbor at all times. Under the TMDL scenario the Deep Channel Designated Use region violates the water quality standard 78.5% of time and volume. Under the maximum anthropogenic reduction scenario, the Deep Channel Designated Use region violates the water quality standard 57.8% of time and volume. Under both of these scenarios, however, the water quality standards are achieved for all other designated uses that are applicable in the Harbor.

The implementation of point source nutrient controls that will be an integral component to meet water quality standards in the Harbor will be executed through the State's Enhanced Nutrient Reduction (ENR) strategy and NPDES permits. The ENR program provides grant funds to local governments to retrofit or upgrade WWTPs from BNR to ENR at their currently approved design capacity. Enhanced nutrient removal technologies allow sewage treatment plants to provide a highly advanced level of nutrient removal. The ENR strategy builds on the success of the biological nutrient removal (BNR) program already in place. Currently, the Patapsco WWTP is designing its new ENR facility, Cox Creek WWTP is planning its new ENR facility, and the Back River WWTP (supplier of processing water to ISG) is planning its new ENR facility. The completion of the planning, design, and construction of these facilities will lead to significant reductions in nutrients discharged into Baltimore Harbor. Upon completion of the ENR upgrades, subsequent NPDES permits for the municipal WWTPs will include nutrient loading limits that will be based upon achieving ENR levels of treatment. The significant industrial NPDES (>0.5 mgd) point sources will also have nutrient limits incorporated into subsequent permits that are reissued following the completion of the TMDL. The reissued NPDES permits will attempt to maintain consistency with the assumptions made in the TMDLs (*e.g.*, flow, nutrients effluent concentrations, DO, *etc.*). Deadlines for completion of ENR upgrades will be incorporated into NPDES permits based on the State's ENR upgrades schedule and, if the permitting timeframe is shorter than the ENR schedule, permits will reflect what can reasonably be accomplished with consideration to the complexity of the engineering and the availability of resources.

The implementation of nonpoint source nutrient controls that will be an integral component to achieve water quality standards in the Harbor will be executed through two approaches,

stormwater NPDES permits and cooperative agricultural reductions. In November 1990, EPA required jurisdictions with a population greater than 100,000 to apply for NPDES Permits for stormwater discharges. The five jurisdictions where the Baltimore Harbor watershed is located, Baltimore City, Baltimore County, Anne Arundel County, Carroll County and Howard County, are required to participate in the stormwater NPDES program, and must comply with the NPDES Permit regulations for stormwater discharges. Subsequently, stormwater management programs have been implemented by the Counties and the City to control MS4 discharges to the maximum extent practicable. For example, Baltimore County stormwater management program encompasses numerous elements including: erosion and sediment control, post-construction runoff management, controlling pollutants associated with road maintenance activities, public education and outreach, and illicit discharge detection and elimination. Additionally, in targeted watersheds, Baltimore County is required to implement watershed restoration for 10% of the County's total impervious surface cover. Baltimore City is required to implement those watershed restoration activities described above for addressing 20% of the City's impervious surfaces. In order to meet this goal, annually, the City will have at least two restoration projects in study, two in design, and two under construction. A brief description of each project, phase, and cost can be found in the City's NPDES stormwater annual report. Details of the County and City programs elements are available through MDE's Water Management Administration – NPDES Stormwater Program.

Additional significant planned implementation measures in the Baltimore Harbor watershed involve the upgrade or separation of combined sewer systems in the City and the upgrade of sanitary sewer systems in Baltimore County. In 2002, Baltimore City, MDE, and U.S. Environmental Protection Agency (EPA) entered into a civil consent decree to address SSOs and combined sewer overflows (CSOs)[1] within its jurisdictional boundaries. See U.S., et al., v. Mayor and City Council of Baltimore, JFM-02-12524, Consent Decree (entered Sept. 30, 2002). Similarly, in 2005, Baltimore County, MDE and EPA entered into a civil consent decree to address SSOs in the County. See U.S., et al. v. Baltimore County, AMD-05-2028, Consent Decree (entered Sept. 20, 2006). The consent decrees require the City and the County to adopt and implement a long term control plan ("LTCP") to evaluate their sanitary sewer systems and to repair, replace, or rehabilitate the system as indicated by the results of those evaluations, with all work to be completed by January 2016 for Baltimore City and by March 2020 for Baltimore County.

Maryland's Water Quality Improvement Act 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. It is reasonable to expect that nonpoint loads can be reduced during growing season conditions. The nutrient load sources during growing season include dissolved forms of the impairing substances from groundwater, the effects of agricultural ditching and animals in the stream, and deposition of

[1] A "combined sewer system" is a sewer system in which stormwater and sanitary sewerage are conveyed through a common set of pipes for treatment at a wastewater treatment plant. A CSO is an overflow from such a combined system. Baltimore City agreed in the Consent Decree to separate the sanitary and stormwater lines in the small area served by a combined system and has completed that separation.

nutrients and organic matter to the streambed from higher flow events. When these sources are controlled in combination, it is reasonable to achieve agricultural nonpoint reductions of the magnitude identified by this TMDL allocation.

Additionally, Howard County is developing a Watershed Restoration Action Strategy for its portion of the Lower North Branch of the Patapsco River (approximately 38 of 118 square miles). The county will utilize this strategy to identify and prioritize watershed restoration efforts, which will include the reduction of nutrient loads from the watershed.

The legislative and policy-derived programs described above will result in significant nutrient reductions and the achievement of water quality standards for all designated uses in the Baltimore Harbor except the Deep Channel. Based on information generated in the TMDL analysis, MDE is unable to ensure that the Deep Channel Designated Use water quality criterion can be met at all times that it is applicable. The regions to which the Deep Channel designated use applies represent approximately 10% of the area of the Harbor. The region subject to potential non-attainment of criteria represents < 5% of the area of the Harbor. The volume of water that does not meet the dissolved oxygen criteria represents approximately 3% of the total volume of the Harbor.

MDE is unable to assure attainment of the Deep Channel Designated Use due to the effects of 170 years of dredging that has incrementally deepened and expanded the size of the Harbors' navigation channels and their associated turning basins and anchorages. As a result, the Harbor has been hydrologically modified. In a portion of the main navigation channel, from the mouth of the Harbor to Fort McHenry, it has been observed that water from the upper portion of the water column does not mix with the lower portion of the water column. This observed stratification of the water column, and the lack of mixing associated with it, occurs every spring/summer/fall. As a result, there are limited regions within the navigation channel (Deep Channel Designated Use) that do not meet the dissolved oxygen criteria during the observed spring/summer/fall stratification period.

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APPENDIX I:

Watershed Report for Biological Impairment of the Gwynns Falls Watershed

Watershed Report for Biological Impairment of the Gwynns Falls Watershed in Baltimore City and Baltimore County, Maryland
Biological Stressor Identification Analysis
Results and Interpretation

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June 2009

EPA Submittal Date:

Table of Contents

List of Figures ii

List of Tables ii

List of Abbreviations iii

Executive Summary iv

1.0 Introduction 1

2.0 Gwynns Falls Watershed Characterization 2
- **2.1 Location** 2
- **2.2 Land Use** 4
- **2.3 Soils/hydrology** 6

3.0 Gwynns Falls Water Quality Characterization 7
- **3.1 Integrated Report Impairment Listings** 7
- **3.2 Biological impairment** 7

4.0 Stressor Identification Results 9

5.0 Conclusions 24

References 25

List of Figures

Figure 1. Location Map of the Gwynns Falls Watershed 3
Figure 2. Eco-Region Location Map of Gwynns Falls Watershed 4
Figure 3. Land Use Map of the Gwynns Falls Watershed 5
Figure 4. Proportions of Land Use in the Gwynns Falls Watershed 6
Figure 5. Gwynns Falls Watershed Primary Dataset Site Locations 8
Figure 6. Final Causal Model for the Gwynns Falls 23

List of Tables

Table 1. Sediment Biological Stressor Identification Analysis Results for the Gwynns Falls 11
Table 2. Habitat Biological Stressor Identification Analysis Results for the Gwynns Falls 12
Table 3. Water Chemistry Biological Stressor Identification Analysis Results for the Gwynns Falls 13
Table 4. Stressor Source Identification Analysis Results for the Gwynns Falls 14
Table 5. Summary of Combined AR Values for Stressor Groups for the Gwynns Falls Watershed 16
Table 6. Summary of Combined AR Values for Source Groups for the Gwynns Falls Watershed 16

List of Abbreviations

AR	Attributable Risk
BIBI	Benthic Index of Biotic Integrity
BSID	Biological Stressor Identification
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
DO	Dissolved Oxygen
FIBI	Fish Index of Biologic Integrity
IBI	Index of Biotic Integrity
MDDNR	Maryland Department of Natural Resources
MDE	Maryland Department of the Environment
MBSS	Maryland Biological Stream Survey
mg/L	Milligrams per liter
NPDES	National Pollutant Discharge Elimination System
SSA	Science Services Administration
TMDL	Total Maximum Daily Load
USEPA	United States Environmental Protection Agency
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment

Executive Summary

Section 303(d) of the federal Clean Water Act (CWA) and the United States Environmental Protection Agency's (USEPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS listed on the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report), the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate via a Water Quality Analysis (WQA) that water quality standards are being met.

Gwynns Falls, located in Baltimore County and Baltimore City was identified in Maryland's Integrated Report as impaired by nutrients, sediments (1996 listings), bacteria (fecal coliform) , and combination benthic/fishes bio-assessment (2002 listings) (MDE 2008). All impairments are listed for non-tidal streams. The 1996 nutrient listing was refined in the 2008 Integrated Report and phosphorus was identified as the specific impairing substance. Similarly, the 1996 sediments listing was refined in the 2008 Integrated Report to a listing for total suspended solids. A TMDL addressing the 2002 bacteria impairment was approved by the USEPA in 2008.

In 2002, the State began listing biological impairments on the Integrated Report. The current Maryland Department of Environment (MDE) biological assessment methodology assesses and lists only at the Maryland 8-digit watershed scale, which maintains consistency with how other listings on the Integrated Report are made, how TMDLs are developed, and how implementation is targeted. The listing methodology assesses the condition of Maryland 8-digit watersheds with multiple impacted sites by measuring the percentage of stream miles that have an Index of Biotic Integrity (IBI) score less than 3, and calculating whether this is significant from a reference condition watershed (i.e., healthy stream, <10% stream miles degraded).

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for Gwynns Falls are as follows: Gwynns Falls and tributaries above Reisterstown Road – Use III - *Nontidal Cold Water*; Dead Run and tributaries – Use IV - *Recreational Trout Waters* (COMAR 2009 a,b,c,d) . In addition, COMAR requires these waterbodies to support at a minimum the Use I designation - *water contact recreation, and protection of nontidal warmwater aquatic life*. The Gwynns Falls watershed is not attaining its designated use of supporting aquatic life because of biological impairments. As an indicator of designated use attainment, MDE uses Benthic and Fish Indices of Biotic Integrity (BIBI/FIBI) developed by the Maryland Department of Natural Resources Maryland Biological Stream Survey (MDDNR MBSS).

The current listings for biological impairments represent degraded biological conditions for which the stressors, or causes, are unknown. The MDE Science Services Administration (SSA) has developed a biological stressor identification (BSID) analysis that uses a case-control, risk-based approach to systematically and objectively determine the predominant cause of reduced biological conditions, thus enabling the Department to most effectively direct corrective management action(s). The risk-based approach, adapted from the field of epidemiology, estimates the strength of association between various stressors, sources of stressors and the

biological community, and the likely impact these stressor have on the degraded sites in the watershed.

The BSID analysis uses data available from the statewide MDDNR MBSS. Once the BSID analysis is completed, a number of stressors (pollutants) may be identified as probable or unlikely causes of poor biological conditions within the Maryland 8-digit watershed study. BSID analysis results can be used as guidance to refine biological impairment listings in the Integrated Report by specifying the probable stressors and sources linked to biological degradation.

This Gwynns Falls watershed report presents a brief discussion of the BSID process on which the watershed analysis is based, and may be reviewed in more detail in the report entitled *Maryland Biological Stressor Identification Process* (MDE 2009). Data suggest that the degradation of biological communities in the Gwynns Falls is strongly associated with urban land use and its concomitant effects: altered hydrology and elevated levels of ammonia, chlorides, and conductivity (a measure of the presence of dissolved substances). The urbanization of landscapes creates broad and interrelated forms of degradation (i.e., hydrological, morphological, and water chemistry) that can affect stream ecology and biological composition. Peer-reviewed scientific literature establishes a link between highly urbanized landscapes and degradation in the aquatic health of non-tidal stream ecosystems.

The results of the BSID analysis, and the probable causes and sources of the biological impairments in the Gwynns Falls, can be summarized as follows:

- The BSID analysis has determined that the biological communities are likely degraded due to inorganic pollutants (i.e., chlorides and conductivity). Inorganic pollutants levels are significantly associated with degraded biological conditions and found in approximately 76% of the stream miles with very poor to poor biological conditions in the Gywnns Falls watershed. Impacts on water quality due to conductivity and chlorides are dependent on prolonged exposure; future monitoring of these inorganic pollutants will help in determining the spatial and temporal extent of this impairment in the watershed. Impervious surfaces and urban runoff cause an increase in contaminant loads from point and nonpoint sources by delivering an array of inorganic pollutants to surface waters. Currently, there is a lack of monitoring data for many of these substances; therefore, additional monitoring of priority inorganic pollutants is needed to more precisely determine the specific cause(s) of impairment.
- The BSID analysis has determined that the biological communities in Gwynns Falls are also likely degraded due to flow/sediment related stressors. Specifically, altered hydrology and increased runoff from urban impervious surfaces have resulted in channel erosion and subsequent elevated suspended sediment transport through the watershed, which are in turn the probable causes of impacts to biological communities. The BSID results thus confirm the 1996 Category 5 listing for total suspended solids as an impairing substance in Gwynns Falls, and link this pollutant to biological conditions in these waters.

- The BSID analysis has identified one water chemistry stressor present (ammonia) at two sites showing a possible association with degraded biological conditions. A more intensive analysis of all available data is recommended to determine if there is an ammonia toxicity impairment in the Gwynns Falls watershed.
- Although there is presently a Category 5 listing for phosphorus in Maryland's 2008 Integrated Report, the BSID analysis did not identify any nutrient stressors (i.e., total nitrogen, total phosphorus, dissolved oxygen, etc.) present and/or nutrient stressors showing a significant association with degraded biological conditions.

1.0 Introduction

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (USEPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS listed on the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report), the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate via a Water Quality Analysis (WQA) that water quality standards are being met. In 2002, the State began listing biological impairments on the Integrated Report. Maryland Department of the Environment (MDE) has developed a biological assessment methodology to support the determination of proper category placement for 8-digit watershed listings.

The current MDE biological assessment methodology is a three-step process: (1) a data quality review, (2) a systematic vetting of the dataset, and (3) a watershed assessment that guides the assignment of biological condition to Integrated Report categories. In the data quality review step, available relevant data are reviewed to ensure they meet the biological listing methodology criteria of the Integrated Report (MDE 2008). In the vetting process, an established set of rules is used to guide the removal of sites that are not applicable for listing decisions (e.g., tidal or black water streams). The final principal database contains all biological sites considered valid for use in the listing process. In the watershed assessment step, a watershed is evaluated based on a comparison to a reference condition (i.e., healthy stream, <10% degraded) that accounts for spatial and temporal variability, and establishes a target value for "aquatic life support." During this step of the assessment, a watershed that differs significantly from the reference condition is listed as impaired (Category 5) on the Integrated Report. If a watershed is not determined to differ significantly from the reference condition, the assessment must have an acceptable precision (i.e., margin of error) before the watershed is listed as meeting water quality standards (Category 1 or 2). If the level of precision is not acceptable, the status of the watershed is listed as inconclusive and subsequent monitoring options are considered (Category 3). If a watershed is classified as impaired (Category 5), then a stressor identification analysis is completed to determine if a TMDL is necessary.

The MDE biological stressor identification (BSID) analysis applies a case-control, risk-based approach that uses the principal dataset, with considerations for ancillary data, to identify potential causes of the biological impairment. Identification of stressors responsible for biological impairments was limited to the round two Maryland Department of Natural Resources (MDDNR) Maryland Biological Stream Survey (MBSS) dataset (2000 – 2004) because it provides a broad spectrum of paired data variables (i.e., biological monitoring and stressor information) to best enable a complete stressor analysis. The BSID analysis then links potential causes/stressors with general causal scenarios and concludes with a review for ecological plausibility by State scientists. Once the BSID analysis is completed, one or several stressors (pollutants) may be identified as probable or unlikely causes of the poor biological conditions within the Maryland 8-digit watershed. BSID analysis results can be used together with a variety

of water quality analyses to update and/or support the probable causes and sources of biological impairment in the Integrated Report.

The remainder of this report provides a characterization of the Gwynns Falls watershed, and presents the results and conclusions of a BSID analysis of the watershed.

2.0 Gwynns Falls Watershed Characterization

2.1 Location

The Gwynns Falls originates in Glyndon, Baltimore County just south of where Highway 795 ends and turns into Route 128. The River flows southeast through the heavily suburbanized area of Reisterstown and Owings Mills crossing under Rt. 140 and Hwy. 795 in the Owings Mills Industrial Park and Corporate Campus areas. Gwynns Falls continues southeast with Red Run and Horsehead Run tributaries entering the main stem, which roughly flows parallel to Hwy. 795. Gwynns Falls again crosses under Hwy. 795 and then Hwy. 695 roughly flowing southeast and paralleling Hwy. 695. The tributary Scotts Level Branch flows into the main stem, which then crosses under Rt. 26 (Liberty Road) before crossing over the Baltimore County/City line. Gwynns Falls flows through Gwynns Falls Park where the tributary Dead Run joins into the main stem where the river, still flowing in a roughly southeasterly direction, crosses under Rt. 40, Rt. 144, Rt. 1, and Hwy. 95 where the tributary Maidens Choice Run joins it. Gwynns Falls then flows past the Carroll Camden Industrial Area and empties into the Middle Branch of the Patapsco River immediately after crossing under the Hwy. 295 and 95 interchange. The drainage area of the Gwynns Falls watershed is 41,700 acres. The location of the watershed is depicted in Figure 1. The watershed area is located in two of three distinct eco-regions identified in the MBSS Index of Biotic Integrity (IBI) metrics (Southerland et al. 2005) (see Figure 2).

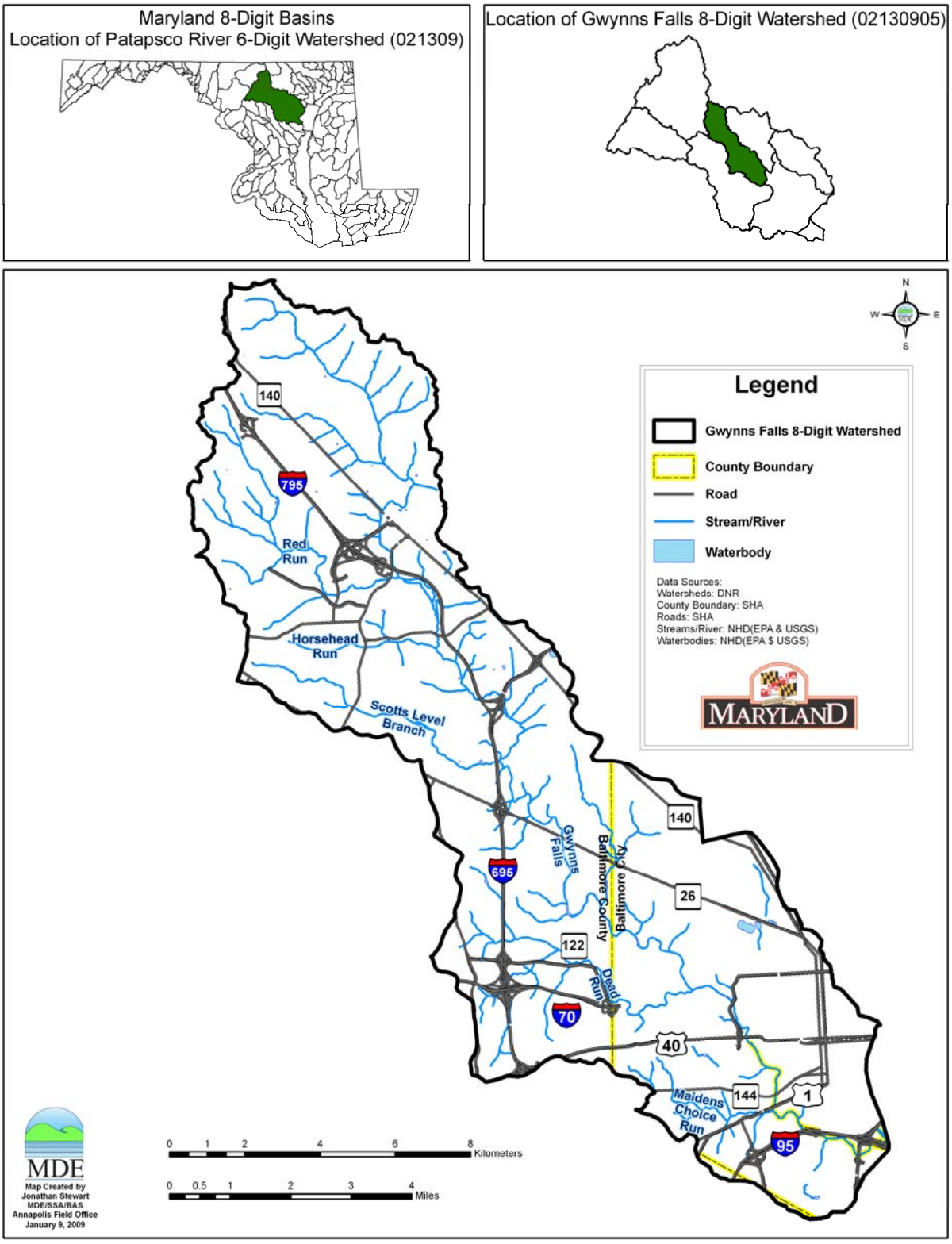


Figure 1. Location Map of the Gwynns Falls Watershed

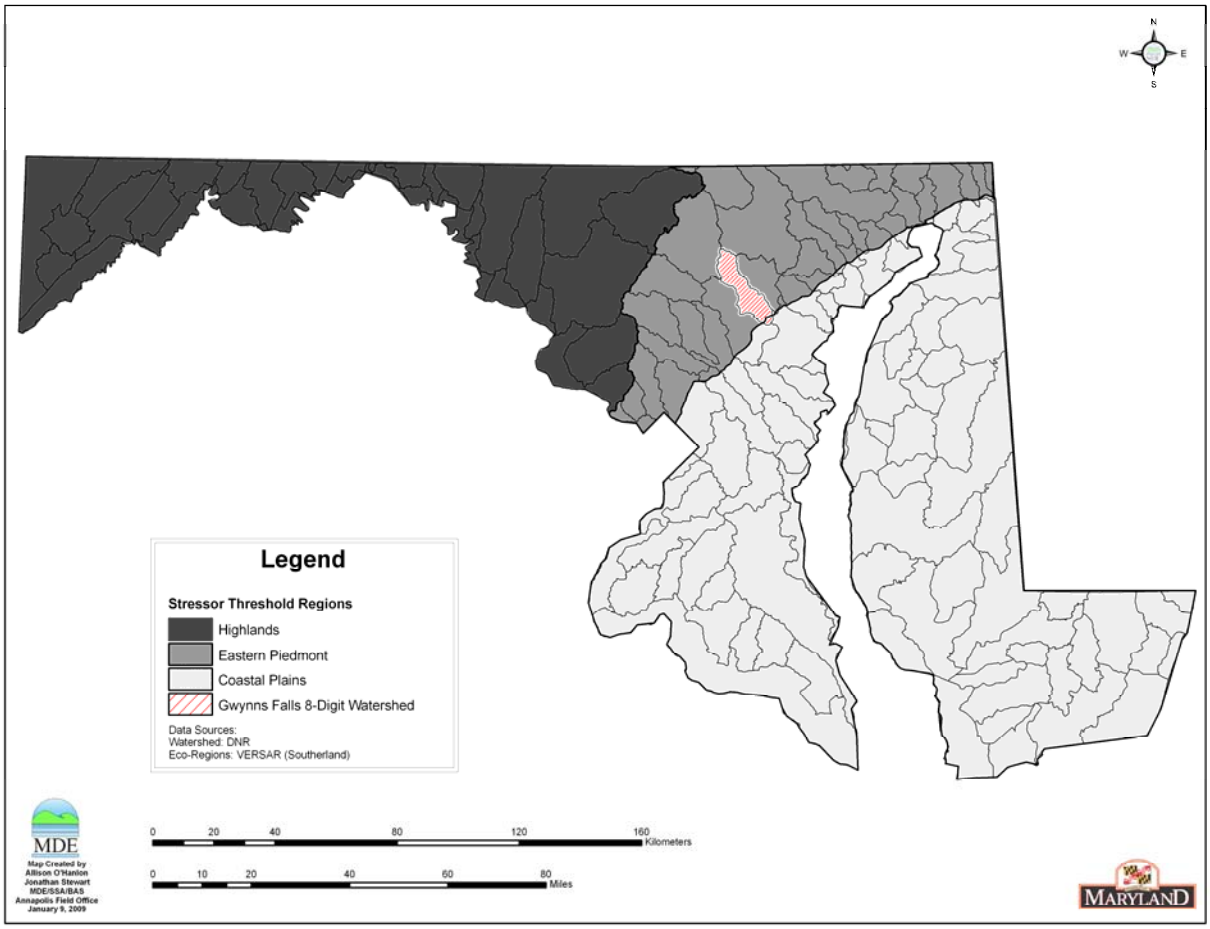


Figure 2. Eco-Region Location Map of Gwynns Falls Watershed

2.2 Land Use

The Gwynns Falls watershed is approximately 41,700 acres in size. The land use in the Gwynns Falls watershed is primarily urban. The watershed contains approximately 33,000 acres (79%)of urban land use. The watershed consists of agricultural land use at 1,400 acres (3%) and 7,000 acres (17%)of forest lands, with the forest found primarily along the main stem and tributaries of Gwynns Falls. Approximately 195 acres of the watershed consist of water. The land use distribution is based on land use/land cover data from the Maryland Department of Planning (MDP 2002). The spatial distributions for each land use are presented in Figure 3 and the land use percentage distribution for the Gwynns Falls watershed is displayed in Figure 4.

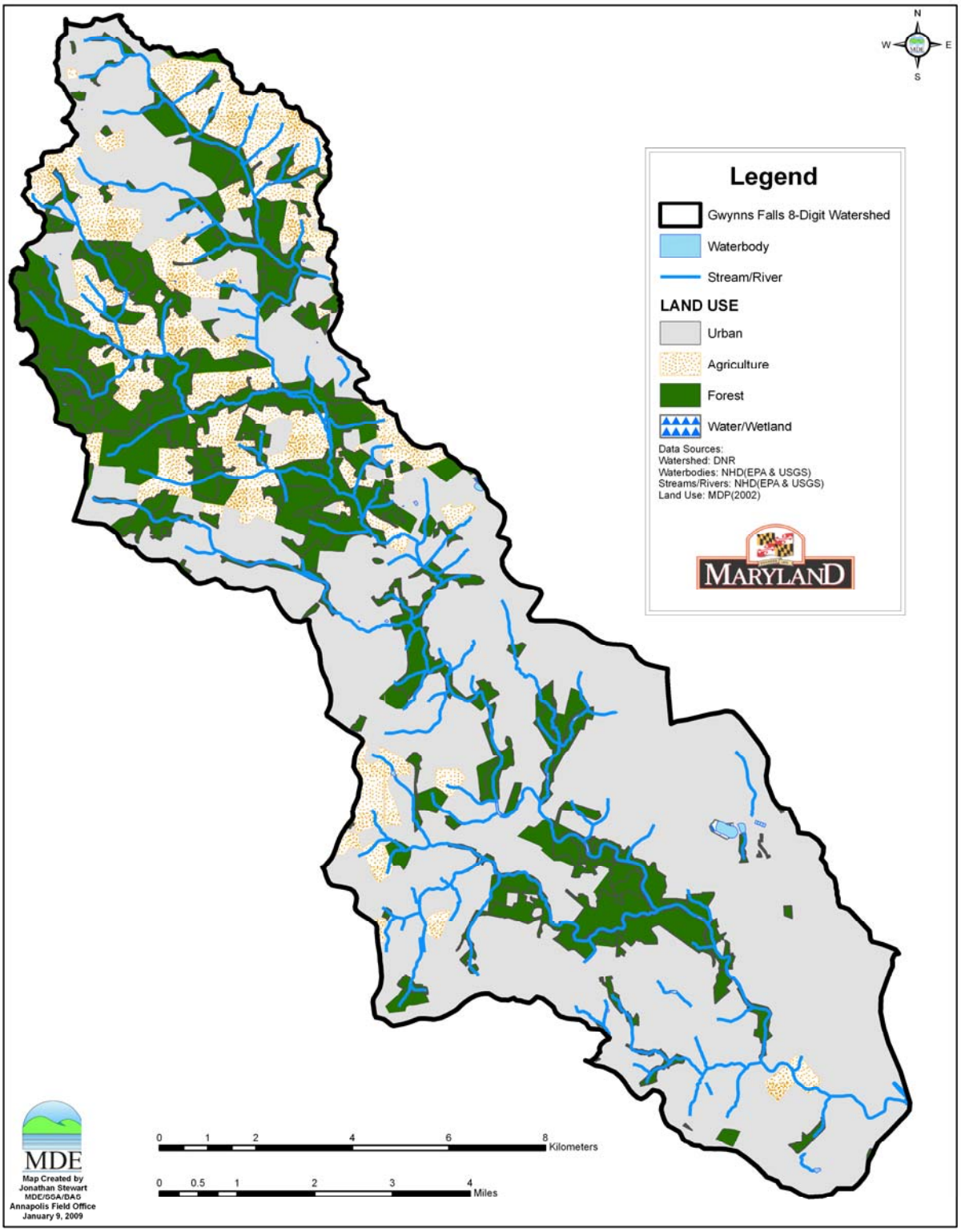


Figure 3. Land Use Map of the Gwynns Falls Watershed

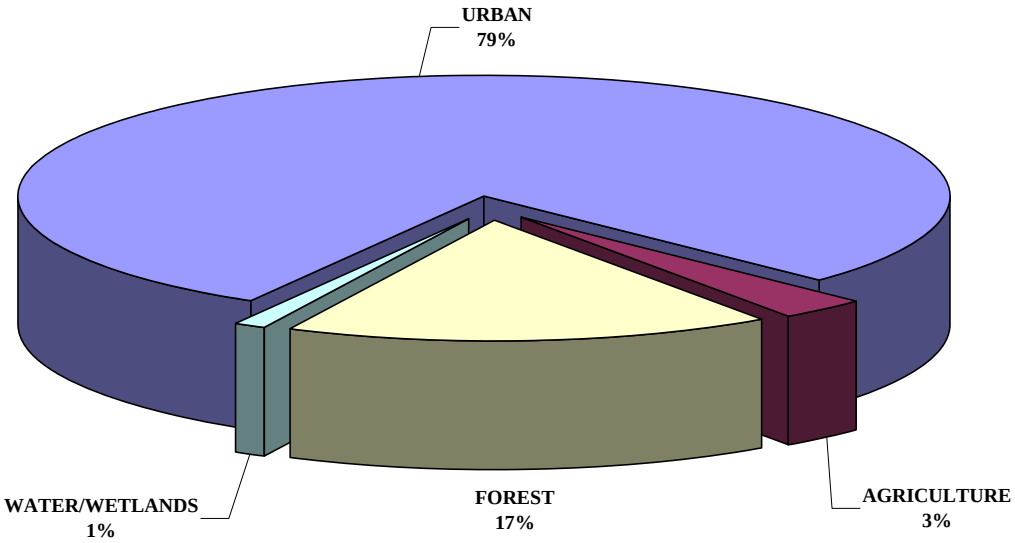


Figure 4. Proportions of Land Use in the Gwynns Falls Watershed

2.3 Soils/hydrology

The Gwynns Falls watershed lies within the Piedmont and Atlantic Coastal Plain Provinces of Central Maryland. The Piedmont Province is characterized by gentle to steep rolling topography, low hills and ridges. Crystalline rocks of volcanic origin consisting primarily of schist and gneiss characterize the surface geology. These formations are resistant to short-term erosion and often determine the limits of stream bank and streambed. These crystalline formations decrease in elevation from northwest to southeast and eventually extend beneath the younger sediments of the Coastal Plain. The fall line represents the transition between the Atlantic Coastal Plain Province and the Piedmont Province. Thick, unconsolidated marine sediments deposited over the crystalline rock of the piedmont province characterize the Atlantic Coastal Plain surface geology. The deposits include clays, silts, sands and gravels. In the areas around the head of tide, the topography is flat, with elevations below 100 feet. The elevations steadily increase going north to approximately 600 feet in the headwaters. Streambeds throughout the basin are comprised of rock and rubble with gradually sloped stream banks.

The Gwynns Falls watershed lies predominantly in the Baile and Lehigh soil series. The Lehigh soil series consists of somewhat poorly drained to moderately well drained, rather shallow soils. The Baile soil series consists of deep, poorly drained, nearly level to gently sloping, dominantly gray soils of the Piedmont Plateau (USDA SCS 1977).

3.0 Gwynns Falls Water Quality Characterization

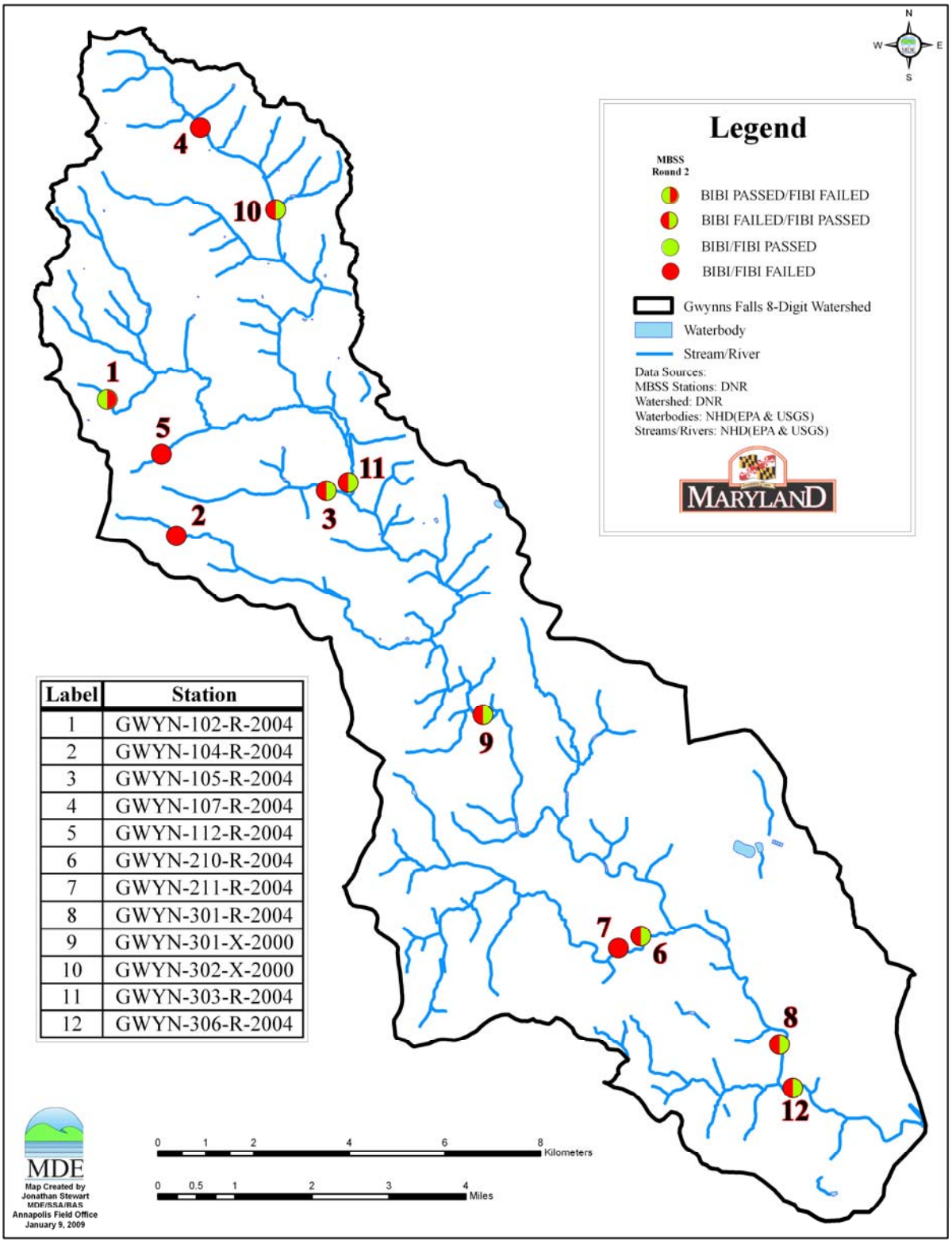
3.1 Integrated Report Impairment Listings

Gwynns Falls was identified in Maryland's Integrated Report as impaired by nutrients, sediments (1996 listings), bacteria (fecal coliform) , and combination benthic/fishes bio-assessment (2002 listings) (MDE 2008). All impairments are listed for non-tidal streams. The 1996 nutrient listing was refined in the 2008 Integrated Report and phosphorus was identified as the specific impairing substance. Similarly, the 1996 sediments listing was refined in the 2008 Integrated Report to a listing for total suspended solids. A TMDL addressing the 2002 bacteria impairment was approved by the USEPA in 2008.

3.2 Biological impairment

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for Gwynns Falls are as follows: Gwynns Falls and tributaries above Reisterstown Road – Use III - *Nontidal Cold Water*; Dead Run and tributaries – Use IV *Recreational Trout Waters* (COMAR 2009 a,b,c,d). In addition, COMAR requires these waterbodies to support at a minimum the Use I designation - *water contact recreation, and protection of nontidal warmwater aquatic life*. A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include support of aquatic life, primary or secondary contact recreation, drinking water supply, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. The criteria developed to protect the designated use may differ and are dependent on the specific designated use(s) of a waterbody.

The Gwynns Falls watershed is listed under Category 5 of the 2008 Integrated Report as impaired for evidence of biological impacts. Approximately 79% of stream miles in the Gwynns Falls watershed are estimated as having benthic and/or fish indices of biological integrity (BIBI/FIBI) in the very poor to poor category. The biological impairment listing is based on the combined results of MDDNR MBSS round one (1995-1997) and round two (2000-2004) data that include twenty-eight stream sites. Twenty-two of the twenty-eight sites have BIBI and or FIBI scores significantly lower than 3.0. The BSID analysis uses the principal data set, containing MBSS Round 2 data only, which includes fifteen sites in the Gwynns Falls watershed. Eleven of the twelve sites have BIBI/FIBI scores significantly lower than 3.0. Figure 5 illustrates the location of principal dataset sites within the Gwynns Falls Watershed.



Label	Station
1	GWYN-102-R-2004
2	GWYN-104-R-2004
3	GWYN-105-R-2004
4	GWYN-107-R-2004
5	GWYN-112-R-2004
6	GWYN-210-R-2004
7	GWYN-211-R-2004
8	GWYN-301-R-2004
9	GWYN-301-X-2000
10	GWYN-302-X-2000
11	GWYN-303-R-2004
12	GWYN-306-R-2004

Figure 5: Gwynns Falls Watershed Primary Dataset Site Locations

4.0 Stressor Identification Results

The BSID process uses results from the BSID data analysis to evaluate each biologically impaired watershed and determine potential stressors and sources. Interpretation of the BSID analysis results is based upon components of Hill's Postulates (Hill 1965), which propose a set of standards that could be used to judge when an association might be causal. The components applied are: 1) the strength of association which is assessed using the odds ratio; 2) the specificity of the association for a specific stressor (risk among controls); 3) the presence of a biological gradient; 4) ecological plausibility which is illustrated through final causal models; and 5) experimental evidence gathered through literature reviews to help support the causal linkage.

The BSID data analysis tests for the strength of association between stressors and degraded biological conditions by determining if there is an increased risk associated with the stressor being present. More specifically, the assessment compares the likelihood that a stressor is present, given that there is a degraded biological condition, by using the ratio of the incidence within the case group as compared to the incidence in the control group (odds ratio). The case group is defined as the sites within the assessment unit with BIBI/FIBI scores significantly lower than 3.0 (i.e., poor to very poor) The controls are sites with similar physiographic characteristics (Highland, Eastern Piedmont, and Coastal region), and stream order for habitat parameters (two groups – 1st and 2nd-4th order), that have good biological conditions.

The common odds ratio confidence interval was calculated to determine if the odds ratio was significantly greater than one. The confidence interval was estimated using the Mantel-Haenzel (MH)(1959) approach and is based on the exact method due to the small sample size for cases. A common odds ratio significantly greater than one indicates that there is a statistically significant higher likelihood that the stressor is present when there are very poor to poor biological conditions (cases) than when there are fair to good biological conditions (controls). This result suggests a statistically significant positive association between the stressor and very poor to poor biological conditions and is used to identify potential stressors.

Once potential stressors are identified (i.e., odds ratio significantly greater than one), the risk attributable to each stressor is quantified for all sites with very poor to poor biological conditions within the watershed (i.e., cases). The attributable risk (AR) defined herein is the portion of the cases with very poor to poor biological conditions that are associated with the stressor. The AR is calculated as the difference between the proportion of case sites with the stressor present and the proportion of control sites with the stressor present.

Once the AR is calculated for each possible stressor, the AR for groups of stressors is calculated. Similar to the AR calculation for each stressor, the AR calculation for a group of stressors is also summed over the case sites using the individual site characteristics (i.e., stressors present at that site). The only difference is that the absolute risk for the controls at each site is estimated based on the stressor present at the site that has the lowest absolute risk among the controls.

After determining the AR for each stressor and the AR for groups of stressors, the AR for all potential stressors is calculated. This value represents the proportion of cases, sites in the

watershed with poor to very poor biological conditions, which would be improved if the potential stressors were eliminated (Van Sickle and Paulsen 2008). The purpose of this metric is to determine if stressors have been identified for an acceptable proportion of cases (MDE 2009).

Through the BSID data analysis, MDE identified habitat parameters, water chemistry parameters, and potential sources significantly associated with poor to very poor fish and/or benthic biological conditions. As shown in Table 1 through Table 3, parameters from the sediment, habitat, and water chemistry groups are identified as possible biological stressors in Gwynns Falls. Parameters identified as representing possible sources are listed in Table 4 and include various urban land use types. Table 5 shows the summary of combined AR values for the stressor groups in the Gwynns Falls watershed. Table 6 shows the summary of combined AR values for the source groups in the Gwynns Falls watershed.

Table 1. Sediment Biological Stressor Identification Analysis Results for the Gwynns Falls

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic	% of case sites with stressor present	% of control sites per strata with stressor present	Possible stressor (Odds of stressor in cases significantly higher than odds of stressors in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by
Sediment	extensive bar formation present	12	11	78	36%	13%	Yes	23%
	moderate bar formation present	12	11	78	64%	43%	No	----
	bar formation present	12	11	78	100%	91%	No	----
	channel alteration marginal to poor	12	11	78	64%	43%	No	----
	channel alteration poor	12	11	78	36%	12%	Yes	24%
	high embeddedness	12	11	78	0%	9%	No	----
	epifaunal substrate marginal to poor	12	11	78	0%	9%	No	----
	epifaunal substrate poor	12	11	78	0%	1%	No	----
	moderate to severe erosion present	12	11	78	18%	60%	No	----
	severe erosion present	12	11	78	0%	13%	No	----
	poor bank stability index	12	11	78	0%	4%	No	----
	silt clay present	12	11	78	100%	100%	No	----

Table 2. Habitat Biological Stressor Identification Analysis Results for the Gwynns Falls

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with stressor present	% of control sites per strata with stressor present	Possible stressor (Odds of stressor in cases significantly higher than odds of stressors in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Stressor
In-Stream Habitat	channelization present	12	11	79	45%	11%	Yes	34%
	instream habitat structure marginal to poor	12	11	78	0%	8%	No	----
	instream habitat structure poor	12	11	78	0%	0%	No	----
	pool/glide/eddy quality marginal to poor	12	11	78	18%	32%	No	----
	pool/glide/eddy quality poor	12	11	78	0%	0%	No	----
	riffle/run quality marginal to poor	12	11	78	27%	12%	No	----
	riffle/run quality poor	12	11	78	9%	1%	No	----
	velocity/depth diversity marginal to poor	12	11	78	36%	33%	No	----
	velocity/depth diversity poor	12	11	78	0%	0%	No	----
	concrete/gabion present	12	11	79	18%	2%	Yes	15%
	beaver pond present	12	11	78	0%	3%	No	----
Riparian Habitat	no riparian buffer	12	11	79	36%	21%	No	----
	low shading	12	11	78	0%	8%	No	----

Table 3. Water Chemistry Biological Stressor Identification Analysis Results for the Gwynns Falls

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with stressor present	% of control sites per strata with stressor present	Possible stressor (Odds of stressor in cases significantly higher than odds of stressors in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Stressor
Water Chemistry	high total nitrogen	12	11	165	0%	47%	No	----
	high total dissolved nitrogen	2	2	56	0%	45%	No	----
	ammonia acute with salmonid present	12	11	165	18%	5%	No	----
	ammonia acute with salmonid absent	12	11	165	18%	3%	Yes	15%
	ammonia chronic with salmonid present	12	11	165	18%	15%	No	----
	ammonia chronic with salmonid absent	12	11	165	18%	4%	No	----
	low lab pH	12	11	165	0%	2%	No	----
	high lab pH	12	11	165	0%	2%	No	----
	low field pH	12	11	164	0%	4%	No	----
	high field pH	12	11	164	0%	2%	No	----
	high total phosphorus	12	11	165	0%	6%	No	----
	high orthophosphate	12	11	165	0%	8%	No	----
	dissolved oxygen < 5mg/l	12	11	164	0%	1%	No	----
	dissolved oxygen < 6mg/l	12	11	164	0%	2%	No	----
	low dissolved oxygen saturation	12	11	152	0%	1%	No	----
	high dissolved oxygen saturation	12	11	152	0%	0%	No	----
	acid neutralizing capacity below chronic level	12	11	165	0%	1%	No	----
	acid neutralizing capacity below episodic level	12	11	165	0%	7%	No	----
	high chlorides	12	11	165	82%	5%	Yes	76%
	high conductivity	12	11	165	82%	6%	Yes	76%
	high sulfates	12	11	165	18%	4%	No	----

Table 4. Stressor Source Identification Analysis Results for the Gwynns Falls

Parameter Group	Source	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with source present	% of control sites per strata with source present	Possible stressor (Odds of stressor in cases significantly higher than odds of sources in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Source
Sources Urban	high impervious surface in watershed	12	11	164	82%	3%	Yes	79%
	high % of high intensity urban in watershed	12	11	165	100%	16%	Yes	79%
	high % of low intensity urban in watershed	12	11	165	82%	5%	Yes	76%
	high % of transportation in watershed	12	11	165	100%	9%	Yes	91%
	high % of high intensity urban in 60m buffer	12	11	164	82%	4%	Yes	78%
	high % of low intensity urban in 60m buffer	12	11	164	91%	6%	Yes	85%
	high % of transportation in 60m buffer	12	11	164	45%	6%	Yes	39%
Sources Agriculture	high % of agriculture in watershed	12	11	165	0%	22%	No	----
	high % of cropland in watershed	12	11	165	0%	3%	No	----
	high % of pasture/hay in watershed	12	11	165	0%	29%	No	----
	high % of agriculture in 60m buffer	12	11	164	0%	13%	No	----
	high % of cropland in 60m buffer	12	11	164	0%	3%	No	----
	high % of pasture/hay in 60m buffer	12	11	164	0%	23%	No	----
Sources Barren	high % of barren land in watershed	12	11	165	0%	10%	No	----
	high % of barren land in 60m buffer	12	11	164	0%	10%	No	----
Sources Anthropogenic	low % of forest in watershed	12	11	165	73%	8%	Yes	65%
	low % of forest in 60m buffer	12	11	164	82%	9%	Yes	73%

Table 4. Stressor Source Identification Analysis Results for the Gwynns Falls (Cont.)

Parameter Group	Source	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with source present	% of control sites per strata with source present	Possible stressor (Odds of stressor in cases significantly higher than odds of sources in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Source
Sources Acidity	atmospheric deposition present	12	11	165	0%	5%	No	----
	AMD acid source present	12	11	165	0%	0%	No	----
	organic acid source present	12	11	165	0%	0%	No	----
	agricultural acid source present	12	11	165	0%	2%	No	----

Table 5. Summary of Combined AR Values for Stressor Groups for the Gwynns Falls Watershed

Parameter Group	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Parameter Group(s) (AR)	
Sediment	24%	94%
In-Stream Habitat	40%	
Riparian Habitat	----	
Water Chemistry	77%	

Table 6. Summary of Combined AR Values for Source Groups for the Gwynns Falls Watershed

Source Group	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Parameter Group(s) (AR)	
Urban	96%	96%
Agriculture		
Barren Land		
Lack of Forest	74%	
Acidity		

Sediment Conditions

BSID analysis results for the Gwynns Falls identified two sediment parameters that have a statistically significant association with poor to very poor stream biological condition: *channel alteration poor, and extensive bar formation present.*

Channel alteration poor was identified as significantly associated with degraded biological conditions in the Gwynns Falls, and found to impact approximately 24% of the stream miles with poor to very poor biological conditions. *Channel alteration poor* measures large-scale modifications in the shape of the stream channel due to the presence of artificial structures (channelization) and/or bar formations. Marginal to poor and poor ratings are expected in unstable stream channels that experience frequent high flows.

Extensive Bar formation present was identified as significantly associated with degraded biological conditions and found in 23% of the stream miles with very poor to poor biological conditions in the Gwynns Falls. This stressor measures the movement of sediment in a stream system, and typically results from significant deposition of gravel and fine sediments and its presence is a metric for the channel alteration rating. Although some bar formation is natural, extensive bar formation indicates channel instability related to frequent and intense high flows that quickly dissipate and rapidly lose the capacity to transport the sediment loads downstream. Excessive sediment loading is expected to reduce and homogenize available feeding and reproductive habitat, degrading biological conditions.

Seventy- nine percent of the Gwynns Falls watershed is comprised of urban land uses. As development and urbanization increased in the Gwynns Falls watershed so did the morphological changes that affect a stream's habitat. The most critical of these environmental changes are those that alter the watershed's hydrologic regime. Increases in impervious surface cover that accompanies urbanization alters stream hydrology, forcing runoff to occur more readily and quickly during rainfall events, thus decreasing the amount of time it takes water to reach streams causing urban streams to be more "flashy" (Walsh et al. 2005). When stormwater flows through stream channels faster, more often, and with more force, the results are stream channel alteration and streambed scouring. The scouring associated with these increased flows leads to accelerated channel erosion, thereby increasing sediment deposition throughout the streambed either through the formation of bars or settling of sediment in the stream substrate.

Some of the impacts associated with erosion and sedimentation smothering the benthic communities, reduced survival rate of fish eggs, and reduced habitat quality from embedding of the stream bottom (Hoffman et al. 2003). All of these processes result in an unstable stream ecosystem that impacts habitat and the dynamics (structure and abundance) of stream benthic organisms (Allan 2004). An unstable stream ecosystem often results in a loss of available habitat from sedimentation, continuous displacement of biological communities from scouring that require frequent re-colonization and the loss of sensitive taxa, with a shift in biological communities to more tolerant species.

The combined AR is used to measure the extent of stressor impact of degraded stream miles, very poor to poor biological conditions, if the sediment stressor were removed. The combined

AR for the sediment stressor group is approximately 24 % suggesting these stressors results in moderate impacts to the degraded stream miles in the Gwynns Falls (Table 5).

In-stream Habitat Conditions

BSID analysis results for the Gwynns Falls identified two in-stream habitat parameters that have a statistically significant association with poor to very poor stream biological condition: *channelization present* and *concrete/gabion present.*

Channelization present was identified as significantly associated with degraded biological conditions and found in 34% of the degraded stream miles in the Gwynns Falls. This stressor measures the presence/absence of channelization in stream banks and its presence is a metric for the channel alteration rating. It describes both the straightening of channels and their fortification with concrete or other hard materials. Channelization inhibits the natural flow regime of a stream resulting in increased flows during storm events that can lead to scouring and, consequently, displacement of biological communities. The resulting bank/channel erosion creates unstable channels and excess sediment deposits downstream.

Concrete/gabion present was identified as significantly associated with degraded biological conditions in the Gwynns Falls, and found to impact approximately 15% of the stream miles with poor to very poor biological conditions. *Concrete/gabion present*, like 'channelized,' inhibits the heterogeneity of stream morphology needed for colonization, abundance, and diversity of fish and benthic communities. Concrete channelization increases flow and provides a homogeneous substrate, conditions which are detrimental to diverse and abundant colonization.

The stressors identified for the in-stream habitat parameter group are intricately linked with habitat heterogeneity. The presence these habitat stressors lower the diversity of a stream's microhabitats and substrates, subsequently causing a reduction in the diversity of biological communities. Channelization has been used in the Gwynns Falls watershed for flood control. The purpose is to increase channel capacity and flow velocities so water moves more efficiently downstream. However, channelization is detrimental for the "well being" of streams and rivers through the elimination of suitable habitat and the creation of excessive flows. Stream bottoms are made more uniform. Habitats of natural streams contain numerous bends, riffles, runs, pools and varied flows, and tend to support healthier and more diversified plant and animal communities than those in channelized streams. The natural structures impacting stream hydrology, which were removed for channelization, also provide critical habitat for stream species and impact nutrient availability in stream microhabitats (Bolton and Schellberg 2001). The refuge cavities removed by channelization not only provide concealment for fish, but also serve as traps for detritus, and are areas colonized by benthic macroinvertebrates. Subsequently, channelized streams retained less leaf litter and supported lower densities of detritivore invertebrates than natural streams. The overall densities and biomasses of macroinvertebrates in channelized streams are very low by comparison with intact natural streams (Laasonen et al. 1998, Haapala & Muotka 1998). Consequently, streams with extensive channelization often have impaired biological community with poor IBI scores is observed.

The combined AR is used to measure the extent of stressor impact of degraded stream miles, very poor to poor biological conditions. The combined AR for the in-stream habitat stressor group is approximately 40 % suggesting these stressors result in impacts to the degraded stream miles in the Gwynns Falls (See Table 5).

Riparian Habitat Conditions

BSID analysis results for Gwynns Falls did not identify any riparian habitat parameters that have statistically significant association with a very poor to poor stream biological condition (i.e., removal of stressors would result in improved biological community).

Water Chemistry

BSID analysis results for the Gwynns Falls identified three water chemistry parameters that have statistically significant association with a very poor to poor stream biological condition (i.e., removal of stressors would result in an improved biological community). These parameters are *high conductivity*, *high chlorides*, and *ammonia acute with salmonid absent.*

High conductivity levels was identified as significantly associated with degraded biological conditions in the Gwynns Falls, and found to impact approximately 76% of the stream miles with poor to very poor biological conditions. Conductivity is a measure of water's ability to conduct electrical current and is directly related to the total dissolved salt content of the water. Most of the total dissolved salts of surface waters are comprised of inorganic compounds or ions such as chloride, sulfate, carbonate, sodium, and phosphate (IDNR 2008). Conductivity and chlorides are closely related. Streams with elevated levels of chlorides typically display high conductivity.

High chloride levels was identified as significantly associated with degraded biological conditions in the Gwynns Falls, and found to impact approximately 76% of the stream miles with very poor to poor biological conditions. High concentrations of chlorides can result from industrial discharges, metals contamination, and application of road salts in urban landscapes. There are no major National Pollutant Discharge Elimination System (NPDES) permitted municipal or industrial discharges in the watershed; however, there are twenty-six minor industrial facilities that are regulated for various parameters. Because NPDES permitting enforcement does not require chloride testing at any of these facilities, data was not available to verify/identify chlorides as a specific pollutant in this watershed. Since there is no metals impairment, application of road salts in the watershed is a likely source of the chlorides and high conductivity levels. Although chloride can originate from natural sources, most of the chloride that enters the environment is associated with the storage and application of road salt. A significant portion of the mainstem of Gwynns Falls parallels Interstate 695 (Baltimore Beltway), which is one of the primary transportation routes in and around Baltimore City. According to Church and Friesz (1993), road salt accumulation and persistence in watersheds poses risks to aquatic ecosystems and to water quality. Approximately 55% of road-salt

chlorides are transported in surface runoff, with the remaining 45% infiltrating through soils and into groundwater aquifers.

Elevated *ammonia acute with salmonid absent* levels was identified as significantly associated with degraded biological conditions in the Gwynns Falls, and found to impact approximately 15% of the stream miles with very poor to poor biological conditions. Two of the twelve MBSS sites displayed exceedence in acute ammonia threshold concentrations. Elevated levels of ammonia can result from industrial discharges, agriculture, atmospheric deposition, and household applications. There are no major NPDES permitted municipal or industrial discharges in the watershed; however, there are twenty-six minor industrial facilities that are regulated for various parameters with zero of the twenty-six permits discharging into the stream segments displaying exceedence in ammonia. Atmospheric deposition would result in more MBSS sites showing elevated ammonia levels than the current two. Detailed analysis of the land use surrounding the two MBSS sites discounts agricultural land use as a potential source of ammonia. Since both sites are located in areas with high proportions of low density urban land use, leaking infrastructure and/or failing septic systems (household applications) could possibly be the source of localized elevated levels of ammonia in the streams. The two sites exceeding acute ammonia tolerances are located in the headwaters of their perspective streams and MBSS sites further down stream show no ammonia tolerance exceedence.

In summary, water chemistry is another major determinant of the integrity of surface waters that is strongly influenced by land-use. Land development within the Gwynns Falls watershed has lead increases in contaminant loads from point and nonpoint sources by adding sediments, nutrients, road salts, toxics, petroleum products, and inorganic pollutants to surface waters. Increased levels of many pollutants like chlorides can be toxic to aquatic organisms and lead to exceedences in species tolerances. The BSID analysis results identified acute ammonia as having a statistically significant association with degraded biological condition in Gwynns Falls. There were two sites exceeding acute ammonia tolerances, which are located in the headwaters of their perspective streams, however MBSS sites further down stream show no ammonia tolerance exceedence. There are no exceedences of any numeric water quality criteria for nutrient impairment (Dissolved Oxygen (D.O.) & pH) within the watershed.

The combined AR is used to measure the extent of stressor impact of degraded stream miles, very poor to poor biological conditions. The combined AR for the water chemistry stressor group is approximately 77% suggesting that these stressors results in impacts to the degraded stream miles in Gwynns Falls (See Table 5).

Currently in Maryland there are no specific numeric criteria that quantify the impact of conductivity and chlorides on the aquatic health of non-tidal stream systems. Since the exact sources and extent of inorganic pollutant loadings are not known, MDE determined that current data are not sufficient to enable identification of the specific pollutant(s) from the array of potential inorganic pollutants inferred from the BSID analysis.

Sources

All eight stressor parameters, identified in Tables 1-3, that are significantly associated with biological degradation in the Gwynns Falls watershed BSID analysis are representative of impacts from urban landscapes. The scientific community (Booth 1991, Konrad and Booth 2002, and Meyer et al. 2005) has consistently identified negative impacts to biological conditions as a result of increased urbanization. A number of systematic and predictable environmental responses have been noted in streams affected by urbanization, and this consistent sequence of effects has been termed "urban stream syndrome" (Meyer et al. 2005). Symptoms of urban stream syndrome include flashier hydrographs, altered habitat conditions, degradation of water quality, and reduced biotic richness, with increased dominance of species tolerant to anthropogenic (and natural) stressors.

Increases in impervious surface cover that accompany urbanization alter stream hydrology, forcing runoff to occur more readily and quickly during rainfall events, decreasing the time it takes water to reach streams and causing them to be more "flashy" (Walsh et al. 2005). Land development can also cause an increase in contaminant loads from point and nonpoint sources. In virtually all studies, as the amount of impervious area in a watershed increases, fish and benthic communities exhibit a shift away from sensitive species to assemblages consisting of mostly disturbance-tolerant taxa (Walsh et al. 2005).

The BSID source analysis (Table 4) identifies various types of urban land uses as potential sources of stressors that may cause negative biological impacts. The combined AR for the source group is approximately 77% suggesting that urban development potentially impact almost all the degraded stream miles in Gwynns Falls (See Table 6).

Summary

Land use in the Gwynns Falls Watershed ranges from a mixture of uses in the upper sections to high percentages of industrial, residential, and other impervious surfaces in the middle and southern sections. By 1994, the watershed had 5.1% agricultural land, 18.1% forested land and 75.8% developed land. Most significantly, 42.2% of the land in the watershed was covered with impervious surface (GFWA 2008). The BSID analysis results suggest that degraded biological communities in the Gwynns Falls watershed are a result of increased urban land use causing channelization and alterations to hydrologic regime. The channelization and altered hydrology has caused frequent high flow events, degradation to in-stream habitat quality, and increased sediment loads, resulting in an unstable stream ecosystem that eliminates optimal habitat.

Due to the increased proportions of urban land use in the Gwynns Falls, the watershed has experienced an increase in contaminant loads from point and nonpoint sources, resulting in levels of inorganic pollutants that can potentially be extremely toxic to aquatic organisms. Alterations to the hydrologic regime, sedimentation, physical habitat, and water chemistry, have all combined to degrade the Gwynns Falls, leading to a loss of diversity in the biological community. The combined AR for all the stressors is approximately 94%, suggesting that sediment, in-stream habitat and water chemistry stressors identified in the BSID analysis would adequately account for the biological impairment in the Gwynns Falls watershed (See Table 5).

The BSID analysis evaluates numerous key stressors using the most comprehensive data sets available that meet the requirements outlined in the methodology report. It is important to recognize that stressors could act independently or act as part of a complex causal scenarios (e.g., eutrophication, urbanization, habitat modification). Also, uncertainties in the analysis could arise from the absence of unknown key stressors and other limitations of the principal data set. The results are based on the best available data at the time of evaluation.

Final Causal Model for the Gwynns Falls

Causal model development provides a visual linkage between biological condition, habitat, chemical, and source parameters available for stressor analysis. Models were developed to represent the ecologically plausible processes when considering the following five factors affecting biological integrity: biological interaction, flow regime, energy source, water chemistry, and physical habitat (Karr, 1991 and USEPA 2007). The five factors guide the selections of available parameters applied in the BSID analyses and are used to reveal patterns of complex causal scenarios. Figure 6 illustrates the final causal model for the Gwynns Falls, with pathways bolded or highlighted to show the watershed's probable stressors as indicated by the BSID analysis.

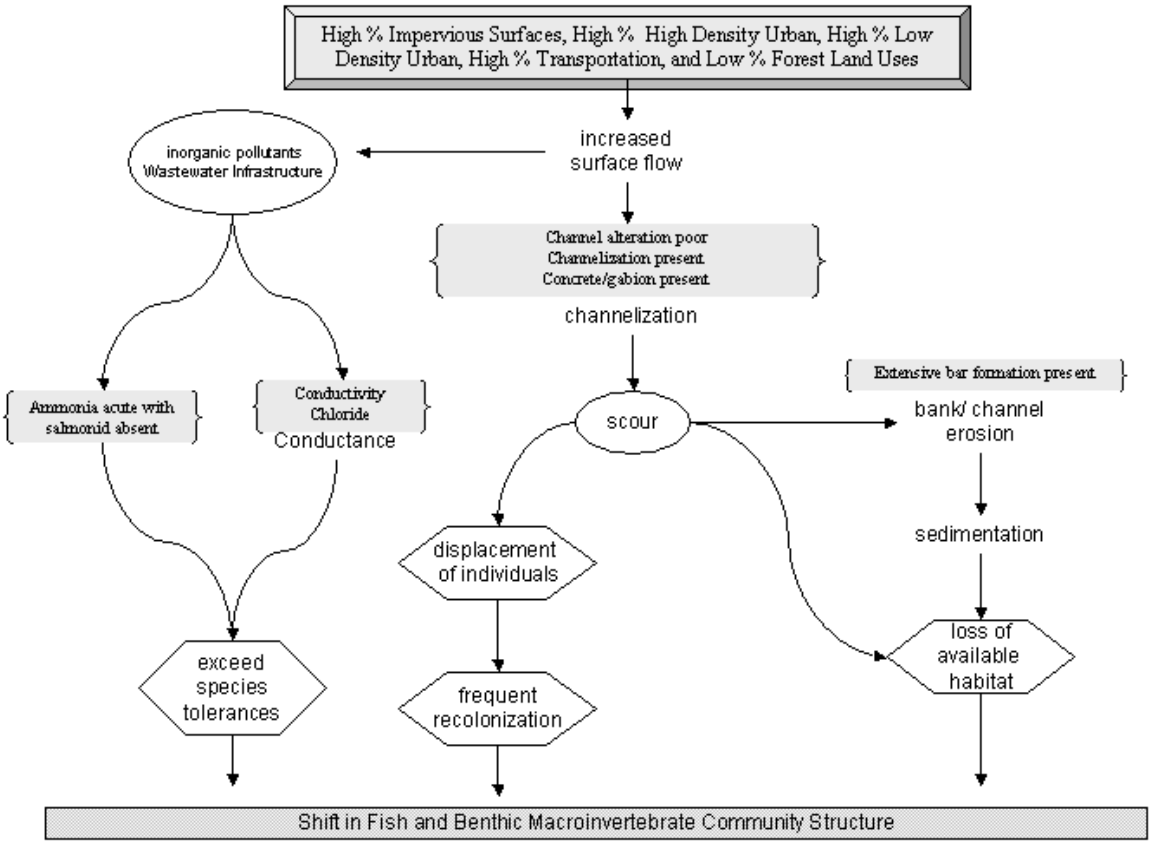


Figure 6. Final Causal Model for the Gwynns Falls

5.0 Conclusions

Data suggest that the Gwynns Falls watershed's biological communities are strongly influenced by urban land use, which alters the hydrologic regime resulting in increased erosion, sediment, and inorganic pollutant loading. There is an abundance of scientific research that directly and indirectly links degradation of the aquatic health of streams to urban landscapes, which often cause flashy hydrology in streams and increased contaminant loads from runoff. Based upon the results of the BSID analysis, the probable causes and sources of the biological impairments of the Gwynns Falls watershed are summarized as follows:

- The BSID analysis has determined that the biological communities are likely degraded due to inorganic pollutants (i.e., chlorides and conductivity). Inorganic pollutants levels are significantly associated with degraded biological conditions and found in approximately 76% of the stream miles with very poor to poor biological conditions in the Gywnns Falls watershed. Impacts on water quality due to conductivity and chloride are dependent on prolonged exposure; future monitoring of these inorganic pollutants will help in determining the spatial and temporal extent of this impairment in the watershed. Impervious surfaces and urban runoff cause an increase in contaminant loads from point and nonpoint sources by delivering an array of inorganic pollutants to surface waters. Currently, there is a lack of monitoring data for many of these substances; therefore, additional monitoring of priority inorganic pollutants is needed to more precisely determine the specific cause(s) of impairment.
- The BSID analysis has determined that the biological communities in Gwynns Falls are also likely degraded due to flow/sediment related stressors. Specifically, altered hydrology and increased runoff from urban impervious surfaces have resulted in channel erosion and subsequent elevated suspended sediment transport through the watershed, which are in turn the probable causes of impacts to biological communities. The BSID results thus confirm the 1996 Category 5 listing for total suspended solids as an impairing substance in Gwynns Falls, and link this pollutant to biological conditions in these waters.
- The BSID analysis has identified one water chemistry stressor present (ammonia) at two sites showing a possible association with degraded biological conditions. A more intensive analysis of all available data is recommended to determine if there is an ammonia toxicity impairment in the Gwynns Falls watershed.
- Although there is presently a Category 5 listing for phosphorus in Maryland's 2008 Integrated Report, the BSID analysis did not identify any nutrient stressors (i.e., total nitrogen, total phosphorus, dissolved oxygen, etc.) present and/or nutrient stressors showing a significant association with degraded biological conditions.

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APPENDIX J:

Water Quality Analysis of Eutrophication for the Gwynns Falls Watershed

Water Quality Analysis of Eutrophication for the Gwynns Falls Watershed in Baltimore County and Baltimore City, Maryland

FINAL

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Table of Contents

List of Figures i
List of Tables i
List of Abbreviations ii
EXECUTIVE SUMMARY iii
1.0 INTRODUCTION 1
2.0 GENERAL SETTING 2
3.0 WATER QUALITY CHARACTERIZATION 6
3.1 Dissolved Oxygen 8
3.2 Chlorophyll *a* 9
3.3 Nutrients 11
3.4 Biological Stressor Identification Analysis 13
4.0 CONCLUSION 14
REFERENCES 15
Appendix A – Tabular Water Quality Data A1

List of Figures

Figure 1: Location Map and Monitoring Stations of the Lower North Branch Patapsco River Watershed 4
Figure 2: Land Use of the Lower North Branch Patapsco River Watershed 5
Figure 3: Lower North Branch Patapsco River Dissolved Oxygen Data for Growing Season Periods May 1999 through October 2007 9
Figure 4: Lower North Branch Patapsco River Chlorophyll *a* Data for Growing Season Periods May 1999 through October 2007 11
Figure 5: Lower North Branch Patapsco River Total Nitrogen Data from May 1999 through October 2007 12
Figure 6: Lower North Branch Patapsco River Total Phosphorus Data from May 1999 through October 2007 13

List of Tables

Table 1: Water Quality Stations in Gwynns Falls Watershed Monitored During 1998-2007 7
Table A-1: MDE Water Quality Data A1
Table A-2: DNR Water Quality Data A9
Table A-3: MBSS Water Quality Data A12

List of Abbreviations

BOD	Biochemical Oxygen Demand
BSID	Biological Stressor Identification
CES	Coastal Environmental Services
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
DNR	Department of Natural Resources
DO	Dissolved Oxygen
EPA	United States Environmental Protection Agency
MBSS	Maryland Biological Stream Survey
MDE	Maryland Department of the Environment
MDP	Maryland Department of Planning
mg/l	Milligrams Per Liter
mi^2	Square Miles
NPDES	National Pollution Discharge Elimination System
NRCS	National Resources Conservation Service
SCS	Soil Conservation Service
SSURGO	Soil Survey Geography
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSI	Trophic State Index
USGS	United States Geological Survey
WQLS	Water Quality Limited Segment
µg/l	Micrograms Per Liter

EXECUTIVE SUMMARY

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS listed on the *Integrated Report of Surface Water Quality in Maryland (Integrated Report)*, the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate that water quality standards are being met (CFR 2007).

Gwynns Falls (assessment unit ID: MD-02130905) was identified on the State of Maryland's *Integrated Report* as impaired by nutrients, sediments (1996 listings), bacteria (fecal coliform), and impacts to biological communities (2002 listings). The designated uses for Gwynns Falls are as follows: Gwynns Falls and tributaries above Reisterstown Road, and Red Run and its tributaries – Use III (Nontidal Cold Water); Dead Run and tributaries – Use IV (Recreational Trout Waters); and all remaining waters – Use I (Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life). See Code of Maryland Regulations (COMAR) 26.08.02.08K(3)(e) & (5)(e). A TMDL was completed in 2006 to address the bacteria listing. The 1996 nutrients listing was refined in the 2008 Integrated Report and phosphorus was identified as the specific impairing substance. Consequently, for the purpose of this report the terms nutrients and phosphorus will be used interchangeably. A TMDL for sediment is scheduled to be submitted to the EPA in 2009, and the listing for impacts to biological communities will be addressed separately at a future date.

A data solicitation for information pertaining to pollutants, including nutrients, in the Gwynns Falls basin (as part of a data solicitation for the Patapsco River basin) was conducted by MDE in November 2007, and all readily available data from the past five years have been considered. Currently, there are no specific numeric criteria for nutrients in Maryland's water quality standards. Nutrients typically do not have a direct impact on aquatic life; rather, they mediate impacts through excessive algal growth leading to low dissolved oxygen. Therefore, the evaluation of potentially eutrophic conditions due to nutrient over-enrichment will be based on whether nutrient-related parameters (i.e., dissolved oxygen levels and chlorophyll *a* concentrations) are found to impair designated uses in the Gwynns Falls (in this case, protection of aquatic life and wildlife, fishing, and swimming).

Recently, MDE developed a biological stressor identification (BSID) methodology to identify the most probable cause(s) of the existing biological impairments in Maryland 8-digit watersheds based on the suite of available physical, chemical, and land use data (MDE 2009a). The BSID analysis for the Gwynns Falls indicates inorganic pollutants, ammonia toxicity, and flow/sediment stressors are associated with impacts to biological communities; these findings will be addressed separately. The BSID analysis did not identify any nutrient stressors present and/or nutrient stressors showing a significant association with degraded biological conditions (MDE 2009b). The results of the BSID study, combined with the analysis of recent water quality data presented in this report, indicate that the Gwynns Falls is not being impaired by nutrients.

This WQA supports the conclusion that a TMDL for nutrients is not necessary to achieve water quality standards in the Gwynns Falls.

Although the waters of the Gwynns Falls do not display signs of eutrophication, the State reserves the right to require future controls if evidence suggests that nutrients from the basin are contributing to downstream water quality problems. In December 2007, EPA approved TMDLs of nitrogen and phosphorus for the Baltimore Harbor. The Gwynns Falls watershed is located upstream of the Baltimore Harbor and drains into the Harbor's tidal waters. Although the amount of nutrients entering the Gwynns Falls is not causing localized impairments, it is contributing to the eutrophication of the downstream tidal waters of the Harbor. Therefore, the TMDL for the Baltimore Harbor requires nutrient reductions in the Gwynns Falls necessary to meet water quality standards in the Harbor. On the same principle, additional reductions may also be required by the forthcoming Chesapeake Bay TMDL, currently under development and due to be established by EPA by the end of 2010.

Barring the receipt of contradictory data, this report will be used to support a revision of the phosphorus listing for the Gwynns Falls watershed, from Category 5 ("waterbody is impaired, does not attain the water quality standard, and a TMDL is required") to Category 2 ("waterbodies meeting some [in this case nutrients-related] water quality standards, but with insufficient data to assess all impairments") when MDE proposes the revision of the *Integrated Report*.

1.0 INTRODUCTION

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS listed on the *Integrated Report of Surface Water Quality in Maryland (Integrated Report)*, the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate that water quality standards are being met (CFR 2007).

A segment identified as a WQLS may not require the development and implementation of a TMDL if more recent information invalidates previous findings. The most common factual scenarios obviating the need for a TMDL are: 1) analysis of more recent data indicating that the impairment no longer exists (i.e., water quality standards are being met); 2) results of a more recent and updated water quality modeling which demonstrates that the segment is attaining standards; 3) refinements to water quality standards or to the interpretation of those standards accompanied by analysis demonstrating that the standards are being met; or 4) identification and correction of errors made in the initial listing.

Gwynns Falls (Assessment Unit ID: MD-02130905) was identified in the *Integrated Report* as impaired by nutrients, sediments (1996 listings), bacteria (fecal coliform), and impacts to biological communities (2002 listings) (MDE, 2008a). The designated uses for Gwynns Falls are as follows: Gwynns Falls and tributaries above Reisterstown Road, and Red Run and its tributaries – Use III (Nontidal Cold Water); Dead Run and tributaries – Use IV (Recreational Trout Waters); and all remaining waters – Use I (Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life). See Code of Maryland Regulations (COMAR) 26.08.02.08K(3)(e) & (5)(e). A TMDL was completed in 2006 to address the bacteria listing. The 1996 nutrients listing was refined in the 2008 *Integrated Report* and phosphorus was identified as the specific impairing substance. Consequently, for the purpose of this report the terms nutrients and phosphorus will be used interchangeably. A TMDL for sediment is scheduled to be submitted to the EPA in 2009, and the listing for impacts to biological communities will be addressed separately at a future date.

This report provides an analysis of recent data that supports the removal of the nutrients (phosphorus) listing for the Gwynns Falls watershed when MDE proposes the revision of the State's *Integrated Report*. The remainder of this report lays out the general setting of the Gwynns Falls watershed area and presents a discussion of the water quality characteristics in the basin in terms of the existing water quality standards relating to nutrients. This analysis supports the conclusion that the waters of the Gwynns Falls watershed do not display signs of eutrophication or nutrient over-enrichment.

2.0 GENERAL SETTING

Location

The Gwynns Falls watershed is located in the Patapsco River Basin within Maryland (see Figure 1). The watershed encompasses 41,710 acres (61 square miles) in Baltimore City and Baltimore County, Maryland. The headwaters of the Gwynns Falls begin in Glyndon, Maryland and flows southeast until its confluence with the Middle Branch of the Patapsco River near downtown Baltimore. Five major tributaries of the Gwynns Falls, listed north to south, include: Red Run, Horsehead Branch, Scotts Level Branch, Dead Run, and Maidens Choice Creek.

Geology/Soils

The Gwynns Falls watershed lies within the Piedmont and Atlantic Coastal Plain Provinces of Central Maryland. The Piedmont Province is characterized by gentle to steep rolling topography, low hills and ridges. The surface geology is characterized by metamorphic crystalline rocks consisting primarily of schist and gneiss. These formations are resistant to short-term erosion and often determine the limits of stream bank and streambed. These crystalline formations decrease in elevation from northwest to southeast and eventually extend beneath the younger sediments of the Coastal Plain. The fall line represents the transition between the Atlantic Coastal Plain Province and the Piedmont Province. The Atlantic Coastal Plain surface geology is characterized by thick, unconsolidated marine sediments deposited over the crystalline rock of the piedmont province. The deposits include clays, silts, sands and gravels. In the areas around the head of tide, the topography is flat, with elevations below 100 feet. The elevations steadily increase going north to approximately 600 feet in the headwaters. Streambeds throughout the basin are comprised of rock and rubble with gradually sloped stream banks.

The Gwynns Falls watershed lies predominantly in the Baile and Lehigh soil series. The Lehigh soil series consists of somewhat poorly drained to moderately well-drained, rather shallow soils. The Baile soil series consists of deep, poorly drained, nearly level to gently sloping, dominantly gray soils of the Piedmont Plateau. Baile soils have a high available moisture capacity and a water table that is seasonally at or near the surface (U.S. Department of Agriculture (USDA), 1995).

Land Use

The 2002 Maryland Department of Planning (MDP) land use/land cover data show that the Gwynns Falls watershed is primarily a residential and commercial region. The watershed contains 33,100 acres of residential land use and commercial land use. Forest lands account for 7,068 acres of the watershed, found primarily along the mainstem and tributaries of Gwynns Falls. A small portion of the watershed, 1,738 acres, consists of crops and pasture lands. The land use spatial distributions for each land use are presented in Figure 2.

Point Sources

There are no municipal or industrial point source facilities with permits regulating their discharges in the Gwynns Falls watershed.

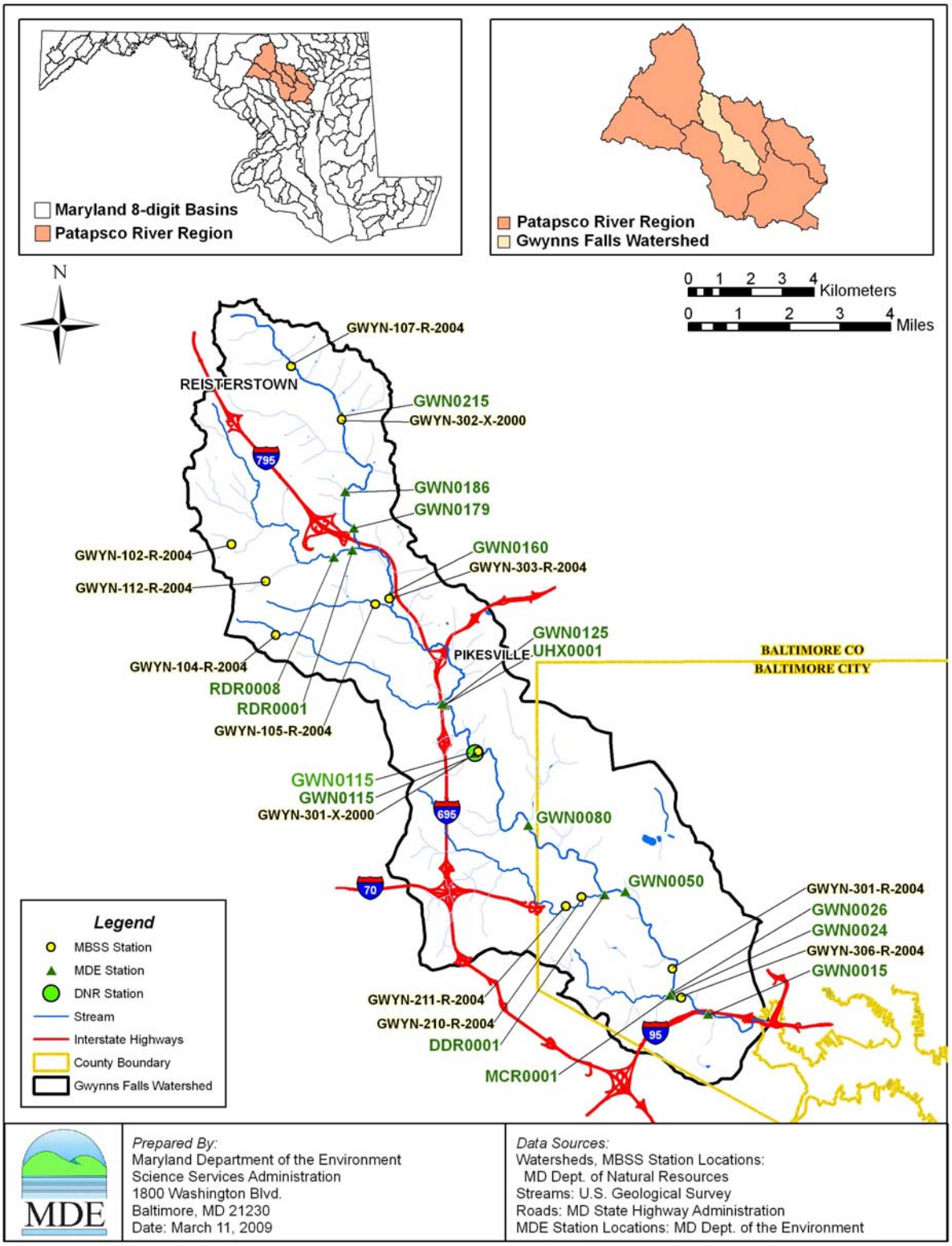

Figure 1: Location Map and Monitoring Stations of the Gwynns Falls Watershed

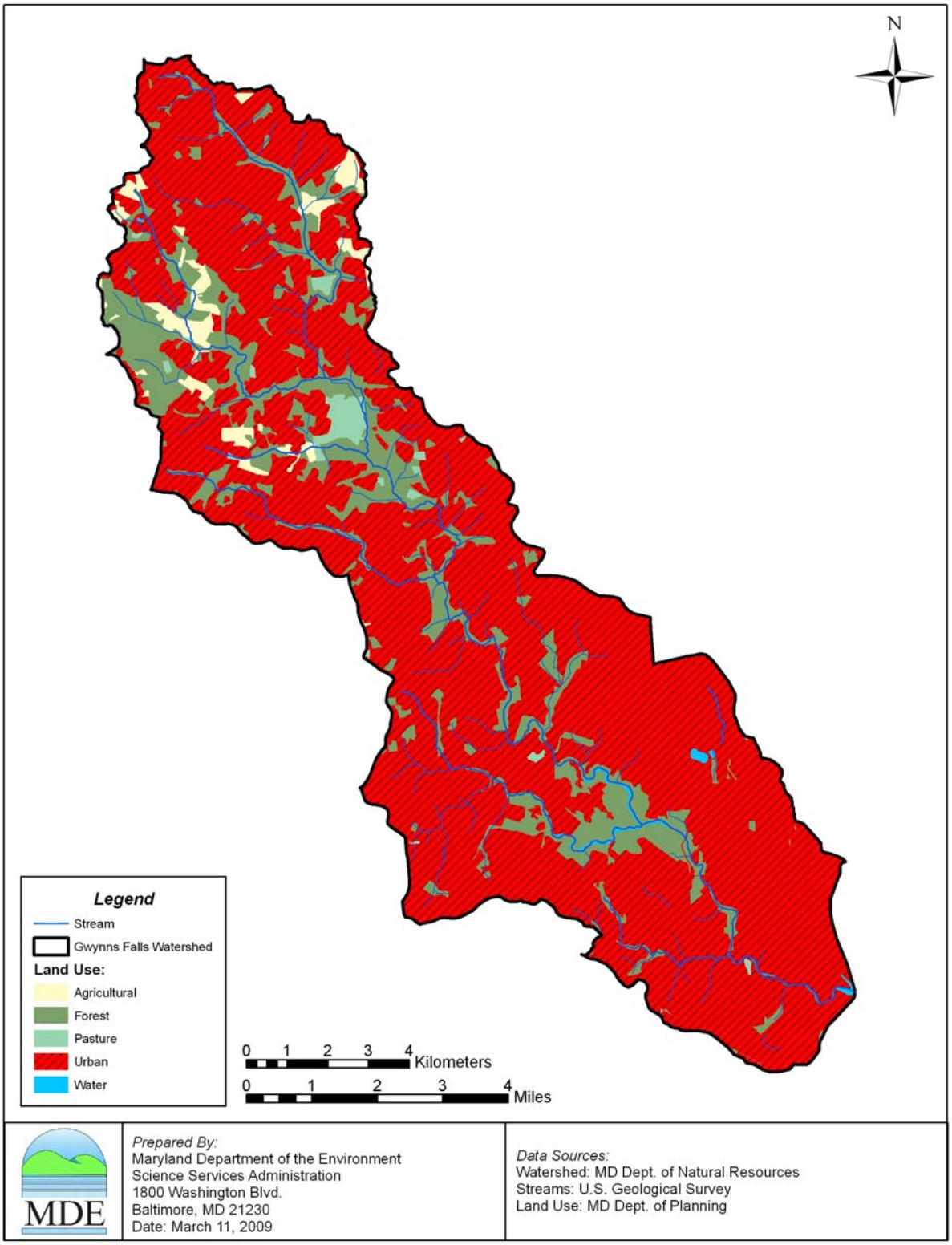

Figure 2: Land Use of the Gwynns Falls Watershed

3.0 WATER QUALITY CHARACTERIZATION

The Maryland Surface Water Use Designation for Gwynns Falls are as follows: Gwynns Falls and tributaries above Reisterstown Road, and Red Run and its tributaries – Use III (Non-tidal Cold Water); Dead Run and tributaries – Use IV (Recreational Trout Waters); and all remaining waters – Use I (Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life) (COMAR 26.08.02.08K(3)(e) & (5)(e)). A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include support of aquatic life, primary or secondary contact recreation, drinking water supply, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. The criteria developed to protect the designated use may differ and are dependent on the specific designated use(s) of a waterbody.

Currently, there are no specific numeric criteria for nutrients in Maryland's water quality standards. Therefore, the evaluation of potentially eutrophic conditions due to nutrient over-enrichment will be based on whether nutrient-related parameters (i.e., dissolved oxygen levels and chlorophyll *a* concentrations) are found to impair designated uses in the Gwynns Falls. The dissolved oxygen (DO) concentration to protect Use I and Use IV waters "may not be less than 5 milligrams per liter (mg/l) at any time" (COMAR 26.08.02.03-3A(2)). The DO concentration to protect Use III waters may not be less than 5 milligrams/liter at any time, with a minimum daily average of not less than 6 milligrams/liter " (COMAR 26.08.02.03-3D(2)). The water quality data presented in this section will show that DO concentrations in the Gwynns Falls and its tributaries meet these criteria, and that Maryland's narrative criteria for chlorophyll *a* are also met.

In addition to the DO and chlorophyll *a* data analysis, the results of a new biological stressor identification (BSID) analysis demonstrate that any biological impairment in the watershed is not caused by nutrient enrichment. Instead, the analysis suggests that the degradation to biological communities in the Gwynns Falls is strongly associated with the extensive urban nature of the watershed, which results in altered hydrology and elevated levels of ammonia[1], chlorides, and conductivity (a measure of the presence of dissolved substances) (MDE 2009b).

A data solicitation was conducted in 2007. All readily available water quality data from the past five years have been considered for this analysis. Water quality data from MDE surveys conducted along the Gwynns Falls from October 1999 through August 2000, October 2002 through December 2005, and January 2007 through December 2007, were used. Maryland Department of Natural Resources (DNR) data used in the analysis were from January 1998 through June 2007. Data from Maryland Biological Stream Survey (MBSS) sampling conducted in April 2000, and March 2004, were also used. Table 2 lists the water quality monitoring stations in the Gwynns Falls watershed with their geographical coordinates. Figures 3 through 6 provide graphical representation of the collected data for the parameters discussed below.

[1] Ammonia is a nitrogen nutrient species which, in excessive amounts has potential toxic effects on aquatic life. Maryland has numeric toxic substance criteria for ammonia for the protection of fresh water aquatic life (COMAR 26.08.02.03-2(H).

Table 3.1: Water Quality Stations in Gwynns Falls Watershed Monitored During 1998-2007

Station ID	Agency/Program	Latitude (Decimal-Degrees)	Longitude (Decimal-Degrees)
GWN0015	MDE	39.271	-76.648
GWN0215	MDE	39.443	-76.783
DDR0001	MDE	39.305	-76.686
GWN0024	MDE	39.269	-76.662
GWN0026	MDE	39.277	-76.662
GWN0050	MDE	39.306	-76.679
GWN0080	MDE	39.325	-76.715
GWN0125	MDE	39.360	-76.745
GWN0160	MDE	39.392	-76.765
GWN0179	MDE	39.411	-76.779
GWN0186	MDE	39.421	-76.782
MCR0001	MDE	39.276	-76.662
RDR0001	MDE	39.405	-76.779
RDR0008	MDE	39.402	-76.786
UHX0001	MDE	39.360	-76.746
GWN0115	DNR/MDE	39.343	-76.726
GWYN-102-R-2004	DNR/MBSS	39.400	-76.820
GWYN-104-R-2004	DNR/MBSS	39.380	-76.800
GWYN-105-R-2004	DNR/MBSS	39.380	-76.770
GWYN-107-R-2004	DNR/MBSS	39.450	-76.800
GWYN-112-R-2004	DNR/MBSS	39.390	-76.810
GWYN-210-R-2004	DNR/MBSS	39.300	-76.690
GWYN-211-R-2004	DNR/MBSS	39.300	-76.700
GWYN-301-R-2004	DNR/MBSS	39.280	-76.660
GWYN-301-X-2000	DNR/MBSS	39.340	-76.730
GWYN-302-X-2000	DNR/MBSS	39.440	-76.780
GWYN-303-R-2004	DNR/MBSS	39.390	-76.760
GWYN-306-R-2004	DNR/MBSS	39.270	-76.650

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 Gwynns Falls watershed designated as Tier II are listed in Table 2.1.

Table 2.1: High Quality (Tier II) Waters in the Loch Raven Reservoir Watershed

Tier II Segment	County	Segment Length (miles)
Red Run 1	Baltimore	1.63

3.1 Dissolved Oxygen

DNR samples were taken in the Gwynns Falls from January 1998 through June 2007. MDE samples were taken from October 1999 through August 2000, October 2002 through December 2005, and January 2007 through December 2007, and MBSS samples were taken in April 2000, and March 2004. Samples taken during the growing season (May through October) show DO concentrations ranging from 5.4 to 11.8 mg/l, all above the DO criterion for Use I waters of 5 mg/l. There is one monitoring station located in Dead Run (DDR0001), a tributary of the Gwynns Falls designated as Use IV. All four samples at this station have DO concentrations above the Use IV criterion of 5 mg/l, with a lowest value of 5.4 mg/l. Gwynns Falls and its tributaries above Reisterstown Road are designated as Use III. Monitoring Stations located above Reisterstown Road are: GWN0179, GWN0186, GWN0215, GWYN107-X and GWYN302-R. In addition, Red Run and its tributaries are designated as Use III. Stations located in Red Run are: RDR0001 and RDR0008. All samples at these seven monitoring stations have DO concentrations above the Use III daily average criterion of 6 mg/l. DO concentrations at these stations located above Reisterstown Road are between 6.6 and 10.9 mg/l. DO data are presented graphically in Figure 3 and in tabular form in Appendix A. The water quality standard for DO is being met in the Gwynns Falls watershed.

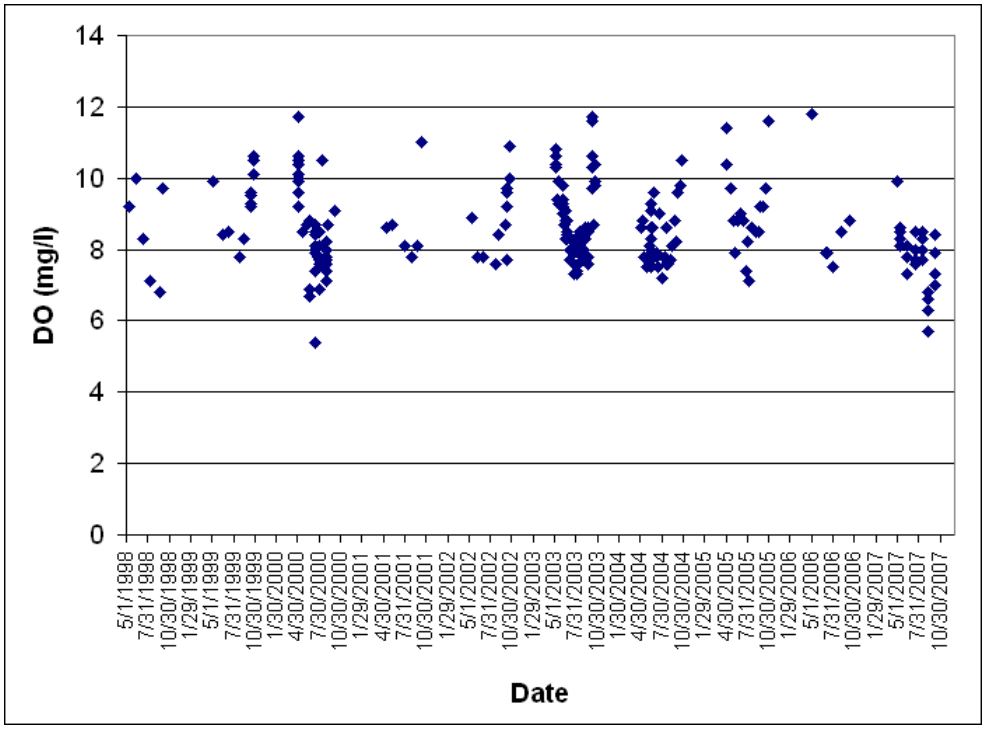

Figure 3: Gwynns Falls Dissolved Oxygen Data for Growing Season Periods May 1999 through October 2007

3.2 Chlorophyll *a*

Currently, Maryland water quality standards do not specify numeric criteria for chlorophyll *a*. However, pollution of waters of the State by any material in amounts sufficient to create a nuisance or interfere with designated uses is prohibited (COMAR 26.08.02.03B(2)). Elevated chlorophyll *a* concentrations, a measure of algal growth, may indicate poor water quality that cannot support a waterbody's designated uses and may constitute a nuisance condition. Nuisance levels of algae can interfere with uses related to recreational activities such as fishing, boating, and aesthetic appreciation. High chlorophyll *a* levels can also present taste, odor, and treatment problems in water supply systems.

Narrative water quality criteria are an important component of the State's water quality standards, but are difficult to incorporate into quantitative water quality or TMDL analyses. In the case of free-flowing non-tidal waters, there is an insufficient understanding of the relationship between chlorophyll *a* concentrations and the waterbody's designated use impairment. However, COMAR includes narrative criteria for acceptable chlorophyll *a* levels in tidal waters. Maryland's numeric interpretation of these criteria for application in estuarine waters, adapted from previously approved nutrient TMDLs, is as follows:

> The chlorophyll *a* concentration goal used by the State in estuarine TMDL analyses is based on guidelines set forth by Thomann and Mueller (1987) and by the EPA Technical

> Guidance Manual for Developing Total Maximum Daily Loads, Book 2, Part 1 (1997). The chlorophyll *a* narrative criterion (COMAR 26.08.02.03-3C(10)) states: "Chlorophyll *a* - Concentrations of chlorophyll *a* in free-floating microscopic aquatic plants (algae) shall not exceed levels that result in ecologically undesirable consequences that would render tidal waters unsuitable for designated uses." The Thomann and Mueller guidelines acknowledge that "'Undesirable levels of phytoplankton [chlorophyll *a*] vary considerably depending on water body." MDE has determined, per Thomann and Mueller, that it is acceptable to maintain chlorophyll *a* concentrations below a maximum of 100 µg/L, and to target, with some flexibility depending on waterbody characteristics, a 30-day rolling average of approximately 50 µg/L (with some flexibility depending on waterbody characteristics). (MDE 2006)

Maryland has also developed guidelines for application of the narrative criteria in drinking water reservoirs. The guidelines, adapted from previously approved TMDLs, are as follows:

> The chlorophyll *a* endpoints selected for public water supply reservoirs are (a) a ninetieth-percentile instantaneous concentration not to exceed 30 µg/l in the surface layers, and (b) a 30-day moving average concentration not to exceed 10 µg/l in the surface layers. The concentration of 10 µg/l corresponds to a score of approximately 53 on the Carlson's Trophic State Index (TSI). This is at the boundary of mesotrophic and eutrophic conditions, which is an appropriate trophic state at which to manage these reservoirs. Mean chlorophyll *a* concentrations exceeding 10 µg/l are associated with peaks exceeding 30 µg/l, which in turn are associated with a shift to blue-green assemblages, which present taste, odor and treatment problems (Walker 1984). Achieving these chlorophyll *a* endpoints should thus safeguard such reservoirs from nuisance algal blooms. (MDE 2008b)

Using the chlorophyll *a* targets for tidal waters and public water supply reservoirs described above as screening values for non-tidal waters, the following data analysis reflects an absence of excessive algal growth in the Gwynns Falls, as indicated by low chlorophyll *a* concentrations in comparison with those values.

DNR and MDE monitoring data in the Gwynns Falls show growing season (May through October) averages, by station, between 1.03 and 2.88 µg/l. These samples show observed chlorophyll *a* concentrations ranging from 0.21 and 14.95 µg/l, with only 2 samples (out of 182) above 10 µg/l. These monitoring data values suggest that chlorophyll *a* concentrations any nuisance issues due to nutrients in the Gwynns Falls or interfering with its designated uses.

The chlorophyll *a* data are presented graphically in Figure 4 and in tabular form in Appendix A.

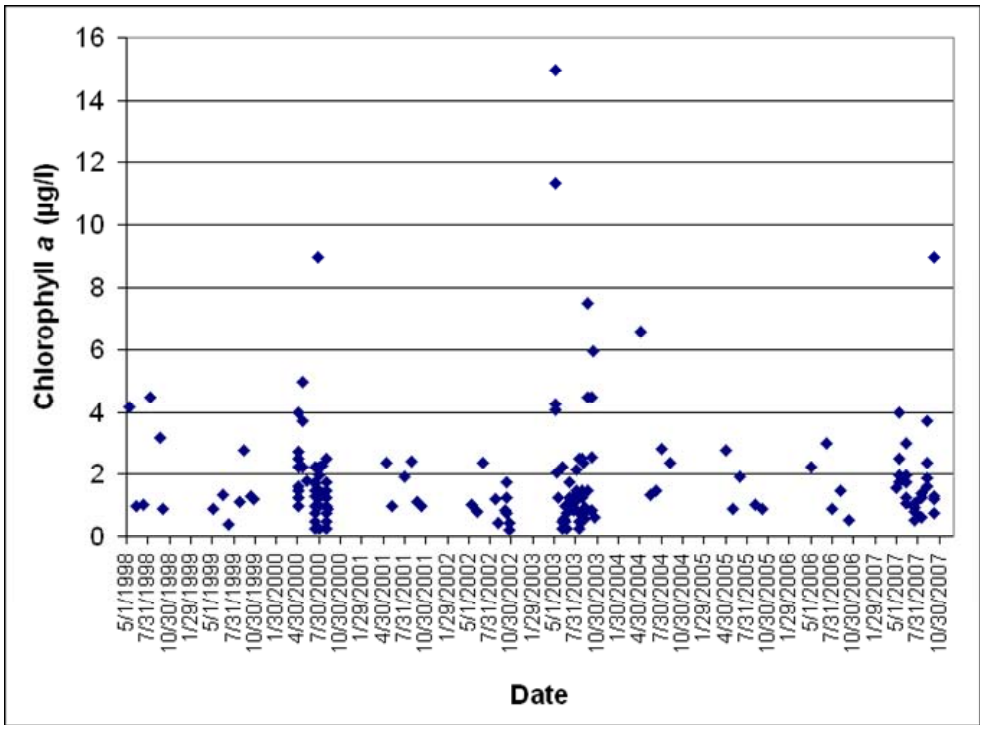

Figure 4: Gwynns Falls Chlorophyll *a* Data for Growing Season Periods May 1999 through October 2007

3.3 Nutrients

In the absence of State water quality standards with specific numeric limits for nutrients, evaluation of potentially eutrophic conditions is based on whether nutrient-related parameters (i.e., dissolved oxygen levels and chlorophyll *a* concentrations) are found to impair the designated uses in the Gwynns Falls (in this case protection of aquatic life and wildlife, fishing, and swimming). Consequently, the nutrients data presented in this section are for informational purposes only.

Total nitrogen (TN) and total phosphorus (TP) data for the Gwynns Falls have been collected as part of this study and the results are presented here for informational purposes, graphically in Figures 5 and 6, and in tabular form in Appendix A. In general, DNR, MDE, and MBSS data show TN concentrations during the growing season (May through October) ranging from 0.89 to 4.39 mg/l and TP concentrations ranging from 0.006 to 0.36 mg/l.

In the absence of specific numeric criteria to assess the TP and TN monitoring data results, MDE evaluated these results using its BSID methodology, which compared Gwynns Falls parameters to the results from similar control sites (i.e., watersheds with no biological impairments) and concluded that nutrients are not likely stressors associated with the degraded biological conditions (MDE 2009b). Current DO conditions in the Gwynns Falls further support this conclusion.

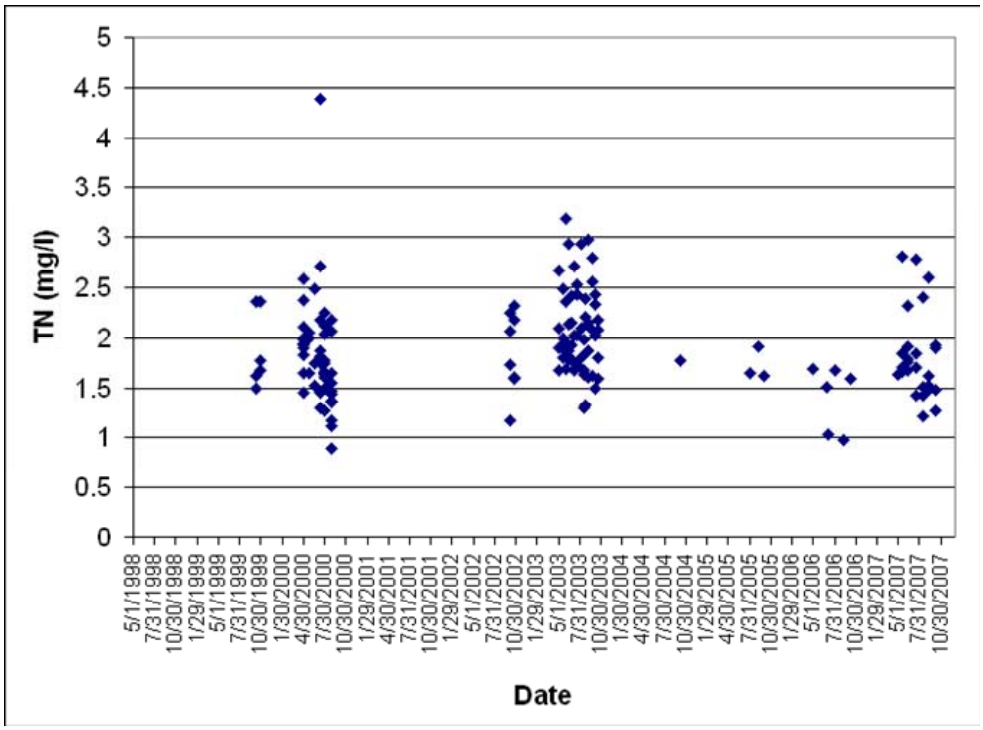

Figure 5: Gwynns Falls Total Nitrogen Data from May 1999 through October 2007

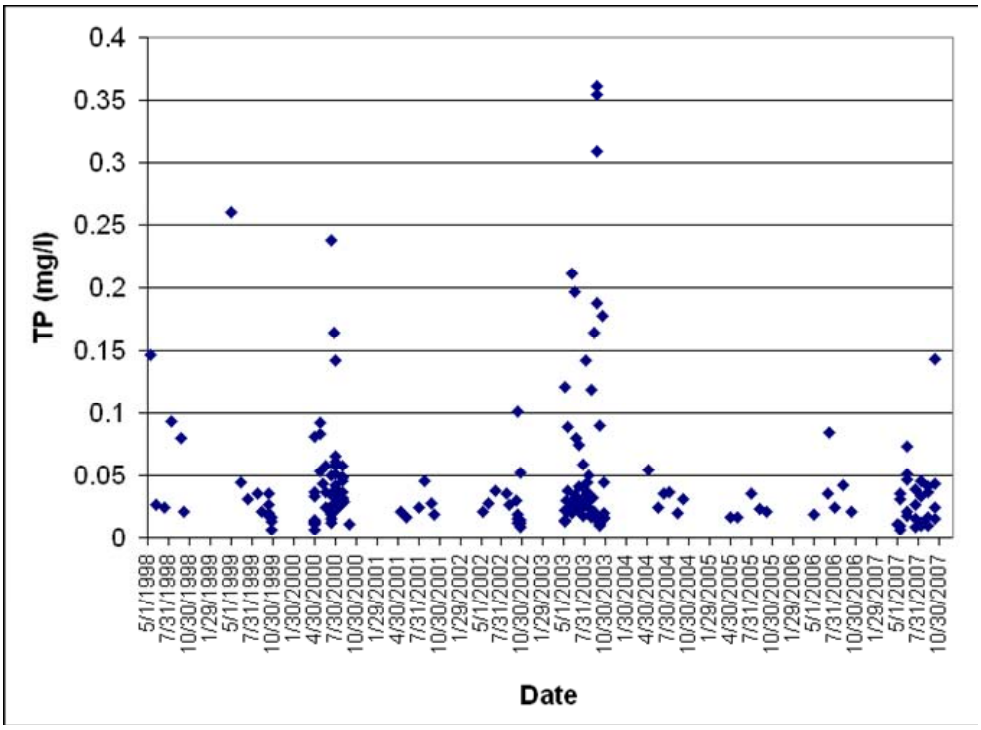

Figure 6: Gwynns Falls Total Phosphorus Data from May 1999 through October 2007

3.4 Biological Stressor Identification Analysis

In the process of evaluating the existing biological impairments, MDE developed a BSID methodology (MDE 2009a). The BSID methodology uses data available from the statewide DNR MBSS. These data are presented in Appendix A. The current MDE biological assessment methodology is a three-step process: (1) a data quality review, (2) a systematic vetting of the dataset, and (3) a watershed assessment that presents the results of this assignment in terms of currently used *Integrated Report* listing categories.

The BSID analysis for the Gwynns Falls watershed did not identify nutrients (as indicated by DO, total nitrogen, total phosphorus, etc.) as potential stressors or indicate any significant association between current nutrient levels and the degraded biological conditions (MDE 2009b). According to this report, nutrients are not causing any impairment to aquatic life or biological communities in the Gwynns Falls.

The BSID analysis results suggest rather that the degradation of biological communities in the Gwynns Falls watershed is strongly associated with the urban nature of the watershed, which has resulted in altered hydrology and elevated levels of ammonia, chlorides, and conductivity (a measure of the presence of dissolved substances). As explained in the BSID report, the urbanization of landscapes creates broad and interrelated forms of degradation (i.e., hydrological, morphological, and water chemistry) that can affect stream ecology and biological composition. Peer-reviewed scientific literature establishes a link between highly urbanized landscapes and degradation in the aquatic health of non-tidal stream ecosystems.

4.0 CONCLUSION

Based on the analysis of data presented in the preceding section of this report, indicating that DO and chlorophyll *a* concentrations are meeting water quality criteria, and on the results of the Gwynns Falls BSID analysis, MDE concludes that currently the Gwynns Falls watershed is not being impaired by nutrients. (The BSID analysis indicates inorganic pollutants, ammonia toxicity, and flow/sediment stressors are associated with impacts to biological communities; these findings will be addressed separately.) Barring the receipt of contradictory data, this report will be used to support a revision of the phosphorus listing for the Gwynns Falls watershed, from Category 5 ("waterbody is impaired, does not attain the water quality standard, and a TMDL is required") to Category 2 ("waterbodies meeting some [in this case nutrients-related] water quality standards, but with insufficient data to assess all impairments"), when MDE proposes the revision of Maryland's *Integrated Report*.

Although the waters of the Gwynns Falls do not display signs of eutrophication, the State reserves the right to require future controls if evidence suggests that nutrients from the basin are contributing to downstream water quality problems. In December 2007, EPA approved TMDLs of nitrogen and phosphorus for the Baltimore Harbor. The Gwynns Falls watershed is located upstream of the Baltimore Harbor and drains into the Harbor's tidal waters. Although the amount of nutrients entering the Gwynns Falls is not causing localized impairments, it is contributing to the eutrophication of the downstream tidal waters of the Harbor. Therefore, the TMDL for the Baltimore Harbor requires nutrient reductions in the Gwynns Falls necessary to meet water quality standards in the Harbor. On the same principle, additional reductions may also be required by the forthcoming Chesapeake Bay TMDL, currently under development and due to be established by EPA by the end of 2010.

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Appendix A – Tabular Water Quality Data

Table A-1: MDE Water Quality Data

STATION	DATE	DO (mg/l)	Chlorophyll *a (ug/l)*	TN (mg/l)	TP (mg/l)
DDR0001	7/12/2000	5.40	1.50	4.387	0.2379
DDR0001	8/2/2000	6.90	1.28	2.249	0.1424
DDR0001	4/4/2000	9.00	12.46	1.226	0.0615
DDR0001	5/3/2000	10.10	2.49	2.380	0.0807
DDR0001	3/8/2000	12.30	5.98	2.546	0.1381
DDR0001	8/31/2000		0.75	1.168	0.0478
GWN0015	9/12/2007	6.30	3.74	1.617	0.0410
GWN0015	6/20/2000	6.70		1.750	0.0574
GWN0015	7/22/2003	7.30	0.85	2.530	0.0587
GWN0015	8/5/2003	7.30	1.50	2.931	0.1421
GWN0015	6/13/2007	7.30	2.99	1.791	0.0737
GWN0015	8/2/2000	7.60	1.00	1.665	0.0654
GWN0015	7/18/2007	7.60	1.09	1.701	0.0386
GWN0015	10/8/2002	7.70	1.25	2.251	0.1008
GWN0015	7/8/2003	7.70	1.74	2.711	0.0740
GWN0015	8/15/2007	7.70	1.37	1.514	0.0460
GWN0015	10/11/2007	7.90	8.97	1.899	0.1429
GWN0015	5/16/2007	8.10	2.49	1.850	0.0309
GWN0015	6/17/2003	8.30	1.00	2.931	0.1968
GWN0015	11/15/2007	8.30	5.48	2.001	0.2281
GWN0015	6/24/2003	8.40	0.75	2.422	0.0801
GWN0015	8/19/2003	8.40	0.25	1.631	0.0498
GWN0015	9/9/2003	8.40	0.75	2.973	0.1642
GWN0015	5/24/2000	8.50	3.74	1.653	0.0837
GWN0015	8/26/2003	8.50	2.49	2.389	0.1194
GWN0015	9/23/2003	8.60	7.48	2.800	0.3613
GWN0015	4/4/2000	8.70	8.97	1.905	0.0854
GWN0015	7/12/2000	8.70	1.71	1.782	0.0498
GWN0015	6/3/2003	9.00	2.24	3.179	0.2106
GWN0015	10/13/1999	9.30		1.625	0.0268
GWN0015	5/20/2003	9.30	1.25	2.490	0.0887
GWN0015	4/25/2007	9.40	2.99	1.424	0.0089
GWN0015	10/21/2003	9.80		2.084	0.0446
GWN0015	10/22/2002	10.00		1.608	0.0521
GWN0015	10/26/1999	10.10	1.22	1.674	0.0171
GWN0015	11/13/2002	10.10	1.50	1.330	0.0750
GWN0015	5/6/2003	10.30	14.95	2.669	0.1208
GWN0015	4/22/2003	10.60	14.20	2.461	0.0761
GWN0015	12/12/2007	10.80		1.686	0.0324
GWN0015	11/25/2002	10.90	0.25	3.229	0.1324
GWN0015	2/29/2000	11.40	3.99	1.788	0.0435

STATION	DATE	DO (mg/l)	Chlorophyll *a (ug/l)*	TN (mg/l)	TP (mg/l)
GWN0015	1/11/2000	11.50	3.49	1.875	0.0545
GWN0015	12/14/1999	11.60	14.95	2.108	0.2640
GWN0015	3/8/2000	11.60	2.74	1.870	0.0314
GWN0015	5/3/2000	11.70	3.99	1.935	0.0367
GWN0015	10/7/2003	11.70	4.49	2.432	0.0902
GWN0015	3/14/2007	11.90	2.74	1.852	0.0148
GWN0015	12/17/2002	12.10		2.157	0.0969
GWN0015	2/4/2003	12.10	29.90	4.100	0.6093
GWN0015	3/18/2003	12.10	4.49	2.419	0.0963
GWN0015	11/30/1999	12.20	0.75	1.641	0.0335
GWN0015	12/3/2002	12.20	0.25	3.091	0.1404
GWN0015	1/7/2003	12.20	0.43	2.932	0.1135
GWN0015	11/16/1999	12.30	2.35	1.515	0.0164
GWN0015	2/23/2000	12.50	1.64	1.881	0.0183
GWN0015	3/4/2003	12.50		3.018	0.1141
GWN0015	1/22/2003	13.10	0.75	4.214	0.2701
GWN0015	1/24/2000	13.30		2.406	0.0236
GWN0015	1/18/2007	13.60	1.00	1.921	0.0174
GWN0015	2/26/2007	13.70	6.48	2.086	0.0442
GWN0015	8/31/2000		1.50	1.171	0.0484
GWN0024	4/4/2000	8.80	5.98	1.737	0.0631
GWN0024	3/8/2000	11.90	3.74	1.789	0.0229
GWN0026	7/22/2003	7.90	1.28	1.717	0.0295
GWN0026	8/5/2003	8.10	1.28	1.693	0.0374
GWN0026	7/8/2003	8.30	1.25	1.671	0.0412
GWN0026	8/26/2003	8.30	1.50	1.323	0.0176
GWN0026	8/19/2003	8.50	0.75	1.303	0.0352
GWN0026	9/23/2003	8.50	4.49	2.550	0.3540
GWN0026	9/9/2003	8.60	0.75	1.602	0.0216
GWN0026	6/24/2003	8.80	1.00	1.782	0.0330
GWN0026	6/17/2003	9.10	0.50	1.770	0.0341
GWN0026	6/3/2003	9.80	0.50	1.696	0.0301
GWN0026	5/20/2003	9.90	1.25	1.892	0.0381
GWN0026	10/21/2003	10.40	0.64	1.586	0.0204
GWN0026	4/22/2003	10.80	14.45	1.487	0.0185
GWN0026	5/6/2003	10.80	11.32	1.671	0.0221
GWN0026	10/7/2003	11.60	2.56	1.501	0.0101
GWN0026	2/4/2003	12.30	37.38	4.330	0.6595
GWN0026	11/25/2002	12.40		1.665	0.0212
GWN0026	3/18/2003	12.60	3.74	1.646	0.0219
GWN0026	12/17/2002	12.90		1.736	0.0248
GWN0026	3/4/2003	13.00		2.183	0.0506
GWN0026	1/7/2003	13.20	0.21	2.050	0.0285
GWN0026	12/3/2002	13.30		1.625	0.0176
GWN0026	1/22/2003	14.00		2.226	0.0144
GWN0050	9/12/2007	5.70	2.39	1.521	0.0365
GWN0050	8/2/2000	8.10	1.99	1.490	0.0508

STATION	DATE	DO (mg/l)	Chlorophyll *a (ug/l)*	TN (mg/l)	TP (mg/l)
GWN0050	6/13/2007	8.10	1.99	1.674	0.0466
GWN0050	5/16/2007	8.30	3.99	1.658	0.0358
GWN0050	8/15/2007	8.30	1.25	1.217	0.0330
GWN0050	10/11/2007	8.40	1.28	1.477	0.0435
GWN0050	7/12/2000	8.50	1.28	1.459	0.0347
GWN0050	7/18/2007	8.50	0.95	1.421	0.0265
GWN0050	4/4/2000	9.00	14.45	1.530	0.0440
GWN0050	11/15/2007	10.00	4.49	1.360	0.0264
GWN0050	4/25/2007	10.50	3.49	1.185	0.0097
GWN0050	5/3/2000	10.60	2.24	1.827	0.0337
GWN0050	12/12/2007	11.70	1.50	1.416	0.0167
GWN0050	3/14/2007	12.40	4.24	1.628	0.0085
GWN0050	2/26/2007	12.90	6.23	1.966	0.0428
GWN0050	1/18/2007	13.90	1.50	1.775	0.0076
GWN0050	3/8/2000	14.20	5.23	1.574	0.0175
GWN0050	8/31/2000		1.50	0.890	0.0367
GWN0080	7/12/2000	7.40	2.24	1.781	0.0360
GWN0080	8/2/2000	8.50	2.24	1.495	0.0615
GWN0080	4/4/2000	8.90	3.49	1.614	0.0451
GWN0080	5/3/2000	9.90	2.74	1.900	0.0337
GWN0080	3/8/2000	12.10	2.24	1.812	0.0205
GWN0080	8/31/2000		0.50	1.434	0.0574
GWN0115	6/20/2000	6.90		1.526	0.0365
GWN0115	8/4/2005	7.10			
GWN0115	8/5/2003	7.40	0.85	1.803	0.0318
GWN0115	7/26/2005	7.40			
GWN0115	5/27/2004	7.50			
GWN0115	7/14/2004	7.50			
GWN0115	8/2/2000	7.60	1.25	1.640	0.0360
GWN0115	8/2/2000	7.60	1.25	1.603	0.0371
GWN0115	7/22/2003	7.60	1.07	2.031	0.0181
GWN0115	7/22/2003	7.60			
GWN0115	9/23/2003	7.60	1.50	2.081	0.3093
GWN0115	9/23/2003	7.60			
GWN0115	9/23/2003	7.60			
GWN0115	8/26/2004	7.60			
GWN0115	8/31/2000	7.80	1.50	1.369	0.0320
GWN0115	8/31/2000	7.80	1.00	1.357	0.0312
GWN0115	5/19/2004	7.80			
GWN0115	7/9/2004	7.80			
GWN0115	8/12/2004	7.80			
GWN0115	8/26/2003	7.90	0.50	1.841	0.0199
GWN0115	6/8/2005	7.90			
GWN0115	7/8/2003	8.00	1.00	1.679	0.0231
GWN0115	7/8/2003	8.00			
GWN0115	8/19/2003	8.00	0.50	1.673	0.0292
GWN0115	8/19/2003	8.00			

STATION	DATE	DO (mg/l)	Chlorophyll *a (ug/l)*	TN (mg/l)	TP (mg/l)
GWN0115	6/10/2004	8.10			
GWN0115	9/10/2004	8.10			
GWN0115	9/29/2004	8.20			
GWN0115	8/5/2003	8.30			
GWN0115	7/12/2000	8.40	1.00	1.746	0.0154
GWN0115	7/12/2000	8.40	1.74	1.749	0.0161
GWN0115	9/9/2003	8.40	0.56	1.876	0.0189
GWN0115	4/4/2000	8.50	6.48	1.688	0.0470
GWN0115	4/4/2000	8.50	5.73	1.702	0.0495
GWN0115	5/24/2000	8.50	4.98	2.059	0.0926
GWN0115	6/24/2003	8.50	0.25	1.930	0.0255
GWN0115	9/9/2003	8.50			
GWN0115	9/15/2005	8.50			
GWN0115	4/22/2004	8.60			
GWN0115	6/24/2004	8.60			
GWN0115	8/17/2004	8.60			
GWN0115	8/18/2005	8.60			
GWN0115	6/17/2003	8.80	0.50	1.874	0.0237
GWN0115	6/17/2003	8.80			
GWN0115	5/13/2004	8.80			
GWN0115	9/23/2004	8.80			
GWN0115	6/23/2005	8.80			
GWN0115	7/13/2005	8.80			
GWN0115	11/6/2003	8.90			
GWN0115	7/22/2004	9.00			
GWN0115	5/3/2000	9.20	1.00	1.994	0.0119
GWN0115	5/3/2000	9.20	1.25	1.984	0.0122
GWN0115	6/3/2003	9.20	0.25	1.955	0.0213
GWN0115	9/22/2005	9.20			
GWN0115	6/3/2003	9.30			
GWN0115	11/13/2002	9.40	0.50	0.981	0.0343
GWN0115	10/13/1999	9.50		1.494	0.0202
GWN0115	6/28/2004	9.60			
GWN0115	10/7/2004	9.60			
GWN0115	10/8/2002	9.70	0.75	1.179	0.0193
GWN0115	10/7/2003	9.70			
GWN0115	11/13/2003	9.70			
GWN0115	5/19/2005	9.70			
GWN0115	10/18/2005	9.70			
GWN0115	10/21/2003	9.80			
GWN0115	10/21/2004	9.80			
GWN0115	4/22/2003	9.90	2.99	1.632	0.0112
GWN0115	4/22/2003	9.90			
GWN0115	5/20/2003	9.90	1.25	1.804	0.0230
GWN0115	5/20/2003	9.90			
GWN0115	10/21/2003	9.90		1.799	0.0158
GWN0115	11/20/2003	9.90			

STATION	DATE	DO (mg/l)	Chlorophyll *a (ug/l)*	TN (mg/l)	TP (mg/l)
GWN0115	5/6/2003	10.40	4.27	1.904	0.0142
GWN0115	5/6/2003	10.40			
GWN0115	10/26/2004	10.50			
GWN0115	10/26/1999	10.60		1.773	0.0132
GWN0115	10/7/2003	10.60		2.025	0.0109
GWN0115	10/22/2002	10.90		1.595	0.0147
GWN0115	1/5/2005	10.90			
GWN0115	3/18/2003	11.10	2.49	1.600	0.0151
GWN0115	4/13/2004	11.10			
GWN0115	4/13/2004	11.10			
GWN0115	11/10/2004	11.10			
GWN0115	12/8/2004	11.10			
GWN0115	12/1/2005	11.10			
GWN0115	12/14/1999	11.20	3.99	1.264	0.1183
GWN0115	4/8/2004	11.20			
GWN0115	1/11/2000	11.30	1.99	1.364	0.0388
GWN0115	11/2/2005	11.30			
GWN0115	3/8/2004	11.40			
GWN0115	5/5/2005	11.40			
GWN0115	11/16/1999	11.50	0.43	1.510	0.0105
GWN0115	12/11/2003	11.50			
GWN0115	12/11/2003	11.50			
GWN0115	11/22/2004	11.50			
GWN0115	2/29/2000	11.60	2.49	1.577	0.0249
GWN0115	10/28/2005	11.60			
GWN0115	3/4/2004	11.80			
GWN0115	11/18/2005	11.80			
GWN0115	11/25/2002	12.20		1.896	0.0154
GWN0115	3/18/2003	12.30			
GWN0115	1/13/2005	12.30			
GWN0115	4/14/2005	12.30			
GWN0115	11/30/1999	12.50	1.00	1.355	0.0191
GWN0115	3/8/2000	12.50	1.74	1.976	0.0103
GWN0115	3/8/2000	12.50	1.74	1.966	0.0099
GWN0115	2/4/2003	12.50	11.96	2.442	0.1502
GWN0115	2/4/2003	12.50			
GWN0115	12/18/2003	12.60			
GWN0115	2/10/2004	12.60			
GWN0115	2/14/2005	12.60			
GWN0115	12/17/2002	12.70		1.691	0.0141
GWN0115	2/23/2000	12.80	0.75	1.966	0.0092
GWN0115	3/4/2003	13.00			
GWN0115	2/22/2005	13.00			
GWN0115	3/4/2003	13.10		1.884	0.0177
GWN0115	2/25/2004	13.10			
GWN0115	3/16/2005	13.10			
GWN0115	12/3/2002	13.20		1.856	0.0075

STATION	DATE	DO (mg/l)	Chlorophyll *a (ug/l)*	TN (mg/l)	TP (mg/l)
GWN0115	1/7/2003	13.30		1.962	0.0143
GWN0115	1/7/2003	13.30			
GWN0115	1/24/2000	13.40		2.445	0.0061
GWN0115	2/20/2004	13.40			
GWN0115	12/20/2004	13.40			
GWN0115	3/18/2004	13.60			
GWN0115	12/4/2003	13.70			
GWN0115	1/29/2004	13.70			
GWN0115	12/15/2004	13.70			
GWN0115	1/20/2005	13.80			
GWN0115	12/15/2005	13.90			
GWN0115	1/8/2004	14.00			
GWN0115	2/2/2005	14.00			
GWN0115	1/22/2003	14.20	0.25	2.296	0.0076
GWN0115	1/22/2003	14.20			
GWN0115	1/23/2004	14.80			
GWN0125	8/31/2000	7.10	1.25	1.468	0.0362
GWN0125	8/2/2000	7.70	1.99	1.650	0.0387
GWN0125	7/12/2000	8.10	1.00	1.821	0.0204
GWN0125	4/4/2000	8.80	5.48	1.762	0.0416
GWN0125	5/3/2000	9.60	1.00	1.924	0.0128
GWN0125	3/8/2000	11.70	1.28	2.082	0.0094
GWN0160	8/5/2003	7.40	2.14	2.101	0.0284
GWN0160	8/2/2000	7.60	1.00	1.742	0.0345
GWN0160	7/22/2003	7.60		2.433	0.0182
GWN0160	8/31/2000	7.70	2.49	1.654	0.0325
GWN0160	7/8/2003	7.70	1.00	2.022	0.0226
GWN0160	8/26/2003	7.80	1.25	2.203	0.0165
GWN0160	9/23/2003	7.80		1.622	0.1879
GWN0160	7/12/2000	8.10	0.75	2.175	0.0184
GWN0160	8/19/2003	8.10	2.49	1.986	0.0247
GWN0160	6/24/2003	8.30		2.153	0.0316
GWN0160	9/9/2003	8.30	0.93	2.157	0.0162
GWN0160	6/17/2003	8.80		2.139	0.0292
GWN0160	4/4/2000	9.10	6.98	1.805	0.0502
GWN0160	6/3/2003	9.40	0.25	2.363	0.0199
GWN0160	10/21/2003	9.80	0.64	2.179	0.0170
GWN0160	5/20/2003	9.90		1.990	0.0219
GWN0160	5/3/2000	10.00	1.50	2.105	0.0120
GWN0160	10/7/2003	10.30	0.85	2.338	0.0135
GWN0160	5/6/2003	10.60	4.06	2.097	0.0137
GWN0160	4/22/2003	11.00	2.99	1.963	0.0135
GWN0160	3/18/2003	11.80	2.49	1.911	0.0163
GWN0160	3/8/2000	12.10	2.06	2.339	0.0100
GWN0160	12/17/2002	12.50		1.983	0.0125
GWN0160	11/25/2002	12.60		2.326	0.0104
GWN0160	12/3/2002	13.20		2.136	0.0068

STATION	DATE	DO (mg/l)	Chlorophyll *a (ug/l)*	TN (mg/l)	TP (mg/l)
GWN0160	3/4/2003	13.20		2.303	0.0241
GWN0160	2/4/2003	13.30	3.63	2.399	0.0204
GWN0160	1/7/2003	14.50		2.195	0.0126
GWN0160	1/22/2003	15.30	1.50	2.676	0.0071
GWN0179	9/12/2007	6.60	1.89	2.604	0.0172
GWN0179	10/11/2007	7.00	0.75	1.928	0.0249
GWN0179	6/13/2007	7.80	1.74	2.317	0.0510
GWN0179	7/18/2007	8.00	0.82	2.777	0.0160
GWN0179	5/16/2007	8.50	1.99	2.812	0.0103
GWN0179	8/15/2007	8.50	0.62	2.404	0.0119
GWN0179	11/15/2007	9.00	1.25	1.730	0.0325
GWN0179	4/25/2007	10.50	1.99	2.399	0.0061
GWN0179	12/12/2007	10.90		2.017	0.0084
GWN0179	3/14/2007	12.30	2.24	2.772	0.0076
GWN0179	2/26/2007	12.90	2.49	2.252	0.0414
GWN0179	1/18/2007	13.70		2.895	0.0063
GWN0186	8/2/2000	7.80	1.50	2.119	0.0417
GWN0186	8/31/2000	8.20	1.25	2.064	0.0366
GWN0186	7/12/2000	8.50	0.75	2.706	0.0198
GWN0186	10/8/2002	9.20	1.25	1.730	0.0159
GWN0186	4/4/2000	9.40	4.98	1.774	0.0367
GWN0186	11/13/2002	9.80	0.50	0.976	0.0258
GWN0186	5/3/2000	10.00	1.25	2.579	0.0120
GWN0186	10/22/2002	10.90	0.21	2.174	0.0117
GWN0186	3/8/2000	11.50	1.31	2.697	0.0084
GWN0215	8/31/2000	8.00	0.25	2.176	0.0299
GWN0215	5/24/2000	8.50	2.24	1.999	0.0532
GWN0215	7/12/2000	8.50	0.50	2.704	0.0197
GWN0215	8/2/2000	8.50	1.50	2.043	0.0575
GWN0215	6/20/2000	8.80		2.480	0.0248
GWN0215	4/4/2000	9.20	3.99	1.508	0.0310
GWN0215	10/13/1999	9.60		2.356	0.0174
GWN0215	5/3/2000	10.00	1.25	2.578	0.0117
GWN0215	10/26/1999	10.50		2.357	0.0065
GWN0215	11/16/1999	11.00	1.28	2.182	0.0136
GWN0215	1/11/2000	11.10		1.834	0.0230
GWN0215	12/14/1999	11.20	2.99	1.297	0.1328
GWN0215	3/8/2000	11.20	0.93	2.701	0.0086
GWN0215	2/29/2000	11.70	1.74	2.148	0.0225
GWN0215	11/30/1999	12.20	0.25	2.334	0.0134
GWN0215	2/23/2000	12.40	1.05	2.613	0.0072
GWN0215	1/24/2000	13.20		2.820	0.0057
MCR0001	4/4/2000	8.90	3.49	1.793	0.0706
MCR0001	3/8/2000	11.20	6.48	1.520	0.0475
RDR0001	8/2/2000	7.60	1.00	1.772	0.0325
RDR0001	8/31/2000	7.60	1.74	1.545	0.0321
RDR0001	7/12/2000	8.10	1.00	1.865	0.0124

STATION	DATE	DO (mg/l)	Chlorophyll *a (ug/l)*	TN (mg/l)	TP (mg/l)
RDR0001	4/4/2000	9.20	3.49	1.305	0.0332
RDR0001	10/8/2002	9.60	1.74	2.062	0.0122
RDR0001	11/13/2002	9.70	1.25	1.179	0.0269
RDR0001	5/3/2000	10.50	1.00	1.644	0.0071
RDR0001	10/22/2002	10.90	0.43	2.312	0.0093
RDR0001	3/8/2000	11.90	1.68	1.975	0.0120
RDR0008	9/12/2007	6.80	1.59	1.483	0.0101
RDR0008	10/11/2007	7.30	1.20	1.266	0.0154
RDR0008	7/18/2007	7.70	0.54	1.848	0.0087
RDR0008	8/15/2007	8.00	0.62	1.419	0.0105
RDR0008	6/13/2007	8.10	1.25	1.916	0.0209
RDR0008	5/16/2007	8.60	1.74	1.703	0.0063
RDR0008	11/15/2007	8.60	1.25	1.227	0.0273
RDR0008	4/25/2007	10.70	1.74	1.338	0.0053
RDR0008	12/12/2007	10.80		1.524	0.0063
RDR0008	3/14/2007	12.00	1.00	1.733	0.0065
RDR0008	2/26/2007	13.10	2.99	1.974	0.0241
RDR0008	1/18/2007	13.80	0.75	1.859	0.0060
UHX0001	8/31/2000	7.40	1.50	1.118	0.0451
UHX0001	8/2/2000	7.50	0.25	1.267	0.0313
UHX0001	7/12/2000	7.90	0.25	1.305	0.0261
UHX0001	4/4/2000	9.20	8.22	1.481	0.0536
UHX0001	5/3/2000	10.40	2.74	1.453	0.0108
UHX0001	3/8/2000	11.30	1.50	1.444	0.0103

Table A-2: DNR Water Quality Data

STATION	DATE	DO (mg/l)	Chlorophyll *a (ug/l)*	TN (mg/l)	TP (mg/l)
GWN0115	9/22/1998	6.80	3.18		0.0800
GWN0115	8/11/1998	7.10	4.49		0.0930
GWN0115	8/3/2004	7.20	2.84		0.0370
GWN0115	8/2/2006	7.50	0.90	1.670	0.0240
GWN0115	8/21/2002	7.60	1.20		0.0350
GWN0115	8/11/2003	7.60	1.20		0.0450
GWN0115	9/8/2004	7.70	2.39		0.0200
GWN0115	8/25/1999	7.80	1.12		0.0360
GWN0115	7/26/2000	7.80	8.97		0.1650
GWN0115	8/28/2001	7.80	2.43		0.0460
GWN0115	6/5/2002	7.80	0.82		0.0280
GWN0115	7/1/2002	7.80	2.39		0.0380
GWN0115	7/12/2004	7.90	1.50		0.0350
GWN0115	6/29/2006	7.90		1.504	0.0350
GWN0115	7/6/2006	7.90	2.99	1.038	0.0850
GWN0115	9/3/2003	8.00	2.39		0.0320
GWN0115	8/14/2000	8.10	2.29		0.0240
GWN0115	7/31/2001	8.10	1.94		0.0250
GWN0115	9/24/2001	8.10	1.12		0.0280
GWN0115	6/12/2007	8.10	1.07	1.754	0.0180
GWN0115	7/15/2003	8.20	1.05		0.0310
GWN0115	8/1/2005	8.20		1.654	0.0350
GWN0115	7/14/1998	8.30	1.05		0.0250
GWN0115	9/15/1999	8.30	2.79		0.0210
GWN0115	6/14/2004	8.30	1.33		0.0240
GWN0115	6/16/1999	8.40	1.35		0.0440
GWN0115	9/3/2002	8.40	0.45		0.0270
GWN0115	7/12/1999	8.50	0.40		0.0310
GWN0115	9/8/2005	8.50	1.05	1.909	0.0230
GWN0115	9/6/2006	8.50	1.50	0.972	0.0420
GWN0115	5/15/2001	8.60	2.39		0.0210
GWN0115	5/3/2004	8.60	6.58		0.0540
GWN0115	6/7/2000	8.70	1.79		0.0430
GWN0115	9/6/2000	8.70	0.90		0.0290
GWN0115	6/6/2001	8.70	1.00		0.0170
GWN0115	10/1/2002	8.70	0.87		0.0300
GWN0115	6/10/2003	8.70	0.60		0.0290
GWN0115	10/15/2003	8.70	5.98		0.1780
GWN0115	6/1/2005	8.80	0.90		0.0170
GWN0115	10/11/2006	8.80	0.53	1.596	0.0210
GWN0115	5/13/2002	8.90	1.05		0.0210

STATION	DATE	DO (mg/l)	Chlorophyll *a (ug/l)*	TN (mg/l)	TP (mg/l)
GWN0115	7/5/2005	9.00	1.94		
GWN0115	10/4/2000	9.10			0.0110
GWN0115	11/2/2006	9.10	2.14	1.507	0.0510
GWN0115	5/12/1998	9.20	4.19		0.1470
GWN0115	10/12/1999	9.20	1.30		0.0350
GWN0115	10/3/2005	9.20	0.90	1.623	0.0210
GWN0115	5/13/2003	9.40	2.08		0.0300
GWN0115	11/3/2003	9.50	0.60		0.0200
GWN0115	5/3/2000	9.60	1.60		0.0140
GWN0115	10/5/2004	9.60		1.769	0.0310
GWN0115	10/6/1998	9.70	0.90		0.0210
GWN0115	12/1/1998	9.90	0.40		0.0180
GWN0115	5/5/1999	9.90	0.91		0.2600
GWN0115	11/4/2004	9.90	1.31		0.0180
GWN0115	5/3/2007	9.90	1.59	1.633	0.0110
GWN0115	6/9/1998	10.00	0.97		0.0270
GWN0115	11/6/2002	10.20	2.39		0.1800
GWN0115	11/6/2001	10.30	0.60		0.0140
GWN0115	5/2/2005	10.40	2.77		0.0170
GWN0115	4/5/2000	10.60	2.39		0.0230
GWN0115	11/4/1998	10.80	0.45		0.0120
GWN0115	11/1/2005	10.80	0.75	1.887	0.0210
GWN0115	4/6/1999	11.00	2.89		0.0160
GWN0115	11/1/2000	11.00	0.84		0.0230
GWN0115	10/9/2001	11.00	1.00		0.0190
GWN0115	12/14/1999	11.10	3.74		0.1260
GWN0115	4/30/2001	11.10	2.62		0.0270
GWN0115	11/16/1999	11.20	0.90		0.0170
GWN0115	1/11/2000	11.20	2.39		0.0480
GWN0115	1/3/2006	11.20	10.96	1.309	0.0790
GWN0115	4/3/2007	11.30	2.80	1.759	0.0085
GWN0115	2/23/1998	11.40	1.40		0.0410
GWN0115	4/4/2005	11.40	0.90		0.0420
GWN0115	1/6/2004	11.50	1.64		0.0340
GWN0115	4/14/1998	11.60	3.09		0.0100
GWN0115	5/1/2006	11.80	2.24	1.692	0.0190
GWN0115	2/2/1999	11.90	3.89		0.0730
GWN0115	12/4/2001	11.90	0.60		0.0100
GWN0115	3/6/2000	12.10	1.65		0.0100
GWN0115	4/2/2002	12.10	1.89		0.0100
GWN0115	3/9/2004	12.10	2.24		0.0160
GWN0115	3/26/2001	12.30	1.33		0.0160
GWN0115	4/1/2003	12.30	2.54		0.0170
GWN0115	4/6/2004	12.30			0.0160
GWN0115	4/11/2006	12.30	2.24	1.496	0.0150
GWN0115	2/10/2004	12.40	0.70		0.0200
GWN0115	1/7/2003	12.50		1.672	0.0100

STATION	DATE	DO (mg/l)	Chlorophyll *a (ug/l)*	TN (mg/l)	TP (mg/l)
GWN0115	2/2/2006	12.50	1.79	1.556	0.0160
GWN0115	3/5/2007	12.50	1.20	1.863	0.0200
GWN0115	1/13/1998	12.60	1.64		0.0210
GWN0115	1/4/2007	12.60	1.92	1.692	0.0130
GWN0115	3/16/1998	12.70	0.45		0.0260
GWN0115	1/14/2002	12.70	0.75		0.0100
GWN0115	2/7/2005	12.80	0.55		0.0170
GWN0115	12/2/2002	12.90	0.30		0.0130
GWN0115	3/7/2005	12.90	3.74		0.0220
GWN0115	12/2/2004	13.00	1.50		0.0360
GWN0115	1/19/2005	13.00	0.12		0.0480
GWN0115	3/9/1999	13.10	1.12		0.0250
GWN0115	2/8/2000	13.10	0.37		0.0170
GWN0115	2/3/2003	13.10	1.40	1.862	0.0150
GWN0115	12/8/2003	13.10			0.0190
GWN0115	3/5/2002	13.20	1.40		0.0260
GWN0115	3/3/2003	13.20	1.20		0.0360
GWN0115	12/5/2000	13.30	0.60		0.0100
GWN0115	2/20/2001	13.30	2.06		0.0180
GWN0115	12/5/2006	13.30	0.75	1.794	0.0130
GWN0115	2/5/2002	13.40	1.35		0.0100
GWN0115	12/6/2005	13.40	0.75	1.698	0.0200
GWN0115	3/1/2006	13.50	1.92	2.124	0.0110
GWN0115	1/23/2001	14.00			0.0190
GWN0115	2/6/2007	14.30	1.35	2.526	0.0105

Table A-3: MBSS Water Quality Data

Station ID	Stream Name	DO (mg/l)	TN (mg/l)	TP (mg/l)
GWYN-104-R-2004	Scotts Level Branch	7.5	1.015	0.059
GWYN-306-R-2004	Gwynns Falls	7.6	1.868	0.024
GWYN-301-R-2004	Gwynns Falls	7.7	1.977	0.033
GWYN-303-R-2004	Gwynns Falls	7.7	1.84	0.016
GWYN-112-R-2004	Red Run UT1	7.9	0.511	0.014
GWYN-107-R-2004	Gwynns Falls	8	2.629	0.024
GWYN-302-X-2000	Gwynns Falls	8	2.143	0.012
GWYN-105-R-2004	Horsehead Branch	8.6	1.306	0.017
GWYN-210-R-2004	Dead Run	8.6	1.601	0.026
GWYN-211-R-2004	Dead Run	9.1	1.404	0.033
GWYN-102-R-2004	Red Run UT2	9.3	1.063	0.013
GWYN-301-X-2000	Gwynns Falls	10.5	1.392	0.015

APPENDIX K:

TMDL of Sediment in the Gwynns Falls Watershed

Total Maximum Daily Load of Sediment in the Gwynns Falls Watershed, Baltimore City and Baltimore County, Maryland

FINAL

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Submitted to:

Watershed Protection Division
U.S. Environmental Protection Agency, Region III
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Table of Contents

List of Figures i
List of Tables i
List of Abbreviations ii
EXECUTIVE SUMMARY iv
1.0 INTRODUCTION 1
2.0 SETTING AND WATER QUALITY DESCRIPTION 3
2.1 General Setting 3
2.1.1. Land Use 5
2.2 Source Assessment 8
2.2.1 Nonpoint Source Assessment 8
2.2.2 Point Source Assessment 12
2.2.3 Summary of Baseline Loads 13
2.3 Water Quality Characterization 15
2.4 Water Quality Impairment 19
3.0 TARGETED WATER QUALITY GOAL 21
4.0 TOTAL MAXIMUM DAILY LOADS AND SOURCE ALLOCATION 22
4.1 Overview 22
4.2 Analysis Framework 22
4.3 Scenario Descriptions and Results 26
4.4 Critical Condition and Seasonality 27
4.5 TMDL Loading Caps 27
4.6 Load Allocations Between Point and Nonpoint Sources 28
4.7 Margin of Safety 31
4.8 Summary of Total Maximum Daily Loads 32
5.0 ASSURANCE OF IMPLEMENTATION 33
REFERENCES 35
APPENDIX A – Watershed Characterization Data A1
APPENDIX B – MDE Permit Information B1
APPENDIX C – Technical Approach Used to Generate Maximum Daily Loads C1

List of Figures

Figure 1: Location Map of the Gwynns Falls Watershed in Baltimore City and Baltimore County, Maryland 4
Figure 2: Land Use of the Gwynns Falls Watershed 7
Figure 3: Percent Impervious vs. Percent Erosional Sediment Load Resultant from Streambank Erosion 12
Figure 4: Monitoring Stations in the Gwynns Falls Watershed 17
Figure 5: Gwynns Falls Watershed TMDL Segmentation 23
Figure C-1: Histogram of CBP River Segment Daily Simulation Results for the Gwynns Falls Watershed C5

List of Tables

Table ES-1: Gwynns Falls Baseline Sediment Loads (ton/yr) vi
Table ES-2 Gwynns Falls Average Annual TMDL of Sediment/Total Suspended Solids (ton/yr) vi
Table ES-3: Gwynns Falls Baseline Load, TMDL, and Total Reduction Percentage vii
Table 1: Land Use Percentage Distribution for the Gwynns Falls Watershed 6
Table 2: Summary of EOF Erosion Rate Calculations 9
Table 3: Gwynns Falls Baseline Sediment Loads (ton/yr) 13
Table 4: Detailed Baseline Sediment Budget Loads Within the Gwynns Falls Watershed 14
Table 5: Monitoring Stations in the Gwynns Falls Watershed 18
Table 6: Gwynns Falls Core/Trend Data 20
Table 7: Gwynns Falls Baseline Load and TMDL 28
Table 8: Gwynns Falls TMDL Reductions by Source Category 29
Table 9: Gwynns Falls TMDL Segment 1 Reductions by Source Category 29
Table 10: Gwynns Falls TMDL Segment 2 Reductions by Source Category 30
Table 11: Gwynns Falls Watershed Average Annual TMDL of Sediment/TSS (ton/yr) 32
Table 12: Gwynns Falls Maximum Daily Loads of Sediment/TSS (ton/day) 32
Table A-1: Reference Watersheds A1
Table B-1: Permit Summary B1
Table B-2: Municipal Permit Data B5
Table B-3: General Mine Permit Data B5
Table B-4: Stormwater Permits[1] B6

List of Abbreviations

BIBI	Benthic Index of Biotic Integrity
BIP	Buffer Incentive Program
BMP	Best Management Practices
BSID	Biological Stressor Identification
CBP P5	Chesapeake Bay Program Phase 5
CV	Coefficient of Variation
CWA	Clean Water Act
DNR	Maryland Department of Natural Resources
EOF	Edge-of-Field
EOS	Edge-of-Stream
EPA	Environmental Protection Agency
EPT	Ephemeroptera, Plecoptera, and Trichoptera
EPSC	Environmental Permit Service Center
ESD	Environmental Site Design
ETM	Enhanced Thematic Mapper
FDC	Flow Duration Curve
FIBI	Fish Index of Biologic Integrity
GIS	Geographic Information System
HSPF	Hydrological Simulation Program – FORTRAN
IBI	Index of Biotic Integrity
LA	Load Allocation
MAL	Minimum Allowable IBI Limit
MBSS	Maryland Biological Stream Survey
MD 8-Digit	Maryland 8-digit Watershed
MDE	Maryland Department of the Environment
MDL	Maximum Daily Load
MGD	Millions of Gallons per Day
mg/l	Milligrams per liter
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer System

NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resource Conservation Service
NRI	Natural Resources Inventory
PCBs	Polychlorinated Biphenyls
PSU	Primary Sampling Unit
RESAC	Regional Earth Science Applications Center
TMDL	Total Maximum Daily Load
Ton/yr	Tons per Year
TSD	Technical Support Document
TSS	Total Suspended Solids
TM	Thematic Mapper
USGS	United Stated Geological Survey
WLA	Waste Load Allocation
WTP	Water Treatment Plant
WQA	Water Quality Analysis
WQIA	Water Quality Improvement Act
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 sediment in the Gwynns Falls watershed (basin number 02130905) (2008 *Integrated Report of Surface Water Quality in Maryland Assessment Unit ID*: MD-02130905). 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, the State is required to either establish a TMDL of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate that water quality standards are being met (CFR 2008b).

The Maryland Department of the Environment (MDE) has identified the waters of the Gwynns Falls watershed on the State's 2008 Integrated Report as impaired by sediments (1996), nutrients – phosphorus (1996), bacteria (2002), and impacts to biological communities (2002) (MDE 2008). The designated uses of the Gwynns Falls mainstem and its tributaries is Use I (Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life), except for the Gwynns Falls mainstem and its tributaries above Reisterstown Road and Red Run and its tributaries, which are designated as Use III (Nontidal Cold Water), and Dead Run and its tributaries, which are classified as Use IV (Recreational Trout Waters) (COMAR 2008a,b,c,d,e).

The TMDL established herein by MDE will address the 1996 sediments listing, for which a data solicitation was conducted, and all readily available data from the past five years have been considered. A TMDL for fecal bacteria was approved by the EPA in 2007, and a Water Quality Analysis (WQA) for nutrients to address the phosphorus listing is scheduled to be submitted to the EPA in 2009. The listing for impacts to biological communities will be refined in the 2010 Integrated Report's list of impaired waterbodies as a result of a stressor identification analysis.

The Gwynns Falls watershed aquatic health scores, consisting of the Benthic Index of Biotic Integrity (BIBI) and Fish Index of Biotic Integrity (FIBI), indicate that the biological metrics for the watershed exhibit a significant negative deviation from reference conditions based on Maryland's biocriteria listing methodology. The biocriteria listing methodology assesses the overall condition of Maryland's 8-digit (MD 8-digit) watersheds that have multiple sites with failing biological metrics by measuring the percentage of stream miles that are degraded, based on the BIBI and FIBI scores at these sites, and then calculating whether the percentage of degraded stream miles differs significantly from reference conditions (i.e., unimpaired watershed <10% stream miles degraded) (Roth et al. 2005; MDE 2008). The objective of the TMDL established herein is to ensure that there will be no sediment impacts affecting aquatic health, thereby establishing a sediment load that supports the Use I/III/IV designations for the Gwynns Falls watershed.

Currently in Maryland, there are no specific numeric criteria that quantify the impact of sediment on the aquatic health of nontidal stream systems. Therefore, to determine

whether aquatic health is impacted by elevated sediment loads, MDE's recently developed *Biological Stressor Identification* (BSID) methodology was applied. The BSID identifies the most probable cause(s) for observed biological impairments throughout MD's 8-digit watersheds by ranking the likely stressors affecting a watershed using a suite of available physical, chemical, and land use data. The ranking of stressors was conducted via a risk-based, systematic, weight-of-evidence approach. The risk-based approach estimates the strength of association between various stressors and a degraded biological community. The BSID analysis then identifies individual stressors (pollutants) as probable or unlikely causes of the poor biological conditions within a given MD 8-digit watershed and subsequently concludes whether or not these individual stressors or groups of stressors are contributing to the impairment (MDE 2009a).

The BSID analysis for the Gwynns Falls watershed concludes that biological communities are likely impaired due to flow/sediment related stressors. Three individual stressors (channelization, channel alteration, and bar formation) that are associated with sediment related impacts and an altered hydrologic regime were identified as being probable causes of the biological impairment. Furthermore, the degradation of biological communities in the watershed is strongly associated with urban land use and its concomitant effects: altered hydrology, sediment related impacts, and elevated levels of sulfate, chlorides, and conductivity (a measure of the presence of dissolved substances) (MDE 2009b).

In order to quantify the impact of sediment on the aquatic health of non-tidal stream systems, a reference watershed TMDL approach was used and resulted in the establishment of a *sediment loading threshold* (Currey et al. 2006). This threshold is based on a detailed analysis of sediment loads from watersheds that are identified as supporting aquatic life (i.e., reference watersheds) based on Maryland's biocriteria (Roth et al. 1998, 2000; Stribling et al. 1998; MDE 2008). This threshold is then used to determine a watershed specific sediment TMDL.

The computational framework chosen for the Gwynns Falls watershed TMDL was the Chesapeake Bay Program Phase 5 (CBP P5) watershed model target *edge-of-field* (EOF) land use sediment loading rate calculations combined with a *sediment delivery ratio*. The *edge-of-stream* (EOS) sediment load is calculated per land use as a product of the land use area, land use target loading rate, and loss from the EOF to the main channel. The spatial domain of the CBP P5 watershed model segmentation aggregates to the MD 8-digit watersheds, which is consistent with the impairment listing.

EPA's regulations require TMDLs to take into account seasonality and critical conditions for stream flow, loading, and water quality parameters (CFR 2008b). The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when it is most vulnerable. The biological monitoring data used to determine the reference watersheds integrates the stress effects over the course of time and thus inherently addresses critical conditions. Seasonality is captured in two components. First, it is implicitly included in biological sampling. Second, the Maryland Biological Stream

Survey (MBSS) dataset included benthic sampling in the spring and fish sampling in the summer.

All TMDLs need to be presented as a sum of waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources generated within the assessment unit, natural background, tributary, and adjacent segment loads. Furthermore, all TMDLs must include a margin of safety (MOS) to account for any lack of knowledge and uncertainty concerning the relationship between loads and water quality (CFR 2008a,b). It is proposed that the estimated variability around the reference watershed group used in this analysis already accounts for such uncertainty, and therefore the MOS is implicitly included.

The Gwynns Falls Total Baseline Sediment Load is 22,048.5 tons per year (ton/yr), which can be further subdivided into a nonpoint source baseline load (Nonpoint Source BL_{GF}) and two types of point source baseline loads: National Pollutant Discharge Elimination System (NPDES) regulated stormwater (NPDES Stormwater BL_{GF}) and regulated process water (Process Water BL_{GF}) (see Table ES-1).

Table ES-1: Gwynns Falls Baseline Sediment Loads (ton/yr)

Total Baseline Load (ton/yr)	=	Nonpoint Source BL_{GF}	+	NPDES Stormwater BL_{GF}	+	Process Water BL_{GF}
22,048.5	=	1,759.3	+	20,076.0	+	213.2

The Gwynns Falls Average Annual TMDL of Sediment/Total Suspended Solids (TSS) is 13,996.2 tons per year. The Load Allocation (LA_{GF}) is 1,759.3 tons per year, the NPDES Stormwater Waste Load Allocation (NPDES Stormwater WLA_{GF}) is 12,023.7 tons per year, and the Process Water Waste Load Allocation (Process Water WLA_{GF}) is 213.2 tons per year (see Table ES-2). This TMDL will ensure that the sediment loads and resulting effects are at a level to support the Use I/III/IV designations for the Gwynns Falls watershed, and more specifically, at a level the watershed can sustain without causing any sediment related impacts to aquatic health. The TMDL, however, will not completely resolve the impairment to biological communities within the watershed. Since the BSID watershed analysis identifies other possible stressors (i.e., chlorides, sulfate, conductivity) as impacting the biological conditions, this impairment remains to be fully addressed through the Integrated Report listing process and the TMDL development process, such that all impairing substances identified as impacting biological communities in the watershed are reduced to levels that will meet water quality standards, as established in future TMDLs for those substances (MDE 2009a).

Table ES-2 Gwynns Falls Average Annual TMDL of Sediment/Total Suspended Solids (ton/yr)

TMDL (ton/yr)	=	LA_{GF}	+	NPDES Stormwater WLA_{GF}	+	Process Water WLA_{GF}	+	MOS
13,996.2	=	1,759.3	+	12,023.7	+	213.2	+	Implicit

Table ES-3: Gwynns Falls Baseline Load, TMDL, and Total Reduction Percentage

Baseline Load (ton/yr)	TMDL (ton/yr)	Total Reduction (%)
22,048.5	13,996.2	36.5

In addition to the TMDL value, a Maximum Daily Load (MDL) is also presented in this document. The calculation of the MDL, which is derived from the TMDL average annual loads, is explained in Appendix C and presented in Table C-1.

Once the EPA has approved this TMDL, and it is known what measures must be taken to reduce pollution levels, implementation of best management practices (BMPs) is expected to take place primarily via the municipal separate storm sewer system (MS4) permitting process for medium and large municipalities. MDE intends for the required reduction to be implemented in an iterative process that first addresses those sources with the largest impact to water quality, with consideration given to ease and cost of implementation.

Maryland has several well-established programs to draw upon, including the Water Quality Improvement Act of 1998 (WQIA) and the Federal Nonpoint Source Management Program (§ 319 of the Clean Water Act). Several potential funding sources available for local governments for implementation are available, such as the Buffer Incentive Program (BIP), the State Water Quality Revolving Loan Fund, and the Stormwater Pollution Cost Share Program.

1.0 INTRODUCTION

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes a Total Maximum Daily Load (TMDL) for sediment in the Gwynns Falls watershed (basin number 02130905) (2008 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID: MD-02130905). Section 303(d)(1)(C) of the federal Clean Water Act (CWA) and the EPA's implementing regulations direct each state to develop a TMDL for each impaired water quality limited segment (WQLS) on the State's Integrated Report, taking into account seasonal variations, critical conditions, and a protective margin of safety (MOS) to account for uncertainty (CFR 2008b). 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 determine the pollutant load reductions needed 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, protection of aquatic life, 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 waters of the Gwynns Falls watershed on the 2008 Integrated Report as impaired by sediments (1996), nutrients – phosphorus (1996), bacteria (2002), and impacts to biological communities (2002) (MDE 2008). The designated uses of the Gwynns Falls mainstem and its tributaries is Use I (Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life), except for the Gwynns Falls mainstem and its tributaries above Reisterstown Road and Red Run and its tributaries, which are designated as Use III (Nontidal Cold Water), and Dead Run and its tributaries, which are classified as Use IV (Recreational Trout Waters) (COMAR 2008a,b,c,d,e).

The TMDL established herein by MDE will address the 1996 sediments listing, for which a data solicitation was conducted, and all readily available data from the past five years have been considered. A TMDL for fecal bacteria was approved by the EPA in 2007, and a Water Quality Analysis (WQA) for nutrients to address the phosphorus listing is scheduled to be submitted to the EPA in 2009. The listing for impacts to biological communities will be refined in the 2010 Integrated Report's list of impaired waterbodies as a result of a stressor identification analysis

The objective of the TMDL established herein is to ensure that there will be no sediment impacts affecting aquatic health, thereby establishing a sediment load that supports the Use I/III/IV designations for the Gwynns Falls watershed. Currently in Maryland, there are no specific numeric criteria that quantify the impact of sediment on the aquatic health of nontidal stream systems. Therefore, to determine whether aquatic health is impacted by elevated sediment loads, MDE's recently developed *Biological Stressor Identification* (BSID) methodology was applied.

The BSID identifies the most probable cause(s) for observed biological impairments throughout Maryland's 8-digit (MD 8-digit) watersheds by ranking the likely stressors affecting a watershed using a suite of available physical, chemical, and land use data. The ranking of stressors was conducted via a risk-based, systematic, weight-of-evidence approach. The risk-based approach estimates the strength of association between various stressors and a degraded biological community. The BSID analysis then identifies individual stressors (pollutants) as probable or unlikely causes of the poor biological conditions within a given MD 8-digit watershed and subsequently concludes whether or not these individual stressors or groups of stressors are contributing to the impairment (MDE 2009a).

In order to quantify the impact of sediment on the aquatic health of non-tidal stream systems, a reference watershed TMDL approach was used and resulted in the establishment of a *sediment loading threshold* (Currey et al. 2006). This threshold is based on a detailed analysis of sediment loads from watersheds that are identified as supporting aquatic life (i.e., reference watersheds) based on Maryland's biocriteria (Roth et al. 1998, 2000; Stribling et al. 1998; MDE 2008). This threshold is then used to determine a watershed specific sediment TMDL.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

Location

The Gwynns Falls is a free flowing stream that originates in Baltimore County, Maryland and flows 25 miles in a southeasterly direction until it empties into the tidal Patapsco River. The watershed is located in the Patapsco River sub-basin of the Chesapeake Bay watershed within Baltimore County and Baltimore City, Maryland and covers approximately 65 square miles (see Figure 1). Five major tributaries of the Gwynns Falls, listed north to south, include: Red Run, Horsehead Branch, Scotts Level Branch, Dead Run, and Maidens Choice Creek. There is one "high quality", or Tier II, stream segment (Benthic Index of Biotic Integrity (BIBI)/Fish Index of Biotic Integrity (FIBI) aquatic health scores > 4 (scale 1-5)), Red Run between the confluences of the stream's 1st and 3rd unnamed tributaries, located within the watershed requiring the implementation of Maryland's antidegradation policy. Also, approximately 0.4% of the watershed is covered by water (i.e., streams, ponds, etc.). The total population in the Gwynns Falls watershed is approximately 315,828 (MDE 2007b).

Geology/Soils

The Gwynns Falls watershed lies within the Piedmont and Atlantic Coastal Plain Geologic Provinces of Central Maryland. The Piedmont Province is characterized by a gentle to steep rolling topography, low hills, and ridges (DNR 2008; MGS 2008; MDE 2000). The surface geology is characterized by crystalline rocks, originally of sedimentary origin that were later transformed via heating into metamorphic rocks, consisting primarily of schist and gneiss. These formations are resistant to short term erosion and often determine the limits of the stream bank and streambed. The formations decrease in elevation from northwest to southeast and eventually extend beneath the younger sediments of the Coastal Plain. The fall line represents the transition between the Atlantic Coastal Plain Province and the Piedmont Province. The Atlantic Coastal Plain surface geology is characterized by thick, unconsolidated marine sediments deposited over the crystalline rock of the piedmont province. The deposits include clays, silts, sands, and gravels. In the areas around the head of tide, the topography is flat, with elevations below 100 feet. The elevations steadily increase going north to approximately 600 feet in the headwaters. Streambeds throughout the basin are comprised of rock and rubble with gradually sloped stream banks (CES 1995). The Gwynns Falls watershed lies predominantly in the Manor-Glenelg soil association in the upper Baltimore County portion of the watershed and the Legore-Aldino-Neshaminy soil association in the lower Baltimore County portion of the watershed (USDA 1977, 1998).

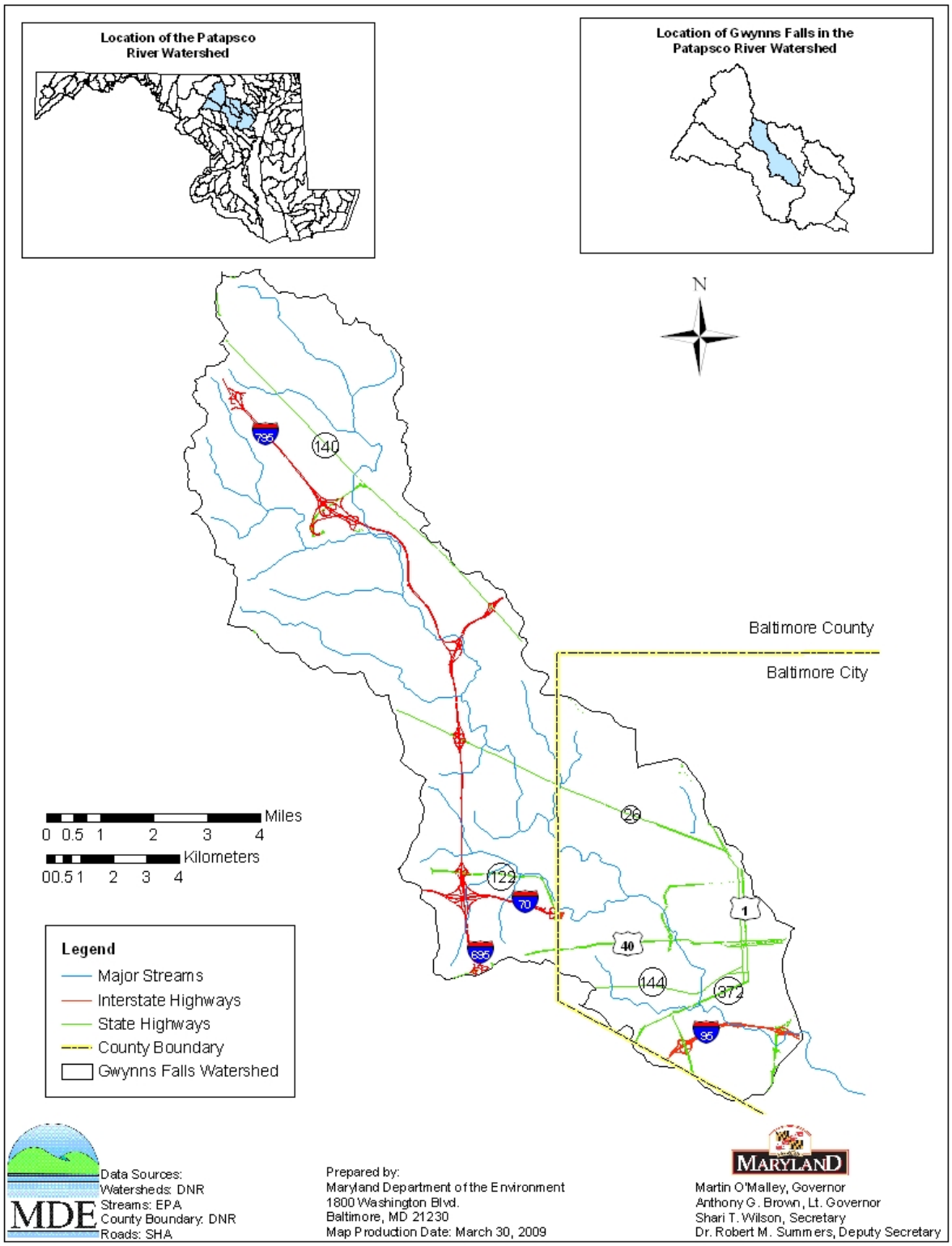

Figure 1: Location Map of the Gwynns Falls Watershed in Baltimore City and Baltimore County, Maryland

2.1.1. Land Use

Land Use Methodology

The land use framework used to develop this TMDL was originally developed for the Chesapeake Bay Program Phase 5 (CBP P5) watershed model.[1] The CBP P5 land use Geographic Information System (GIS) framework was based on two distinct layers of development. The first GIS layer was developed by the Regional Earth Science Applications Center (RESAC) at the University of Maryland and was based on satellite imagery (Landsat 7-Enhanced Thematic Mapper (ETM) and 5-Thematic Mapper (TM)) (Goetz et al. 2004). This layer did not provide the required level of accuracy that is especially important when developing agricultural land uses. In order to develop accurate agricultural land use calculations, the CBP P5 used county level U.S. Agricultural Census data as a second layer (USDA 1982, 1987, 1992, 1997, 2002).

Given that land cover classifications based on satellite imagery are likely to be least accurate at edges (i.e., boundaries between covers), the RESAC land uses bordering agricultural areas were analyzed separately. If the agricultural census data accounted for more agricultural use than the RESAC's data, appropriate acres were added to agricultural land uses from non-agricultural land uses. Similarly, if census agricultural land estimates were smaller than RESAC's, appropriate acres were added to non-agricultural land uses.

Adjustments were also made to the RESAC land cover to determine developed land uses. RESAC land cover was originally based on the United States Geological Survey (USGS) protocols used to develop the 2000 National Land Cover Database. The only difference between the RESAC and USGS approaches was RESAC's use of town boundaries and road densities to determine urban land covered by trees or grasses. This approach greatly improved the accuracy of the identified urban land uses, but led to the misclassification of some land adjacent to roads and highways as developed land. This was corrected by subsequent analysis. To ensure that the model accurately represented development over the simulation period, post-processing techniques that reflected changes in urban land use have been applied.

The result of this approach is that CBP P5 land use does not exist in a single GIS coverage; instead it is only available in a tabular format. The CBP P5 watershed model is comprised of 25 land uses. Most of these land uses are differentiated only by their nitrogen and phosphorus loading rates. The land uses are divided into 13 classes with distinct sediment erosion rates. Table 1 lists the CBP P5 generalized land uses, detailed land uses, which are classified by their erosion rates, and the acres of each land use in the Gwynns Falls watershed. Details of the land use development methodology have been summarized in the report entitled *Chesapeake Bay Phase 5 Community Watershed Model* (US EPA 2008).

[1] The EPA Chesapeake Bay Program developed the first watershed model in 1982. There have been many upgrades since the first phase of this model. The CBP P5 was developed to estimate flow, nutrient, and sediment loads to the Bay.

Gwynns Falls Watershed Land Use Distribution

The Gwynns Falls watershed consists primarily of urban land use (87.5%), with a small amount of forest land use (10.5%). There are also small amounts of crop (1.7%) and pasture (0.2%). A detailed summary of the watershed land use areas is presented in Table 1, and a land use map is provided in Figure 2.

Table 1: Land Use Percentage Distribution for the Gwynns Falls Watershed

General Land Use	Detailed Land Use	Area (Acres)	Percent	Grouped Percent of Total
Crop	Animal Feeding Operations	13.1	0.0	
	Hay	73.6	0.2	
	High Till	144.3	0.3	
	Low Till	470.9	1.1	
	Nursery	1.1	0.0	1.7
Extractive	Extractive	15.9	0.0	0.0
Forest	Forest	4,328.9	10.4	
	Harvested Forest	43.7	0.1	10.5
Pasture	Pasture	86.6	0.2	
	Trampled Pasture	0.2	0.0	0.2
Urban	Urban: Barren (Construction)	357.7	0.9	
	Urban: Impervious	13,582.9	32.7	
	Urban: Pervious	22,436.8	54.0	87.5
Total		41,555.8	100.0	100.0

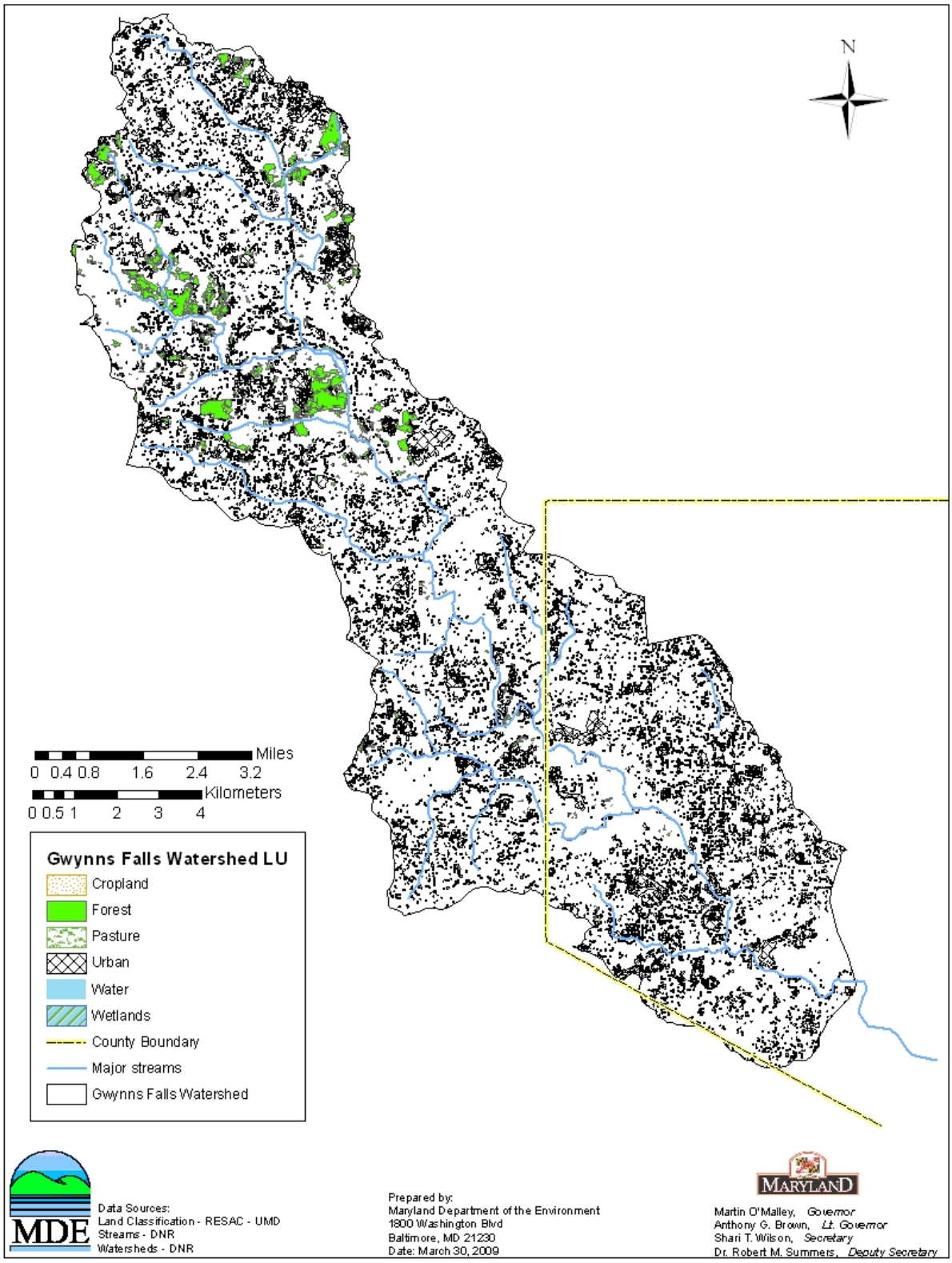

Figure 2: Land Use of the Gwynns Falls Watershed

2.2 Source Assessment

The Gwynns Falls Watershed Total Baseline Sediment Load can be subdivided into nonpoint and point source loads. This section summarizes the methods used to derive each of these distinct source categories.

2.2.1 Nonpoint Source Assessment

In this document, the nonpoint source loads account for sediment loads from unregulated stormwater runoff within the Gwynns Falls watershed. This section provides the background and methods for determining the nonpoint source baseline loads generated within the Gwynns Falls watershed (Nonpoint Source BL_{GF}).

General load estimation methodology

Nonpoint source sediment loads generated within the Gwynns Falls watershed are estimated based on the *edge-of-stream (EOS) calibration target loading rates* from the CBP P5 model. This approach is based on the fact that not all of the *edge-of-field* (EOF) sediment load is delivered to the stream or river (some of it is stored on fields down slope, at the foot of hillsides, or in smaller rivers or streams that are not represented in the model). To calculate the actual EOS loads, a *sediment delivery ratio* (the ratio of sediment reaching a basin outlet compared to the total erosion within the basin) is used. Details of the methods used to calculate sediment load have been summarized in the report entitled *Chesapeake Bay Phase 5 Community Watershed Model* (US EPA 2008).

Edge-of-Field Target Erosion Rate Methodology

EOF target erosion rates for agricultural land uses and forested land use were based on erosion rates determined by the Natural Resource Inventory (NRI). NRI is a statistical survey of land use and natural resource conditions conducted by the Natural Resources Conservation Service (NRCS) (USDA 2006). Sampling methodology is explained by Nusser and Goebel (1997).

Estimates of average annual erosion rates for pasture and cropland are available on a county basis at five-year intervals, starting in 1982. Erosion rates for forested land uses are not available on a county basis from NRI; however, for the purpose of the CBP Phase 2 watershed model, NRI calculated average annual erosion rates for forested land use on a watershed basis. These rates are still being used as targets in the CBP P5 model.

The average value of the 1982 and 1987 surveys was used as the basis for EOF target loads. The erosion rates from this period do not reflect best management practices (BMPs) or other soil conservation policies introduced in the wake of the effort to restore the Chesapeake Bay. To compensate for this, a BMP factor was included in the loading estimates using best available “draft” information from the CBP P5. Rates for urban pervious, urban impervious, and barren land were based on a combination of best professional judgment, literature analysis, and regression analysis. Table 2 lists erosion rates specific to the Gwynns Falls watershed.

Table 2: Summary of EOF Erosion Rate Calculations

Land Use	Data Source	Baltimore County (tons/acre/year)	Baltimore City (tons/acre/year)
Forest	Phase 2 NRI	0.46	0.47
Harvested Forest[1]	Average Phase 2 NRI (x 10)	3	3
Nursery	Pasture NRI (x 9.5)	12.26	2.57
Pasture	Pasture NRI (1982-1987)	1.29	0.27
Trampled pasture[2]	Pasture NRI (x 9.5)	12.26	2.57
Animal Feeding Operations[2]	Pasture NRI (x 9.5)	12.26	2.57
Hay[2]	Crop NRI (1982-1987) (x 0.32)	3.18	0.8
High Till	Crop NRI (1982-1987) (x 1.25)	12.42	3.14
Low till With Manure[2]	Crop NRI (1982-1987) (x 0.75)	7.45	1.89
Pervious Urban	Intercept Regression Analysis	0.74	0.74
Extractive	Best professional judgment	10	10
Barren	Literature survey	20	20
Impervious	100% Impervious Regression Analysis	5.18	5.18

Notes: [1]Based on an average of NRI values for the Chesapeake Bay Phase 5 segments.
[2]NRI score data adjusted based on land use.

Sediment Delivery Ratio: The base formula for calculating *sediment delivery ratio*s in the CBP P5 model is the same as the formula used by the NRCS (USDA 1983).

$$DF = 0.417762 * A^{-0.134958} - 0.127097 \qquad \text{(Equation 2.1)}$$

where
DF (delivery factor) = the sediment delivery ratio
A = drainage area in square miles

In order to account for the changes in sediment loads due to distance traveled to the stream, the CBP P5 model uses the *sediment delivery ratio*. Land use specific *sediment delivery ratios* were calculated for each river segment using the following procedure:

(1) mean distance of each land use from the river reach was calculated;

(2) *sediment delivery ratio*s for each land use were calculated (drainage area in Equation 2.1 was assumed to be equal to the area of a circle with radius equal to the mean distance between the land use and the river reach).

Edge-of-Stream Loads

Edge-of-stream loads are the loads that actually enter the river reaches (i.e., the mainstem of a watershed). Such loads represent not only the erosion from the land but all of the intervening processes of deposition on hillsides and sediment transport through smaller rivers and streams.

Streambank Erosion

Many studies have documented the relationship between high amounts of connected impervious surfaces, increases in storm flows, and stream degradation in the form of streambank erosion (Schueler 1994; Arnold and Gibbons 1996). In many urbanized watersheds, small stream channels have been replaced by sewer pipes. As a result, impervious surfaces such as rooftops, parking lots, and road surfaces are now directly connected to the main stream channel via the storm sewer system. During a storm event, this causes a greater amount of precipitation to flow more rapidly into a given stream channel once it reaches the surface. Furthermore, less water infiltrates into the ground both during and after a storm event, thereby limiting the amount of groundwater recharge to a stream. This altered urban hydrology typically causes abnormally high flows in streams during storms and abnormally low flows during dry periods. The high flows occurring during storm events increase sheer stress and cause excessive erosion of streambanks and streambeds, which leads to degraded stream channel conditions for biological communities (MDE 2007a).

Two methods of estimating streambank erosion were presented in the *Total Maximum Daily Loads of Sediment/Total Suspended Solids for the Anacostia River Basin, Montgomery and Prince George's Counties, Maryland and The District of Columbia*. The first estimate uses the Anacostia Hydrological Simulation Program – FORTRAN (HSPF) watershed model in conjunction with the Penn State University streambank

erosion equation (Evans et al. 2003). The analysis estimated that approximately 73% of the total annual sediment load within the Anacostia River watershed could be attributed to streambank erosion (MDE 2007a).

The second method analyzes the long term relationship between flow and total suspended solids (TSS) concentrations to quantify the effects of an altered urban hydrology on watershed sediment loads. Changes in hydrology in the Anacostia River watershed were characterized using daily flow data from the USGS gage stations. The long-term changes over time in the flow duration curves (FDCs) for each of these stations was quantified using a type of statistical analysis known as "quantile regression." The portion of the FDC representing the highest flows was determined to have increased significantly over time, consistent with hydrologic alteration from increased impervious surfaces. Also, a "sediment rating curve" (i.e., the relationship between suspended sediment concentration and flow) was computed and combined with the FDCs to estimate annual sediment loads before and after increased development (i.e., altered hydrology). The results of the analysis indicate that approximately 75% of the total annual sediment load in the Anacostia River watershed is due to alterations in hydrology (MDE 2007a).

Using CBP P5 urban sediment EOF target values, MDE developed a formula for estimating the percent of erosional sediment resultant from streambank erosion (i.e., that portion of the total urban sediment load attributed to stream bank erosion) based on the amount of impervious land within a watershed. The equation uses the urban sediment loading factors to estimate the proportion of the urban sediment load from stream bank erosion. The assumption is that as impervious surfaces increase, the upland sources decrease, flow increases, and the change in sediment load results from increased streambank erosion. While this formula only represents an empirical approximation, it is consistent with results from the Anacostia River Sediment TMDL and recognizes that stream bank erosion can be a significant portion of the total sediment load. The formula is as follows:

$$\%E = \frac{I * L_I}{I * L_I + (1 - I)L_P} \qquad \text{(Equation 2.2)}$$

where:
% E = percent erosional sediment resultant from streambank erosion
I = percent impervious
L_I = Impervious urban land use EOF load
L_P = Pervious urban land use EOF load

The relationship demonstrated in equation 2.2 is expressed graphically in Figure 3. Using the equation, the Anacostia River watershed (23% impervious) would equate to approximately a 68% erosional sediment load resultant from streambank erosion. Per Table 1, approximately 33% of the Gwynns Falls watershed is covered by impervious surfaces. This would equate to approximately a 77% erosional sediment load resultant from streambank erosion.

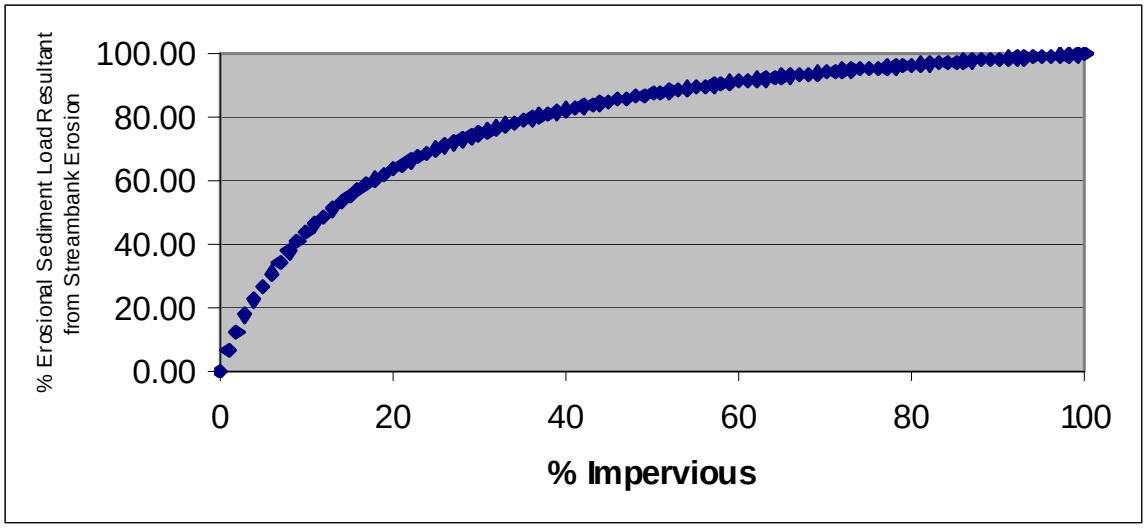

Figure 3: Percent Impervious vs. Percent Erosional Sediment Load Resultant from Streambank Erosion

For this TMDL, erosional sediment resultant from streambank erosion represents an aggregate load within the total urban impervious EOF loads as described in the report *Chesapeake Bay Phase V Community Watershed Model* (US EPA 2008) and is not explicitly reported.

2.2.2 Point Source Assessment

A list of 57 active permitted point sources that contribute to the sediment load in the Gwynns Falls watershed was compiled using MDE's Environmental Permit Service Center (EPSC) database. The types of permits identified include individual municipal, individual municipal separate storm sewer systems (MS4s), general mineral mining, general industrial stormwater, and general MS4s. The permits can be grouped into two categories, process water and stormwater. The process water category includes those loads generated by continuous discharge sources whose permits have TSS limits. The stormwater category includes all National Pollutant Discharge Elimination System (NPDES) regulated stormwater discharges. Other permits that do not meet these conditions are considered *de minimis* in terms of the total sediment load.

The sediment loads for the 5 process water permits (Process Water BL_{GF}) are calculated based on their TSS limits and corresponding flow information. The 52 NPDES Phase I or Phase II stormwater permits identified throughout the Gwynns Falls watershed are regulated based on BMPs and do not include TSS limits. In the absence of TSS limits, the NPDES regulated stormwater baseline load (NPDES Stormwater BL_{GF}) is calculated using methods described in Section 2.2.1 and watershed specific urban land use sediment delivery factors. A detailed list of the permits appears in Appendix B.

2.2.3 Summary of Baseline Loads

Table 3 summarizes the Gwynns Falls Baseline Sediment Load, reported in tons per year (ton/yr) and presented in terms of nonpoint and point source loadings.

Table 3: Gwynns Falls Baseline Sediment Loads (ton/yr)

Total Baseline Load (ton/yr)	=	**Nonpoint Source BL_{GF}**	+	**NPDES Stormwater BL_{GF}**	+	**Process Water BL_{GF}**
22,048.5	=	1,759.3	+	20,076.0	+	213.2

Table 4 presents a breakdown of the Gwynns Falls Total Baseline Sediment Load, detailing loads per land use. The largest portion of the sediment load is from urban land (92%). The remainder of the sediment load is from crop land (5%) and forest (2%), with small amounts from other land uses.

Table 4: Detailed Baseline Sediment Budget Loads Within the Gwynns Falls Watershed

General Land Use	Detailed Land Use	Load (Ton/Yr)	Percent	Grouped Percent of Total
Crop	Animal Feeding Operations	34.9	0.2	
	Hay	49.9	0.2	
	High Till	361.3	1.6	
	Low Till	740.1	3.4	
	Nursery	2.9	0.0	5.4
Extractive	Extractive	34.3	0.2	0.2
Forest	Forest	482.0	2.2	
	Harvested Forest	31.7	0.1	2.3
Pasture	Pasture	21.6	0.1	
	Trampled Pasture	0.7	0.0	0.1
Urban[1]	Urban: Barren (Construction)	1069.8	4.9	
	Urban: Impervious	15,507.8	70.3	
	Urban: Pervious	3,498.4	15.9	91.1
	Process Water	213.2	1.0	1.0
Total		22,048.5	100.0	100.0

Note: [1] The urban land use load represents the permitted stormwater load.

2.3 Water Quality Characterization

The Gwynns Falls watershed was originally listed on Maryland's 1996 303(d) List as impaired by elevated sediments from nonpoint sources, with supporting evidence cited in Maryland's 1996 305(b) report. The 1996 305(b) report did not directly state that elevated sediments were a concern, and it has been determined that the sediment listing was based on best professional judgment (MDE 2004; DNR 1996).

Currently in Maryland, there are no specific numeric criteria for suspended sediments. Therefore, to determine whether aquatic health is impacted by elevated sediment loads, MDE's recently developed biological stressor identification methodology was applied. The primary goal of the BSID analysis is to identify the most probable cause(s) for observed biological impairments throughout MD's 8-digit watersheds (MDE 2009a).

The BSID analysis applies a case-control, risk-based, weight-of-evidence approach to identify potential causes of biological impairment. The risk-based approach estimates the strength of association between various stressors and a degraded biological community. The BSID analysis then identifies individual stressors (pollutants) as probable or unlikely causes of the poor biological conditions within a given MD 8-digit watershed and subsequently reviews ecological plausibility/concludes whether or not these individual stressors or groups of stressors are contributing to the impairment (MDE 2009a).

The primary dataset for BSID analysis is round two Maryland Department of Natural Resources (DNR) Maryland Biological Stream Survey (MBSS) data (collected between 2000-2004) because it provides a broad spectrum of paired data variables, which allow for a more comprehensive stressor analysis. The MBSS is a robust statewide probability-based sampling survey for assessing the biological conditions of wadeable, non-tidal streams (Klauda et al. 1998; Roth et al. 2005). It uses a fixed length (75 m) randomly selected stream segment for collecting site level information within a primary sampling unit (PSU), also defined as a watershed. The randomly selected stream segments, from which field data are collected, are selected using either stratified random sampling with proportional allocation, or simple random sampling (Cochran 1977). The random sample design allows for unbiased estimates of overall watershed conditions. Thus, the dataset facilitated case-control analyses because 1) in-stream biological data are paired with chemical, physical, and land use data variables that could be identified as possible stressors and 2) it uses a probabilistic statewide monitoring design.

The BSID analysis groups the individual stressors (physical and chemical variables) into three generalized parameters in order to assess how the resulting impacts of these stressors can alter the biological community and structure. The three generalized parameters include: sediment, habitat, and water chemistry. Identification of a sediment/flow stressor as contributing to the biological impairment is based on the results of the individual stressor associations within both the sediment and habitat parameters that reveal the effects of sediment related impacts or an altered hydrologic regime (MDE 2009a).

In addition to the MBSS round two data applied within the BSID analysis, data from the Maryland DNR Core/Trend Program was also used for water quality characterization in the TMDL. The program collected benthic macroivertebrate data between 1976 and 2006. This data was used to calculate four benthic community measures: total number of taxa, the Shannon Weiner diversity index, the modified Hilsenhoff biotic integrity index, and percent Ephemeroptera, Plecoptera, and Trichoptera (EPT). DNR has extensive monitoring data for two stations on the mainstem of the Gwynns Falls through the Core/Trend program. One station is located at Liberty Road and the other at Route 1. (See Figure 4 and table 5) (DNR 2007).

Gwynns Falls Watershed Monitoring Stations

A total of 30 water quality monitoring stations were used to characterize the Gwynns Falls Watershed. Twenty-eight biological/physical habitat monitoring stations from the MBSS program round one and two data collection were used to characterize the Gwynns Falls Watershed in Maryland's 2008 Integrated Report. The BSID analysis used the 12 biological/physical habitat monitoring stations from the MBSS program round two data collection. Additionally, two biological monitoring stations from the Maryland Core/Trend monitoring network were applied within the TMDL analysis. All stations are presented in Figure 4 and listed in Table 5.

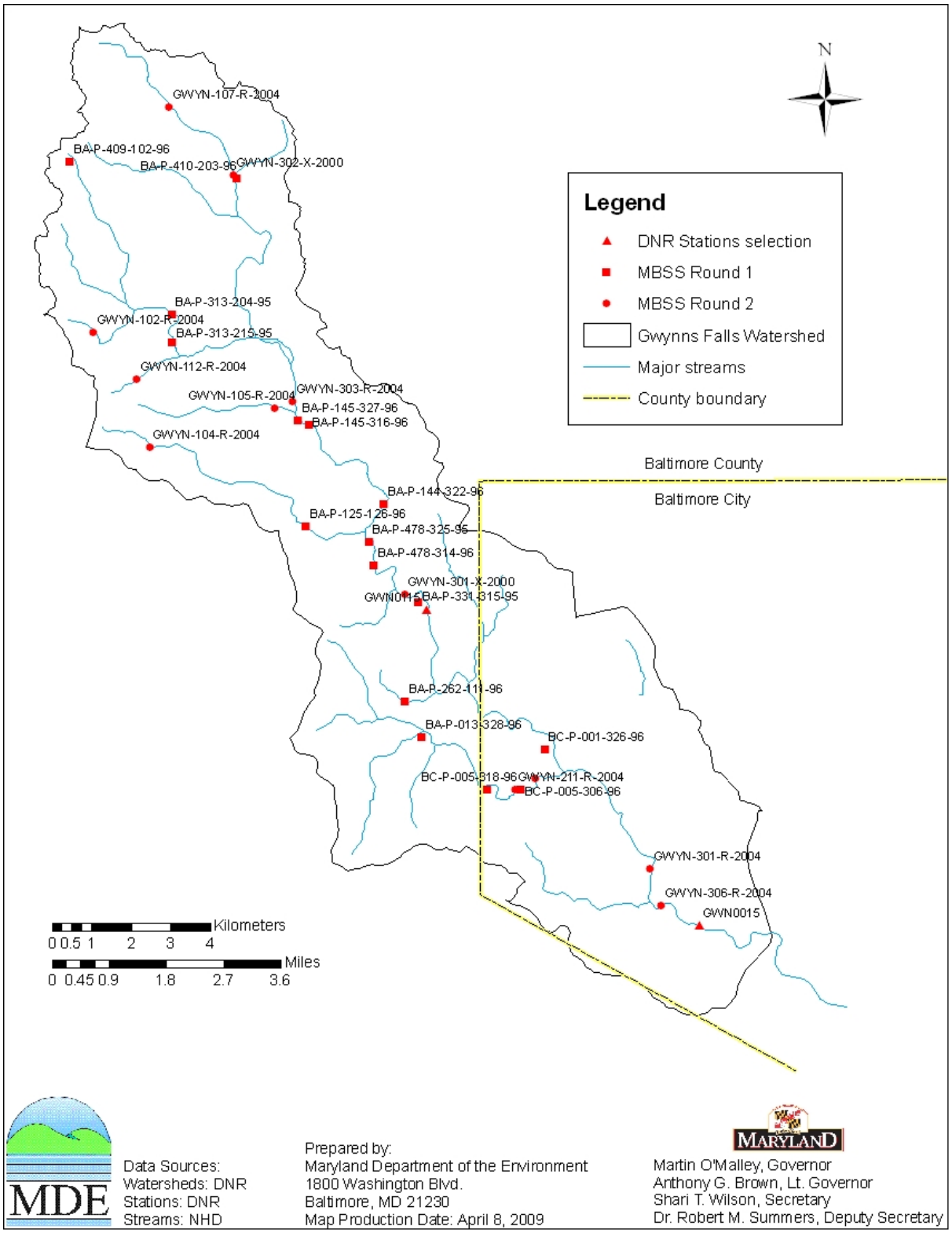

Figure 4: Monitoring Stations in the Gwynns Falls Watershed

Table 5: Monitoring Stations in the Gwynns Falls Watershed

Site Number	Sponsor	Site Type	Site Name	Latitude (dec degrees)	Longitude (dec degrees)
BA-P-013-328-96	MD DNR	MBSS, Round 1	DEAD RUN	39.3140	-76.7280
BA-P-125-126-96	MD DNR	MBSS, Round 1	SCOTTS LEVEL BR	39.3620	-76.7620
BA-P-144-322-96	MD DNR	MBSS, Round 1	GWYNNS FALLS	39.3670	-76.7390
BA-P-145-316-96	MD DNR	MBSS, Round 1	GWYNNS FALLS	39.3850	-76.7610
BA-P-145-327-96	MD DNR	MBSS, Round 1	GWYNNS FALLS	39.3860	-76.7640
BA-P-262-111-96	MD DNR	MBSS, Round 1	GWYNNS FALLS UT1	39.3220	-76.7330
BA-P-313-204-95	MD DNR	MBSS, Round 1	RED RUN	39.4102	-76.8012
BA-P-313-215-95	MD DNR	MBSS, Round 1	RED RUN	39.4040	-76.8009
BA-P-331-315-95	MD DNR	MBSS, Round 1	GWYNNS FALLS	39.3446	-76.7289
BA-P-409-102-96	MD DNR	MBSS, Round 1	RED RUN	39.4450	-76.8310
BA-P-410-203-96	MD DNR	MBSS, Round 1	GWYNNS FALLS	39.4410	-76.7820
BA-P-478-314-96	MD DNR	MBSS, Round 1	GWYNNS FALLS	39.3530	-76.7420
BA-P-478-325-95	MD DNR	MBSS, Round 1	GWYNNS FALLS	39.3583	-76.7434
BC-P-001-326-96	MD DNR	MBSS, Round 1	GWYNNS FALLS	39.3110	-76.6920
BC-P-005-306-96	MD DNR	MBSS, Round 1	DEAD RUN	39.3020	-76.6990
BC-P-005-318-96	MD DNR	MBSS, Round 1	DEAD RUN	39.3020	-76.7090
GWYN-102-R-2004	MD DNR	MBSS, Round 2	RED RUN UT 2	39.4062	-76.8241
GWYN-104-R-2004	MD DNR	MBSS, Round 2	SCOTTS LEVEL BR	39.3801	-76.8078
GWYN-105-R-2004	MD DNR	MBSS, Round 2	HORSEHEAD BR	39.3888	-76.7709
GWYN-107-R-2004	MD DNR	MBSS, Round 2	GWYNNS FALLS	39.4572	-76.8018
GWYN-112-R-2004	MD DNR	MBSS, Round 2	RED RUN UT 1	39.3955	-76.8114
GWYN-210-R-2004	MD DNR	MBSS, Round 2	DEAD RUN	39.3044	-76.6949
GWYN-211-R-2004	MD DNR	MBSS, Round 2	DEAD RUN	39.3019	-76.7008
GWYN-301-R-2004	MD DNR	MBSS, Round 2	GWYNNS FALLS	39.2838	-76.6614
GWYN-301-X-2000	MD DNR	MBSS, Round 2	GWYNNS FALLS	39.3464	-76.7331
GWYN-302-X-2000	MD DNR	MBSS, Round 2	GWYNNS FALLS	39.4419	-76.7831
GWYN-303-R-2004	MD DNR	MBSS, Round 2	GWYNNS FALLS	39.3904	-76.7656
GWYN-306-R-2004	MD DNR	MBSS, Round 2	GWYNNS FALLS	39.2755	-76.6582
GWN0015	MD DNR	Trend	Route 1	39.3140	-76.7280
GWN0115	MD DNR	Core	Liberty road	39.3620	-76.7620

2.4 Water Quality Impairment

The Maryland water quality standards surface water use designations for the Gwynns Falls mainstem and its tributaries is Use I (Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life), except for the Gwynns Falls mainstem and its tributaries above Reisterstown Road and Red Run and its tributaries, which are designated as Use III (Nontidal Cold Water), and Dead Run and its tributaries, which are classified as Use IV (Recreational Trout Waters) (COMAR 2008a,b,c,d,e). The water quality impairment of the Gwynns Falls watershed addressed by this TMDL is caused by an elevated sediment load beyond a level that the watershed can sustain without causing any sediment related impacts to aquatic health, where aquatic health is based on benthic and fish Index of Biotic Integrity (IBI) scores, as demonstrated via the BSID analysis for the watershed.

The Gwynns Falls watershed is listed on Maryland's 2008 Integrated Report as impaired for impacts to biological communities. Greater than 79% of the stream miles in the Gwynns Falls watershed are assessed as having degraded biological conditions (when compared to regional reference indices). The biological impairment listing is based on the combined results of MBSS round one (1995-1997) and round two (2000-2004) data, which includes twenty-eight stations. Twenty-two of the twenty-eight stations have degraded BIBI/FIBI scores significantly lower than 3.0 (MDE 2008). As mentioned in Section 2.3, however, only MBSS round 2 data were used in the BSID analysis. See Figure 4 and Table 5 for station locations and information.

The results of the BSID analysis for the Gwynns Falls watershed are presented in a report entitled *Watershed Report for Biological Impairment of the Gwynns Falls Watershed in Baltimore City and Baltimore County, Maryland Biological Stressor Identification Analysis Results and Interpretation* (MDE 2009b). The report states that the degradation of biological communities in the Gwynns Falls watershed is strongly associated with urban land use and its concomitant effects: altered hydrology, sediment related impacts, and elevated levels of sulfate, chlorides, and conductivity (a measure of the presence of dissolved substances).

The BSID analysis has determined that the biological impairment in the Gwynns Falls watershed is due in part to flow/sediment related stressors. Specifically, the analysis confirmed that individual stressors within the sediment and habitat parameter groupings were contributing to the biological impairment in the watershed. Also, the analysis identified the following stressors within the sediment and habitat parameter groupings as having a statistically significant association with impaired biological communities at the respective percentage of degraded sites: channelization (34%), channel alteration (poor: 24%), and bar formation (extensive: 23%). Overall, sediment and flow stressors within the sediment and habitat parameter groupings were identified at approximately 24% and 40%, respectively, of the degraded sites throughout the watershed (MDE 2009b). Therefore, since sediment is identified as a stressor to the biological communities in the Gwynns Falls watershed, a TMDL is required.

As a supplement to the MBSS round two data used in the BSID analysis, the biological monitoring results from the two Maryland DNR Core/trend stations along the mainstem of the Gwynns Falls indicate that mainstem water quality can be classified as poor to fair/good based on percent EPT, taxa number, biotic index, and diversity index (see Table 6). Statistical analysis of the long term Core/Trend data indicates since 1977, that one station has shown improvement and one station has shown no change (DNR 2007). The poor water quality status for Station GWN0015 is consistent with the results of the MBSS data at the nearby upstream station, GWYN-306-R-2004.

Table 6: Gwynns Falls Core/Trend Data

Site Number	Current Water Quality Status	Trend Since 1970's
GWN0015	POOR	NO CHANGE
GWN0115	FAIR/GOOD	SLIGHT IMPROVEMENT

3.0 TARGETED WATER QUALITY GOAL

The objective of the sediment TMDL established herein is to reduce sediment loads, and subsequent effects on aquatic health, in the Gwynns Falls watershed to levels that support the Use I/III/IV designations (Water contact recreation, and protection of Nontidal Warmwater Aquatic Life) (Nontidal Coldwater) (Recreational Trout Waters) (COMAR 2008a,b,c,d,e). Assessment of aquatic health is based on Maryland's biocriteria protocol, which evaluates both the amount and diversity of the benthic and fish community through the use of the IBI (Roth et al. 1998, 2000; Stribling et al. 1998; MDE 2008).

Reductions in sediment loads are expected to result from decreased watershed and streambed erosion, which will then lead to improved benthic and fish habitat conditions. Specifically, sediment load reductions are expected to result in an increase in the number of benthic sensitive species present, an increase in the available and suitable habitat for a benthic community, a possible decrease in fine sediment (fines), and improved stream habitat diversity, all of which will result in improved water quality.

The TMDL, however, will not completely resolve the impairment to biological communities within the watershed. Since the BSID watershed analysis identifies other possible stressors (i.e., chlorides, sulfate, conductivity) as impacting the biological conditions, this impairment remains to be fully addressed through the Integrated Report listing process and the TMDL development process, such that all impairing substances identified as impacting biological communities in the watershed are reduced to levels that will meet water quality standards, as established in future TMDLs for those substances (MDE 2009a).

4.0 TOTAL MAXIMUM DAILY LOADS AND SOURCE ALLOCATION

4.1 Overview

This section describes how the sediment TMDL and the corresponding allocations were developed for the Gwynns Falls watershed. Section 4.2 describes the analysis framework for estimating sediment loading rates and the assimilative capacity of the watershed stream system. Section 4.3 summarizes the scenarios that were used in the analysis and presents results. Section 4.4 discusses critical conditions and seasonality. Section 4.5 explains the calculations of TMDL loading caps. Section 4.6 details the load allocations, and Section 4.7 explains the rationale for the margin of safety. Finally, Section 4.8 summarizes the TMDL.

4.2 Analysis Framework

Since there are no specific numeric criteria that quantify the impact of sediment on the aquatic health of nontidal stream systems, a reference watershed approach will be used to establish the TMDL. Furthermore, as the BSID analysis established a link between biological impairment and sediment related stressors, the reference watershed approach will utilize a biological endpoint.

Watershed Model

The watershed model framework chosen for the Gwynns Falls watershed TMDL was the CBP P5 long-term average annual watershed model EOS loading rates. The spatial domain of the CBP P5 watershed model segmentation aggregates to the MD 8-digit watersheds, which is consistent with the impairment listing. The EOS loading rates were used because actual time variable CBP P5 calibration and scenario runs are currently being developed and are not yet available. These target-loading rates are used to calibrate the land use EOS loads within the CBP P5 model and thus should be consistent with future CBP modeling efforts.

The nonpoint source and NPDES stormwater baseline sediment loads generated within the Gwynns Falls watershed are calculated as the sum of corresponding land use EOS loads within the watershed and represent a long-term average loading rate. Individual land use EOS loads are calculated as a product of the land use area, land use target loading rate, and loss from the EOF to the main channel. The loss from the EOF to the main channel is the *sediment delivery ratio* and is defined as the ratio of the sediment load reaching a basin outlet to the total erosion within the basin. A *sediment delivery ratio* is estimated for each land use type based on the proximity of the land use to the main channel. Thus, as the distance to the main channel increases, more sediment is stored within the channels (i.e., *sediment delivery ratio* decreases). Details of the data sources for the unit loading rates can be found in Section 2.2 of this report.

The Gwynns Falls watershed was evaluated using two watershed TMDL segments (see Figure 5). TMDL Segment 1 represents the sediment loads generated in the northwestern portion of the watershed. TMDL Segment 2 represents the sediment loads generated in the southeastern portion of the watershed.

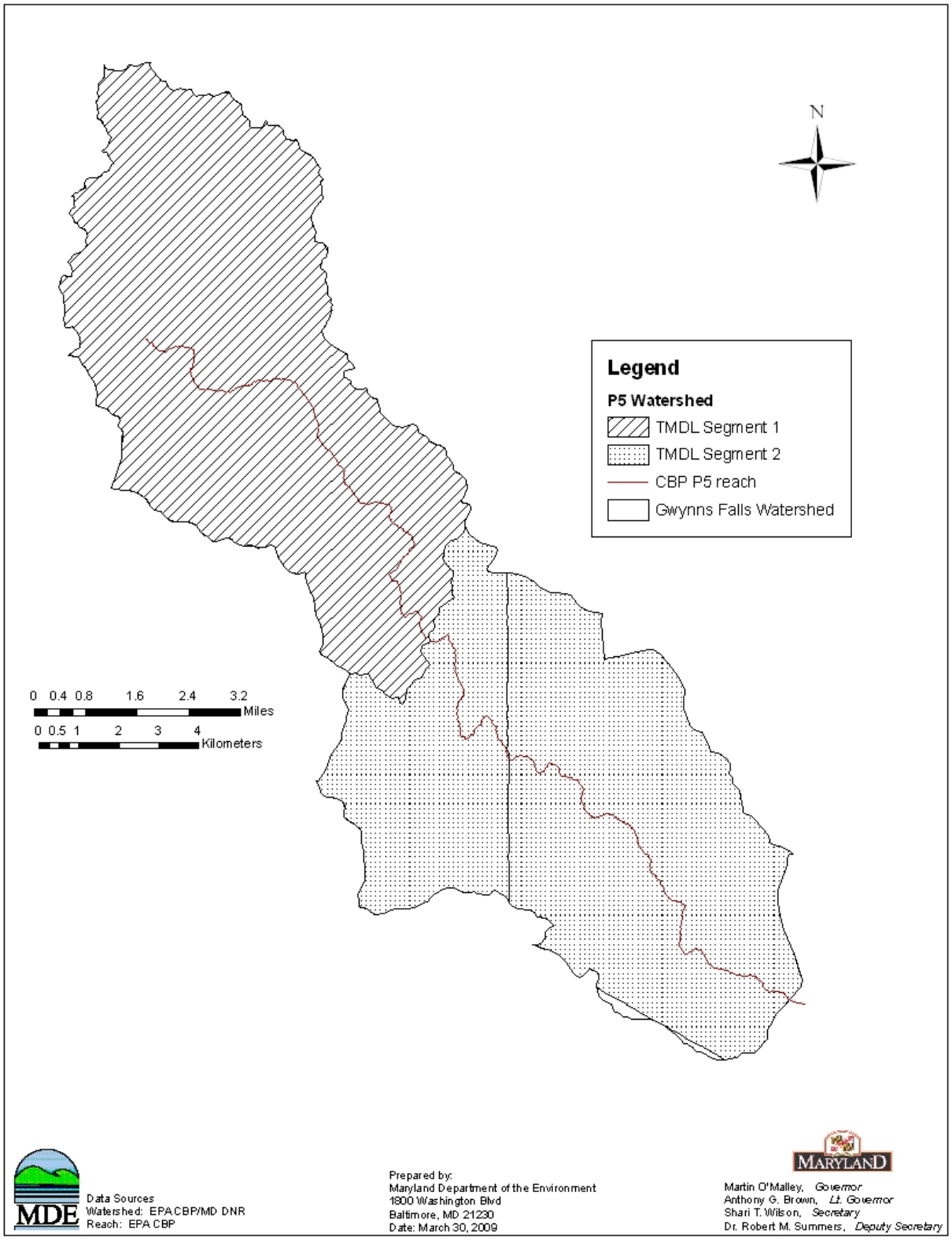

Figure 5: Gwynns Falls Watershed TMDL Segmentation

Reference Watershed Approach

Currently in Maryland, there are no specific numeric criteria that quantify the impact of sediment on the aquatic health of non-tidal stream systems. Therefore, in order to quantify the impact of sediment on the aquatic health of non-tidal stream systems, a reference watershed TMDL approach was used and resulted in the establishment of a *sediment loading threshold* for watersheds within the Highland and Piedmont physiographic regions (Currey et al. 2006). Reference watersheds were determined based on Maryland's biocriteria methodology. The biocriteria methodology assesses biological impairment at the 8-digit watershed scale based on the percentage of MBSS monitoring stations, translated into watershed stream miles, that are degraded. Individual monitoring station impairment is determined based on BIBI/FIBI scores lower than the Minimum Allowable IBI Limit (MAL), which is calculated based on the average annual allowable IBI value of 3.0 (on a scale of 1 to 5). Applying the MAL threshold helps avoid classification errors when assessing biological impairment (Roth et al. 1998, 2000; Stribling et al. 1998; MDE 2008).

Comparison of watershed sediment loads to loads from reference watersheds requires that the watersheds be similar in physical and hydrological characteristics. To satisfy this requirement, Currey et al. (2006) selected reference watersheds only from the Highland and Piedmont physiographic regions (see appendix A for the list of reference watersheds). This region is consistent with the non-coastal region that was identified in the 1998 development of FIBI and subsequently used in the development of BIBI (Roth et al. 1998; Stribling et al. 1998).

To reduce the effect of the variability within the Highland and Piedmont physiographic regions, the watershed sediment loads were then normalized by a constant background condition, the all forested watershed condition. This new normalized term, defined as the *forest normalized sediment load* (Y_n), represents how many times greater the current watershed sediment load is than the *all forested sediment load*. A similar approach was used by EPA Region 9 for sediment TMDLs in California (e.g., Navarro River or Trinity River TMDLs), where the loading capacity was based on an analysis of the amount of human-caused sediment delivery that can occur in addition to natural sediment delivery, without causing adverse impacts to aquatic life. The *forest normalized sediment load* for this TMDL is calculated as the current watershed sediment load divided by the *all forested sediment load*. The equation for the *forest normalized sediment load* is as follows:

$$Y_n = \frac{y_{ws}}{y_{for}} \qquad \text{(Equation 4.1)}$$

where:

Y_n = forest normalized sediment load
y_{ws} = current watershed sediment load (ton/yr)
y_{for} = all forested sediment load (ton/yr)

Nine reference watersheds were selected from the Highland/Piedmont region. Reference watershed *forest normalized sediment loads* were calculated using CBP P5 2000 land use in order to maintain consistency with MBSS sampling years. The median and 75th percentile of the reference watershed *forest normalized sediment loads* were calculated and found to be 3.3 and 4.2 respectively. These values are in close agreement with more complex methods used to determine the *sediment loading threshold* in previous nontidal sediment TMDLs. Therefore, the median value of 3.3 was established as the *sediment loading threshold* as an environmentally conservative approach to develop this TMDL (see Appendix A for more details).

The *forest normalized sediment loads* for the Gwynns Falls watershed (estimated as 4.3 and 5.9 for TMDL Segments 1 and 2 respectively) were calculated using CBP P5 2005 landuse, to best represent current conditions. A comparison of the Gwynns Falls watershed *forest normalized sediment loads* to the *forest normalized reference sediment load* (also referred to as the *sediment loading threshold*) demonstrates that both TMDL segments exceed the *sediment loading threshold*, indicating that they are receiving loads that are above the maximum allowable load that the watershed can sustain and still meet water quality standards.

4.3 Scenario Descriptions and Results

The following analyses allow a comparison of baseline conditions (under which water quality problems exist) with future conditions, which project the water quality response to various simulated sediment load reductions. The analyses are grouped according to baseline conditions and future conditions associated with TMDLs.

Baseline Conditions

The baseline conditions are intended to provide a point of reference by which to compare the future scenario that simulates conditions of a TMDL. The baseline conditions typically reflect an approximation of nonpoint source loads during the monitoring time frame, as well as estimated point source loads based on discharge data for the same period.

The Gwynns Falls watershed baseline sediment loads are estimated using the CBP P5 target EOS land use sediment loading rates with 2005 land use. Watershed loading calculations, based on the CBP P5 segmentation scheme, are represented by multiple CBP P5 model segments within each TMDL segment. The sediment loads from these segments are combined to represent the baseline condition. The point source sediment loads are estimated based on the existing permit information. Details of these loading source estimates can be found in Section 2.2 and Appendix B of this report.

Future (TMDL) Conditions

This scenario represents the future conditions of maximum allowable sediment loads whereby there will be no sediment related impacts to aquatic health. In the TMDL calculation, the allowable load for the impaired watershed is calculated as the product of the *sediment loading threshold* (determined from watersheds with a healthy biological community) and the Gwynns Falls *all forested sediment load* (see Section 4.2). The resulting load is considered the maximum allowable load the watershed can sustain without causing any sediment related impacts to aquatic health.

The TMDL loading and associated reductions are averaged at the MD 8-digit watershed scale, which is consistent with the original listing scale. It is important to recognize that some subwatersheds may require higher reductions than others, depending on the distribution of the land use.

The formula for estimating the TMDL is as follows:

$$TMDL = \sum_{i=1}^{n} Yn_{ref} \cdot y_{forest_i} \qquad \text{(Equation 4.2)}$$

where
TMDL = allowable load for impaired watershed (ton/yr)
Yn_{ref} = sediment loading threshold = forest normalized reference sediment load (3.3)
y_{forest_i} = all forested sediment load for segment *i* (ton /yr)
i = CBP P5 model segment
n = number of CBP P5 model segments in watershed

The Gwynns Falls watershed allowable sediment load is estimated using equation 4.2.

4.4 Critical Condition and Seasonality

EPA's regulations require TMDLs to take into account seasonality and critical conditions for stream flow, loading, and water quality parameters (CFR 2008b). The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when it is most vulnerable. The biological monitoring data used to determine the reference watersheds integrates the stress effects over the course of time and thus inherently addresses critical conditions. Seasonality is captured in two components. First, it is implicitly included through the use of the biological monitoring data. Second, the MBSS dataset included benthic sampling in the spring and fish sampling in the summer.

4.5 TMDL Loading Caps

This section presents the Gwynns Falls watershed average annual sediment TMDL. This load is considered the maximum allowable long-term average annual load the watershed can sustain without causing any sediment related impacts to aquatic health.

The long-term average annual TMDL was calculated for both TMDL Segment 1 and Segment 2 (see Figure 5) independently, based on Equation 4.2 and set at a load 3.3 times the all forested condition. In order to attain the TMDL loading cap calculated for the segments, reductions will be applied to the predominant controllable sources. If only these predominant (generally the largest) sources are controlled, water quality standards can be achieved in the most effective, efficient, and equitable manner. Urban land was identified as the most extensive predominant controllable source in both of the TMDL segments.

Currently, MDE requires that large and medium MS4s retrofit 10% of existing urban land area where there is failing or no stormwater management every permit cycle (5 years). This level of restoration has been determined to be the current maximum feasible, regulated stormwater reduction scenario. Therefore, the reductions applied within this TMDL analysis are consistent with this 10% retrofit goal to existing urban land every 5

years with an estimated 65% TSS reduction efficiency from future stormwater BMPs (Claytor and Schueler 1997; Baldwin et al. 2007; Baish and Caliri 2009).

If the TMDL still is not achieved after applying the current maximum feasible urban stormwater reductions, then constant reductions will be applied to the remaining predominant controllable sources (i.e., significant contributors of sediment to the stream system), independent of jurisdiction. In addition to urban land, predominant sources typically include high till crops, low till crops, hay, pasture, and harvested forest, but additional sources might need to be controlled in order to ensure that the TMDL is attained.

The Gwynns Falls Baseline Load and TMDL are presented in Table 7.

Table 7: Gwynns Falls Baseline Load and TMDL

	Baseline Load (ton/yr)	**TMDL** (ton/yr)	**Reduction** (%)
TMDL Segment 1	8,474.7	6,481.3	23.5
TMDL Segment 2	13,573.6	7,514.9	44.6
Total	22,048.5	13,996.2	36.5

4.6 Load Allocations Between Point and Nonpoint Sources

Per EPA regulation, all TMDLs need to be presented as a sum of waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint source loads generated within the assessment unit, as well as natural background, tributary, and adjacent segment loads (CFR 2008a). Consequently, the Gwynns Falls watershed TMDL allocations are presented in terms of WLAs (i.e., point source loads identified within the watershed) and LAs (i.e., the nonpoint source loads within the watershed). The State reserves the right to allocate the TMDL among different sources in any manner that is reasonably calculated to protect aquatic life from sediment related impacts.

As described in Section 4.5, reductions were only applied to the regulated urban stormwater sources. Furthermore, reductions were only applied to urban areas developed prior to 1985 (i.e., approximate areas with no stormwater management). This is consistent with MS4 permit requirements for retrofitting existing urban areas at a rate of 10% every 5 years. The reduction in sediment loads associated with retrofitting 10% of existing urban areas every 5 years, with an estimated 65% TSS reduction efficiency, represents the current maximum feasible reduction scenario from the urban land use within the watershed.

In this watershed, in addition to urban land, crop and pasture were identified as the predominant controllable sources; however, no reductions were applied to these sources, since the TMDL is achieved when the current maximum feasible reductions are applied to the regulated urban stormwater sources in the watershed. Forest is the only non-controllable source, as it represents the most natural condition in the watershed, and no reductions were applied to permitted process water sources because at 1.0% of the total load, such controls would produce no discernable water quality benefit.

Table 8 summarizes the TMDL results for the Gwynns Falls watershed, derived by applying the current maximum feasible reductions to the applicable urban sediment sources. Tables 9 and 10 summarize the TMDL scenarios for TMDL Segments 1 and 2 individually. The reductions associated with the current maximum feasible scenario result in sediment loading reductions greater than those needed to achieve the TMDL. Thus, the TMDL results in Tables 8, 9, and 10 represent a feasible reduction scenario from the applicable urban sediment sources, determined using the current maximum feasible reduction scenario as a basis. The TMDL results in an overall reduction of 36% for the Gwynns Falls watershed. For more detailed information regarding the Gwynns Falls Watershed TMDL nonpoint source LA, please see the technical memorandum to this document entitled "*Significant Sediment Nonpoint Sources in the Gwynns Falls Watershed*".

Table 8: Gwynns Falls TMDL Reductions by Source Category

Baseline Load Source Categories		**Baseline Load** (ton/yr)	**TMDL Components**	**TMDL** (ton/yr)	**Reduction** (%)
Nonpoint Source		1,759.3	**LA**	1,759.3	0.0%
Point Source	Urban	20,076.0	**WLA**	12,023.7	40.1%
	Permits	213.2		213.2	0.0%
TOTAL		**22,048.5**		**13,996.2**	**36.5%**

Table 9: Gwynns Falls TMDL Segment 1 Reductions by Source Category

Baseline Load Source Categories		**Baseline Load** (ton/yr)	**TMDL Components**	**TMDL** (ton/yr)	**Reduction** (%)
Nonpoint Source		1,507.0	**LA**	1,507.0	0.0
Point Source	Urban	6,967.7	**WLA**	4,974.2	28.6
	Permits	0.1		0.1	0.0
TOTAL		**8,474.7**		**6,481.3**	**23.5**

Table 10: Gwynns Falls TMDL Segment 2 Reductions by Source Category

Baseline Load Source Categories		**Baseline Load** (ton/yr)	**TMDL Components**	**TMDL** (ton/yr)	**Reduction** (%)
Nonpoint Source		252.3	**LA**	252.3	0.0
Point Source	Urban	13,108.2	**WLA**	7,049.5	46.2
	Permits	213.1		213.1	0.0
TOTAL		**13,573.6**		**7,514.9**	**44.6**

The WLA of the Gwynns Falls watershed is allocated to two permitted source categories, Process Water WLA and Stormwater WLA. The categories are described below.

Process Water WLA

Process Water permits with specific TSS limits and corresponding flow information are assigned to the WLA. In this case, detailed information is available to accurately estimate the WLA. If specific TSS limits are not explicitly stated in the process water permit, then TSS loads are expected to be *de minimis*. If loads are *de minimis*, then they pose little or no risk to the aquatic environment and are not a significant source.

Process Water permits with specific TSS limits include:

- Individual industrial facilities
- Individual municipal facilities
- General mineral mining facilities

There are 5 process water sources with explicit TSS limits, which include 1municipal sources, and 4 mineral mines. The total estimated TSS load from all of the process water sources is based on current permit limits and is equal to 213.2 ton/yr. As mentioned above, no reductions were applied to this source because at 1.0% of the total load, such controls would produce no discernable water quality benefit. For a detailed list of the 5 process water sources including information on their permit limits, please see Appendix B. For information regarding the allocations to individual process water point sources, please see the technical memoranda to this document entitled "*Significant Sediment Point Sources in the Gwynns Falls Watershed*".

Stormwater WLA

Per EPA requirements, "stormwater discharges that are regulated under Phase I or Phase II of the NPDES stormwater program are point sources that must be included in the WLA portion of a TMDL" (US EPA 2002). Phase I and II permits can include the following types of discharges:

- Small, medium, and large MS4s – these can be owned by local jurisdictions, municipalities, and state and federal entities (e.g., departments of transportation, hospitals, military bases),

- Industrial facilities permitted for stormwater discharges, and
- Small and large construction sites.

EPA recognizes that available data and information are usually not detailed enough to determine WLAs for NPDES regulated stormwater discharges on an outfall-specific basis (US EPA 2002). Therefore, NPDES regulated stormwater loads within the Gwynns Falls watershed will be expressed as a single NPDES stormwater WLA. 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 2002).

The Gwynns Falls NPDES stormwater WLA is based on reductions applied to the sediment load from the urban land use of the watershed derived from the current maximum feasible stormwater reduction scenario and may include legacy or other sediment sources. Some of these sources may also be subject to controls from other management programs. The Gwynns Falls NPDES stormwater WLA requires an overall reduction of 40.1% (see Table 8).

As stormwater assessment and/or other program monitoring efforts result in a more refined source assessment, MDE reserves the right to revise the current NPDES stormwater WLA provided the revisions are reasonably calculated to protect aquatic life from sediment related impacts.

For more information on the methods used to calculate the baseline urban sediment load, see Section 2.2.2. For a detailed list of all of the NPDES regulated stormwater discharges within the watershed, please see Appendix B, and for information regarding the NPDES stormwater WLA distribution amongst these discharges, please see the technical memorandum to this document entitled "*Significant Sediment Point Sources in the Gwynns Falls Watershed*".

4.7 Margin of Safety

All TMDLs must include a margin of safety to account for any lack of knowledge and uncertainty concerning the relationship between loads and water quality (CFR 2008b). It is proposed that the estimated variability around the reference watershed group used in this analysis already accounts for such uncertainty. Analysis of the reference group *forest normalized sediment loads* indicates that approximately 75% of the reference watersheds have a value of less than 4.2. Also, 50% of the reference watersheds have a value less than 3.3. Based on this analysis the *forest normalized reference sediment load* (also referred to as the *sediment loading threshold*) was set at the median value of 3.3 (Currey et al. 2006). This is considered an environmentally conservative estimate, since 50% of the reference watersheds have a load above this value, which when compared to the 75% value, results in an implicit margin of safety of approximately 18%.

4.8 Summary of Total Maximum Daily Loads

The average annual Gwynns Falls watershed TMDL is summarized in Table 11. The TMDL is the sum of the LA, NPDES Stormwater WLA, Process Water WLA, and MOS. The Maximum Daily Load (MDL) is summarized in Table 12 (See Appendix C for more details).

Table 11: Gwynns Falls Watershed Average Annual TMDL of Sediment/TSS (ton/yr)

TMDL (ton/yr)	=	LA_{GF}	+	NPDES Stormwater WLA_{GF}	+	Process Water WLA_{GF}	+	MOS
13,996.2	=	1,759.3	+	12,023.7	+	213.2	+	Implicit

Table 12: Gwynns Falls Maximum Daily Loads of Sediment/TSS (ton/day)

MDL (ton/day)	=	LA_{GF}	+	NPDES Stormwater WLA_{GF}	+	Process Water WLA_{GF}	+	MOS
558.7	=	70.4	+	486.5	+	1.82	+	Implicit

5.0 ASSURANCE OF IMPLEMENTATION

This section provides the basis for reasonable assurances that the sediment TMDL will be achieved and maintained. 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 (CFR 2008b). Maryland has several well-established programs to draw upon, including the Water Quality Improvement Act of 1998 (WQIA) and the Federal Nonpoint Source Management Program (§ 319 of the Clean Water Act).

Potential funding sources available for local governments for implementation include the Buffer Incentive Program (BIP), the State Water Quality Revolving Loan Fund, and the Stormwater Pollution Cost Share Program. Details of these programs and additional funding sources can be found at http://www.dnr.state.md.us/bay/services/summaries.html.

Potential BMPs for reducing sediment loads and resulting impacts can be grouped into three general categories. The first is directed toward agricultural lands, the second towards urban (developed) land, and the third applies to all land uses. Since urban land was identified as the most extensive primary, predominant controllable source of sediment within the watershed (i.e., 92% of the total Gwynns Falls Baseline Sediment Load), and based on current maximum feasible reductions to regulated urban stormwater, the entirety of the required sediment reductions within the Gwynns Falls watershed are attributed to urban (developed) land use. The various BMPs applicable to reducing urban sediment loads are discussed below.

Sediment from urban areas can be reduced by stormwater retrofits, impervious surface reduction, street sweeping, inlet cleaning, increases in urban tree canopy cover, and stream restoration. Stormwater retrofits include modification of existing stormwater structural practices to address both water quality and flow control. The majority of the sediment reductions required from the urban areas within the Gwynns Falls watershed are attributed to streambank erosion (see section 2.2.1). Therefore, flow controls must be installed to reduce sheer stress and limit bank erosion in order to address this portion of the urban sediment load. Additionally, impervious surface reduction results in a change in hydrology that could also reduce streambank erosion. In terms of upland urban sediment loads, stormwater retrofit reductions range from as low as 10% for dry detention to approximately 80% for wet ponds, wetlands, infiltration practices, and filtering practices (US EPA 2003). It is anticipated that the implementation of the TMDL will include the array of urban BMPs and practices outlined above. Implementation is expected to occur primarily via the MS4 permitting process for medium and large municipalities, which requires that these jurisdictions retrofit 10% of the existing urban land area every permit cycle, or 5 years.

It has been estimated that the average TSS removal efficiencies for BMPs installed between the years of 1985-2002 and post 2002, which are reflective of the stormwater management regulations in place during these time periods, is 50% and 80%, respectively (Claytor and Schueler 1997; Baldwin et al. 2007; Baish and Caliri 2009). Based on these average TSS reduction efficiencies, BMP specific reduction efficiencies as estimated by

CBP, and best professional judgment, MDE estimates that future stormwater retrofits, which are expected to be implemented as part of the 10% retrofit goal to existing urban land every 5 years, will have approximately a 65% reduction efficiency for TSS, which is subject to change over time. Additionally, any new development in the watershed will be subject to the Stormwater Management Act of 2007 and will be required to use environmental site design (ESD) to the maximum extent practicable.

All non-forested land uses can benefit from improved riparian buffer systems. A riparian buffer reduces the effects of upland sediment sources through trapping and filtering. Riparian buffer efficiencies vary depending on type (grass or forested), land use (urban or agriculture), and physiographic region. The CBP estimates riparian buffer sediment reduction efficiencies in the Gwynns Falls region to be approximately 50% (US EPA 2006). Additionally, reforestation, whether adjacent to part of the watershed stream system or in a watershed's interior, can decrease upland sediment sources as well.

In summary, through the use of the aforementioned funding mechanisms and best management practices, there is reasonable assurance that this TMDL can be implemented.

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APPENDIX A – Watershed Characterization Data

Table A-1: Reference Watersheds

MD 8-digit Name	MD 8-digit	Percent stream mile degraded (%)[1,2]	Forest Normalized Sediment Load[3]
Deer Creek	02120202	11	3.9
Broad Creek	02120205	12	4.5
Little Gunpowder Falls	02130804	15	3.3
Prettyboy Reservoir	02130806	16	3.7
Middle Patuxent River	02131106	20	3.2
Brighton Dam	02131108	11	4.2
Sideling Creek	02140510	20	1.9
Fifteen Mile Creek	02140511	4	1.6
Savage River	02141006	7	2.5
Median			**3.3**
75th			**4.2**

Notes: [1]Percent stream miles degraded within an 8-digit watershed is based on the percentage of impaired MBSS stations within the watershed (MDE 2008).
[2]The percent stream miles degraded threshold to determine if an 8-digit watershed is impaired for impacts to biological communities is based on a comparison to reference conditions (MDE 2008).
[3]Forest normalized sediment loads based on Maryland watershed area only (consistent with MBSS random monitoring data).

APPENDIX B – MDE Permit Information

Table B-1: Permit Summary

Permit #	NPDES	Facility	County	City	Type	TMDL
04DP0681	MD0003034	ASHBURTON WATER FILTRATION PLANT	BALTIMORE CITY	BALTIMORE	WMA2M	Process Water WLA
00MM0975	MDG490975	ARUNDEL CORPORATION - DELIGHT QUARRY	BALTIMORE COUNTY	REISTERSTOWN	WMA5	Process Water WLA
00MM9722	MDG499722	LARRY E. KNIGHT, INC.	BALTIMORE COUNTY	GLYNDON	WMA5	Process Water WLA
00MM9831	MDG499831	S & G CONCRETE - GRANTLEY	BALTIMORE CITY	BALTIMORE	WMA5	Process Water WLA
00MM9866	MDG499866	AJO CONCRETE CONTRACTING, INC	BALTIMORE CITY	BALTIMORE	WMA5	Process Water WLA
02SW0025		SOLO CUP OPERATING CORPORATION (SCOC)	BALTIMORE COUNTY	OWINGS MILLS	WMA5SW	Stormwater WLA
02SW0034		FOUNDRY SERVICE & SUPPLY CO., INC.	BALTIMORE COUNTY	PIKESVILLE	WMA5SW	Stormwater WLA
02SW0155		NURAD TECHNOLOGIES, INC.	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW0306		QUEST INTERNATIONAL FLAVORS & FOOD INGREDIENTS	BALTIMORE COUNTY	OWINGS MILLS	WMA5SW	Stormwater WLA
02SW0659		PITT OHIO EXPRESS, INC. - BALTIMORE	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW0703		BALTIMORE CITY DPW - WESTERN SUBSTATION	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW0705		BALTIMORE CITY DPW - NORTHWESTERN SUBSTATION	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW0712		NEW ENGLAND MOTOR FREIGHT	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW0739		RUBBER MILLERS, INC.	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW0777		EMANUEL TIRE COMPANY-MORELAND	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW0779		SAFETY-KLEEN SYSTEMS, INC. - BALTIMORE	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW0805		GEORGE G. RUPPERSBERGER & SONS, INC.	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA

Permit #	NPDES	Facility	County	City	Type	TMDL
02SW0848		UNITED PARCEL SERVICE - VERO ROAD	BALTIMORE COUNTY	BALTIMORE	WMA5SW	Stormwater WLA
02SW0864		P. FLANIGAN & SONS INC. - WESTPORT	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW0868		BALTIMORE CONCRETE PRODUCTS, INC.	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW0930		ESTES EXPRESS LINES	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1014		P. FLANIGAN & SONS, INC.	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1016		CAPITOL CAKE COMPANY	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1027		NATIONAL INSTRUMENT COMPANY, INC.	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1053		LIGON AND LIGON, INC.	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1137		WOODLAWN MOTOR COACH, INC.	BALTIMORE COUNTY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1138		ALL SUPPLIES & PARTS, INC. - ASAP COMPRESSORS	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1206		TRIFINITY MANUFACTURING BALTIMORE, LLC	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1216		UNITED IRON AND METAL, LLC	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1248		POTTS & CALLAHAN, INC. - GWYNNS FALLS	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1272		UNILEVER BESTFOODS NORTH AMERICA	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1297		WINCHESTER HOMES, INC.	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1307		NORTHWEST TRANSFER STATION	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1375		MR. MARTIN L. REESE	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1398		DANIEL G. SCHUSTER, LLC. - OWINGS MILLS	BALTIMORE COUNTY	OWINGS MILLS	WMA5SW	Stormwater WLA
02SW1492		CRUSADER CHEMICAL COMPANY, INC.	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA

Permit #	NPDES	Facility	County	City	Type	TMDL
02SW1495		CARROLL AWNING COMPANY, INC.	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1563		CHEMLIME N.J., INC.	BALTIMORE COUNTY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1656		JOE CORBI'S WHOLESALE PIZZA	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1657		ALPHARMA USHP - BALTIMORE	BALTIMORE COUNTY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1673		MTA - NORTHEAST MAINTENANCE SHOP	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1677		MTA - NORTHWEST BUS DIVISION	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1716		SHIRE U.S. MANUFACTURING, INC.	BALTIMORE COUNTY	OWINGS MILLS	WMA5SW	Stormwater WLA
02SW1778		TRIAD INCORPORATED	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1836		PATUXENT MATERIALS, INC. - BALTIMORE	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1884		CRISPY BAGEL COMPANY	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1912		DECKER'S SALVAGE COMPANY, INC	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1964		BALTIMORE COUNTY BUREAU OF HIGHWAYS - SHOP 2	BALTIMORE COUNTY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1978		P & J CONTRACTING COMPANY, INC.	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1992		BEVERAGE CAPITAL CORPORATION	BALTIMORE COUNTY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1996		MTA - OLD COURT METRO MAINTENANCE FACILITY	BALTIMORE COUNTY	PIKESVILLE	WMA5SW	Stormwater WLA
02SW2009		SHA - OWINGS MILLS SHOP	BALTIMORE COUNTY	OWINGS MILLS	WMA5SW	Stormwater WLA
02SW3031		RALOID CORPORATION	BALTIMORE COUNTY	REISTERSTOWN	WMA5SW	Stormwater WLA
05DP3317	MD0068314	BALTIMORE COUNTY MS4	BALTIMORE	COUNTY-WIDE	WMA6	Stormwater WLA
99DP3315	MD0068292	BALTIMORE CITY MS4	BALTIMORE CITY	CITY-WIDE	WMA6	Stormwater WLA
99DP3313	MD0068276	STATE HIGHWAY ADMINSTRATION MS4	ALL PHASE I	STATE-WIDE	WMA6	Stormwater WLA

Permit #	NPDES	Facility	County	City	Type	TMDL
		MDE GENERAL PERMIT TO CONSTRUCT	ALL	ALL		Stormwater WLA

Notes: [1]TMDL column identifies how the permit was considered in the TMDL allocation.
[2]WTP = Water Treatment Plant
[3]WWTP = Wastewater Treatment Plant

Table B-2: Municipal Permit Data

Facility name	**NPDES #**	**MDE Permit #**	**Flow** (MGD[1])	**Permit Avg Monthly Conc.** (mg/l[2])	**Permit Avg. Weekly Conc.** (mg/l)
ASHBURTON WATER FILTRATION PLANT	MD0003034	04DP0681	7.0	20	30

Table B-3: General Mine Permit Data

Facility name	**NPDES #**	**MDE Permit #**	**Flow** (MGD)	**Permit Avg Quarterly Conc.** (mg/l)	**Permit Daily Max Conc.** (mg/l)
ARUNDEL CORPORATION - DELIGHT QUARRY	MDG490975	00MM0975	0.001	30	66
LARRY E. KNIGHT, INC.	MDG499722	00MM9722	0.001	30	60
S & G CONCRETE - GRANTLEY	MDG499831	00MM9831	0.005	30	60
AJO CONCRETE CONTRACTING, INC	MDG499866	00MM9866	0.001	30	60

Table B-4: Stormwater Permits[1]

Permit #	Facility	NPDES Group
02SW0025	SOLO CUP OPERATING CORPORATION (SCOC)	Phase I
02SW0034	FOUNDRY SERVICE & SUPPLY CO., INC.	Phase I
02SW0155	NURAD TECHNOLOGIES, INC.	Phase I
02SW0306	QUEST INTERNATIONAL FLAVORS & FOOD INGREDIENTS	Phase I
02SW0659	PITT OHIO EXPRESS, INC. - BALTIMORE	Phase I
02SW0703	BALTIMORE CITY DPW - WESTERN SUBSTATION	Phase I
02SW0705	BALTIMORE CITY DPW - NORTHWESTERN SUBSTATION	Phase I
02SW0712	NEW ENGLAND MOTOR FREIGHT	Phase I
02SW0739	RUBBER MILLERS, INC.	Phase I
02SW0777	EMANUEL TIRE COMPANY-MORELAND	Phase I
02SW0779	SAFETY-KLEEN SYSTEMS, INC. - BALTIMORE	Phase I
02SW0805	GEORGE G. RUPPERSBERGER & SONS, INC.	Phase I
02SW0848	UNITED PARCEL SERVICE - VERO ROAD	Phase I
02SW0864	P. FLANIGAN & SONS INC. - WESTPORT	Phase I
02SW0868	BALTIMORE CONCRETE PRODUCTS, INC.	Phase I
02SW0930	ESTES EXPRESS LINES	Phase I
02SW1014	P. FLANIGAN & SONS, INC.	Phase I
02SW1016	CAPITOL CAKE COMPANY	Phase I
02SW1027	NATIONAL INSTRUMENT COMPANY, INC.	Phase I
02SW1053	LIGON AND LIGON, INC.	Phase I
02SW1137	WOODLAWN MOTOR COACH, INC.	Phase I
02SW1138	ALL SUPPLIES & PARTS, INC. - ASAP COMPRESSORS	Phase I
02SW1206	TRIFINITY MANUFACTURING BALTIMORE, LLC	Phase I
02SW1216	UNITED IRON AND METAL, LLC	Phase I
02SW1248	POTTS & CALLAHAN, INC. - GWYNNS FALLS	Phase I
02SW1272	UNILEVER BESTFOODS NORTH AMERICA	Phase I
02SW1297	WINCHESTER HOMES, INC.	Phase I
02SW1307	NORTHWEST TRANSFER STATION	Phase I
02SW1375	MR. MARTIN L. REESE	Phase I

Permit #	Facility	NPDES Group
02SW1398	DANIEL G. SCHUSTER, LLC. - OWINGS MILLS	Phase I
02SW1492	CRUSADER CHEMICAL COMPANY, INC.	Phase I
02SW1495	CARROLL AWNING COMPANY, INC.	Phase I
02SW1563	CHEMLIME N.J., INC.	Phase I
02SW1656	JOE CORBI'S WHOLESALE PIZZA	Phase I
02SW1657	ALPHARMA USHP - BALTIMORE	Phase I
02SW1673	MTA - NORTHEAST MAINTENANCE SHOP	Phase I
02SW1677	MTA - NORTHWEST BUS DIVISION	Phase I
02SW1716	SHIRE U.S. MANUFACTURING, INC.	Phase I
02SW1778	TRIAD INCORPORATED	Phase I
02SW1836	PATUXENT MATERIALS, INC. - BALTIMORE	Phase I
02SW1884	CRISPY BAGEL COMPANY	Phase I
02SW1912	DECKER'S SALVAGE COMPANY, INC	Phase I
02SW1964	BALTIMORE COUNTY BUREAU OF HIGHWAYS - SHOP 2	Phase I
02SW1978	P & J CONTRACTING COMPANY, INC.	Phase I
02SW1992	BEVERAGE CAPITAL CORPORATION	Phase I
02SW1996	MTA - OLD COURT METRO MAINTENANCE FACILITY	Phase I
02SW2009	SHA - OWINGS MILLS SHOP	Phase I
02SW3031	RALOID CORPORATION	Phase I
05DP3317	BALTIMORE COUNTY MUNICIPAL SEPARATE STORM SEWER	Phase I
99DP3315	BALTIMORE CITY MS4	Phase I
99DP3313	STATE HIGHWAY ADMINSTRATION MS4	Phase I
	MDE GENERAL PERMIT TO CONSTRUCT	Phase I/II

Notes: [1] Although not listed in this table, some individual permits from Tables B-2 and B-3 incorporate stormwater requirements and are accounted for within the NPDES stormwater WLA (specifically the "Other" Regulated Stormwater Allocation in the Technical Memorandum *Significant Sediment Point Sources in the Gwynns Falls Watershed* accompanying this TMDL report) as well additional Phase II permitted MS4s, such as military bases, hospitals, etc.

APPENDIX C – Technical Approach Used to Generate Maximum Daily Loads

Summary

This appendix documents the technical approach used to define maximum daily loads of sediment consistent with the average annual TMDL in the Gwynns Falls watershed, which is considered the maximum allowable load the watershed can sustain without causing any sediment related impacts to aquatic health. The approach builds upon the modeling analysis that was conducted to determine the sediment loadings and can be summarized as follows.

- The approach defines maximum daily loads for each of the source categories.
- The approach builds upon the TMDL modeling analysis that was conducted to ensure that average annual loading targets do not cause any sediment related impacts to aquatic health.
- The approach converts daily time-series loadings into TMDL values in a manner that is consistent with available EPA guidance on generating daily loads for TMDLs (US EPA 2007).
- The approach considers a daily load level of a resolution based on the specific data that exists for each source category.

Introduction

This appendix documents the development and application of the approach used to define maximum daily load values. It is divided into sections discussing:

- Basis for approach
- Options considered
- Selected approach
- Results of approach

Basis for approach

The overall approach for the development of daily loads was based upon the following factors:

- **Average Annual TMDL:** The basis of the average annual sediment TMDL is that cumulative high sediment loading rates have negative impacts on the biological community. Thus, the average annual sediment load was calculated so as to not cause any sediment related impacts to aquatic health.
- **CBP P5 Watershed Model Sediment Loads:** There are two spatial calibration points for sediment within the CBP P5 watershed model framework. First, EOS loads are calibrated to long term EOS target loads. These target loads are the loads used to determine an average annual TMDL. Furthermore, the target loads were used in the TMDL because, as calibration targets, they are expected to

remain relatively unchanged during the final calibration stages of the CBP P5 model, and therefore will be the most consistent with the final CBP P5 watershed model sediment loading estimates. Currently, the CBP P5 model river segments are being calibrated to daily monitoring information for watersheds with a flow greater that 100 cfs, or an approximate area of 100 square miles.

- **Draft EPA guidance document entitled "Developing Daily Loads for Load-based TMDLs":** This guidance document provides options for defining maximum daily loads when using TMDL approaches that generate daily output (US EPA 2007).

The rationale for developing TMDLs expressed as *daily* loads was to accept the existing average annual TMDL, but then develop a method for converting this number to a maximum *daily* load – in a manner consistent with EPA guidance and available information.

Options considered

The draft EPA guidance document for developing daily loads does not specify a single approach that must be adhered to, but rather it contains a range of acceptable options (US EPA 2007). The selection of a specific method for translating a time-series of allowable loads into the 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.

This section describes the range of options that were considered when developing methods to calculate Gwynns Falls Maximum Daily Loads.

Level of Resolution

The level of resolution pertains to the amount of detail used in specifying the maximum daily load. The draft EPA guidance document on daily loads provides three categories of options for level of resolution, all of which are potentially applicable for the Gwynns Falls watershed:

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 (US EPA 2007).

Probability Level

All TMDLs have some probability of being exceeded, with the specific probability being either explicitly specified or implicitly assumed. This level of probability directly or indirectly reflects 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 document 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 the best professional judgment of the developers (US EPA 2007). 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

The approach selected for defining a Gwynns Falls Maximum Daily Load was based upon the specific data that exists for each source category. The approach consists of unique methods for each of the following categories of sources:

- Approach for Nonpoint Sources and Stormwater Point Sources within the Gwynns Falls watershed
- Approach for Process Water Point Sources within the Gwynns Falls watershed

Approach for Nonpoint Sources and Stormwater Point Sources within the Gwynns Falls watershed

The level of resolution selected for the Gwynns Falls Maximum Daily Load was a representative daily load, expressed as a single daily load for each loading source. This approach was chosen based upon the specific data that exists for nonpoint sources and stormwater point sources within the Gwynns Falls watershed. Currently, the best available data is the CBP P5 model daily time series calibrated to long-term average annual loads (per landuse). The CBP reach simulation results are calibrated to daily monitoring information for watershed segments with a flow typically greater that 100 cfs, but they have not been through appropriate peer review. Therefore, it was concluded that it would not be appropriate to apply the absolute values of the reach simulation model results to the TMDL, and the annual loads were used instead. However, it was assumed that the distribution of the daily values was correct, in order to calculate a normalized statistical parameter to estimate the maximum daily loads.

The maximum daily load was estimated based on three factors: a specified probability level, the average annual sediment TMDL, and the coefficient of variation (CV) of the CBP P5 Gwynns Falls reach simulation daily loads. The probability level (or exceedance frequency) is based upon guidance from EPA (US EPA 1991) where examples suggest that when converting from a long-term average to a daily value, the z-score corresponding to the 99th percentile of the log-normal probability distribution should be used. The average annual sediment TMDL is estimated from the CBP P5 EOS target loads. The calculation of the CV is described below.

The CBP P5 Gwynns Falls reach simulation consisted of a daily time series beginning in 1985 and extending to the year 2005. The CV was estimated by first converting the daily sediment load values to a log distribution and then verifying that the results approximated the normal distribution (see Figure C-1). Next, the CV was calculated using the arithmetic mean and standard deviation results from the log transformation. The log-transformed values were used to reduce the possible influence of outliers. The resulting CV of 15.4 was calculated using the following equation:

$$CV = \frac{\beta}{\alpha} \qquad \text{(Equation C.1)}$$

where:
CV = coefficient of variation
$\beta = \alpha\sqrt{e^{\sigma^2} - 1}$
$\alpha = e^{(\mu + 0.5*\sigma^2)}$
α = mean (arithmetic)
β = standard deviation (arithmetic)
μ = mean of logarithms
σ =standard deviation of logarithms

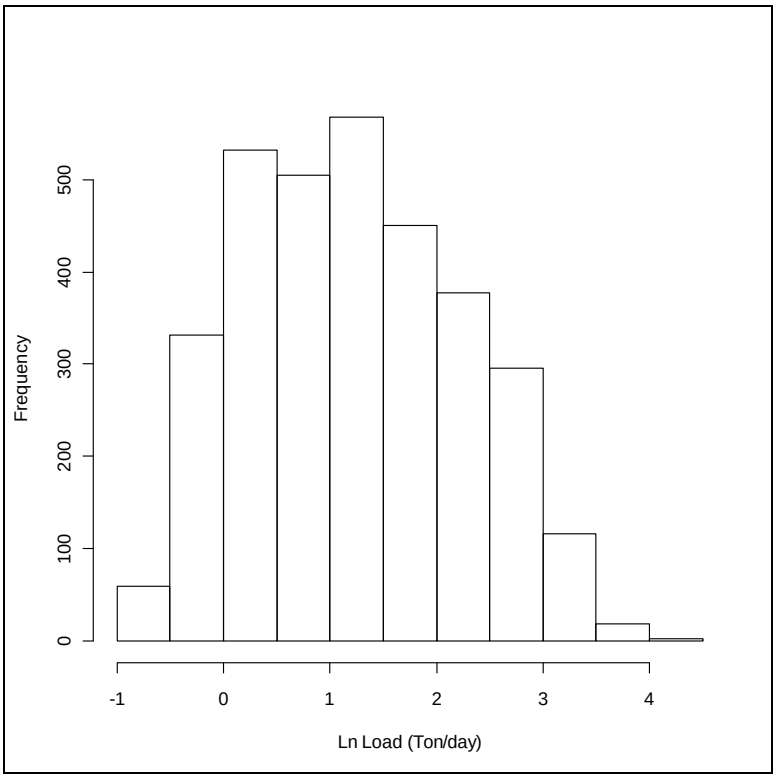

Figure C-1: Histogram of CBP River Segment Daily Simulation Results for the Gwynns Falls Watershed

The maximum "daily" load for each contributing source is estimated as the long-term average annual load multiplied by a factor that accounts for expected variability of daily loading values. The equation is as follows:

$$MDL = LTA * e^{(z\sigma - 0.5\sigma^2)} \qquad \text{(Equation C.2)}$$

where:
MDL = Maximum daily load
LTA = Long term average (average annual load)
Z = z-score associated with target probability level
$\sigma = \ln(CV^2+1)$
CV = Coefficient of variation based on arithmetic mean and standard deviation

Using a z-score associated with the 99th percent probability, a CV of 15.4, and consistent units, the resulting dimensionless conversion factor from long term average annual loads to a maximum daily load is 14.96. The average annual Gwynns Falls TMDL of sediment/TSS is reported in ton/year, and the conversion from ton/year to a maximum daily load in ton/day is 0.04 (e.g. 14.96/365)

<u>Approach for Process Water Point Sources within the Gwynns Falls watershed</u>

The TMDL also considers contributions from other point sources (i.e., sources other than stormwater point sources) in the watershed that have NPDES permits with sediment

limits. As these sources are generally minor contributors to the overall sediment load, the TMDL analysis that defined the average annual TMDL did not propose any reductions for these sources and held each of them constant at their existing technology-based NPDES permit monthly (or daily if monthly was not specified) limit for the entire year.

The approach used to determine maximum daily loads for these sources was dependent upon whether a maximum daily load was specified within the permit. If a maximum daily limit was specified, then the reported average flow was multiplied by the daily maximum limit to obtain a maximum daily load. If a maximum daily limit was not specified, the maximum daily loads were calculated based on the guidance provided in the Technical Support Document (TSD) for Water Quality-based Toxics Control (US 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 Gwynns Falls TMDL of sediment/TSS is reported in ton/yr, and the conversion from ton/yr to a maximum daily load in ton/day is 0.0085 (e.g. 3.11/365)

Results of approach

This section lists the results of the selected approach to define the Gwynns Falls Maximum Daily Loads.

- Calculation Approach for Nonpoint Sources and Stormwater Point Sources within the Gwynns Falls watershed

LA_{GF} (Ton/day) = Average Annual TMDL LA_{GF} (ton/yr) * .04

Stormwater WLA_{GF} (Ton/day) = Average Annual TMDL Stormwater WLA_{GF} (ton/yr) * .04

- Calculation Approach for Process Water Point Sources within the Gwynns Falls watershed
    - For permits with a daily maximum limit:

Process Water WLA_{GF} (ton/day) = Permit flow (mgd) * Daily maximum permit limit(mg/l) * 0.0042

    - For permits without a daily maximum limit:

Process Water WLA_{GF} (Ton/day) = Average Annual TMDL WLA_{GF} Other (ton/yr)* 0.0085

Table C-1: Gwynns Falls Maximum Daily Loads of Sediment/TSS (ton/day)

MDL (ton/day)	**=**	**LA_{GF}**	**+**	**NPDES Stormwater WLA_{GF}**	**+**	**Process Water WLA_{GF}**	**+**	**MOS**
558.7	=	70.4	+	486.5	+	1.82	+	Implicit