Lower Monocacy River

Watershed Restoration Action Strategy (WRAS)

Supplement: EPA A-I Requirements

Frederick County, Maryland

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Version 1.0

Submitted to

Maryland Department of Environment,
Science Services Administration

And

Environmental Protection Agency,
Office of State and Watershed Partnerships, Water Protection Division

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A. Identification of Causes & Sources of Impairment			
a.) Sources of impairment are identified and described	Accepted – WRAS	Page 4	Pages 2-7
b.) Specific sources of impairment are geographically identified (i.e. mapped)	Accepted – WRAS	Pages 17-20, Map 17, 18, 19, 21, 22, 23, 24, 25, 26, 27	Appendix A
c.) Pollution loads are attributed to each source of impairment and quantified	Not Accepted		Pages 7-9 and Appendices B, C, and D
d.) Data sources are accurate and verifiable, assumptions can be reasonable justified	Accepted – WRAS	N/A	N/A
e.) Watershed-level estimate of necessary pollution control is provided (i.e. overall load reduction goal)	Accepted – WRAS	Page 11	Pages 10-13
B. Expected Load Reductions			
a.) Load reductions achieve environmental goal (e.g. TMDL allocation)	Not Accepted		Tables N (page 14) and O (page 15) and page 15-18
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c.) Expected load reductions are estimated for each management measure identified in Element C	Not Accepted		Tables N (page 14) and O (page 15)
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a.) Specific management measures are identified and rationalized (i.e. why this management measure will help achieve goal)	Accepted – WRAS	Natural Resource Management Page	Tables Q (page 19) and S (page 23)
b.) Proposed management measures are strategic and feasible for the watershed	Accepted – WRAS	Natural Resource Management Page	Tables Q (page 19) and S (page 23)
c.) Proposed management measures achieve load reduction goals	Accepted – WRAS	Natural Resource Management Page	Tables N (page 14) and O (page 15)
d.) Critical/Priority implementation areas have been identified	Accepted – WRAS	Pages 21-22 and 32-65, Map 37-44, 17, 18, 19, 21, 22, 23, 24, 25, 26, 27	Page 26

EPA A-I Requirement Page Reference			
Elements	**EPA Acceptance Current Status**	**Lower Monocacy River WRAS Page Reference**	**Lower Monocacy River WRAS Supplement: EPA A-I Requirements Page Reference**
e.) The extent of expected implementation is quantified (i.e. x miles of streambank fencing)	Accepted – WRAS	Natural Resource Management Page	Tables R (page 22) and T (page 25)
f.) Adaptive management process in place to evaluate effectiveness of management measures	Accepted – WRAS	Natural Resource Management Page	Pages 40-42
D. Technical and Financial Assistance Needs			
a.) Cost estimates reflect all planning and implementation costs	Accepted – WRAS	Natural Resource Management Page	Tables Q (page 19) and S (page 23)
b.) Cost estimates are provided for each management measure	Accepted – WRAS	Natural Resource Management Page	Tables Q (page 19) and S (page 23)
c.) All potential Federal, State, Local, and Private funding sources are identified	Accepted – WRAS	Natural Resource Management Page	Pages 26-27
d.) Funding is strategically allocated – activities are funded with appropriate source (e.g. NRCS funds for BMP cost share)	Accepted – WRAS	Natural Resource Management Page	Pages 26-27
E. Information, Education, and Public Participation			
a.) A Stakeholder outreach strategy has been developed	Accepted – WRAS	Page 6-9	Pages 27-31, Appendix G
b.) All relevant stakeholders (i.e. State, Federal, Local, Private) are identified and involved in outreach process	Accepted – WRAS	Pages 6-9	Pages 27-31, Appendix G
c.) Public meetings and forums have been/are scheduled to be held	Accepted – WRAS	Page 9	Pages 27-31, Appendix G
d.) Educational/Outreach materials will be/have been disseminated	Accepted – WRAS	Pages 6-9	Pages 27-31, Appendix G
F/G. Schedule and Milestones			
a.) Implementation schedule includes specific dates and expected accomplishments	Accepted – WRAS	Page 23	Pages 31-36, Tables X (page 35) and AA (page 40)
b.) Implementation schedule follows a logical sequence	Accepted – WRAS	Natural Resource Management Page	Pages 31-36, Tables X (page 35) and AA (page 40)
c.) Implementation schedule covers a reasonable timeframe	Accepted – WRAS	Natural Resource Management Page	Pages 31-36, Tables X (page 35) and AA (page 40)
d.) Measurable milestones with expected completion dates are identified to evaluate progress	Not Accepted		Pages 37-40, Table AA (page 40)
e.) A phased approach with interim milestones is used to ensure continuous implementation	Not Accepted		Pages 31-40, Tables X (page 35) and AA (page 40)

EPA A-I Requirement Page Reference			
Elements	**EPA Acceptance Current Status**	**Lower Monocacy River WRAS Page Reference**	**Lower Monocacy River WRAS Supplement: EPA A-I Requirements Page Reference**
H. Load Reduction Evaluation Criteria			
a.) Proposed criteria effectively measure progress toward load reduction goal	Not Accepted		Pages 40-42
b.) Criteria include both: quantitative measures of implementation progress and pollution reduction; and qualitative measures of overall program success (including public involvement and buy-in)	Not Accepted		Pages 40-42
c.) Interim WQ indicator milestones are clearly identified; the indicator parameters can be different from the WQ standard violation	Not Accepted		Pages 40-42, Table AA (page 40)
d.) Adaptive management approach is in place, with threshold criteria identified to trigger modifications	Not Accepted		Pages 40-42
I. Monitoring Component			
a.) Monitoring plan includes an appropriate number of monitoring stations	Not Accepted		Pages 42-51, Table BB (page 43)
b.) Monitoring plan has an adequate sampling frequency	Not Accepted		Pages 42-51
c.) Monitoring plan will effectively measure evaluation criteria identified in Element H	Not Accepted		Pages 42-51

Introduction

The Lower Monocacy River Watershed Restoration Action Strategy (WRAS) Supplement provides an update to the original Lower Monocacy River WRAS that was completed in May 2004. It addresses specific elements required by EPA to be "included in watershed-based plans to restore waters impaired by nonpoint source pollution using incremental Section 319 funds" as stated in the Federal Register (Vol. 68, No 205, pg 60659-60660). The components of each element are listed to provide the reader with background information on the criteria. Page, map and/or table citations are provided for those elements that were addressed in the original version of the Lower Monocacy River WRAS. Greater detail is provided in instances where additional information has become available since the completion of the WRAS. Because the WRAS is viewed as a "living" document, regular updates are expected as the priorities of the County and the Monocacy & Catoctin Watershed Alliance (MCWA or the Alliance) change. Some elements of the Lower Monocacy River WRAS Supplement: EPA A-I Requirements document are specific to the Linganore Creek and Bennett Creek watersheds. They were the focus of the original version of the Lower Monocacy River WRAS and are continuing to be prioritized for this initial update. Currently, the only approved TMDL in Frederick County is for Lake Linganore located within the Linganore Creek watershed and efforts under an existing grant (Urban Wetlands Program, Bennett Creek Watershed Pilot) and an upcoming grant (Bennett Creek Urban BMP Demonstration Project) are targeted in the Bennett Creek watershed. Updates to the existing information to include other watersheds within the Lower Monocacy River watershed will be added to the Supplement as they become available.

Element A: Identification of Causes and Sources of Impairment

An identification of the causes and sources or groups of similar sources that will need to be controlled to achieve the load reductions estimated in this watershed-based plan (and to achieve any other watershed goals identified in the watershed-based plan), as discussed in Element B.

a) ***Sources of impairment are identified and described***
b) ***Specific sources of impairment are geographically identified (i.e., mapped)***
c) ***Pollution loads are attributed to each source of impairment and quantified***
d) ***Data sources are accurate and verifiable, assumptions can be reasonably justified***
e) ***Watershed-level estimate of necessary pollution control is provided (i.e., overall load reduction goal)***

Addressed in the Lower Monocacy WRAS on pages 4, 11, 17-20 and on Maps 17, 18, 19, 21, 22, 23, 24, 25, 26, and 27[1]

The Lower Monocacy River and Its Watershed

Frederick County is approximately 667 mi^2. The portion of the Lower Monocacy River watershed within Frederick County is approximately 264 mi^2, or roughly a third of the County. In order to better measure water quality and progress towards eliminating impairments, the County's Watershed Management Section has divided the County into twenty watersheds. Each watershed has been further divided into subwatersheds and catchments.

The watersheds were developed from catchment delineations, performed in 2008. The catchments were dissolved within larger drainage areas that were previously defined by Frederick County as "management units". There are nine watersheds within the Lower Monocacy River watershed, shown in Map 42 (Appendix B) and listed in Table A.

The subwatersheds were developed from catchment delineations by dissolving the catchments within larger drainage areas defined by major tributaries and practical designations. Subwatersheds were created that are approximately 1,000 to 4,000 acres in size.

The catchments were delineated primarily from Frederick County Digital Elevation Models (DEMS, 2005). The catchments within or along the County boundary are approximately 200 to 500 acres in size; while areas entirely outside of Frederick County are consolidated into larger catchments that extend to the topographic watershed divide. Further refinements, including alignment with stream confluences shown in Frederick County's stream layer (2000), were made based on 1:24,000 USGS topographic maps and boundary data for adjacent counties.

Table A: Watersheds, subwatersheds, and catchments within the Lower Monocacy River watershed

Watershed Name	Number of Subwatersheds	Number of Catchments
Ballenger Creek	5	34
Bennett Creek	15	103
Carroll Creek	4	34

[1] As referenced in the "Elements and Evaluation Criteria" document for the Lower Monocacy WRAS from EPA

Watershed Name	Number of Subwatersheds	Number of Catchments
Israel Creek	6	63
Lower Bush Creek	5	32
Lower Linganore Creek	9	53
Monocacy Direct Southwest	4	23
Upper Bush Creek	4	28
Upper Linganore Creek	10	55

Watershed Impairments and Total Maximum Daily Loads (TMDLs)

The Lower Monocacy River watershed and its subwatersheds have been listed on the 303(d) list for the following impairments: sediment, nutrients, fecal coliform bacteria, and biological impairments. The watershed is also threatened by increasing imperviousness. From MDE: "The Maryland Department of the Environment (MDE) has identified the Lower Monocacy River on the State of Maryland's 303(d) list as impaired by the following (years listed in parentheses): fecal coliform (2002), nutrients (1996), sediments (1996) and impacts to biological communities (2002, 2004, and 2006). Lake Linganore, an impoundment within the Lower Monocacy River basin, was listed for nutrients and sediments in 1996."

Approved TMDLs

The only approved and adopted TMDL within the Lower Monocacy River watershed is for Lake Linganore for phosphorus and sediment. Regulatory limits are established in the "Total Maximum Daily Loads of Phosphorus and Sediments for Lake Linganore", MDE, approved March 13, 2003. According to this TMDL, "The annual TMDL for phosphorus is 5,288 lbs/yr and the TMDL for sediments is 7,073 tons/yr. The phosphorus TMDL nonpoint source (NPS) allocation is 4,150 lbs/year, and the point source (PS) allocation is 609 lbs/yr."

Submitted TMDLs

A draft of the "Total Maximum Daily Loads of Fecal Bacteria for the Lower Monocacy River Basin in Carroll, Frederick, and Montgomery Counties, Maryland" was submitted for approval on September 27, 2007. According to the report:

> The fecal bacteria long-term annual average TMDL for the Lower Monocacy River watershed is 679,529 billion MPN E. coli/year, with a maximum daily load of 7,398 billion MPN E. coli/day. These total loads represent the sum of individual TMDLs for the nine Lower Monocacy River subwatersheds. The long-term annual average TMDL represents a reduction of approximately 88.3 % from the baseline load of 5,783,324 billion MPN/year. The TMDL is distributed between a load allocation (LA) for nonpoint sources and waste load allocations (WLAs) for point sources, including National Pollutant Elimination System (NPDES) wastewater treatment plants (WWTPs) and NPDES regulated stormwater discharges, including municipal separate storm sewer systems (MS4s).
>
> The long-term annual average allocations are as follows: the LA is 430,893 billion MPN E coli/year. The WWTP WLA is 46,881 billion MPN E. coli/year. The Stormwater WLA is 201,755 billion MPN E. coli/year. The margin of safety (MOS) has been incorporated using a conservative assumption by estimating the loading capacity of the stream based on a more stringent water quality endpoint

concentration. The E. coli water quality criterion concentration was reduced by 5%, from 126 MPN/100ml to 119.7 MPN/100ml.

The maximum daily loads, estimated using predicted long-term annual average TMDL concentrations (after source controls), are allocated as follows: the LA is 4,571 billion MPN E.coli/day, the Stormwater WLA is 1,963 billion MPN E. coli/day, and the WWTP WLA is 399 billion MPN E. coli/day.

TMDLs Under Development

TMDLs for the Lower Monocacy River watershed for sediment and nutrients will be under development during 2008 and 2009. As they are completed, the Supplement will be updated to reflect the new information. The Draft TMDL for Sediment is scheduled to be released some time after June 2008 per Anna Soehl of MDE.

Additional Stream Corridor Assessments (SCAs)

As discussed in the Lower Monocacy River WRAS, a Stream Corridor Assessment (SCA) for the Lower Monocacy River watershed began in January 2003 and was completed by September 2003. Seventy-five miles of the approximately 600 miles of stream in the Lower Monocacy River watershed were walked. The branches surveyed were: the Talbot, Town, and Woodville Branches in the Lower Linganore Creek watershed (Map 6 on page 24 of the Lower Monocacy River WRAS), and the Bear, Fahrney, North, Pleasant, and Urbana Branches in the Bennett Creek watershed (Map 16 on page 36 of the Lower Monocacy River WRAS). These branches were selected because it was felt that they were representative of the general land use of the Lower Monocacy River watershed as a whole.

Since the completion of the Lower Monocacy River WRAS in May 2004, the County has worked with the Maryland Department of Natural Resources (DNR) to complete additional SCAs. SCAs have been performed in Ballenger Creek, Upper Linganore Creek, and Lower Linganore Creek. Additionally, an SCA in the Rock/Carroll Creek watershed (performed before WRAS) was obtained. Results from these additional SCA surveys are summarized below.

BALLENGER CREEK STREAM CORRIDOR ASSESSMENT[2]

(Excerpted from full report dated June 2005 and available in its entirety at http://www.dnr.state.md.us/streams/stream_corridor.html)

The Stream Corridor Assessment fieldwork consisted of walking approximately 32.93 miles of stream, the majority of mapped stream miles in the Ballenger Creek watershed. The SCA identified a total of 192 problem sites, 27 representative sites and 2 comment sites in the Ballenger Creek watershed. Problem sites include: 50 pipe outfalls, 42 inadequately forested buffers, 38 fish passage barriers, 34 erosion sites, 10 unusual conditions, 8 channel alterations, 6 trash dumping sites, and 4 exposed pipes. Table B presents a summary of survey results. Maps 1-11, in Appendix A, illustrate locations and severity rankings for the identified problem sites.

Table B: Summary of results from Ballenger Creek SCA Survey

Identified Problems	Number of Sites	Total Estimated Length	Very Severe	Severe	Moderate	Low Severity	Minor
Channel Alterations	8	N/A	0	1	4	1	2
Inadequate	42	Left bank: 96,796 feet (18.33	10	9	9	5	9

[2] Hunicke, J and Yetman, K. 2005. Ballenger Creek Stream Corridor Assessment Survey. Maryland Department of Natural Resources, Annapolis, MD.

Identified Problems	Number of Sites	Total Estimated Length	Very Severe	Severe	Moderate	Low Severity	Minor
Buffers		miles) Right bank: 87,036 feet (16.48 miles)					
Trash Dumping	6	N/A	0	1	2	1	2
Erosion Site	34	73,387 feet (13.9 miles)	1	6	14	11	2
Exposed Pipe	4	N/A	0	0	2	2	0
Fish Barrier	38	N/A	0	5	13	10	10
Pipe Outfalls	50	N/A	0	1	6	19	24
Unusual Conditions	10	N/A	1	2	2	4	1
Total	**192**		**12**	**25**	**52**	**53**	**50**
Representative Sites	27						
Comments	2						

UPPER LINGANORE CREEK STREAM CORRIDOR ASSESSMENT[3]

(Excerpted from full report dated February 2006 and available in its entirety upon request)

The Stream Corridor Assessment fieldwork for the Upper Linganore Creek watershed consisted of walking about 66 miles of the approximate 125 miles of stream in the Frederick County portion of the watershed. Field crews did not survey streams in Talbot Branch, Town Creek, or Woodville Branch, which were part of a previous SCA survey conducted in 2003 (Czwartacki and Yetman, 2004). Survey teams identified 247 potential environmental problems within the Upper Linganore Creek watershed. The most frequently observed potential problem sites were inadequately forested buffers, reported at 80 sites (36.39 miles of stream length) and erosion sites, reported at 72 sites (22.52 miles of stream length). Most inadequate buffers ranked as very severe or severe, while most erosion sites ranked as moderate to low in severity.

Other potential environmental problems recorded during the survey included: 56 fish migration barriers, 17 pipe outfalls, 8 unusual conditions, 6 trash dumping sites, 4 channel alterations, and 4 exposed pipes (Table C). Most sites in these remaining categories ranked as low to minor in severity throughout the watershed. Additionally, the survey recorded descriptive information for 30 representative sites and 6 comment sites. Maps 12-20, in Appendix A, illustrate locations and severity rankings for the identified problem sites.

Table C: Summary of results from the Upper Linganore Creek SCA Survey

Potential Problem Identified	Number of Sites	Estimated Length and Percent of Surveyed Streams	Very Severe	Severe	Moderate	Low Severity	Minor
Channel Alterations	4	1,739 feet (0.33 miles), 0.50%*	0	0	2	2	0
Erosion Site	72	121,373 feet (22.52 miles), 34%*	2	6	29	26	9
Exposed Pipe	4	N/A	0	0	0	1	3
Fish Barrier	56	N/A	0	0	1	3	52
Inadequate Buffer	80	192,158.55 feet (36.39 miles), 55%	38	12	10	7	13
Pipe Outfall	17	N/A	0	0	0	8	9
Trash Dumping	6	N/A	0	1	0	1	4
Unusual Condition	8	N/A	0	0	1	1	6
Total	**247**		**40**	**19**	**43**	**49**	**96**
Representative Sites	30						
Comments	6						

[3] Patterson, A. and Yetman, K. 2006. Upper Linganore Creek Stream Corridor Assessment Survey. Maryland Department of Natural Resources, Annapolis, MD.

*Length measurements are taken from GIS results and reflect the number of stream miles affected by each potential problem type.

LOWER LINGANORE CREEK STREAM CORRIDOR ASSESSMENT[4]

(Excerpted from full report dated June 2005 and available in its entirety at http://www.dnr.state.md.us/streams/stream_corridor.html)

The Stream Corridor Assessment fieldwork consisted of walking approximately 94.61 miles, the majority of the mapped stream miles in the Lower Linganore Creek watershed. Fieldwork was completed in March 2004. Survey teams identified 114 potential environmental problems within the Lower Linganore Creek watershed. At the time of the survey, the most frequently observed environmental problem was inadequately forested buffers, reported as 63 sites or 30.61 miles along the left bank and 32.25 miles along the right bank of the streams. Other potential environmental problems recorded during the survey include: 20 erosion sites, 11 fish passage barrier sites, 7 pipe outfalls, 5 channel alterations, 3 trash dumping, 3 unusual conditions, 2 exposed pipes, and no in or near-stream construction sites. Additionally, the survey recorded descriptive information for 32 representative sites and 1 comment site. Table D presents a summary of survey results. Maps 21-32, in Appendix A, illustrate locations and severity rankings for the identified problem sites.

Table D: Summary of results from Lower Linganore Creek SCA Survey

Identified Problems	Number of Sites	Total Estimated Length	Very Severe	Severe	Moderate	Low Severity	Minor
Channel Alterations	5	N/A	0	0	2	1	2
Inadequate Buffers	63	Left bank: 161,635 feet (30.61 miles) Right bank: 170,258 feet (32.25 miles)	0	9	17	28	9
Trash Dumping	3	N/A	0	0	1	2	0
Erosion Site	20	67,316 feet (12.75 miles)	0	4	7	7	2
Exposed Pipe	2	N/A	0	0	1	1	0
Fish Barrier	11	N/A	0	5	3	2	1
Pipe Outfalls	7	N/A	0	1	2	3	1
Unusual Conditions	3	N/A	0	0	2	1	0
Total	**114**		**0**	**19**	**35**	**45**	**15**
Representative Sites	32						
Comments	1						

ROCK AND CARROLL CREEK STREAM CORRIDOR ASSESSMENT[5]

(Excerpted from full report dated December 2000 and available in its entirety at upon request)

Approximately 19 miles of stream in the Carroll/Rock Creek watershed were surveyed and a total of 191 environmental problems were identified. The most common environmental problem seen during the SCA Survey was inadequate stream buffers, which were reported at 56 sites. Other potential environmental problems identified during the survey include: pipe outfalls at 40 sites, stream erosion at 37 sites, fish migration blockages at 22 sites, stream channel alterations at 16 sites, exposed pipes at 9 sites, unusual conditions at 5 sites, unrestricted livestock access to the stream at 5 sites, and 1 site where new construction was occurring near the stream. Table E

[4] Hunicke, J. and Yetman, K. 2005. Lower Linganore Creek Stream Corridor Assessment Survey. Maryland Department of Natural Resources, Annapolis, MD.
[5] Rice, P. and Yetman, K. 2000. Carroll and Rock Creeks Stream Corridor Assessment Survey. Maryland Department of Natural Resources, Annapolis, MD.

presents a summary of survey results. Maps 33-41, in Appendix A, illustrate locations and severity rankings for the identified problem sites.

Table E: Summary of results from Rock and Carroll Creeks SCA Survey

Identified Problems	Number of Sites	Total Estimated Length	Very Severe	Severe	Moderate	Low Severity	Minor
Channel Alterations	16	N/A	5	1	5	4	1
Inadequate Buffers	56	37,210 feet (7.0 miles)	8	23	19	4	2
Erosion Site	37	6,573 feet (1.2 miles)	2	8	25	2	0
Exposed Pipe	9	N/A	0	0	3	5	1
Fish Barrier	22	N/A	0	3	14	4	1
Pipe Outfalls	40	N/A	0	3	21	15	1
Unusual Conditions	5	N/A	1	0	2	2	0
Livestock	5		1	2	1	1	0
Near Stream Construction	1		0	0	0	1	0
Total	**191**		**17**	**40**	**90**	**38**	**6**
Representative Sites	42						

Pollutant Loads by Watershed, Subwatershed, and Catchment

Pollutant loads for phosphorus, sediment, and nitrogen; the total impervious area; percent impervious; and the stream status of the watershed (from the Impervious Cover Model, Appendix E) have been calculated based on the land use for each of the watersheds, subwatersheds, and/or catchments within the Lower Monocacy River watershed, as appropriate. For purposes of time, calculations at the subwatershed and catchment scale were performed for the Bennett Creek and Linganore Creek watersheds only (Appendix C and D). Similar calculations will be performed for the other watersheds within the Lower Monocacy River watershed as each is studied through a Watershed Management Plan and Stream Restoration/Stormwater Management Facility Retrofit Assessment. As they are completed, the data will be added to this Supplement.

Pollutant loads were calculated using loading rate coefficients for each pollutant by land use (Table F) and the number of acres in each land use by watershed, subwatershed and/or catchment. Pollutant loading rate coefficients were obtained from MDE in 2005 and the land use data is from 2002 Land Use/Land Cover for Maryland from the Maryland Department of Planning. Land use was calculated in GIS by clipping the land use overlay to the watershed, subwatershed, and catchment boundaries. Land use acreages were entered into the County's Implementation Database where estimated pollutant loads were generated. The values obtained from this process on all three scales (watershed, subwatershed, and catchment) are one component used for the prioritization of restoration and/or protection locations. Table G provides a list of the land use types used for this analysis and the acreages for Frederick County and the Lower Monocacy River watershed.

Table F: Loading Rate Coefficients for each Pollutant by Land Use[6]

	Loading Rate Coefficients			
Land Use Type	**Phosphorus (lbs/ac/yr)**	**Nitrogen (lbs/ac/yr)**	**Sediment (tons/ac/yr)**	**Imperviousness**
Barren	0.535	8.924	0.0818	0.086

[6] Nitrogen, phosphorus, and sediment coefficients from Jim George with MDE: Boynton, 1993; Atmos Dep from Lung, 1994; Shahane, 1982; Novotny and Chesters, 1981; NURP, 1983; Sweetin and Melvin, 1985; Haith and Showmaker, 1987; Chapra, 1997; Thomann and Mueller, 1987; Chesapeake Bay Program, 1996. Impervious coefficients from Center for Watershed Protection.

	Loading Rate Coefficients			
Land Use Type	**Phosphorus (lbs/ac/yr)**	**Nitrogen (lbs/ac/yr)**	**Sediment (tons/ac/yr)**	**Imperviousness**
Commercial/Industrial	0.669	5.8	0.10229	0.8
Cropland	1.606	14.724	0.24556	0.019
Forest	0.026	1.874	0.024	0.015
HDR*	1.182	4.462	0.15	0.28
LDR*	0.687	1.339	0.02859	0.09
MDR*	0.984	1.428	0.0587	0.21
Open Urban	0.535	8.924	0.0818	0.086
Pasture	3.123	8.031	0.4775	0.019
Water/Wetlands	-0.223	0.0000001	-0.034	1

Table G: Land Use Types and Acreages for Frederick County and the Lower Monocacy River Watershed

Land Use Type	Acres in Frederick County	Acres in Lower Monocacy	Lower Monocacy Percentage
Barren	56.91	49.87	87.63%
Commercial/Industrial	14,743.96	9,537.24	64.69%
Cropland	178,158.99	63,793.1	35.81%
Forest	145,432.63	48,616.04	33.43%
HDR	800.6	668.48	83.50%
LDR	35,907.33	18,497.22	51.51%
MDR	13,498.47	8,440.58	62.53%
Open Urban	6,233.53	3,968.18	63.66%
Pasture	28,965.65	14,817.7	51.16%
Water/Wetlands	3,297.2	804.49	24.40%
Total	**427,095.27**	**169,192.9**	**39.61%**

*HDR = High-density residential
*MDR = Medium-density residential
*LDR = Low-density residential

Pollutant Loads for the Lower Monocacy River Watershed

Table H lists the pollutant loads for phosphorus, sediment, and nitrogen; the total impervious area in acres; percent impervious; and the stream status of the watershed based on the Impervious Cover Model (Appendix E) for the entire Lower Monocacy River watershed. Phosphorus, nitrogen, and sediment loads are shown in pounds or tons per year and pounds or tons per year per acre.

Table H: Pollutant Loads and Imperviousness for the Lower Monocacy River watershed

Watershed	Watershed Area (acres)	Phosphorus (lbs/yr)	Phosphorus (lbs/yr/ac)	Nitrogen (lbs/yr)	Nitrogen (lbs/yr/ac)	Sediment (tons/yr)	Sediment (tons/yr/ac)	Impervious Area (acres)	Percent Impervious	Stream Status
Lower Monocacy River	169,192.9	180,145.35	1.06	1,280,373.77	7.57	26,308.73	0.16	14,627.1	5.6%	Sensitive

Pollutant Loads by Watershed

Table I lists the pollutant loads for phosphorus, sediment, and nitrogen; the total impervious area in acres; percent impervious; and the stream status of the watershed based on the Impervious Cover Model for the nine watersheds within the Lower Monocacy River watershed.

Estimated pollutant loadings per year by watershed for phosphorus, nitrogen, and sediment are illustrated in Maps 43-45. Estimated pollutant loadings per year, per acre for phosphorus, nitrogen, and sediment are illustrated in Maps 46-48. The estimated impervious area for each watershed is illustrated in Map 49. The stream status based on impervious area for each watershed is illustrated in Map 50. Maps 43-50 can be found in Appendix B.

Table I: Pollutant Loads and Imperviousness by Watershed

Watershed	Watershed Area (acres)	Phosphorus (lbs/yr)	Phosphorus (lbs/yr/ac)	Nitrogen (lbs/yr)	Nitrogen (lbs/yr/ac)	Sediment (tons/yr)	Sediment (tons/yr/ac)	Impervious Area (acres)	Percent Impervious	Stream Status
Ballenger Creek	14,846.78	15,797.49	1.06	109,705.4	7.39	2,190.79	0.15	2,841.67	19.14%	Non-Supporting
Bennett Creek	49,582.83	32,946.82	0.66	260,882.3	5.26	5,139.64	0.10	4,894.09	9.87%	Sensitive
Carroll Creek	14,871.64	16,810.91	1.13	79,249.22	5.33	2,207.99	0.15	3,768.7	25.34%	Non-Supporting
Israel Creek	24,694.3	28,667.23	1.16	227,126.6	9.20	4,336.3	0.18	1,326.6	5.37%	Sensitive
Lower Bush Creek	12,495.06	13,092.4	1.05	90,386.12	7.23	1,983.05	0.16	796.22	6.37%	Sensitive
Lower Linganore Creek	24,135.25	23,549.4	0.98	156,333.5	6.48	3,319.9	0.14	1,730.78	7.17%	Sensitive
Monocacy Direct Southwest	9,989.9	12,432.62	1.24	108,644.2	10.88	1,881.62	0.19	998.48	9.99%	Sensitive
Upper Bush Creek	8,869.21	8,226.84	0.93	38,097.97	4.30	1,043.84	0.12	572.34	6.45%	Sensitive
Upper Linganore Creek	29,010.23	35,146.35	1.21	280,975.8	9.69	5,319.37	0.18	929.77	3.20%	Sensitive

Pollutant Loads by Subwatershed and Catchment

The pollutant loads for phosphorus, sediment, and nitrogen; the total impervious area in acres; percent impervious; and the stream status of the watershed for the subwatersheds and catchments in the Bennett Creek and Linganore Creek watersheds can be found in Appendices C and D respectively. The subwatershed and catchment values for the other watersheds within the Lower Monocacy River watershed will be added to the Supplement as they are calculated.

Watershed Load Reduction Goals

Two load reduction goals have been set: one for the entire Lower Monocacy River watershed and one for Lake Linganore, located within the Linganore Creek watershed, where a TMDL was established in March 2003.

Lower Monocacy River Watershed Load Reduction Goal

In the absence of a TMDL for the Lower Monocacy River watershed, the overall load reduction goal will be based on Maryland's nutrient allocations for the Chesapeake Bay. Maryland's nutrient allocation has been proportionally allocated to the ten Maryland drainage basins that drain to the Chesapeake Bay (http://www.dnr.state.md.us/bay/tribstrat/index.html). Frederick County and the Lower Monocacy River watershed are located within the Upper Potomac River basin, which was allocated a load as part of the Chesapeake Bay load allocation process stemming from the 2000 Chesapeake Bay Agreement. Through the Tributary Strategy development process, a list of BMPs and the level of BMP implementation necessary to achieve the Upper Potomac River basin allocation were identified. These BMPs and level of implementation were used to calculate the Lower Monocacy River watershed load reduction goals.

The Maryland DNR tracks the level of BMP implementation associated with the Tributary Strategies at the drainage basin and County scale. However, for the purposes of this Supplement, a level of BMP implementation and load reduction goal at the Lower Monocacy River watershed scale is needed. The level of implementation and load reduction goal for the Lower Monocacy River watershed were calculated in the following way:

Each identified BMP treats impairments from a particular land use (i.e. cover crops treat cropland or a rain garden can treat open urban land). The percent of each land use type found in the Lower Monocacy River watershed was calculated based on the land use acreages for the Lower Monocacy River watershed and Frederick County (Table G). The percentages were used to calculate the proportion of BMP implementation possible within the Lower Monocacy River watershed based on the County implementation numbers (i.e. cover crops treat cropland and 35.81% of cropland acres in Frederick County are within the Lower Monocacy River watershed. Therefore, 35.81% of the cover crops to be installed in Frederick County are assumed to be located within the Lower Monocacy River watershed). This provides a level of BMP implementation for the Lower Monocacy River watershed. In order to translate the level of BMP implementation into a load reduction goal, load reduction efficiencies for the selected BMPs were used to calculate the expected load reduction assuming full BMP implementation.

The timeframe established for the Upper Potomac River Basin Tributary Strategy implementation was 25 years. Since implementation goals for the Lower Monocacy River watershed are based on the Upper Potomac River Basin Tributary Strategy, the implementation timeframe for the Lower Monocacy River watershed will also be 25 years. The 25-year phased implementation (2008-2033) is divided into five 5-year implementation phases (Element F/G) to allow for interim evaluation and plan updates (Element H).

Urban and agricultural BMPs implemented within Frederick County are tracked by different agencies. Agricultural BMPs are tracked by DNR through the Upper Potomac River Basin Tributary Strategy. Frederick County's Watershed Management Section tracks urban BMPs using their Implementation Database. Therefore, the watershed goals have been presented separately. **Note:** BMP implementation, associated with agricultural practices and adopted in this Supplement, is directly from the Upper Potomac River Basin Tributary Strategy. The timeframe spans 25 years from 1985-2010. When new agricultural goals are adopted through the Tributary

Strategy program, the Supplement will be updated. Table J presents the 25-year load reduction goal from agricultural BMP implementation. Table K presents the 25-year load reduction goal from urban BMP implementation.

Table J: 25-year Load Reduction Goal for Agricultural BMP Implementation

Treated Impairment	Projected Load Reduction
Sediment/Total Suspended Solids (TSS)	18,342,280 lbs
Nitrogen	582,949 lbs
Phosphorus	57,337 lbs

Table K: 25-year Load Reduction Goal for Urban BMP Implementation

Treated Impairment	Projected Load Reduction
Sediment/Total Suspended Solids (TSS)	2,348,084 lbs
Nitrogen	67,049 lbs
Phosphorus	11,615 lbs

The total reduction goal over 25 years for TSS is 20,690,364 pounds (or 10,345 US short tons), for nitrogen is 649,998 pounds, and for phosphorus is 68,952 pounds.

Lake Linganore Load Reduction Goal From the Established TMDL

As discussed earlier, a TMDL for Lake Linganore was adopted in March 2003. The load reduction goal was calculated based on the current and allowable loads as established in the TMDL. Lake Linganore is a man-made lake and never existed in nature, in part due to a naturally high level of sediment transport. Frederick County will be working with USGS to evaluate the sediment loads using transport calculations. Transport calculations are a more robust method that will correlate to sediment loads, as opposed to the methods used to develop the TMDL. The method used to develop the TMDL applies a coefficient to each land use type and multiplies by the acres of each type to get loads. The SWMM takes additional information into account, such as soil erodibility, slope, rainfall, and other factors; for this reason, we propose to use the SWMM estimates as the pollutant load estimates until USGS data becomes available.

The TMDL requires a 90% reduction of phosphorus and roughly a 45% reduction of sediment. No BMPs are 90% effective, so even with 100% implementation, Frederick County cannot physically meet the goal. The goals for the TMDL are established based on load calculations from land use coefficients, similar to how we have calculated loads for the Tributary Strategies. For Linganore, Frederick County has used a more detailed model that takes other factors such as soil erodibility and rainfall into consideration. For this reason, Frederick County proposes using the current load estimates generated by the SWMM model to calculate the load reduction required to achieve the TMDL. These estimates require an 83.5% reduction in phosphorus and a 21% reduction in sediment. The loads from the SWMM model will be used until Frederick County and USGS are able to evaluate actual TSS using field observations.

Therefore, Tables L and M present load reduction goals as they relate to the TMDL and the SWMM model prepared by Versar, Inc. Data generated from the SWMM has been included in Appendix D. Table L presents the 1-year and 25-year phosphorus load reduction goals for urban, agricultural, and forest lands for the Lake Linganore drainage. Table M presents the 1-year and 25-year sediment load reduction goals for urban, agricultural, and forest lands for the Lake Linganore drainage area.

The 25-year NPS allowable load is 103,750 lbs for phosphorus and 158,650 toms for TSS. The total 25-year NPS reduction goal required to meet the allowable load (using the

current pollutant loads from the TMDL document) is 1,168,900 lbs for phosphorus and 130,975 tons for TSS. The total 25-year NPS reduction goal required to meet the allowable load (using the current pollutant loads from the SWMM model) is 697,775 lbs for phosphorus and 43,050 tons for TSS. The reductions in phosphorus and sediment required to meet the Lake Linganore TMDL exceed the Tributary Strategy reductions for the entire Lower Monocacy River watershed.

Once USGS data is available, Frederick County will need to conduct a "Use Attainability Analysis" to determine reasonable load reductions from an aggressive but achievable implementation schedule for the proposed management measures. Frederick County plans to meet the goals from the Upper Potomac River Basin Tributary Strategy for the Lower Monocacy River watershed, determine loads and reductions for the Linganore TMDL using a more robust scientific method, and develop a revised plan for meeting the TMDL based on the "Use Attainability Analysis". The watershed plan will be updated as new data becomes available.

Table L: 1-year and 25-year phosphorus load reductions goals from the Lake Linganore Watershed TMDL versus load reduction goals from SWMM

	1-Year Total	25-Year Total	1-Year Ag	25-Year Ag	1-Year Urban	25-Year Urban	1-Year Forest	25-Year Forest
	(lbs/yr)	(lbs)	(lbs/yr)	(lbs)	(lbs/yr)	(lbs)	(lbs/yr)	(lbs)
TMDL								
Current NPS Load	50,906.0	1,272,650.0	42,180.6	1,054,515.0	8,352.1	208,802.5	373.3	9,332.5
Current PS Load	223.3	5,582.5						
Current Total Load	51,129.3	1,278,232.5	42,180.6	1,054,515.0	8,352.1	208,802.5	373.3	9,332.5
Allowable Load (NPS)	**4,150.0**	**103,750.0**	**3,577.0**	**89,425.0**	**547.8**	**13,695.0**	**24.9**	**622.5**
Allowable Load (PS)	**609.0**	**15,225.0**						
Margin of Safety (MOS)*	529.0	13,225.0						
Total Allowable Load	**5,288.0**	**132,200.0**						
Total Reduction Goal	45,841.3	1,146,032.5						
NPS Reduction Goal	46,756.0	1,168,900.0	38,603.6	965,090.0	7,804.3	195,107.5	348.4	8,710.0
Total Percent Reduction	89.7%	89.7%						
NPS Percent Reduction	91.8%	91.8%	91.5%	91.5%	93.4%	93.4%	93.3%	93.3%
SWMM								
Current NPS Load	32,061.0	801,525.0	27,636.6	690,914.6	4,232.1	105,801.3	192.4	4,809.2
Allowable Load (NPS)	**4,150.0**	**103,750.0**	**3,577.0**	**89,425.0**	**547.8**	**13,695.0**	**24.9**	**622.5**
Allowable Load (PS)	**609.0**	**15,225.0**						
Margin of Safety (MOS)*	529.0	13,225.0						
Total Allowable Load	**5,288.0**	**132,200.0**						
Total Reduction Goal	26,773.0	669,325.0						
NPS Reduction Goal **	27,911.0	697,775.0	24,059.6	601,489.6	3,684.3	92,106.3	167.5	4,186.7
Total Percent Reduction	83.5%	83.5%						
NPS Percent Reduction	87.1%	87.1%	87.1%	87.1%	87.1%	87.1%	87.1%	87.1%

*The MOS is intended to conservatively account for uncertainties in estimating water quality in natural systems. The MOS for phosphorus is established as 10%

**Note that total reduction goals are less than NPS reduction goals because the TMDL gives additional future loads to point sources.

Table M: 1-year and 25-year sediment load reductions goals from the Lake Linganore Watershed TMDL versus load reduction goals from SWMM

	1-Year Total	25-Year Total	1-Year Ag	25-Year Ag	1-Year Urban	25-Year Urban	1-Year Forest	25-Year Forest
	(tons/yr)	(tons)	(tons/yr)	(tons)	(tons/yr)	(tons)	(tons/yr)	(tons)
TMDL								
Current NPS Load*	11,585.0	289,625.0	10,025.0	250,625.0	1,215.0	30,375.0	345.0	8,625.0
Allowable Load (NPS)	**6,346.0**	**158,650.0**	**5,660.6**	**141,515.0**	**533.1**	**13,327.5**	**152.3**	**3,807.5**
Allowable Load (PS)	**707.0**	**17,675.0**						
Margin of Safety (MOS)**	0.0	0.0						
Total Allowable Load	**7,053.0**	**176,325.0**						
Total Reduction Goal	4,532.0	113,300.0						
NPS Reduction Goal	5,239.0	130,975.0	4,364.4	109,110.0	681.9	17,047.5	192.7	4,817.5
NPS Percent Reduction	45.2%	45.2%	43.5%	43.5%	56.1%	56.1%		
SWMM								
Current Load	8,068	201,700	7,197	179,916	678	16,943	193.632	4840.8
Allowable Load (NPS)	**6,346**	**158,650**	**5,661**	**141,515**	**533**	**13,328**	**152.3**	**3807.5**
Allowable Load (PS)	**707**	**17,675**						
Margin of Safety (MOS)*	0	0						
Total Allowable Load	**7,053**	**176,325**						
Total Reduction Goal	1,015	25,375						
NPS Reduction Goal ***	1,722	43,050	1,536	38,401	145	3,615	41	1,033
Total Percent Reduction	13%	13%						
NPS Percent Reduction	21%	21%	21%	21%	21%	21%	21%	21%

*Assumes no load from PS
**TMDL document says that the MOS for sediment is implicit because phosphorus binds to sediment and the MOS for phosphorus has already been established at 10%
***Note that total reduction goals are less than NPS reduction goals because the TMDL gives additional future loads to point sources.

Watershed Load Reductions for Fecal Coliform and Biological Impairments

MDE has not yet published guidance on how to address these contaminants; more information will be forthcoming when the TMDLs are published. Watershed load reduction goals will be established at that time and the Supplement will be updated.

Element B: Expected Load Reductions

An estimate of load reductions expected for the management measures described in Element C

a) ***Load reductions achieve environmental goal (e.g. TMDL allocation)***
b) ***Desired load reductions are quantified for each source of impairment identified in Element A***
c) ***Expected load reductions are estimated for each management measure identified in Element C***
d) ***Data sources and/or modeling processes are accurate and verifiable, assumptions can be reasonably justified***

Expected Load Reductions for Nitrogen, Phosphorus and TSS

Expected Load Reductions from Agricultural BMPs

Through the Upper Potomac River Basin Tributary Strategy, a suite of agricultural BMPs has been identified for implementation. These BMPs are described in greater detail in Table Q under Element C. Table N represents the 25-year estimated load reductions associated with each BMP type based on the calculated level of implementation for the Lower Monocacy River watershed.

The total 25-year estimated pollutant load reduction from full implementation of the agricultural BMPs is 582,949 lbs for nitrogen, 57,337 lbs for phosphorus, and 18,342,280 lbs (or 9,171 US short tons) for TSS.

Table N: Estimated 25-year Load Reductions for Agricultural BMPs for the Lower Monocacy River Watershed

BMP Type	Unit Type	Nitrogen Reduction (lbs)	Phosphorus Reduction (lbs)	Sediment Reduction (lbs)
Buffers Forested - Agriculture	Acre	9,414	3,695	1,130,232
Tree Planting - Agriculture	Acre	0	1,361	356,175
Animal Waste Management - Livestock	Systems	993	385	0
Animal Waste Management - Poultry	Systems	4	1	0
Conservation Tillage	Acre	63,691	5,016	8,615,894
Cover Crops*	Acre	173,774	5,040	1,849,876
Buffers Grassed - Agriculture	Acre	2,280	1,305	399,352
Nutrient Management	Acre	230,335	21,360	0
Retirement Highly Erodible Land	Acre	6,433	2,070	654,589
Soil Conservation & Water Quality Plans	Acre	85,828	13,105	4,007,970
Stream Protection with Fencing	Acre	7,973	3,100	1,053,603
Stream Protection without Fencing	Acre	564	219	77,096
Wetland - Agriculture	Acre	1,660	680	197,493
TOTAL		**582,949**	**57,337**	**18,342,280**

***Cover Crops = values for both cover crops and commodity cover crops**

Expected Load Reductions from Urban BMPs

Through the Upper Potomac River Basin Tributary Strategy, a suite of urban BMPs has been identified for implementation. These BMPs are described in greater detail in Table S under Element C. Table O represents the 25-year estimated load reductions associated with each BMP type based on the calculated level of implementation for the Lower Monocacy River watershed.

The total 25-year estimated pollutant load reduction from the implementation of the urban BMPs is 67,049 lbs for nitrogen, 11,615 lbs for phosphorus, and 2,348,084 lbs (or 1,174 US short tons) for TSS.

Note: There are a number of urban restoration practices utilized by the members of the Alliance that are part of the Bay Program Model but have not been included in the Upper Potomac River Basin Tributary Strategy. In order to have a more complete "restoration toolbox", the practices used by the Alliance have been categorized within the broad BMP types from the Upper Potomac River Basin Tributary Strategy. If an urban practice is referred to as a **BMP type**, it was identified through the Upper Potomac River Basin Tributary Strategy. If an urban practice is referred to as a **Proposed Management Measure (PMM)**, it is used by the Alliance to meet the goals of the Lower Monocacy River WRAS. Table P illustrates how the Upper Potomac River Basin

Tributary Strategy BMP types and the Alliance PMMs relate. All tables referencing urban practices will have a column listing the BMP Type and the Proposed Management Measure. More than one PMM can fit under a BMP Type. Note also that new BMPs may be added to the strategy over time as the Bay Program lists them.

Table O: Estimated 25-year Load Reductions for Urban BMPs for the Lower Monocacy River Watershed

BMP Type	Unit Type	Nitrogen Reduction (lbs)	Phosphorus Reduction (lbs)	Sediment Reduction (lbs)
Erosion and Sediment Control	Acre	2,794	487	149,331
Stream Restoration, Urban	Linear Feet	19	3	2,437
Stormwater Management	Acre	28,210	4,535	2,186,095
Tree Planting*	Acre	86	10	1,920
Buffers Forested, Urban	Acre	309	20	8,301
Nutrient Management, Mixed	Acre	17,183	2,564	0
Enhanced Septic Denitrification	Systems	13,967	0	0
Nutrient Management, Urban	Acre	4,481	3,996	0
TOTAL		**67,049**	**11,615**	**2,348,084**

*Tree planting=tree planting on both mixed open and urban pervious land

Table P: BMP types versus Proposed Management Measures (PMMs)

BMP Type	PMM
Buffers Forested, Urban	Urban Streamside Forest Buffers
	Urban Grass Buffers
	Urban Wetland Creation
Tree Planting*	Urban Upland Grass Meadow
	Urban Upland Tree Planting
Stormwater Management	Urban Nonstructural runoff treatment including Bioretention, Rain Barrels, wetlands
	Rain Gardens
	Retrofit pond to provide Water Quality Treatment Comm/Ind (i.e. wetlands)
	Street Sweeping Vacuum Bimonthly
	Porous Pavers
	Urban Runoff Treatment New Development
Stream Restoration, Urban	Stream Restoration/ Bank Stabilization
Erosion and Sediment Control	Erosion and Sediment Control
Nutrient Management, Mixed	Nutrient Management, Mixed
Nutrient Management, Mixed	Nutrient Management, Mixed
Enhanced Septic Denitrification	Septic Denitrification
	Septic Replacement with Sewer (MDR)

*Tree planting=tree planting on both mixed open and urban pervious land

Expected Load Reductions for Fecal Coliform and Biological Impairments

MDE has not yet published guidance on how to use BMPs to address these contaminants; more information will be forthcoming when the TMDLs are published. The Supplement will be updated to address these contaminants.

Achieving Environmental Goal

Lower Monocacy River Watershed

As discussed under the *Watershed Load Reduction Goals* section in Element A, in the absence of a TMDL, the goal for the Lower Monocacy River watershed was set based on the proportion of the Upper Potomac River Basin Tributary Strategy BMPs that can be implemented within the

Lower Monocacy River watershed. The agricultural and urban BMPs proposed above represent this calculated proportion. If they are implemented fully, as planned, the watershed load reduction goal for the Lower Monocacy River watershed will be met. As BMP implementation options are updated through the Upper Potomac River Basin Tributary Strategy and/or TMDLs are established for the Lower Monocacy River watershed, the plan will be updated to address new load reduction goals. As there are no TMDL allocations for the Bennett Creek Watershed, it is assumed that meeting the Tributary Strategy goals for the Lower Monocacy River watershed will meet the goals for Bennett Creek watershed.

The total reduction goal for the Lower Monocacy River watershed over 25 years is 20,690,364 lbs (or 10,345 US short tons) for TSS, 649,998 lbs for nitrogen, and 68,952 lbs for phosphorus. This goal will be met with the efforts outlined in this plan.

Lake Linganore Watershed

The Lake Linganore watershed currently has a TMDL for phosphorus and sediment as discussed under Element A. The Linganore watershed is encompassed within the larger Lower Monocacy River watershed. The types of BMPs listed above have been established for implementation in the Lower Monocacy River watershed and therefore are also applicable for implementation within the Lake Linganore watershed.

As shown in Tables W and Y (Element F/G), a number of urban BMPs have already been established within the Lake Linganore watershed. Those implemented thus far (2005-2010) have had an estimated reduction of 624 lbs of nitrogen per year, 48.4 lbs of phosphorus per year, and 8.9 tons of sediment per year. The estimated 25-year nutrient reduction associated with these projects is 15,600 lbs of nitrogen, 1,210 lbs of phosphorus, and 222 tons of sediment. Assuming a consistent level of implementation over 25 years, a 25-year reduction would amount to 78,000 pounds of nitrogen, 6,050 pounds of phosphorus and 1,110 tons of sediment.

As noted in the section entitled *Lake Linganore Load Reduction Goal from the Established TMDL*,

> The TMDL requires a 90% reduction of phosphorus and roughly a 45% reduction of sediment. No BMPs are 90% effective, so even with 100% implementation, Frederick County cannot physically meet the goal. The goals for the TMDL are established based on load calculations from land use coefficients, similar to how we have calculated loads for the Tributary Strategies. For Linganore, Frederick County has used a more detailed model that takes other factors such as soil erodibility and rainfall into consideration. For this reason, Frederick County proposes using the current load estimates generated by the SWMM model to calculate the load reduction required to achieve the TMDL. These estimates require an 83.5% reduction in phosphorus and a 21% reduction in sediment. The loads from the SWMM model will be used until Frederick County and USGS are able to evaluate actual TSS using field observations.

Based on BMP pollutant removal efficiencies from the Maryland Tributary Strategies "Technical Reference For Maryland's Tributary Strategies", those BMPs that are most efficient at reducing pollutant loads require land conversion. For example, the top most efficient agricultural BMPs include tree planting and/or grass buffers except stream fencing which is only 67.5% effective. Only a select number of acres can be put into tree planting and/or grass buffers before productive land is lost through forest conversion. Therefore, increased implementation of nutrient management plans (which are within the top most efficient BMPS) rather than just tree plantings or grass buffer plantings would be required in order to keep agricultural land in production. However, this BMP is only 25% efficient at removing phosphorus. The top urban BMPs provide pollutant treatment using infiltration practices. If all urban land is retrofitted and treated using infiltration practices, only 72% of the phosphorus would be treated. The next most efficient urban BMP is tree planting which requires land conversion.

With 56% (or 29,066.24 acres) of the Lake Linganore drainage area in agricultural land use and 16% (or 8,304 acres) in developed land use, successful agricultural and urban BMP implementation is key to achieving the TMDL goals. Therefore, Frederick County will be working with USGS under contract to calculate the yields from actual sediment sources within the lake's drainage area. Agricultural and urban goals will be addressed through the "Use Attainability Analysis" to make them more compatible with current land use.

Frederick County proposes to address the reduction goals obtained using the current pollutant loads from the SWMM model until USGS estimates are available. With this in mind, the 25-year urban reduction goal required to meet the TMDL for phosphorus in is 92,106.3 lbs and for TSS is 3,615 tons. At current implementation levels, Frederick County will meet 6.6% of the urban phosphorus and TSS goals in the next 25 years. Frederick County will conduct a "Use Attainability Analysis" to determine reasonable load reductions from an aggressive but achievable implementation schedule for the proposed management measures. Frederick County will also continue to pursue additional resources to address the TMDL.

Data Sources and Modeling Processes

DATA SOURCES

The nitrogen and phosphorus removal efficiencies used to estimate load reductions for the BMPs listed are from:

- Maryland Tributary Strategies. "Technical Reference For Maryland's Tributary Strategies." January 2003.

The sediment removal efficiencies used to estimate load reductions for BMPs listed are from:

- U.S. Geological Survey. "A Summary Report of Sediment Processes in the Chesapeake Bay and Watershed." Water-Resources Investigations Report 03-4123. 2003. Pg 97 Table 7.4

The costs for implementation for BMPs listed are from:

- Maryland Tributary Strategies. "Technical Reference For Maryland's Tributary Strategies." January 2003.
- "Economic Analyses of Nutrient and Sediment Reductions to Restore Chesapeake Bay Water Quality", USEPA CBP 9/2003
- Practical experience in Frederick County

MODELING PROCESS

The Implementation Database has been designed to automatically calculate pollutant loads by watershed, subwatershed, and catchment. It will also calculate the expected pollutant load reduction based on literature values for installed BMPs. As described under Element I, there are a number of screens in the Implementation Database prompting the user to enter specific information about the watershed and the project. Pollutant loads are calculated using loading rate coefficients for each pollutant by land use (Table F) and the number of acres of each land use by watershed, subwatershed and/or catchment. Pollutant loading rate coefficients were obtained from MDE in 2005 and the land use data is from 2002 Land Use/Land Cover for Maryland from the Maryland Department of Planning. Land use was calculated in GIS by clipping the land use overlay for Frederick County to the watershed, subwatershed, and catchment boundaries. Land use acreages were entered into the County's Implementation Database where estimated pollutant loads were generated using the loading rate coefficients in Table F. Estimated load reductions associated with BMP implementation are calculated using the BMPs implemented, the size of the project (total BMP units), and the land use on which the project is installed. BMP efficiencies were obtained from the sources listed above.

Element C: Proposed Management Measures (PMMs)

A description of the nonpoint source management measures that will need to be implemented to achieve the load reductions estimated under Element B (as well as other watershed goals identified in this watershed-based plan), and an identification (using a map or a description) of the critical areas in which those measures will be needed to implement this plan.

- ***a) Specific management measures are identified and rationalized (i.e. what this management measure will help achieve goals)***
- ***b) Proposed management measures are strategic and feasible for the watershed***
- ***c) Proposed management measures achieved load reduction goals***
- ***d) Critical/Priority implementation areas have been identified***
- ***e) The extent of expected implementation is quantified (e.g. x miles of stream bank fenced, etc.)***
- ***f) Adaptive management process in place to evaluate effectiveness of management measures***

Addressed in the Lower Monocacy WRAS on pages 21-22, 32-65, in Table 16: Natural Resource Management Priorities, and on Maps 37-44, 17, 18, 19, 21, 22, 23, 24, 25, 26, and 27[7].

Potential Agricultural PMMs for Installation

Tables Q and R show the proposed agricultural PMMs and level of implementation for the Lower Monocacy River watershed. Table Q provides a description of the PMM, information on project life, capital costs, cost/year, and cost ratio for pollutant removal. Table R shows the level of implementation proposed for the Lower Monocacy River watershed over the 25-year phased implementation timeframe.

Table Q: Proposed Management Measures for Water Quality and Habitat for Agricultural Land

BMP Type/PMM	Description of BMP/PMM	Life of Project (years)	Capital Costs/unit treated (do not include maint.)	Amortized Costs/(unit treated*yr) to provide basis of cost comparison; Benefit to Cost Ratio of pollutant removal; other benefits
Soil Conservation & Water Quality Plans	A comprehensive plan that addresses natural resource management on agricultural lands and utilizes BMPs that control erosion and sediment loss and manage runoff. Does not include cost of BMPs implemented with animal waste systems, retirement of highly erodible land, nutrient management plans.	1	$35.00/(ac-yr)	$35.00/(ac-yr)
Conservation Tillage	Conservation tillage reduction (lb/ac-yr) = hi-till load - low-till load. Includes cost of purchasing tillage/planting equipment and overestimates cost when old equipment is used.	1	$2.72/(ac-yr)	$2.72/(ac-yr)
Cover Crops	A high level of nutrients may remain in the soil after harvesting, regardless of nutrient use/efficiency/yield, esp. during drought years. Small grains planted w/o fertilizer in Sept/early Oct reduces nitrate-leaching losses and decrease erosion, thus decreasing sed. and phos. loads. Implementation of NMPI separate, this acre can be counted twice. $17/ac costs based on seed and chemical costs plus $13/ac labor and equipment.	1	$30/(ac-yr)	$30/yr

[7] As referenced in the "Elements and Evaluation Criteria" document for the Lower Monocacy WRAS from EPA

BMP Type/PMM	Description of BMP/PMM	Life of Project (years)	Capital Costs/unit treated (do not include maint.)	Amortized Costs/(unit treated*yr) to provide basis of cost comparison; Benefit to Cost Ratio of pollutant removal; other benefits
Commodity Cover Crops	A high level of nutrients may remain in the soil after harvesting, regardless of nutrient use/efficiency/yield, esp. during drought years. Small grains planted w/o fertilizer in Sept/early Oct reduces nitrate-leaching losses and decrease erosion, thus decreasing sed. and phos. loads. Implementation of NMPI separate, this acre can be counted twice. $17/ac costs based on seed and chemical costs plus $13/ac labor and equipment.	1	$30/(ac-yr)	$30/yr
Animal Waste Management – Livestock	Designed for proper handling, storage, and utilization of wastes generated from confined animal operations and include a means of collecting, scraping, or washing wastes from confinement areas into appropriate waste storage structures. Does not apply to pasture- waste must be collectable and disposable. Uses manure acre as defined as waste generated by 150 animal units (one animal unit = 1000 lbs) in confinement. Based on avg. number of animal units per acre. (Avg. animal units/operation/150)*(waste storage reduction lb per yr/animal base acres). Does not include fertilizer savings from manure use.	15	Avg. cost $55,584/system plus 14% assistance costs.	$3,705.60
Animal Waste Management – Poultry	Designed for proper handling, storage, and utilization of wastes generated from confined animal operations and include a means of collecting, scraping, or washing wastes from confinement areas into appropriate waste storage structures. Costs include $23,357 plus 14% assistance amortized over 15 years. Uses manure acre as defined as waste generated by 150 animal units (one animal unit = 1000 lbs) in confinement. Based on avg. number of animal units per acre. (Avg. animal units/operation/150)*(waste storage reduction lb per yr/animal base acres).	10	$35,398.00/system	$1775.13/(system-yr)
Runoff Control	Consist of practices such as upslope diversions and directed downspouts to minimize offsite water entering the confinement facility. Cost per facility estimated at $7,058 or 11% of livestock waste mgmt systems.	10	$7,058/system	$471/(system-yr)
Nutrient Management	Comprehensive plan that describes the optimum use of nutrients to minimize loss while maintaining yield. Revised every 2-3 years. Required under WQ improvement act of 1998. NMPA reduction lb/ac-yr = (NMPI reduction *1MM)/cropland acres NMPI % red'n = red'n lb/ac-yr/(cropland weighted avg. load)*100	3	$19.00/(ac-yr)	$7.00
Stream Protection With Fencing	Involves the fencing of narrow strips of land along streams to completely exclude livestock. CREP funding. Controllable load = 0.75 * (pasture load - forest load). 35 feet wide treated per linear mile of fence = 4.2 ac. Applies to "bad pasture" The edge-of-field loading for N/P/sediment is 12x "good pasture."	10	$578/ac	$104
Stream Protection Without Fencing	Involves the use of troughs or "watering holes" in remote locations away from streams, as well as the placement of stream crossings. CREP funding. Reduction (lb/ac-yr) = 0.375 * (Pasture load - Forest load)	10	$417/ac	$75

BMP Type/PMM	Description of BMP/PMM	Life of Project (years)	Capital Costs/unit treated (do not include maint.)	Amortized Costs/(unit treated*yr) to provide basis of cost comparison; Benefit to Cost Ratio of pollutant removal; other benefits
Retirement of Highly Erodible Land	Involves the removal of highly erodible land from crop or hay production. The land is planted into either grass or forest and is usually not disturbed for at least ten years. Incentives in CREP. Most farmers prefer to treat rather than retire. Assumes acres planted in pasture grass-conservative. Retired land reduction (lb/ac-yr) = Weighted avg. cropland load - weighted avg. pasture load. Cost based on CREP payment plus avg. incurred loss due to retirement.	1	$120/(ac-yr)	$120/(ac-yr)
Buffers Forested – Agriculture	1/3 acre of riparian buffer treats 1 ac. Establishment of linear wooded areas along streams and rivers. Help filter nutrients, sed., other pollutants from runoff and nutrients from groundwater. Does not include highly urban areas. Timber revenues not included. Gives an annualized capital cost of $108 per acre, of which 85% is installation cost. Cost-sharing. Costs range from $33-$70/ac-yr over 25 year life expectancy of CREP. Additional opportunity cost of $70/yr not included. MACS pays $900/ac for 15-yr practice. Annualizing the total installation and early maintenance costs of $1,517 at 5% over 25 years is available for the installation costs at rates ranging from 75% to 100%. In addition, CREP programs offer annual maintenance payments of $5/ac/yr. One-time incentive payments are also available in Maryland, and Maryland also offers an additional sign-up bonus.	15	$1,517/ac	Net gain $34/(ac-yr)
Buffers Grassed – Agriculture	Assumed to be 100 ft wide on streamside. 2-ac upland estimated for every buffer acre. Assumes buffer acres. One buffer acre for every 435.6 lf of 100 ft wide.	10	$7 per acre-year for practice plus $75/ac-yr opportunity cost. Does not include potential revenues from hay.	$7 per acre-year for practice plus $75/ac-yr opportunity cost. Does not include potential revenues from hay.
Tree Planting – Agriculture	Includes any tree plantings on ag land except those along rivers and streams (within 350 feet). Does not include reforestation, which replaces timber from harvest. Costs are $600 up front amortized over 20 years and does not include tree tubes. Includes nursery and labor costs. CREP. Land use conversion from ag to forest.	25	$1,284 /ac	$20/(ac-yr)

BMP Type/PMM	Description of BMP/PMM	Life of Project (years)	Capital Costs/unit treated (do not include maint.)	Amortized Costs/(unit treated*yr) to provide basis of cost comparison; Benefit to Cost Ratio of pollutant removal; other benefits
Wetland – Agriculture	Not SWM. Reestablishment of wetlands on sites where they used to exist. May include restoration, creation, and enhancement acreage. SW cost-share program provides up to 75% grants to local governments, small creeks and estuaries 50%. Also CREP, WHIP (Wetland Habitat Incentive Program), EQIP (Env. Quality Incentive Program) provide cost shares. Many restored through control of Phragmites. Ducks Unlimited very active. Lit on nontidal wetlands for nutrient reduction of NPS is limited. Convert ag land use to forest or wetland to achieve nutrient loads. Includes Emergent Marsh and Palustrine Forested. Avg. reduction of nutrient = upland drainage area * nutrient removal efficiency * weighted factor determined by wetland functional class and position in watershed * land use loading rate of upland area in lb/ac-yr. Every acre wetland treats 2-ac upland.	25	$1284/ac	$51.36
Stream Restoration	Average Costs for Stream Restoration Work from 1999 USDA-NRCS Cost Table Filter Strip: Site Prep and Seeding: $475/ac Rip. Forest Buffer: Site Prep $75/ac, Tree Planting $800/ac, Tree Shelters $3.00/ea, Seeding $400/ac Fish Hab. Improvement: Stream Boulder Placement: $50/ea, Log/wood frames $3.00/lf, rock riprap $50/cu yd Stream bank Stabilization: Brush Mattressing $6.00/lf, plant cuttings $.50 ea, fiber rolls $12.00/lf, live stakes $2/ea, erosion control blanket $2/sq yd, herbaceous plants $2/ea	15	$417/ac	$75

Table R: Agricultural Implementation Goals for the Lower Monocacy River Watershed

BMP Type/PMM	Units	Implementation Goal	Per Year Goal
Buffers Forested – Agriculture	Acres	2,233	89.32
Tree Planting – Agriculture	Acres	444	17.76
Animal Waste Management – Livestock	Systems	165	6.6
Animal Waste Management - Poultry	Systems	3	0.12
Conservation Tillage	Acres/yr	24,032	961.28
Cover Crops*	Acres/yr	25,111	100.44
Buffers Grass – Agriculture	Acre	789	31.56
Nutrient Management	Acres	47,897	1,915.88
Retirement of Highly Erodible Land	Acres	2,185	87.4
Soil Conservation & Water Quality Plant	Acres	58,292	2,331.68
Stream Protection with Fencing	Acres	1,471	58.84

BMP Type/PMM	Units	Implementation Goal	Per Year Goal
Stream Protection without Fencing	Acres	207	8.28
Wetland – Agriculture	Acres	376	15.04

*** Cover Crops=values for both cover crops and commodity cover crops**

Potential Urban PMMs for Installation

Tables S and T show the proposed urban PMMs and level of implementation for the Lower Monocacy River watershed. Table S provides a description of the PMM, information on project life, capital costs, costs/year, and cost ratio for pollutant removal. Table T shows the level of implementation proposed for the Lower Monocacy River watershed over the 25-year phased implementation timeframe.

Table S: Proposed Management Measures for Water Quality and Habitat for Urban Land

PMM	BMP Type	Description of Best Management Practice	Life of Project (years)	Capital Costs/unit treated (do not include maint.)	Amortized Costs/(unit treated*yr) to provide basis of cost comparison; Benefit to Cost Ratio of pollutant removal; other benefits
Urban Streamside Forest Buffers	Buffers Forested, Urban	Streamside (riparian) plantings slow and filter runoff. Cost effective BMP. Approximately 60% of 1434 miles of waterways in County lack 100-foot buffer.	25	$428/ac	$17.17/(ac*yr); $60.55/lb phos, $6.67/lb sed, $4.01/lb nit; provides bank stability, in stream shading, habitat.
Urban Grass Buffers	Buffers Forested, Urban	Assumed to be 100 ft wide on streamside. 2-ac upland estimated for every buffer acre. Assumes buffer acres. One buffer acre for every 435.6 lf of 100 ft wide. $7 per acre-year for practice.	25	$425/ac	$17.00/(ac*yr)
Urban Upland Grass Meadow	Tree Planting*	Meadow establishment outside of riparian buffer area	25	$425/ac	$17.00/(ac*yr)
Urban Upland Tree Planting	Tree Planting*	Planting in urban areas not within 500 foot riparian buffer	25	$1287.50/ac	$51.50/(ac*yr)
Urban Nonstructural runoff treatment including Bioretention, Rain Barrels, wetlands	Stormwater Management	Landscaping feature designed to trap water temporarily to allow filtration into soil and nutrient uptake by plants. Addresses water quality from first flush of pollution.	25	$2,000-4,000/ac	$315/(ac*yr); $744/lb phos, $6.71/lb sed., $668.45/lb nit
Rain Gardens	Stormwater Management	Landscaping feature designed to trap water temporarily to allow filtration into soil and uptake by plants within 24 hours. Addresses water quality from first flush of pollution.	25	$14,931/ac	$1398.72/(ac*yr)
Stream Restoration/ Bank Stabilization	Stream Restoration, Urban	Natural Stream Channel Design (NSCD) techniques restore stability of stream corridor, prevent erosion, improve habitat. Assume 1% of streams need restoration	25	$107-185/lf	$12/(lf*yr); reductions specific to projects; Sediment and phosphorus reduction from in stream sources, habitat improvements.
Retrofit pond to provide Water Quality Treatment Comm/Ind (i.e. wetlands)	Stormwater Management	Retrofits include increasing detention storage; installing water quality improvements like sediment forebays, micropools, wetlands, or riparian buffer; modifying or replacing riser structures to reduce discharge rates; and adding infiltration features such as sand filters or bioretention areas.	25	$2,000-4,000/ac	$315/(ac*yr); $1,023/ lb phos, $3.35/lb sed., $164/lb nit

PMM	BMP Type	Description of Best Management Practice	Life of Project (years)	Capital Costs/unit treated (do not include maint.)	Amortized Costs/(unit treated*yr) to provide basis of cost comparison; Benefit to Cost Ratio of pollutant removal; other benefits
Urban Wetland Creation	Buffers Forested, Urban	Establishment of wetlands or reestablishment of wetlands on sties where they used to exist. May include restoration, creation, or enhancement acreage. Lit. on nontidal wetlands for nutrient reduction of NPS is limited.	25	$1284/ac	$51.36
Street Sweeping Vacuum Bimonthly	Stormwater Management	Also called vacuum-assisted or small-micron-particulate sweepers. Two general types are available: wet and dry. The dry type combines a mechanical (broom-sweeping) process with a vacuum to capture small particles it stirs up. The wet type uses water for dust suppression. Scrubber-type machines apply water to the pavement so that fine particles are suspended, then vacuum up the mixture. Note life of project is the expected life of a $75,000 street sweeper and that per unit costs and life of equipment differ based on frequency of use. 2500 miles of county road lanes at approx. 8 ft avg. width per lane.	4	$75,000 per street sweeper equipment, operating costs	$0.02/(lf*yr) or approx $871/(ac*yr); exact reductions are under scientific review; removal of heavy metals and salts especially important in urban areas.
Porous Pavers	Stormwater Management	Replace pavement with paver blocks.	25	$50,000/ac	$2,871.39/(ac*yr)
Septic Denitrification	Enhanced Septic Denitrification	Take typical septic systems and increase the nitrogen removal capabilities using methods such as: constructed wetlands, composting toilets, elevated sand mounds, intermittent sand filters etc.	25	Implementation is $5,500 per system	$420.00 ($5,500 over 25 years plus 200 per year maintenance)
Urban Runoff Treatment New Development	Stormwater Management	Stormwater management for new development	25	$3,477/ac	$450 /(ac*yr)
Septic Replacement with Sewer (MDR)	Enhanced Septic Denitrification	The replacement of septic systems with wastewater treatment plants (WWTP). Cost up-front is $20,000 and is amortized. Increased sewer capacity spurs development.	25	$20,000/system	$800 per unit

* Calculate areas for projects with linear feet by multiplying stream restoration by 100 feet and street sweeping by 25 feet.
* Tree planting = tree planting on both mixed open and urban pervious land

Table T: Urban Implementation Goals for the Lower Monocacy River Watershed

BMP Type	PMM	Units	Implementation Goal	Per Year Goal
Buffers Forested, Urban	Urban Streamside Forest Buffers Urban Grass Buffers Urban Wetland Creation	Acres	73	2.92
Tree Planting*	Urban Upland Grass Meadow Urban Upland Tree Planting	Acres	20	0.8
Stream Restoration, Urban	Stream Restoration/ Bank Stabilization	Linear feet	956	38.24
Sediment and Erosion Control	Sediment and Erosion Control	Acres	1,460	58.4
Stormwater Management	Retrofit pond to provide Water Quality Treatment Comm/Ind (i.e. wetlands) Street Sweeping Vacuum Bimonthly Porous Pavers Urban Nonstructural runoff treatment including Bioretention, Rain Barrels, wetlands Rain Gardens Urban Runoff Treatment New Development	Acres	6,780	271.2
Nutrient Management	Nutrient Management, Mixed	Acres	18,461	738.44
Nutrient Management	Nutrient Management, Urban	Acres	17,427	697.08
Enhanced Septic Denitrification	Septic Denitrification Septic Replacement with Sewer (MDR)	Systems	17,784	711.36

* Tree planting = tree planting on both mixed open and urban pervious land

Additional Critical/Priority Implementation Areas

Since the completion of the Lower Monocacy River WRAS, additional resources have been obtained by the County to further identify and prioritize implementation in critical areas. These resources include maps of Frederick County brook trout populations, designated uses for the streams in Frederick County, and wellhead protection areas. These areas, combined with the SCA data, the estimated pollutant loads, impervious area and stream status are used to prioritize watersheds, subwatersheds, and catchments for restoration and/or protection.

Brook Trout Streams

Frederick County has a few remaining native brook trout populations. In an effort to identify and prioritize those areas where brook trout remain, Frederick County's Watershed Management Section mapped (Map 69, Appendix F) the known locations of all trout populations (brook, brown, and rainbow trout). Those streams with remaining native brook trout populations have been given highest priority for protection and/or restoration.

Designated Uses

Frederick County's Watershed Management Section mapped the designated uses assigned for all of the streams in Frederick County (Map 70, Appendix F). This map is being used to further prioritize restoration efforts for those streams that are not meeting their assigned designated use because the water quality is too poor; and to further prioritize protection efforts for those streams that are still meeting their designated use but may be threatened due to changing land use in the surrounding watershed.

From MDE: "The Lower Monocacy River, upstream of US Route-40, and its tributary Israel Creek have been designated as Use IV-P waterbodies (Recreational Trout Waters and Public Water Supply). Downstream of Route US-40, the Lower Monocacy River is designated as a Use I-P waterbody (Water Contact Recreation, Protection of Aquatic Life and Public Water Supply). Additional tributaries of the Lower Monocacy River-- Carroll Creek, Rocky Fountain Run, Little Bennett Creek, Furnace Branch, Ballenger Creek and Bear Branch--are designated as Use III-P waterbodies (Nontidal Cold Water and Public Water Supply). See Code of Maryland Regulations (COMAR) 26.08.02.08P."

Wellhead Protection Areas

The County's wellhead protection areas have also been mapped (Map 71, Appendix F). Restoration and/or protection efforts are targeted for these areas in order to continue to provide adequate groundwater recharge with high water quality.

Element D: Technical and Financial Assistance Needs

An estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon, to implement this plan

- ***a) Cost estimates reflect all planning and implementation costs***
- ***b) Cost estimates are provided for each management measure***
- ***c) All potential Federal, State, Local, and Private funding sources are identified***
- ***d) Funding is strategically allocated – activities are funded with appropriate sources (e.g. NRCS funds for BMP cost share)***

Addressed in the Lower Monocacy WRAS in Table 16: Natural Resource Management Priorities[8]

County Funding Sources

The County has received funding from a number of sources since the completion of the Lower Monocacy River WRAS. These sources include but are not limited to the Chesapeake Bay Trust (CBT), the Environmental Protection Agency (EPA) 319(h) Program, the County's Capital Improvement Program (CIP) budget, County Operating funds, and the National Fish and Wildlife Foundation (NFWF).

Funding from Monocacy & Catoctin Watershed Alliance Partnerships

The partners in the Monocacy & Catoctin Watershed Alliance (MCWA) also provide resources for funding restoration projects. The Alliance, its history, and partners are discussed in greater detail under Element E.

In most cases, the funding for restoration project implementation does not come from one source. Rather, money from a variety of sources is leveraged through Alliance partnerships. Collaboration on projects results in the involvement of many partners who can bring a variety of funding sources and technical resources/expertise to the table. Such collaborations are facilitated through the County's Community Restoration Coordinator.

Element E: Information, Education, and Public Participation Component

An information/education component that will be used to enhance the public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented

- ***a) A Stakeholder outreach strategy has been developed***
- ***b) All relevant stakeholders (i.e. State, Federal, Local, Private) are identified and involved in outreach process***
- ***c) Public meetings and forums have been/are scheduled to be held***
- ***d) Educational/Outreach Materials will be/have been disseminated***

Addressed in the Lower Monocacy WRAS on pages 6-9 and in Table 17: Community Education and Outreach Priorities[8]

Monocacy & Catoctin Watershed Alliance (MCWA or the Alliance)

The Monocacy & Catoctin Watershed Alliance (MCWA or the Alliance) is a mutual, collaborative, non-advocacy effort among individuals and organizations desiring to work together to improve the health of the Monocacy and Catoctin watersheds. Growing out of more than two years of action planning for the Upper and Lower Monocacy River WRASes, a Frederick County coordinated and State assisted local planning process, participants decided to continue their affiliation and cooperation at its conclusion in order to help foster WRAS plan implementation.

[8] As referenced in the "Elements and Evaluation Criteria" document for the Lower Monocacy WRAS from EPA

Alliance History

After the Upper and Lower Monocacy River WRAS process was complete, implementation efforts for the Lower Monocacy River WRAS plan began and members of the two Steering Committees desired to keep the efforts of the Lower Monocacy and Upper Monocacy WRAS Steering Committees alive. The Monocacy & Catoctin Watershed Alliance is what evolved out of the group planning initiative. The Alliance developed a logo and hosted its first booth in the City Streets, Country Roads exhibit of the Great Frederick Fair in September 2004. During bimonthly planning meetings starting in July 2005, the group approved the final website design and agreed upon a structure under which the Alliance would operate.

How the Alliance Works

The Alliance helps Frederick County Division of Public Works (DPW) to leverage the resources of outside groups to meet the goals outlined in the WRAS plans. The WRAS Coordinator role at the County shifted to a Community Restoration Coordinator role when grant money was awarded for Lower Monocacy River WRAS plan implementation. The Community Restoration Coordinator works to coordinate the efforts of the Alliance partners in the implementation of the Lower and Upper Monocacy River WRAS plans.

Community groups with local problems and potential ideas for community restoration projects approach a member of the Alliance and request help. Requests are often referred to the Community Restoration Coordinator who alerts appropriate partners to the potential project and facilitates initial conversations or meetings to discern the best strategy for planning and securing the needed resources. Often, if several interested community groups are concentrated in a particular watershed, the funding and collaborative potential for the project increases.

Alliance Partners

Table U provides an alphabetical listing of Monocacy & Catoctin Watershed Alliance partners, how to contact them for information, and what types of services they can provide.

Table U: Monocacy & Catoctin Watershed Alliance Partners

Quick Index to MCWA Partners			
Organization Name	**Primary Contact**	**Telephone**	**Types of Assistance**
Audubon Society of Central Maryland http://www.centralmdaudubon.org/	Ron Polniaszek (Chapter President)	301.831.5060 (Frederick County)	• Attracting, feeding, observing and identifying birds and butterflies in your backyard • Developing bird and butterfly-friendly habitat using native plants • Restoring and managing wildlife habitat • Education
	Bill Becraft (Sanctuary Manager)	410.795.6546 (Carroll County) 410.531.6658 (Howard County)	
Canaan Valley Institute http://www.canaanvi.org/	Kristin Mielcarek	304 678-3446	• Nitrogen reducing replacement septic systems with flush tax $ • Technical assistance & training • Stream restoration • Geospatial services • Applied science • Organizational development
Catoctin Land Trust	Geordie Newman	301.271.2823	• Conservation easements • Education of landowners
Catoctin Mountain Park http://www.nps.gov/cato/	Becky Lancosky	301.416.0536	• Water quality testing & monitoring • GIS support • Design of outreach materials
Chesapeake Bay Foundation http://www.cbf.org/	Rob Schnabel Marcy Damon	443.482.2175 443 482-2156	• Technical assistance on restoration projects

Quick Index to MCWA Partners			
Organization Name	**Primary Contact**	**Telephone**	**Types of Assistance**
			• Volunteer training • Assistance seeking grant funding • Environmental education
Chesapeake Wildlife Heritage http://www.cheswildlife.org/	Geordie Newman	410.310.6270	• Design & installation of habitat management plans for farms & backyards • Habitat restoration • Invasive species control • Tree plantings, warm season grass planting & wetland restoration
Community Commons http://www.communitycommons.org/	Jamie Thurman	310.662.3000	• Monocacy River trail • Greener Lifestyle Series
Frederick County Conservation Club	John Smucker	301.845.7368	• Create a stream restoration experience for young community members that provides long lasting knowledge, appreciation and action • Assist in education efforts from the planning of lessons to delivery methods
Frederick County Forest Conservancy District Board http://www.dnr.state.md.us/forests/programapps/fboards.asp	Mike Kay	301.473.8417	• Tree selection • Developing planting plans • Training in invasive plant management
Frederick County Master Gardeners http://www.agnr.umd.edu/Extension/local/Frederick/MG/index.cfm	Elyse Phillips	301 371-7728	• Education • Speakers for existing organizations • Presentations on Bay Wise landscaping strategy using native plants
	Susan Trice	301.600.1596	
Frederick County Division of Planning http://www.co.frederick.md.us/index.asp?nid=100	Tim Goodfellow	301.600.1138	• Mapping & GIS analysis • Property ownership information • Zoning & comprehensive plan designations
	Carole Larsen	301.600.1135	
Frederick County Watershed Management Section http://www.co.frederick.md.us/index.asp?nid=518	Shannon Moore	301.600.1413	• GIS services, mapping & analysis • Coordination of MCWA, partners, and community restoration • Wetland research • Public outreach & education about watershed health
	Kay Schultz	301.600.1741	
	Jessica Hunicke	301.600.1350	
Friends of Rural Roads of Frederick County	Susan Hanson	301.371.4274	• Promote the preservation of remaining gravel roads in Frederick County and support County Rural Roads Program • Provide information about rural roads and alternatives to paving roads in rural areas
Friends of Waterford Park http://www.friendsofwaterfordpark.org/	Ginny Brace	301.682.6135	• Provide assistance on how to develop a "Friends" group • Education about invasive species that are widespread in the area
Interstate Commission on the Potomac River Basin (ICPRB) http://www.potomacriver.org/index.htm	Jennifer Willoughby	301.694.1908 ext 109	• Grant writing • Development of watershed organizations • Event posting through media outlets & website
Maryland Chapter of the American Chestnut Foundation	Kathy Marmet	301.639.8491	• Education and research about the backcross breeding program to restore the American Chestnut tree to its native

Quick Index to MCWA Partners			
Organization Name	**Primary Contact**	**Telephone**	**Types of Assistance**
http://www.mdtacf.com/	Robert Strasser	240.285.8199	range
Maryland Forest Service http://www.dnr.state.md.us/forests/	Mike Kay	301.473.8417	• Professional forestry services • Development of forest stewardship plans • Education
Hood College http://www.hood.edu/	Drew Ferrier	301.696.3660	• Provides meeting space • Hosts workshops on scientific topics, e.g. endocrine disruptors • Can provide technical assistance with water quality topics
Monocacy National Battlefield http://www.nps.gov/mono/	Andrew Banasik	301.696.0130	• Field assessment & tech. assist. • GIS, education & training in water quality monitoring • Exotic plant management & control
Mount St. Mary's University http://www.msmary.edu/	Jeffrey Simmons	301 447-5820 ext 4863	• Environmental restoration • Tom's Creek water monitoring • Outreach & education
New Forest Society http://www.emmitsburg.net/nfs/index.htm	Elizabeth Prongas	301.271.4459	• Free trees to CREP landowners & others • Educational workshops • Outreach & involvement with young children in tree planting
Potomac Conservancy http://www.potomac.org/	Bryan Seipp Heather Montgomery (trees for school campuses)	301.608.1188 ext 207 301 608.1188 ext 209	• Conservation easement language, monitoring, & negotiation • Science-based forestry advice-tree planting, harvesting, BMPs, road closures & maintenance, stand delineation & management • Rain garden design & installation for community restoration projects
Potomac Valley Fly Fishers, Inc http://www.pvflyfish.org/	Lou Stohlman John Brognard	240.215.4211 301.371.4205	• Issues regarding the protection and restoration of fisheries • Issues regarding stream protection and restoration • Promote fly fishing as a sportsman like and enjoyable way of fishing; and the most consistent with the preservation and wise use of our resources
Soil Conservation District (Frederick and Catoctin) http://www.nrcs.usda.gov/	Mark Seibert Moana Himes Terry Welsh (assists with school wetland projects)	301 695-2803 ext 3	• Technical assistance to agricultural land owners on soil and water conservation • Packaging of applications for federal and state financial assistance • Awards, tours and recognition of leadership and good practices in soil and water conservation
ThorpeWood http://www.thorpewood.org/	Sam Castleman Jason McCauley	301.271.2823	• Meeting facilities for conference & community gatherings • Volunteers for restoration projects • Access to technical expertise in natural resource, legal, & appraisal areas
Western Maryland Resource Conservation & Development Council http://users.erols.com/wmarylandrcd/index.htm	Phil Pannill Aaron Cook	301.791.4010	• Forest restoration • Forest management • Exotic & invasive plant management, volunteer training

Alliance Outreach and Activities

Alliance partners have developed a number of outreach and education initiatives since it began such as: the Alliance website (www.watershed-alliance.com), quarterly electronic newsletters, an Alliance booth at the Great Frederick Fair, a Monocacy & Catoctin Watershed Alliance brochure, and the Watershed Steward Program. Copies of outreach material can be found in Appendix G. Articles on the website are updated on a quarterly basis and often highlight the projects and efforts of Alliance partners. The quarterly electronic newsletter is sent to approximately 830 households in Frederick County.

The Watershed Steward Program was developed to recognize the efforts of community members to protect and restore the natural resources of the Monocacy & Catoctin watersheds by implementing voluntary conservation and best management practices on their property. Watershed Steward signs are available to community members who meet the criteria in one of eight different categories:

- Improving Watershed Health Through Community Partnerships
- Rain Gardens
- Forest Conservation Practice
- Agricultural Conservation Practice
- Forest Land Protection
- Farm Land Protection
- Tree Planting
- Wildlife Habitat Improvement

Element F/G: Schedule and Milestones

A schedule for implementing the nonpoint source management measures identified in this plan that is reasonable expeditious and a description of interim, measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented

a) Implementation schedule includes specific dates and expected accomplishments
b) Implementation schedule follows a logical sequence
c) Implementation schedule covers a reasonable time frame
d) Measurable milestones with expected completion dates are identified to evaluate progress
e) A phased approach with interim milestones is used to ensure continuous implementation

Implementation Schedule

The Lower Monocacy River WRAS was completed in May 2004 with funding for project installation beginning in 2005. Funding is currently available to continue BMP installation through 2010. Using this five-year span (2005-2010) as a guide, as well as the timeframe adopted from the Upper Potomac River Basin Tributary Strategy, a phased 25-year implementation schedule for the Lower Monocacy River watershed has been proposed. The 25-year implementation phase will be divided into five 5-year phases during which partners will work towards implementing the objectives listed in Tables 16 and 17 from the Lower Monocacy River WRAS as well as Tables Q and S under Element C. The implementation phases are listed below:

- **Phase 1:** June 2008-June 2013
- **Phase 2:** June 2013-June 2018
- **Phase 3:** June 2018-June 2023
- **Phase 4:** June 2023-June 2028
- **Phase 5:** June 2028-June 2033

No single objective or BMP type/PMM has been given priority since the Monocacy & Catoctin Watershed Alliance represents a diverse group of partners with unique priorities and agendas. Rather, the objectives discussed in Tables 16 and 17 of the WRAS and the BMP type/PMM listed in Tables Q and S under Element C are a comprehensive prioritization of the solutions to treat the problems identified in the Lower Monocacy River watershed during the planning process.

The three Lower Monocacy River watersheds that were the primary focus of the WRAS are the Lower Linganore Creek watershed, the Upper Linganore Creek watershed, and the Bennett Creek watershed and are therefore given the highest priority for implementation.

The current project schedule has been included to illustrate the level of implementation that has occurred since the initial plan adoption. The proposed project schedule outlines the level of implementation expected to be complete by the end of each implementation phase. This schedule will be used to assess the outputs and level of success of implementation (Element H).

Current Project Schedule

AGRICULTURAL SCHEDULE

As discussed previously, adopted BMP implementation associated with agricultural practices is for the 25-year timeframe ranging from 1985-2010. Table V presents the progress of implementation from 1985-2007 and the level of implementation remaining (2008-2010). When new goals are adopted through the Tributary Strategy program, the Supplement will be updated.

Table V: Agricultural Implementation for the Lower Monocacy River watershed

BMP Type/PMM	Units	Implementation Progress* (1985-2007)	Remaining Implementation (2008-2010)
Soil Conservation & Water Quality Plans	Acres	21,943	36,349
Conservation Tillage	Acres/yr	16,996	7,036
Cover Crops**	Acres/yr	5,595	19,516
Animal Waste Management – Livestock	Systems	1.53	164
Animal Waste Management – Poultry	Systems	0	3
Nutrient Management	Acres	42,280	5,617
Stream Protection with Fencing	Acres	360	1,111
Stream Protection without Fencing	Acres	724	-517
Retirement of Highly Erodible Land	Acres	856	1,329
Buffers Forested – Agriculture	Acres	1,482	751
Buffers Grassed – Agriculture	Acres	1,761	-972
Tree Planting – Agriculture	Acres	354	90
Wetland – Agriculture	Acres	42	334
Alternative Manure Management	Acres	1,627	-1,627

*Source: CMP Watershed Model Run Final, 02-25-07 (For Frederick County and the Upper Potomac River Basin)
**Cover Crops = values for both cover crops and commodity crops
***Negative values indicate that the Tributary Strategy goal for the practice has technically been attained based on tracked data reflecting current levels of implementation through the 2007 reporting cycle; however, subsequent implementation is expected to continue for these practices

URBAN SCHEDULE

The following section illustrates the progress of urban project installation since the completion of the Lower Monocacy River WRAS. All projects listed have either been funded or have received approval for funding. Table W lists the project name; status of the project (completed, in progress, or in planning) and year of implementation; the watershed in which the project was implemented; type of PMM; and the BMP Type.

Table W: Urban Implementation since WRAS Completion

Project Number	Restoration Project Name	Status, Year of Implementation	Watershed	PMM	BMP Type
1	Ballenger Creek Elementary School Stream Restoration	Completed 2007	Ballenger Creek	Stream Restoration	Stream Restoration
				Urban Streamside Forest Buffer	Buffers Forested, Urban
2	Urbana High School Low Impact Development Retrofit	Completed 2007	Lower Bush Creek	Urban Nonstructural, Bioretention	Stormwater Management
3	Pinecliff Park Stream Restoration	In Design as of December 2007	Lower Linganore Creek	Stream Restoration	Stream Restoration
				Urban Streamside Forest Buffer	Buffers Forested, Urban
4	Water Quality treatment at Public Safety Training Facility	In Progress 2007-2009	Lower Linganore Creek	Retrofit pond to provide Water Quality Treatment	Stormwater Management
5	Backyard Buffer	Ongoing	All watersheds	Urban Streamside Forest Buffer	Buffers Forested, Urban
6	Septic Upgrades	In Progress 2007-2008	All watersheds	Septic Denitrification	Enhanced Septic Denitrification
7	Bennett Creek Restoration Initiative	June 2005-August 2006	Bennett Creek (Fahrney and Pleasant Branches)	Urban Streamside Forest Buffer	Buffers Forested, Urban
				Rain Gardens	Stormwater Management
				Urban Wetland Creation	Buffers Forested, Urban
8	Waterford Park Restoration	Completed 2007	Carroll Creek	Urban Streamside Forest Buffer	Buffers Forested, Urban
9	Fred Archibald Sanctuary Reforestation	Completed 2007	Lower Linganore Creek	Urban Streamside Forest Buffer	Buffers Forested, Urban
10	Carroll Creek Stream Restoration	Completed 2007	Carroll Creek	Stream Restoration	Stream Restoration
11	Nancy Adamson Native Hedgerow Garden	Completed	Carroll Creek	Urban Upland Tree Planting	Tree Planting
12	Street Sweeping - Roads and Bridges	Ongoing	All watersheds	Street Sweeping Vacuum	Stormwater Management
13	Stormwater Management	Ongoing	All watersheds	Stormwater Management	Stormwater Management
14	Erosion and Sediment Control	Ongoing	All watersheds	Sediment and Erosion Control	Sediment and Erosion Control
15	**Libertytown Stewards Project**				
15a	*Liberty Village Rain Gardens*	Completed 2005-2007	Upper Linganore Creek	Rain Garden	Stormwater Management
15b	*Liberty Elementary School Rain Gardens*			Rain Garden	Stormwater Management
15c	*St. Peter the Apostle Roman Catholic Church Stream Restoration*			Urban Grass Buffers	Buffers Forested, Urban
				Urban Streamside Forest Buffer	Buffers Forested, Urban

Project Number	Restoration Project Name	Status, Year of Implementation	Watershed	PMM	BMP Type
15d	*Libertytown Community Park Plantings*			Urban Streamside Forest Buffer and Urban Upland Tree Planting	Buffers Forested, Urban and Tree Planting
16	**Linganore Total Maximum Daily Load (TMDL) Urban Demonstration Project**				
16a	*Holly Hills HOA Riparian Planting*	Completed 2007	Lower Linganore Creek	Urban Streamside Forest Buffer	Buffers Forested, Urban
16b	*Holly Hills HOA Riparian Planting II*		Lower Linganore Creek	Urban Streamside Forest Buffer	Buffers Forested, Urban
16c	*Holly Hills Country Club Riparian Planting*		Lower Linganore Creek	Urban Streamside Forest Buffer	Buffers Forested, Urban
16d	*Deer Crossing Elementary Rain Garden*		Lower Linganore Creek	Rain Garden	Stormwater Management
16e	*Mt. Airy Village Gate Park*	Completed 2008	Upper Linganore Creek	Urban Streamside Forest Buffer	Buffers Forested, Urban
				Urban Streamside Forest Buffer	Buffers Forested, Urban
16f	*Mt. Airy East West Park*			Urban Streamside Forest Buffer	Buffers Forested, Urban
				Urban Upland Tree Planting	Tree Planting
16g	*Mt. Airy Windy Ridge Park*			Urban Streamside Forest Buffer	Buffers Forested, Urban
16h	*Libertytown Community Park Plantings*	Completed 2007	Upper Linganore Creek	Rain Garden	Stormwater Management
				Urban Grass Buffers	Buffers Forested, Urban
				Urban Streamside Forest Buffer	Buffers Forested, Urban
16i	*Pinecliff Park Tree Planting*	Completed 2007	Lower Linganore Creek	Urban Streamside Forest Buffer	Buffers Forested, Urban
17	**Schoolyard Habitat**				
17a	*West Frederick Middle Tree Planting*	Completed 2005	Carroll Creek	Urban Streamside Forest Buffer	Buffers Forested, Urban
17b	*Governor Thomas Johnson Middle School Raised Bed Rain Garden*	Completed 2005	Carroll Creek	Rain Garden	Stormwater Management
17c	*Governor Thomas Johnson Middle School Rain Garden*	Completed 2006	Carroll Creek	Rain Garden	Stormwater Management
17d	*Tuscarora Elementary Tree Planting*	Completed 2007	Ballenger Creek	Urban Streamside Forest Buffer	Buffers Forested, Urban
18	**Urban Wetlands Program, Bennett Creek Watershed Pilot**				
18a	*Windsor Knolls Middle School Wetland Creation*	In Planning, Fall 2008	Bennett Creek	Urban Wetland Creation	Buffers Forested, Urban
18b	*Urbana High School Wetland Creation*	In Planning, Fall 2008	Bennett Creek	Urban Wetland Creation	Buffers Forested, Urban
18c	*Worthington Manor Golf Course Wetland**	In Planning, Fall 2008-Spring 2009	Bennett Creek	Urban Wetland Creation	Buffers Forested, Urban
19	**Bennett Creek Urban BMP Demonstration Project**				
19a	*Riparian buffer and open urban tree planting*	In Planning, 2009-2019	Bennett Creek	Urban Streamside Forest Buffer	Buffers Forested, Urban
19b	*Urban BMPs*	In Planning, 2009-2010	Bennett Creek	Rain gardens, rain barrels, urban wetland creations, etc.	--

***Awaiting final approval from EPA for funds for the Worthington Manor Golf Course wetland.**

Proposed Project Schedule

Table X presents the phased implementation schedule of the urban PMMs listed in Table S under Element C. It assumes full implementation with equal implementation of PMMs during each phase.

Table X: PMM Implementation Schedule for Urban Practices in the Lower Monocacy River watershed

PMM	BMP Type	Units	Phase 1: 5-year Implementation (2008-2013)	Phase 2: 10-year Implementation (2008-2018)	Phase 3: 15-year Implementation (2008-2023)	Phase 4: 20-year Implementation (2008-2028)	Phase 5: 25-year Implementation (2008-2033)
Urban Streamside Forest Buffers	Buffers Forested, Urban	Acres	2.92	29.2	43.8	58.4	73
Urban Grass Buffers							
Urban Wetland Creation							
Urban Upland Grass Meadow	Tree Planting*	Acres	0.8	8	12	16	20
Urban Upland Tree Planting							
Stream Restoration/ Bank Stabilization	Stream Restoration, Urban	Linear feet	191.2	382.4	573.6	764.8	956
Retrofit pond to provide Water Quality Treatment Comm/Ind (i.e. wetlands)	Stormwater Management	Acres	271.2	2,712	4,068	5,424	6,780
Street Sweeping Vacuum Bimonthly							
Porous Pavers							
Urban Nonstructural runoff treatment including Bioretention, Rain Barrels, wetlands							
Rain Gardens							
Urban Runoff Treatment New Development							
Nutrient Management, Mixed	Nutrient Management	Acres	738.44	7,384.4	11,076.6	14,768.8	18,461
Nutrient Management, Urban	Nutrient Management	Acres	3,485.4	6,970.8	10,456.2	13,941.6	17,427
Sediment and Erosion Control	Sediment and Erosion Control	Acres	58.4	584	876	1,168	1,460

PMM	BMP Type	Units	Phase 1: 5-year Implementation (2008-2013)	Phase 2: 10-year Implementation (2008-2018)	Phase 3: 15-year Implementation (2008-2023)	Phase 4: 20-year Implementation (2008-2028)	Phase 5: 25-year Implementation (2008-2033)
Septic Denitrification Septic Replacement with Sewer (MDR)	Enhanced Septic Denitrification	Systems	3,556.8	7,113.6	10,670.4	14,227.2	17,784

Measurable Milestones

The project load reductions based on literature values (Table O) and level of BMP implementation (Table T), as tracked in the Implementation Database, will be used as milestones to evaluate implementation progress. Annual status reports of progress will be shared with the Alliance and a comprehensive review and evaluation of progress will occur at the end of each 5-year phase. If it becomes apparent that these milestones are not being meet, the goals set forth in the Lower Monocacy River WRAS will be reevaluated and updated as discussed under Element H.

The County's Watershed Management Section began tracking urban BMP implementation when the Lower Monocacy River WRAS was completed and implementation began. An Implementation Database was developed to track the BMPs used to address the impairments listed for Frederick County, the expected pollutant and impervious reductions associated with each BMP, the level of implementation of each type of BMP, their associated costs, and the Monocacy & Catoctin Watershed Alliance partner responsible for implementation. How the Implementation Database tracks this information is discussed under Element I.

The load reduction milestones associated with each phase of implementation are based on the more specific PMMs utilized by the Alliance (Table P). Because the level of implementation (Table T) is based on the BMP type from the Upper Potomac River Basin Tributary Strategy, and a number of the PMMs (with different efficiencies) can be categorized under one BMP type, it is difficult to calculate the expected load reductions from the PMMs based on the BMP type implementation numbers. Therefore, the successful installation of PMMs, since the completion of the Lower Monocacy River WRAS, was used as a guide for developing the load reduction milestones. Table Y illustrates the current level of implementation tracked over the 5-year period (2005-2010) since the completion of the WRAS. The table includes project name, project size, area treated by the project, estimated pollutant reductions for sediment/total suspended solids (TSS), nitrogen, phosphorus, and the impervious area treated by the implemented projects.

Table Y: Estimated Load Reductions from Urban Implementation since WRAS Completion

Project Number	Restoration Project Name	Project Size	Size Treated by Project	Reduction			
				Sediment/Total Suspended Solids (TSS)	Nitrogen	Phosphorus	Treated Impervious Area
				(lb/yr)	(lbs/yr)	(lbs/yr)	(acres)
1	Ballenger Creek Elementary School Stream Restoration	605 lf	605 lf	1542.80	12.10	2.20	0.00
		1 ac	3 ac	343.60	12.90	0.90	4.00
2	Urbana High School Low Impact Development Retrofit	School = 2.83 ac	2.83 ac	231.60	5.41	0.80	2.83
3	Pinecliff Park Stream Restoration	930 lf	930 lf	2371.50	18.60	3.30	0.00
		15.5 ac	46.4 ac	4554.60	186.30	14.50	46.40
4	Water Quality treatment at Public Safety Training Facility	1 ac	15 ac	1227.50	28.70	4.30	15.00
5	Backyard Buffer	2500 sq. ft/bag distributed	26 ac	3205.43	119.90	7.94	26.00
6	Septic Upgrades	62 upgrades	62 ac	0.00	48.70	0.00	62.00

Project Number	Restoration Project Name	Project Size	Size Treated by Project	Reduction			
				Sediment/Total Suspended Solids (TSS)	Nitrogen	Phosphorus	Treated Impervious Area
				(lb/yr)	(lbs/yr)	(lbs/yr)	(acres)
7	Bennett Creek Restoration Initiative	3 ac	9 ac	1030.60	38.60	2.60	9.00
		1.25 ac	1.25 ac	58.70	0.60	0.50	1.25
		1 ac	10 ac	1596.00	17.40	3.00	10.00
8	Waterford Park Restoration	6.17 ac	18.5 ac	2118.60	79.20	5.20	18.50
9	Fred Archibald Sanctuary Reforestation	4 ac	12 ac	1374.24	25.70	1.70	12.00
10	Carroll Creek Stream Restoration	200 lf	0.23 ac	510.00	4.00	0.70	0.23
11	Nancy Adamson Native Hedgerow Garden	0.5 ac	0.5 ac	47.40	2.10	0.26	0.50
12	Street Sweeping - Roads and Bridges*	936.89 ac	936.89 ac	0.00	0.00	0.00	936.89
13	Stormwater Management	7,993.8 ac	7,993.8 ac	1,185,644.00	15,300.00	2,460.00	0.00
14	Erosion and Sediment Control	1,141.1 ac	1,141.1 ac	116,72	2,184.10	381.70	0.00
15	**Libertytown Stewards Project**						
15a	*Liberty Village Rain Gardens*	400 sq. ft.	0.43 ac	20.20	0.20	0.20	0.43
15b	*Liberty Elementary School Rain Gardens*	500 sq. ft.	0.25 ac	20.50	0.50	0.10	0.25
15c	*St. Peter the Apostle Roman Catholic Church Stream Restoration*	0.1 ac	0.18 ac	15.60	0.60	0.05	0.18
		600 lf	1.5 ac	171.80	6.40	0.40	7.48
15d	*Libertytown Community Park Plantings*	0.043 ac	0.1296 ac	14.84	0.56	0.037	0.13
16	**Linganore Total Maximum Daily Load (TMDL) Urban Demonstration Project**						
16a	*Holly Hills HOA Riparian Planting*	0.5 ac	1.5 ac	171.80	6.40	0.40	1.50
16b	*Holly Hills HOA Riparian Planting II*	1.5 ac	4.5 ac	515.30	19.30	1.30	4.50
16c	*Holly Hills Country Club Riparian Planting*	3.5 ac	10.5 ac	1202.50	45.00	3.00	10.50
16d	*Deer Crossing Elementary Rain Garden*	600 sq. ft	0.40 ac	32.41	0.76	0.11	0.40
16e	*Mt. Airy Village Gate Park*	2.2 ac	6.6 ac	755.80	28.20	1.90	6.60
		0.28 ac	0.84 ac	96.20	3.60	0.20	0.84
16f	*Mt. Airy East West Park*	0.8 ac	2.4 ac	274.80	10.30	0.70	2.40
		3 ac	9 ac	854.00	38.60	4.70	9.00
16g	*Mt. Airy Windy Ridge Park*	12 ac	36 ac	4122.70	154.20	10.20	36.00
16h	*Libertytown Community Park Plantings*	1282 sq. ft.	1.10 ac	89.85	2.10	0.32	1.10
		2.7 ac	8.1 ac	702.34	26.00	2.30	8.10
		6 ac	18 ac	2061.36	77.10	5.10	18.00
16i	*Pinecliff Park Tree Planting*	0.048 ac	0.14 ac	16.50	0.60	0.04	0.14
17	**Schoolyard Habitat**						
17a	*West Frederick Middle Tree Planting*	1.2 ac	3.6 ac	412.30	15.40	1.02	3.60
17b	*Governor Thomas Johnson Middle School Raised Bed Rain Garden*	0.02 ac	0.06 ac	6.90	0.30	0.01	0.06

Project Number	Restoration Project Name	Project Size	Size Treated by Project	Reduction			
				Sediment/Total Suspended Solids (TSS)	Nitrogen	Phosphorus	Treated Impervious Area
				(lb/yr)	(lbs/yr)	(lbs/yr)	(acres)
17c	*Governor Thomas Johnson Middle School Rain Garden*	100 sq. ft	0.5 ac	23.50	0.20	0.20	0.50
17d	*Tuscarora Elementary Tree Planting*	0.136 ac	0.407 ac	46.60	1.70	0.12	0.41
18	**Urban Wetlands Program, Bennett Creek Watershed Pilot**						
18a	*Windsor Knolls Middle School Wetland Creation*	0.8 ac	13.6 ac	2,170.18	23.66	4.50	13.60
18b	*Urbana High School Wetland Creation*	0.29 ac	3.66 ac	584.04	6.37	1.21	3.66
18c	*Worthington Manor Golf Course Wetland**	1.5 ac	20 ac	10,505.00	88.34	36.23	20.00
19	**Bennett Creek Urban BMP Demonstration Project**						
19a	*Riparian buffer and open urban tree planting*	12 ac	36 ac	4,122.72	154.21	10.21	36.00
19b	*Urban BMPs*	2.7 ac	30 ac	2,454.96	57.42	8.63	30.00

The estimated pollutant reductions associated with each project have been added to get a total estimated pollutant load reduction for the 5-year period since the completion of the Lower Monocacy River WRAS. Projected 1-year Incremental Reduction values were obtained by subtracting the reductions associated with street sweeping and stormwater management facilities and dividing by five (Table Z). It is assumed that the pollutant removal and area treated by the street sweeping and existing stormwater management facilities from current development cannot increase over time, and therefore the reductions should be counted only once rather than cumulatively like other PMMs. The Projected 1-year Incremental Reductions were used to calculate the Total Projected Reductions expected at the end of each phase (Tables AA) by multiplying the Projected 1-year Incremental Reduction by the number of years of implementation and then adding in the reductions associated with street sweeping and stormwater management facilities.

Table Z: Estimated Pollutant Load Reductions Since WRAS Completion and Projected 1-year Reductions for Phased Implementation for Urban BMPs

Treated Impairment	Estimated Reductions Since WRAS Completion (2005-2010)	Projected 1-year Reduction
Nitrogen	94,261.65 lbs	15,792.33 lbs
Phosphorus	14,913.95 lbs	2,490.79 lbs
Sediment/Total Suspended Solids (TSS)	6,770,201 lbs	1,116,912.2 lbs

Table AA: Projected Pollutant Reductions for Phased Implementation for Urban BMPs

Treated Impairment	Phase 1: Projected 5-year Reduction (2008-2013)	Phase 2: Total Projected 10-year Reduction (2008-2018)	Phase 3: Total Projected 15-year Reduction (2008-2023)	Phase 4: Total Projected 20-year Reduction (2008-2028)	Phase 5: Total Projected 25-year Reduction [Full Implementation] (2008-2033)
Sediment/Total Suspended Solids (TSS)	6,770,201 lbs	12,354,762 lbs	17,939,323 lbs	23,523,884 lbs	29,108,445 lbs
Nitrogen	94,261.65 lbs	173,223.3 lbs	252,184.95 lbs	331,146.6 lbs	410,108.25 lbs
Phosphorus	14,913.95 lbs	27,367.9 lbs	39,821.85 lbs	52,275.8 lbs	64,729.75 lbs

Element H: Load Reduction Evaluation Criteria

A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made towards attaining water quality standards and, if not, the criteria for determining whether this watershed-based plan needs to be revised or, if a nonpoint source TMDL needs to be revised

- ***a) Proposed criteria effectively measure progress toward load reduction goal***
- ***b) Criteria include both: quantitative measures of implementation progress and pollution reduction; and qualitative measures of overall program success (including public involvement and buy-in)***
- ***c) Interim WQ indicator milestones are clearly identified; the indicator parameters can be different from the WQ standard violation***
- ***d) An Adaptive Management approach is in place, with threshold criteria identified to trigger modifications***

The evaluation of progress will be measured on two levels – quantitative and qualitative. Quantitative measures will evaluate **implementation levels** and **progress towards load reduction goals through pollution reduction**. Qualitative measures will evaluate **overall program success**. Table X under Element F/G presents the quantitative criteria for evaluating implementation progress and Table AA under Element F/G presents the quantitative criteria for evaluating pollution reduction. Overall program success will be evaluated using program goals and monitoring for physical habitat and in-stream biological community status performed through the Frederick County Stream Survey (FCSS).

Implementation levels will be tracked by the County's Watershed Management Section using the Implementation Database (Element I). The County will enter all installed urban restoration projects on an annual basis. The actual BMP implementation level from the Implementation Database will be compared with the projected BMP implementation level from Table X. The annual status of implementation progress will be presented to the Alliance in order to provide interim progress reports. Alliance members will evaluate how many projects have been completed, are in progress, or in planning to determine if the annual level of implementation is adequate to meet the 5-year milestone (Table X). At the end of each 5-year phase, the members of the Alliance will review the progress as tracked in the Implementation Database. If actual implementation levels are 20% higher or lower than the projected implementation levels, the plan will be reevaluated and updated.

In the instances that the **implementation progress** is found to be inadequate based on the threshold criteria identified, in Table X, Alliance members will evaluate the current implementation strategy to determine why the goals are not being met. Questions to be considered may include but are not limited to: Is additional funding required? Are additional partners required? Is more staff needed for project implementation? Is more education and outreach to the public needed to get projects installed on private property? Do the milestones need to be adjusted? Are there some BMPs that are being implemented at a faster rate or more successfully than others? If so, why? Are the goals still attainable based on the current land use? Any changes to the implementation strategy will be included in the updated WRAS, as appropriate.

Pollution reduction will be measured using both modeling and monitoring. Yearly revisions to pollutant loading estimates will be modeled by calculating loads (using the land use coefficient method) and subtracting literature values for pollutant removals of installed BMPs. Geomorphological methods will be used in 2008-2010 in Linganore to determine sediment and phosphorus yields and sources. Physical, chemical and biological monitoring will be completed through a five-year sampling cycle of water quality parameters measured through the FCSS (Element I). Water chemistry, physical habitat, and in-stream biological community status data will be available at the end of each five-year FCSS sampling cycle. These data will be used as a proxy to determine if the BMPs are addressing the TMDL and Upper Potomac River Basin Tributary Strategy goals. The State's development of water quality indicators from this MBSS-type data is central to both state and local efforts. The State's monitoring efforts through the MBSS and other programs are also key to providing data needed to evaluate success (Element I – *Statewide Monitoring Efforts*). The data from the first five years of the FCSS will be used to establish a baseline and goals for a watershed report card. If the measured reductions are more than 20% higher or lower than baseline for any of the parameters, the plan will be modified every five years.

In the instance that the **pollution reductions** are inadequate, based on the monitoring data, but the **implementation progress** is adequate, based on project tracking and modeling, Alliance members will reanalyze existing watershed conditions, monitoring methods, and modeling methods to investigate possible explanations. Questions to be considered may include but are not limited to: Is it possible that conditions in the watershed have changed to counteract the nutrient reductions of the installed restoration projects? Is it possible that the installed restoration projects are not performing as expected or have failed since the last time they were monitored? Is it possible that the nutrient reductions for the project, as cited in literature, could be incorrect for the area where the project was installed? Are other BMPs more effective at reducing nutrients and sediment than those implemented? If so, should those BMPs be prioritized for implementation or should their level of implementation be increased? Based on the findings, Alliance members will updated the WRAS on a five-year cycle to reflect the changes required to meet the watershed goals.

Overall program success will be evaluated using trends identified through physical habitat and in-stream biological community, as reported in the watershed report card, as well as evaluation of overall program goals set during the WRAS planning process (page 5 and Tables 16 and 17). The FCSS collects benthic macroinvertebrate and physical habitat data along with water quality data as discussed under Element I. At the end of each 5-year phase, the overall trend for benthic macroinvertebrates and physical habitat will be evaluated. Trend data from the three State-maintained core trend monthly sampling stations on the Monocacy River Mainstem (Element I) will also be included in this evaluation. If the biology or habitat is determined to be impaired (using MBSS scoring metrics) and the trend is not towards improvement, the plan will be reevaluated and updated to better support a positive trend. Because variables other than general watershed condition can affect the physical habitat and in-stream biological community trends, this data will be evaluated in conjunction with the water quality data. If water quality is shown to improve but physical habitat and in-stream biological community declines, other potential impacts, such as severe weather conditions, will be evaluated.

In addition to the physical habitat and in-stream biological community trends, the overall program goals established during the initial WRAS planning process and identified on page 5 as well as the objectives from Tables 16 and 17 of the Lower Monocacy River WRAS will be evaluated. Alliance members will consider progress towards meeting the stated goals and the continued relevance of the goals. If the goals of the Alliance have changed over time, they will be updated as appropriate.

Finally, **TMDL status** will also be evaluated to determine if the WRAS requires updating. As discussed under Element A, one TMDL exists within the Lower Monocacy River watershed (a TMDL for sediment and phosphorus for Lake Linganore); one TMDL has been submitted for approval (a TMDL for fecal coliform for the Lower Monocacy River watershed); and two TMDLs are currently under development (TMDLs for sediment and nutrients for the Lower Monocacy River watershed). If a previously approved TMDL is changed, the WRAS will be reevaluated and updated to reflect this change. The monitoring and measurement of **implementation progress**, **pollution reduction**, and **overall program success** will be used to supplement TMDL analysis and to provide a foundation to refine both the approved TMDL and the Lower Monocacy River WRAS. Upon approval of a new TMDL, the Lower Monocacy River WRAS will be reevaluated and updated as appropriate.

Element I: Monitoring Component

A monitoring component to evaluate the effectiveness of the implementation efforts over time, measures against criteria established in Element H

- ***a) Monitoring plan includes an appropriate number of monitoring stations***
- ***b) Monitoring plan has an adequate sampling frequency***
- ***c) Monitoring plan will effectively measure evaluation criteria identified in Element H***

This section has been divided into Countywide and Statewide monitoring efforts. The Countywide efforts include: 1) project specific monitoring; 2) the monitoring program developed by Frederick County to measure and track water quality; and 3) the Implementation Database developed by the County to track restoration projects. Statewide monitoring efforts discuss monitoring in Frederick County on a broader scale. This data can be used to supplement the data already collected and tracked by the County.

Countywide Monitoring Efforts

All projects are monitored to ensure that their specific goals are met. Monitoring of project success is performed for each project based on its goals and can include photographs, species survival tracking, nutrient and sediment monitoring, or biological monitoring to name a few. Post-construction monitoring for all larger Capital Improvement Program (CIP) projects will be performed for five years to measure implementation success. BMP reduction numbers and other modeling and monitoring methods will be used to verify success of smaller community restoration projects. Additional Countywide and Statewide efforts will also be used to measure project success and water quality improvement.

Project Specific Monitoring

Table BB lists the urban PMMs from Element C and discusses what monitoring parameters are used to measure project success; how the project is monitored; and the frequency of monitoring.

Table BB: Project Specific Monitoring Parameters, Methods, and Timeframe

PMM	BMP Type	Monitoring Parameter	Monitoring Methods	Monitoring Frequency
Urban Streamside Forest Buffers	Buffers Forested, Urban	Monitor for plant survival, invasive species; expect 75-80% survival rate (if mortality is measured, perform infill plantings)	Use photographic evidence; tree counts; species protected, introduced, and eradicated tracked in Implementation Database; use literature values to calculate nutrient reductions	Annual
Urban Grass Buffers	Buffers Forested, Urban	Monitor for plant survival (% of area surviving), invasive species; expect 75-80% survival rate (if mortality is measured, perform infill plantings)	Use photographic evidence; species coverage; species protected, introduced, and eradicated tracked in Implementation Database; use literature values to calculate nutrient reductions	Annual
Urban Upland Grass Meadow	Tree Planting*	Monitor for plant survival (% of area surviving), invasive species; expect 75-80% survival rate (if mortality is measured, perform infill plantings)	Use photographic evidence; species coverage; species protected, introduced, and eradicated tracked in Implementation Database; use literature values to calculate nutrient reductions	Annual
Urban Upland Tree Planting	Tree Planting*	Monitor for plant survival, invasive species; expect 75-80% survival rate (if mortality is measured, perform infill plantings)	Use photographic evidence; tree counts; species protected, introduced, and eradicated tracked in Implementation Database; use literature values to calculate nutrient reductions	Annual
Urban Nonstructural runoff treatment including Bioretention, Rain Barrels, wetlands	Stormwater Management	Two project types: community restoration (**CR**) & capital improvement program (**CIP**) **CR:** monitor for species survival; expect 75-80% survival rate (if mortality is measured, perform infill planting); inspection that facility is meeting the retention goal **CIP:** monitor for species survival; expect 75-80% survival rate (if mortality is measured, perform infill planting); inspection that facility is meeting the retention goal; and monitor nutrient red'n using ISCO automatic sampler (QAPP available)	Use photographic evidence; visual inspections; species protected, introduced, and eradicated tracked in Implementation Database; use literature values to calculate nutrient reductions	**CR:** Annual **CIP:** Annual for first 5 years, then once every 3 years

PMM	BMP Type	Monitoring Parameter	Monitoring Methods	Monitoring Frequency
Rain Gardens	Stormwater Management	Two project types: community restoration (CR) & capital improvement program (CIP) **CR:** monitor for species survival; expect 75-80% survival rate (if mortality is measured, perform infill planting); inspection that facility is meeting the retention goal **CIP:** monitor for species survival; expect 75-80% survival rate (if mortality is measured, perform infill planting); inspection that facility is meeting the retention goal; and monitor nutrient red'n using ISCO automatic sampler (QAPP available)	Use photographic evidence; visual inspections; species protected, introduced, and eradicated tracked in Implementation Database; use literature values to calculate nutrient reductions	Annual
Stream Restoration/ Bank Stabilization	Stream Restoration, Urban	Monitor for stream stability; species survival; species presence/absence	Perform geomorphic assessments (longitudinal profiles and cross sections); perform biological survey of watershed using techniques from FCSS	Annual
Retrofit pond to provide Water Quality Treatment Comm/Ind (i.e. wetlands)	Stormwater Management	Inspection that facility is meeting the retention goal; and monitor nutrient red'n using ISCO automatic sampler (QAPP available)	Visual inspection, photographic evidence; perform biological survey of watershed using techniques from FCSS	Annual for first 5 years, then once every 3 years
Urban Wetland Creation	Buffers Forested, Urban	Monitor for plant survival, invasive species; expect 75-80% survival rate (if mortality is measured, perform infill plantings); monitor for species presence/absence	Use photographic evidence; visual inspections; species protected, introduced, and eradicated tracked in Implementation Database; use literature values to calculate nutrient reductions; use protocols from Urban Wetland Program to assess veg, birds, and amphibians; perform biological monitoring of streams in vicinity using FCSS	Annual
Street Sweeping Vacuum Bimonthly	Stormwater Management	-- *Others are conducting research, Supplement will be updated as more information becomes available	Use literature values to calculate nutrient reductions	Annual
Porous Pavers	Stormwater Management	Use ISCO auto sampler to measure nutrient reductions; monitor for species presence/absence in surrounding watershed	Use literature values to calculate nutrient reductions and compare to actual values; perform biological monitoring of streams in vicinity using FCSS	Annual
Septic Denitrification	Enhanced Septic Denitrification	Biological and chemical monitoring	Perform biological and chemical monitoring of streams in vicinity using FCSS	Annual
Urban Runoff Treatment New Development	Stormwater Management	Inspection that facility is meeting the retention goal; and monitor nutrient red'n using ISCO automatic sampler (QAPP available)	Visual inspection, photographic evidence	Annual
Septic Replacement with Sewer (MDR)	Enhanced Septic Denitrification	Biological and chemical monitoring	Perform biological and chemical monitoring of streams in vicinity using FCSS	Annual

Frederick County Stream Survey (FCSS)

*The following text is excerpted from Frederick County's 2007 Annual Report compiled by Versar, Inc. and Frederick County Division of Public Works (available in its entirety at: http://www.watershed-alliance.com/mcwa_pubs.html#AnnualReport2007)

SURVEY DESIGN

The Frederick County Stream Survey (FCSS) is a probability-based survey (with random site selection) using rapid benthic macroinvertebrate and physical habitat assessment methods to provide information on the County's streams at a finer scale than is currently available through the Maryland Biological Stream Survey (MBSS).

The FCSS has been modeled after the statewide MBSS to leverage MBSS reference conditions, IBIs, stressor identification methods, and other tools. MBSS methods are being used to collect rapid benthic macroinvertebrate, physical habitat, and water quality data. Because of resource constraints, fish community surveys will not be conducted in the countywide survey; however, the County will continue to use fish community assessments as an important tool during other stream sampling efforts.

WATER QUALITY PARAMETERS

Field surveys will be conducted using the MBSS Round Three field methods described by Stranko et al. (2007) and modified as follows. The FCSS will make a single visit to each site during the Spring Index Period (March through April) to collect a benthic macroinvertebrate sample, measure in-situ water quality, measure stream discharge, collect an aqueous grab sample, and record all spring and summer MBSS habitat, index period and vernal pool data. Temperature logs, stream gradient, number of anodes and stream width, and summer fauna data will not be recorded as part of the FCSS. Water samples will be analyzed in the laboratory using MBSS laboratory methods for the parameters listed in Table CC.

Table CC: Analytical parameters, using MBSS protocols, for FCSS water samples
Nitrite Nitrogen
Nitrite Nitrogen + Nitrate Nitrogen
Ammonia
Total Nitrogen
Orthophosphate
Total Phosphate
Dissolved Organic Carbon
Turbidity

Benthic macroinvertebrate samples collected during the FCSS will be processed according to protocols in the MBSS benthic laboratory manual (Boward and Friedman 2000). Namely, identification of a 100-organism subsample to the genus taxonomic level, with the exception of oligochaete worms, which will be identified to family level. Benthic identification data will be entered by laboratory staff into an Access database containing tolerance values and other ancillary data to streamline data management and enhance quality control.

FREQUENCY AND SAMPLE SITE LOCATIONS

Analysis of MBSS data indicates that a minimum of 10 sites must be sampled in each watershed to obtain estimates of stream condition with adequate precision. Therefore, the County's survey includes random selection and sampling of 200 sites stratified across the County's 20 watershed management units. The survey will sample 50 sites per year for four years to complete the countywide assessment, which will have the benefit of minimizing the influence of wet and dry years on the survey results. This four-year assessment cycle will provide a snapshot of stream condition in Frederick County that will be repeated on a regular schedule into the future. One or more years between cycles may be reserved for special studies. The phased implementation (Element F/G) has been scheduled to allow for adequate monitoring to be performed so that analysis of monitoring data from the Lower Monocacy River watershed and its watersheds can be performed at the end of each implementation phase.

Reporting of survey data will occur at the conclusion of each sampling year following data analysis. Because the survey design spreads the 10 sample points targeted for each watershed over a four-year period to minimize variation in weather, area-wide estimates at the watershed level will not be available until after the fourth year. However, an area-wide estimate will be possible for the County after the first year, as well as other areas that have a minimum of 10 sampling sites (e.g. basin level estimates for the Lower Monocacy River watershed). Estimates for smaller areas and more precise estimates for larger areas can be made as additional sampling data become available following the second or third sampling years. A pilot survey was conducted for Bennett Creek watershed in 2007. Field crews sampled 15 sites providing enough sample sites from which to draw baseline water quality conditions for the Bennett Creek watershed, a priority watershed for the Lower Monocacy River WRAS. Appendix H provides a draft outline for the report from this pilot study.

The survey uses a sample frame that consists of the Frederick County portion of the MBSS 1:100,000-scale stream network. The MBSS does not sample streams larger than fourth-order because they are generally not wadeable. Therefore, stream segments considered by MBSS to be too large to sample are also excluded from the Countywide survey.

Once the sample frame was developed, survey locations were randomly assigned along the stream network using a FORTRAN-based program. Site selection within a watershed included the simple random selection of 10 target sites plus the selection of 140 "extra sites" to a total of 150 sites using GIS. Extra sites were selected to ensure that a sufficient number of sites remained available for sampling after permission denials and unsampleable sites were removed from consideration. The random sample points chosen on the GIS were designated as the midpoint of the 75-meter sampling segment in the field. Sites selected less than 75 meters from another randomly selected site (both upstream and downstream) were eliminated to avoid overlap. The order in which sites were randomly picked was included in the attribute data to maintain the random nature of the site selection process.

The FCSS obtains landowner permission to access and sample all stream sites. Building upon procedures developed for the MBSS and previous Frederick County monitoring programs, the randomly selected site picks are used in conjunction with landowner information obtained from the current Maryland Property View GIS data product to develop a mailing list. Permission letters, along with a postage-paid reply postcard and an informational page of Frequently Asked Questions, are then sent to each property owner needed to access individual sites. Landowner responses, both granting and denying access, are compiled and recorded in the Landowner database. Often, permission must be obtained from multiple landowners to access a single site and follow-up phone calls are made as necessary to obtain remaining permission needed for the target number of sites. Once sufficient permission have been obtained within a watershed to sample the target number of sites, two to three sites per year of the survey, field crews will visit the sites in the order they were randomly selected. If sites are found to be unsampleable, then crews proceed to the next site on the list for which permission has been granted.

Tracking Implementation using the Implementation Database

The Watershed Management Section has developed an Implementation Database to estimate current pollutant loads, track project implementation, and calculate associated pollutant load reductions. The load reductions resulting from restoration activities are calculated using EPA Chesapeake Bay Program – Best Management Practice Pollutant Reduction Efficiencies. Where necessary, the County will use other values on more refined local data or appropriately justified reduction calculation methods for control practices that are not tracked by the Chesapeake Bay Program.

The Chesapeake Bay Program will track non-county funded projects via reporting by the State agencies (some private land owner pollution controls that are not subsidized by government funding are not tracked). The Chesapeake Bay Program presently tracks implementation information at a coarser geographic resolution than the County. Efforts are under way to improve the resolution of the Bay Program tracking information.

The Implementation Database has a Watershed Form, Land Use Form, BMP Form, Pollutant Load Form, MCWA Project Tracker Form, and a Query Screen. Information specific to each watershed is entered into the Watershed Form. The information can be entered on the watershed, subwatershed, and/or catchment scale. Once the watershed information has been added, information about the land use acreage for each watershed, subwatershed, and/or catchment is entered into the Land Use Form. Standard information about the costs and pollutant removal efficiencies is entered for each potential BMP in the BMP Form. A standard list has been provided but can be updated as new techniques become available. The Pollutant Load Form contains static information about the pollutant loads from each land use type. The MCWA Project Tracker Form allows the user to enter project specific information and the level of BMP implementation. It calculates the estimated pollutant reductions based on land use and level of implementation. The County is working to develop the capacity to include detailed maps of project locations in the MCWA Project Tracker form. The Query Screen allows the user to pull a variety of relevant information from all of the forms discussed above.

The database is updated as new information on BMPs and project implementation becomes available. Each year, the County summarizes the work completed. It is at this time that the members of the Monocacy & Catoctin Watershed Alliance review their implementation progress and discuss options to change priorities, increase efforts, and/or evaluate methods.

Figures 1 and 2 are screen shots from the Implementation Database to provide an idea of what type of information is tracked for the potential BMPs for implementation as well as the project that are installed. Figure 1 is a screen shot of the BMP Form. The information tracked on this form includes the type of BMP, a description, the land use to which it can be applied, the cost/unit and unit type, the level and location of implementation, the associated pollutant reductions, and the pollutant removal efficiencies. Figure 2 is a screen shot of the MCWA Project Tracker. The information tracked on this form includes all details of a project from where it is installed, who is responsible for the installation, source of project funding, estimated pollutant reductions and impervious area treatment based on project size, partners, costs for installation, and what kind of monitoring is being performed.

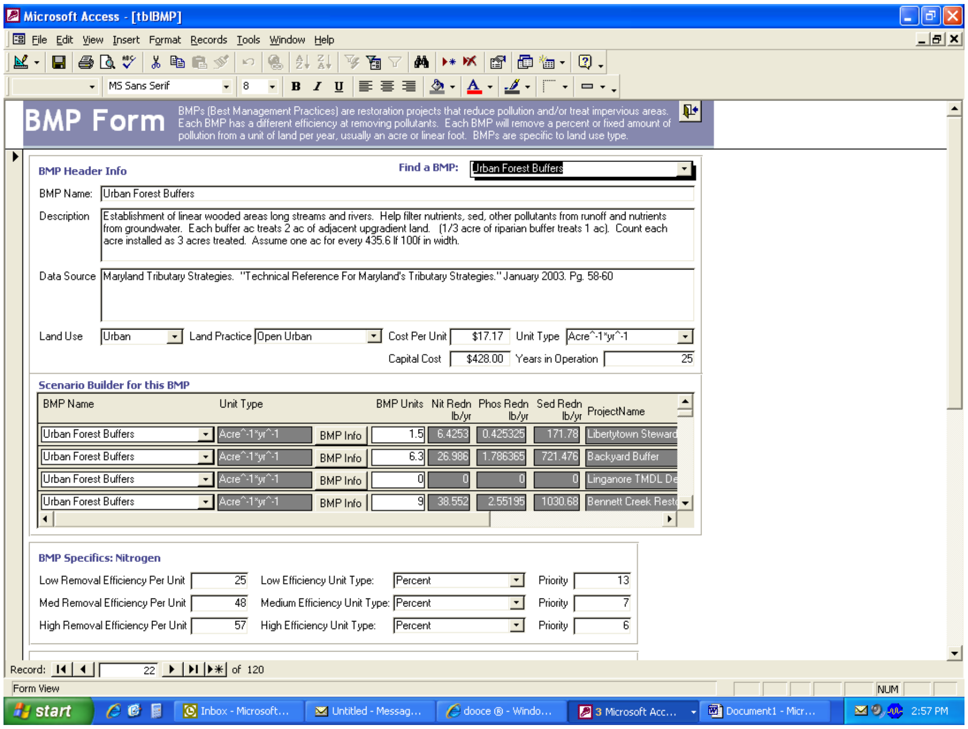


Figure 1: Screen shot of BMP form from the Implementation Database

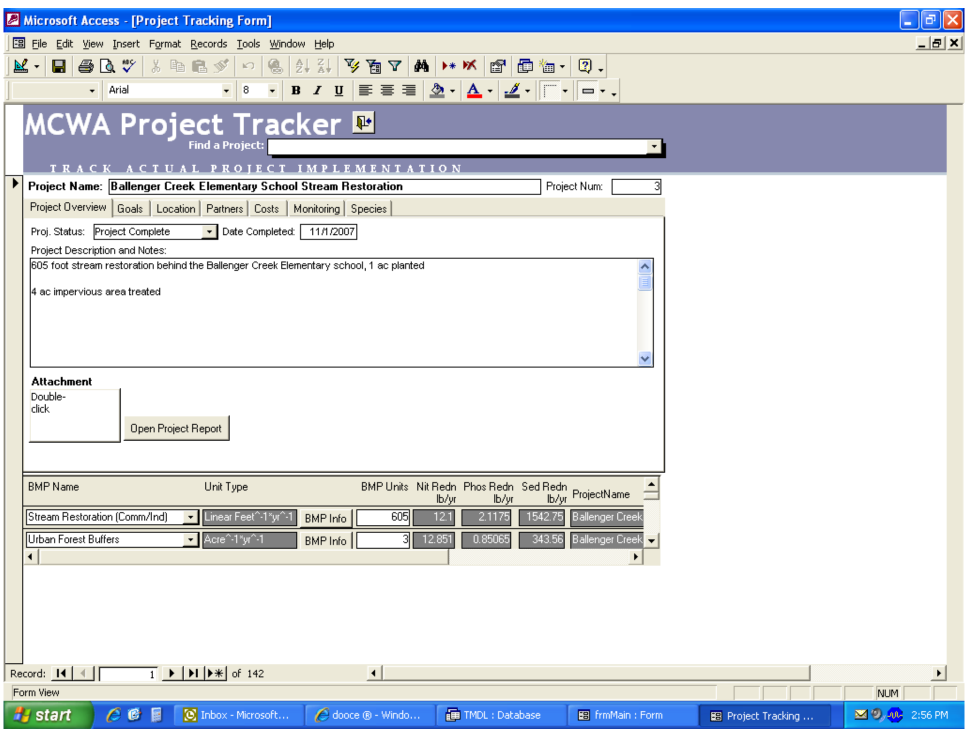


Figure 2: Screen shot of MCWA Project Tracker

Statewide Monitoring Efforts

According to *Maryland's TMDL Implementation Guidance for Local Governments* (May 2006), the State is responsible for assessing whether water quality standards are being attained:

> "The State is responsible for water quality monitoring to identify impaired waters and to evaluate water quality to determine if TMDLs are being achieved. Local governments or other groups may conduct additional monitoring to supplement the State monitoring. This may be done to document the effectiveness of innovative projects and programs, or to provide additional information about impaired waterbodies and pollutant sources."

This is done using an array of monitoring programs that are described in *Maryland's Water Quality Monitoring Strategy,* updated in 2004:

http://www.mde.state.md.us/assets/document/water/WQPlanning_MonitoringStrategy_Sep04.pdf

The State's monitoring strategy is in the process of being updated, with a completion date scheduled for Summer 2009. The State's routine monitoring includes the following elements:

- Maryland Biological Stream Survey
- Maryland Core and Trend Monitoring Stations
- Bacteria Monitoring
- Fish and Shellfish Tissue Monitoring for Toxic Substances
- Watershed Cycling Monitoring

Each of these elements is described in greater detail below but not all of them apply to Frederick County or the Lower Monocacy River watershed.

Maryland Biological Stream Survey

The Maryland Department of Natural Resources (DNR) implements probabilistic monitoring of fish and macroinvertebrate communities in wadeable streams and rivers in Maryland. Known as the Maryland Biological Stream Survey (MBSS), the monitoring provides indices of biological integrity and underlying data of which the indices are composed. The Maryland Department of Environment uses the indices for assessing whether aquatic life designated uses are being achieved in non-tidal streams under Maryland's water quality standards. The underlying MBSS data are also analyzed to help identify the stressors that are impacting the biological integrity, and can serve as interim measures of progress (See Section H). Finally, the MBSS data is used to identify high quality (Tier II) waters for protection under Maryland's anti-degradation policy, a part of the State water quality standards framework.

The MBSS monitoring design ensures that a sufficient number of random samples are included in each Maryland 8-digit basin to support 303(d) listing decisions. This data provides an estimate of stream miles impacted, which can serve as a measure of incremental progress (See Section H).

Additional information on the MBSS program is available on DNR's website at: http://www.dnr.state.md.us/streams/mbss/.

Maryland Core and Trend Monitoring Stations

The Maryland Department of Natural Resources maintains a network of 54 monitoring stations on fourth-order streams and larger non-tidal rivers to assess the status and trends in water quality at a broad scale. Water quality samples from these major streams and rivers have been collected monthly since 1986. Status and trends are determined annually for total chlorophyll, specific conductance, dissolved oxygen, a variety of nitrogen and phosphorus species, sulfate, total alkalinity, total organic carbon, total suspended solids, turbidity, and water temperature.

There are three State-maintained core trend monthly sampling stations on the Monocacy River Mainstem that are important for the Lower Monocacy River watershed (Map 6 of the Lower Monocacy River Watershed Characterization). Station MON0269 is just upstream of the Lower Monocacy River watershed and effectively monitors upstream inputs to the Lower Monocacy. Station MON0155 is just downstream of the confluence of Linganore Creek with the Mainstem. Station MON0020 is at the downstream end of the river and effectively monitors inputs from nearly the entire Lower Monocacy River watershed. Together, these monitoring stations provide an effective foundation for periodic and long-term assessment of the water quality status and change over time for the entire Lower Monocacy River watershed. The most recent executive summary of assessment findings from these stations is available at: http://www.dnr.state.md.us/bay/tribstrat/upper_pot/up_status_trends.html.

For each of these stations, more specific information on the water quality parameters collected and recent findings is available. A map of monitoring station locations is available at: http://www.dnr.state.md.us/streams/status_trend/land_use2.html. The findings specific to stations MON0269, MON0155, and MON0020 can be found by scrolling through the table to find the station of interest and clicking on the station ID number. The findings can also be found in Appendix D.

Additionally, information on the status and trends for all of Maryland's core trend stations, including the Lower Monocacy River stations, for the period 1986-2004 is available at: http://www.dnr.state.md.us/streams/status_trend/index.html

Bacteria Monitoring

Certain types of bacteria are indicators of potential pathogens. Maryland conducts monitoring for bacteria in three general areas:

- Non-tidal General Contact Recreation Waters: Bacteria monitoring is conducted as part of Maryland's five-year cycling strategy described below. The monitoring design ensures that a sufficient number samples are collected in representative areas to determine whether standards are being achieved within a Maryland 8-digit basin (i.e. the Lower Monocacy River watershed).
- Public Beaches: not relevant to the Lower Monocacy River watershed
- Shellfish Harvesting Waters: not relevant to the Lower Monocacy River watershed

Fish and Shellfish Tissue Monitoring for Toxic Substances

Maryland monitors about ten (10) selected commercial and recreational harvesting areas in non-tidal and tidal tributaries and lakes each year on a rotating basis. This program ensures that aquatic resources harvested from State waters are safe for human consumption, and provides information on potential sources and trends in water pollution levels. Bioaccumulation in fish tissue is a natural means of concentrating toxic substances that might be present in very low concentrations. These substances can be difficult and costly to measure directly. Thus, the fish tissue monitoring serves as a cost-effective screening system for identifying additional monitoring needs. Additional information on this program is available at http://www.mde.state.md.us/CitizensInfoCenter/Health/fish_advisories/index.asp

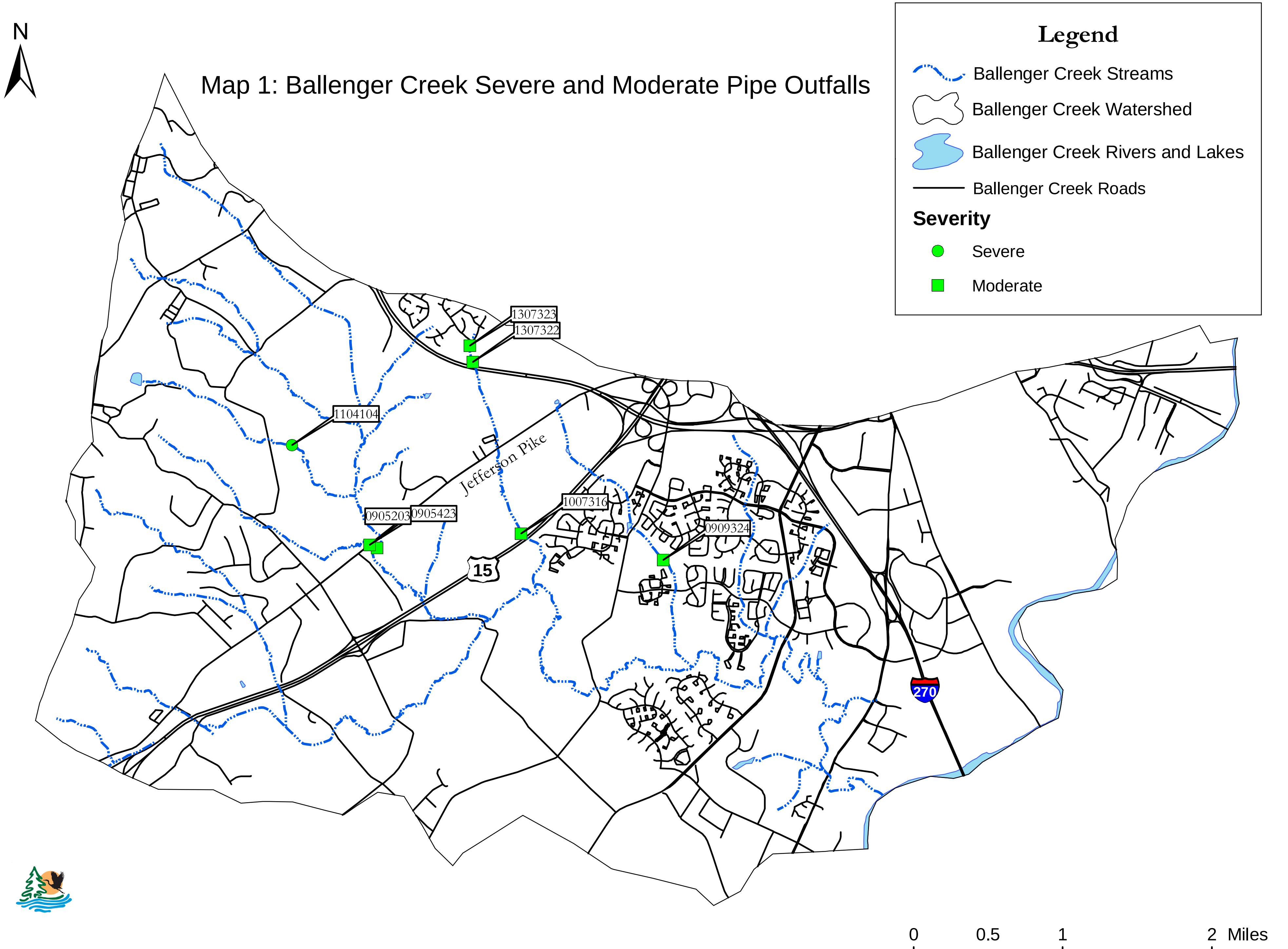
Watershed Cycling Monitoring

Monitoring is conducted for on a 5-year rotational basis to evaluate progress on water resource restoration and to help target TMDL implementation.

- 12-digit watershed outlet monitoring: Flow and concentrations of key pollutants will be monitored on a monthly basis to provide an intensive set of data once every five years.
- Tidal rivers and impoundments will be assessed for chlorophyll and other key constituents needed to evaluate progress on TMDL implementation.
- Subbasin synoptic surveys, consisting of a large number of stations up in the headwaters of each Maryland 8-digit watershed will be conducted.
- Biological impairment investigations

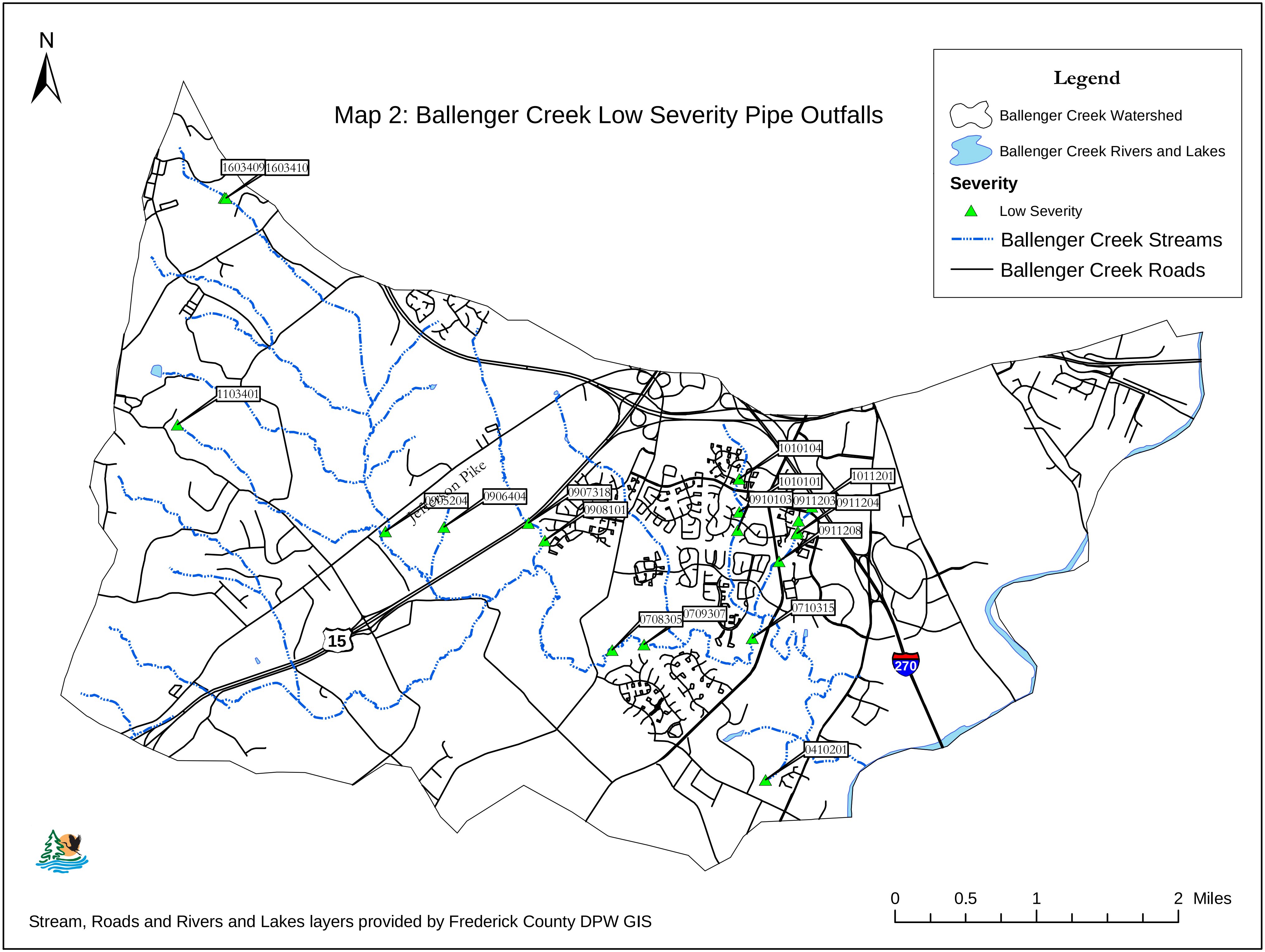
Appendix A: Stream Corridor Assessment Maps

Map 1: Ballenger Creek Severe and Moderate Pipe Outfalls



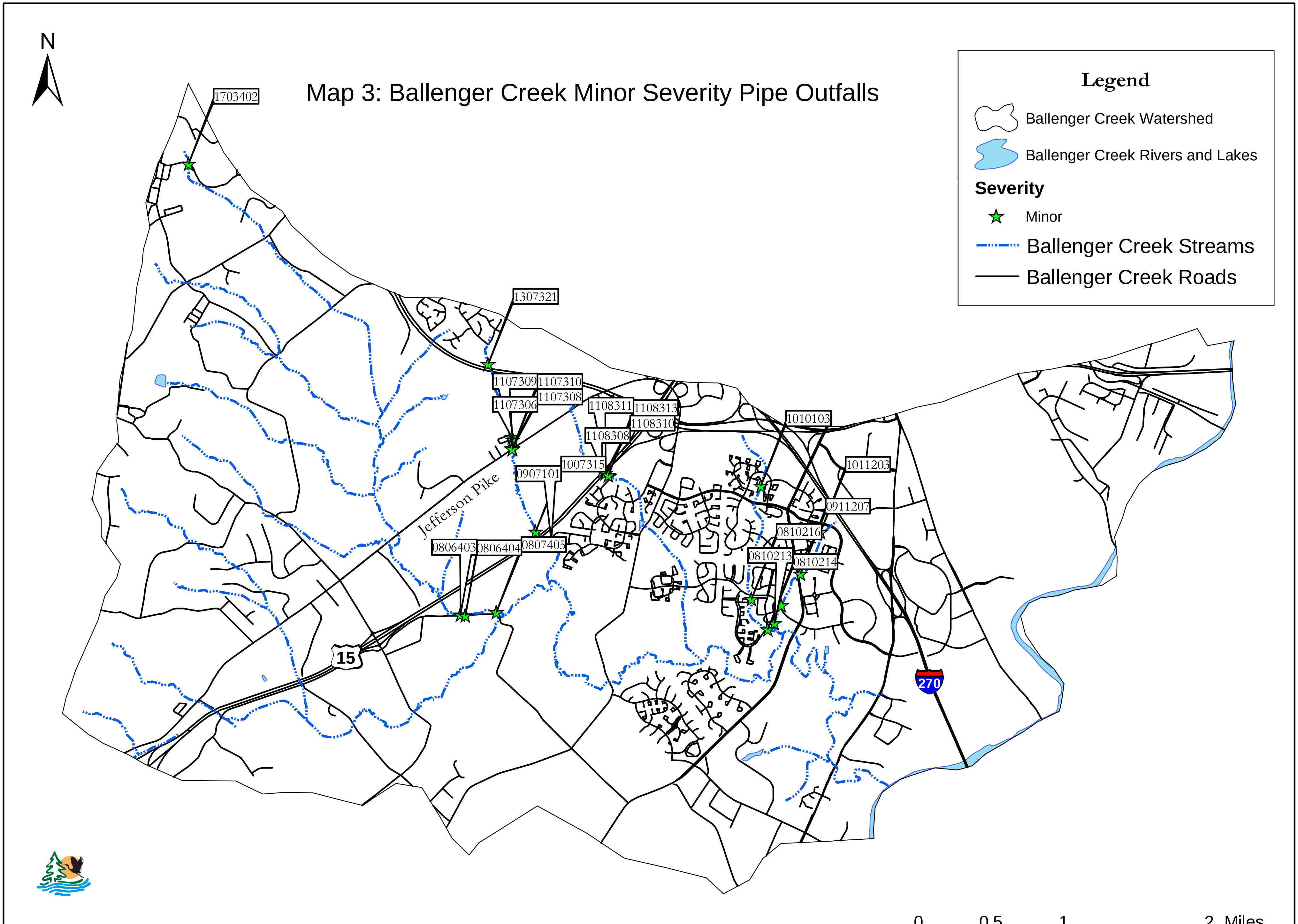
Stream, Roads and Rivers and Lakes layers provided by Frederick County DPW GIS

Map 2: Ballenger Creek Low Severity Pipe Outfalls



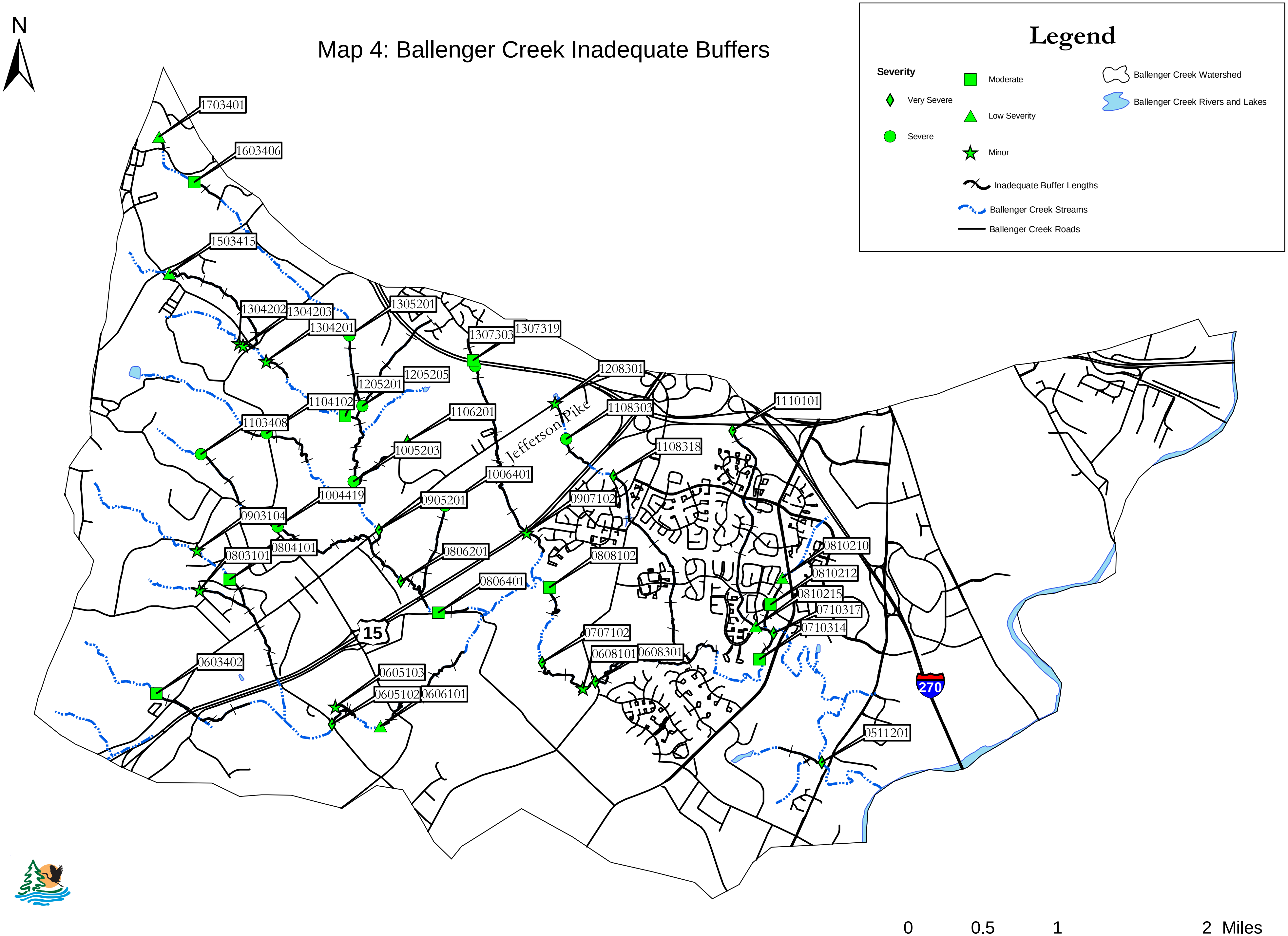
Stream, Roads and Rivers and Lakes layers provided by Frederick County DPW GIS

Map 3: Ballenger Creek Minor Severity Pipe Outfalls



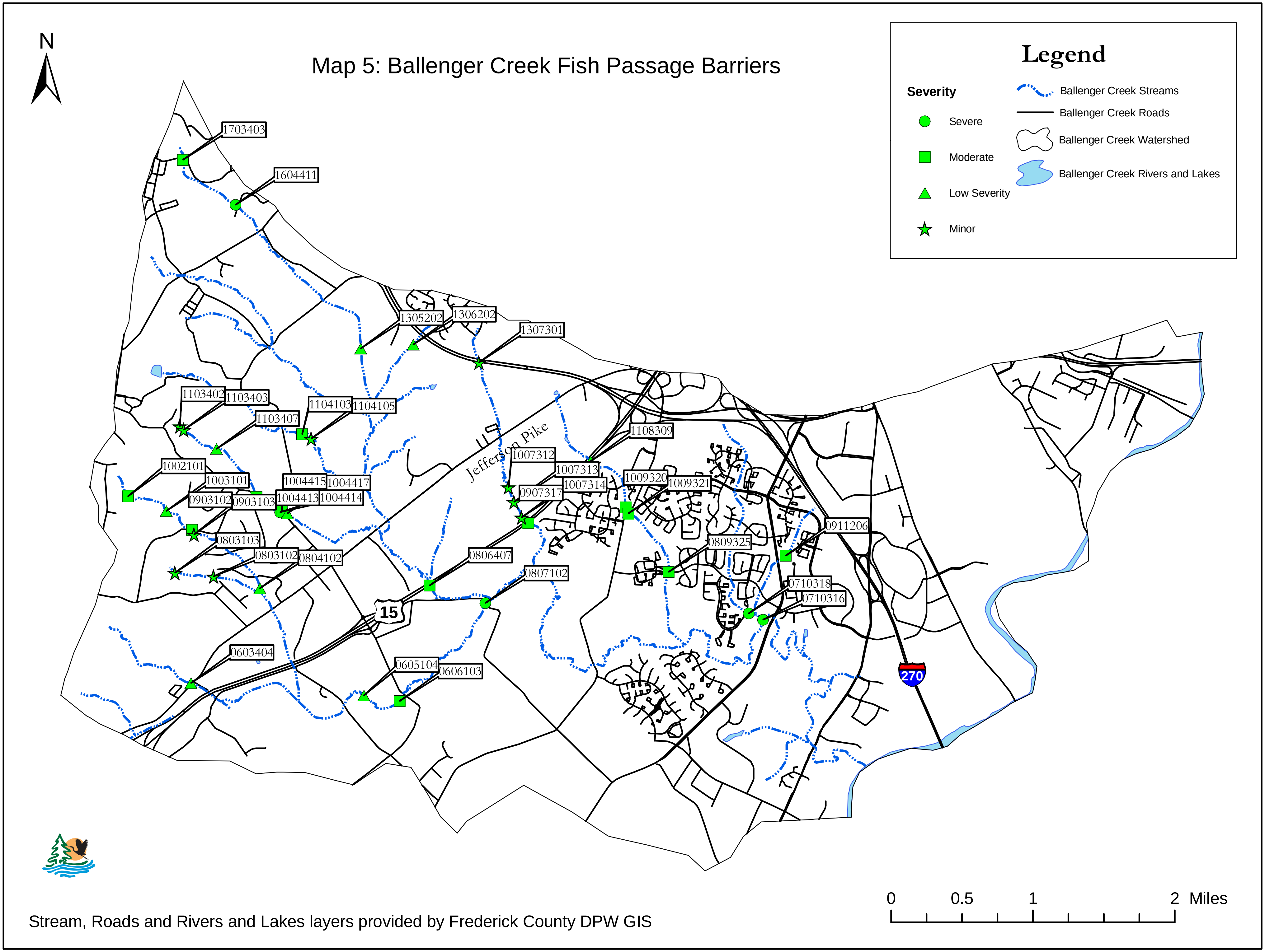
Stream, Roads and Rivers and Lakes layers provided by Frederick County DPW GIS

Map 4: Ballenger Creek Inadequate Buffers

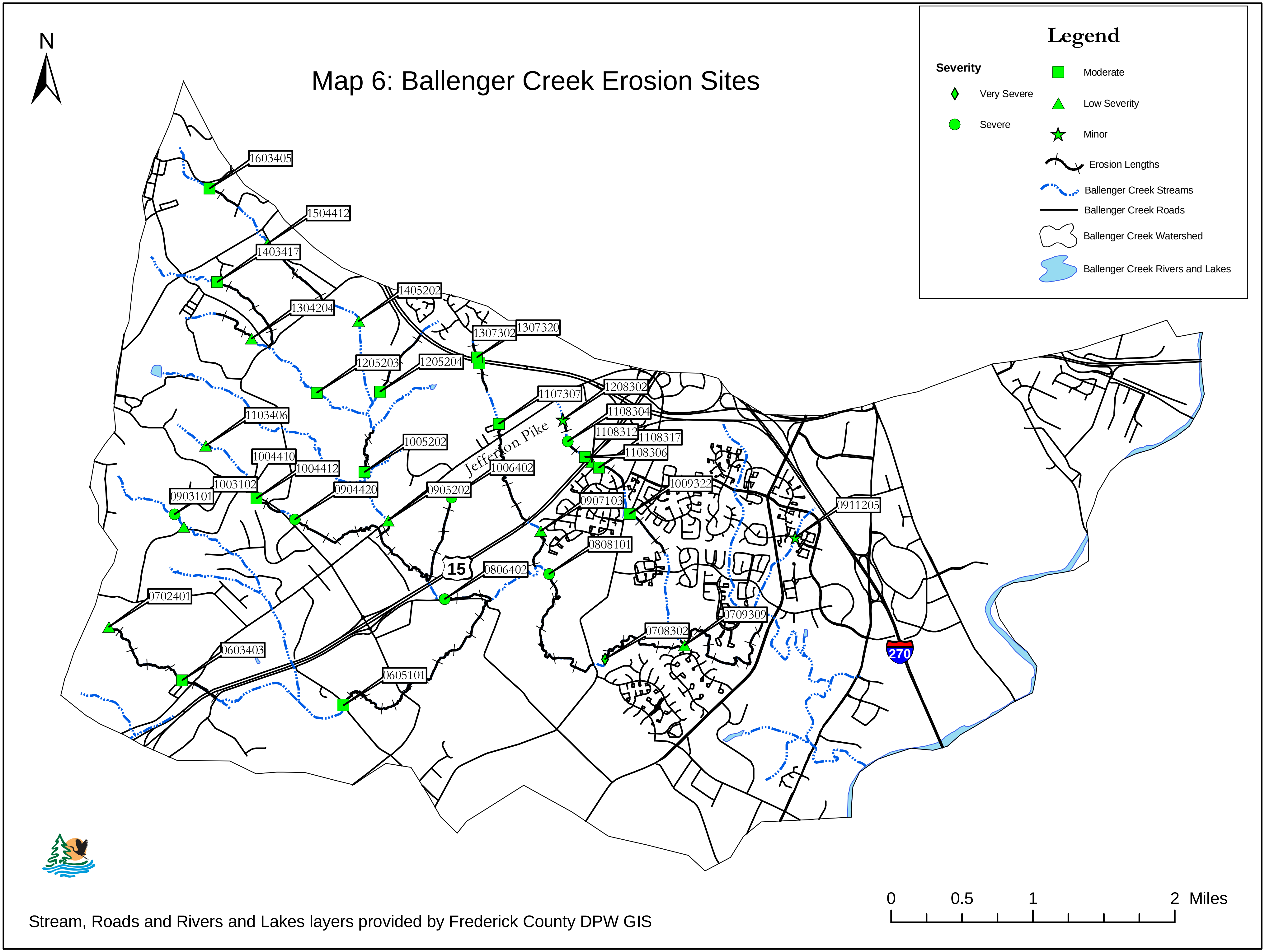


Stream, Roads and Rivers and Lakes layers provided by Frederick County DPW GIS

Map 5: Ballenger Creek Fish Passage Barriers

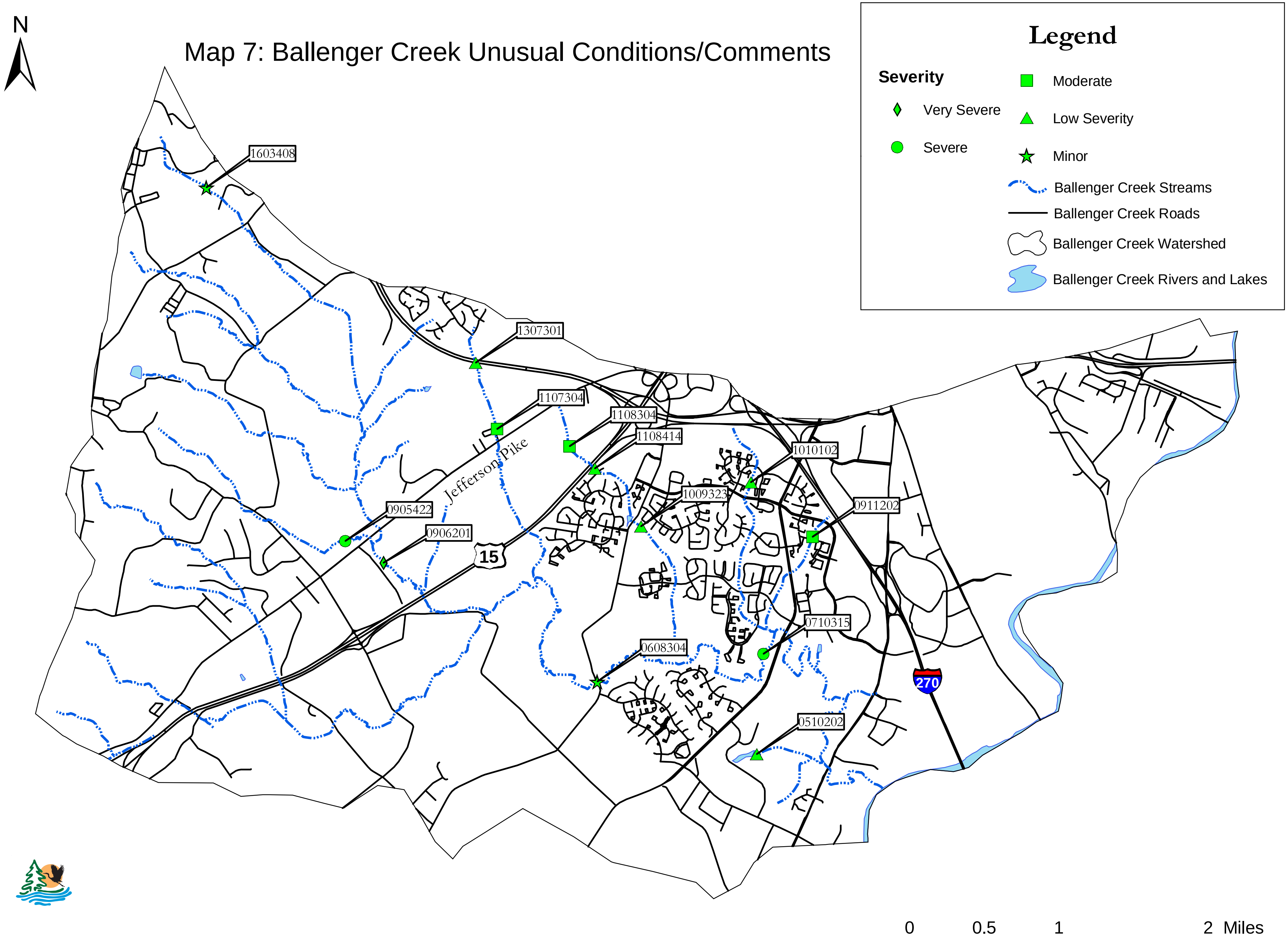


Stream, Roads and Rivers and Lakes layers provided by Frederick County DPW GIS

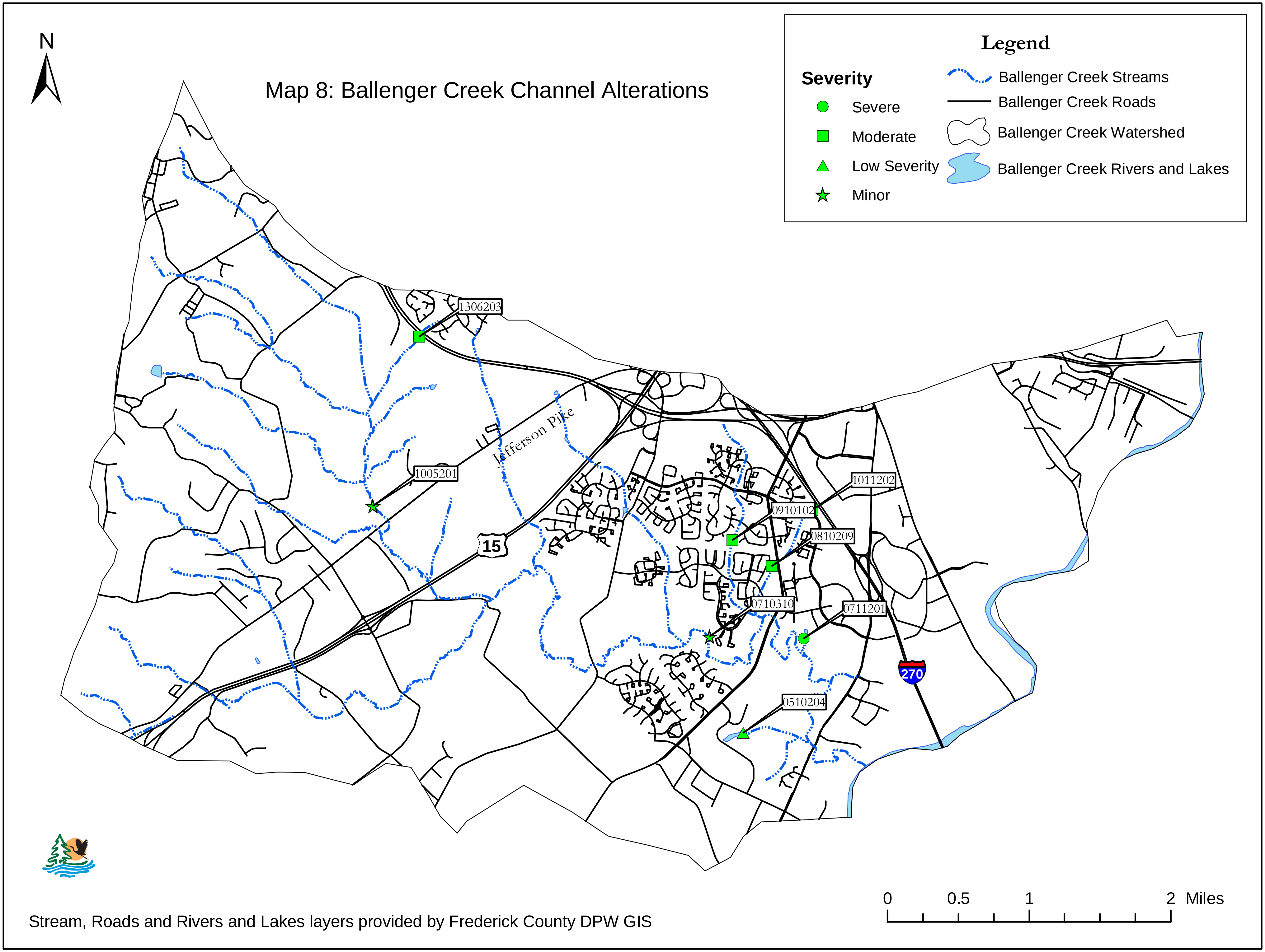


Map 6: Ballenger Creek Erosion Sites
N
Legend
Severity
Very Severe
Severe
Moderate
Low Severity
Minor
Erosion Lengths
Ballenger Creek Streams
Ballenger Creek Roads
Ballenger Creek Watershed
Ballenger Creek Rivers and Lakes
1603405
1504412
1403417
1405202
1304204
1307302
1307320
1205203
1205204
1208302
1107307
1108304
1103406
1108312
1108317
1108306
1005202
1004410
1004412
1006402
1003102
0904420
0905202
1009322
0903101
0907103
0911205
0808101
15
0806402
0702401
0709309
0708302
0603403
270
0605101
Jefferson Pike
0
0.5
1
2
Miles
Stream, Roads and Rivers and Lakes layers provided by Frederick County DPW GIS

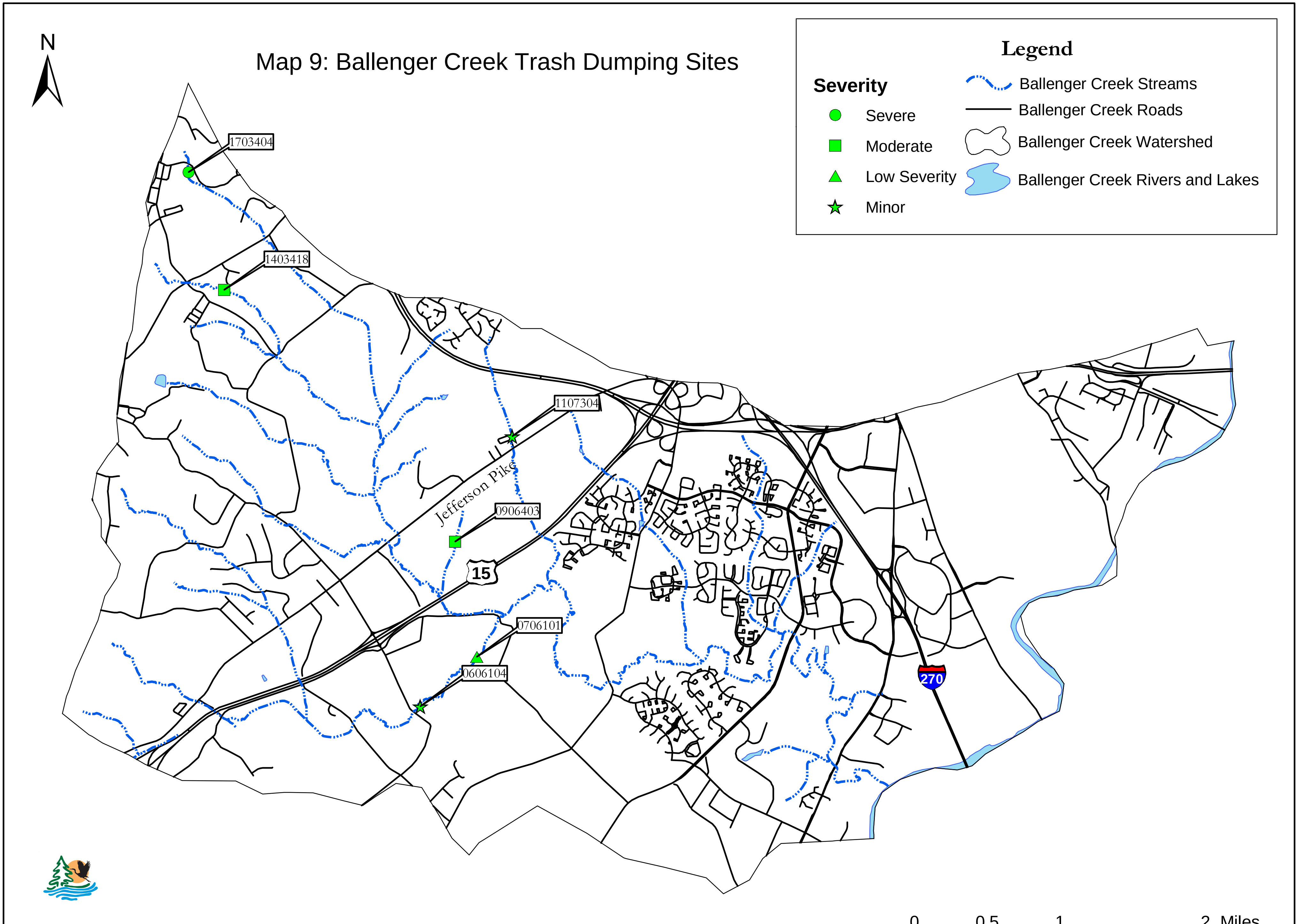
Map 7: Ballenger Creek Unusual Conditions/Comments



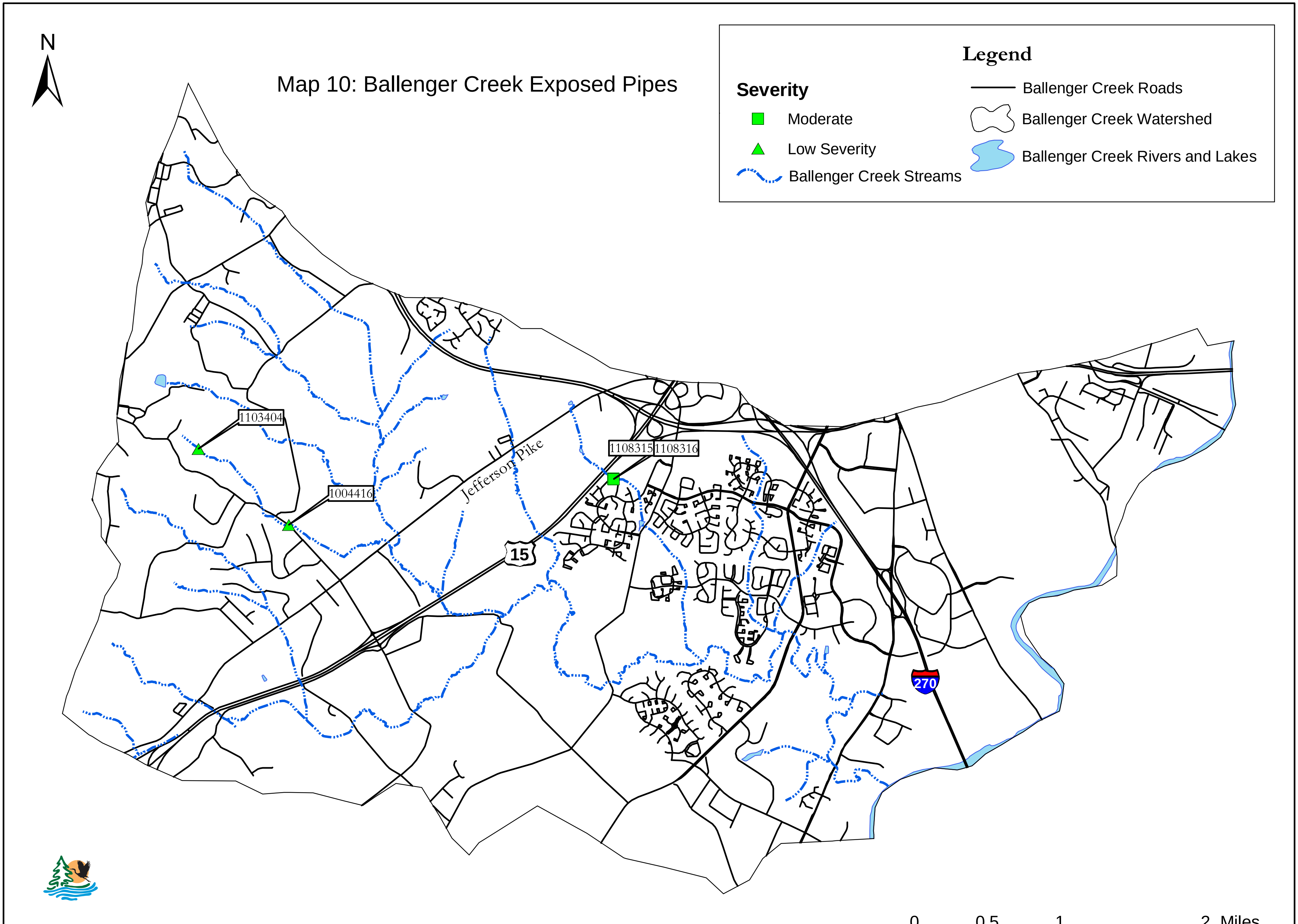
Stream, Roads and Rivers and Lakes layers provided by Frederick County DPW GIS



Map 8: Ballenger Creek Channel Alterations
N
Legend
Severity
Severe
Moderate
Low Severity
Minor
Ballenger Creek Streams
Ballenger Creek Roads
Ballenger Creek Watershed
Ballenger Creek Rivers and Lakes
1306203
1005201
Jefferson Pike
15
1011202
0910102
0810209
0710310
0711201
270
0510204
0
0.5
1
2
Miles
Stream, Roads and Rivers and Lakes layers provided by Frederick County DPW GIS

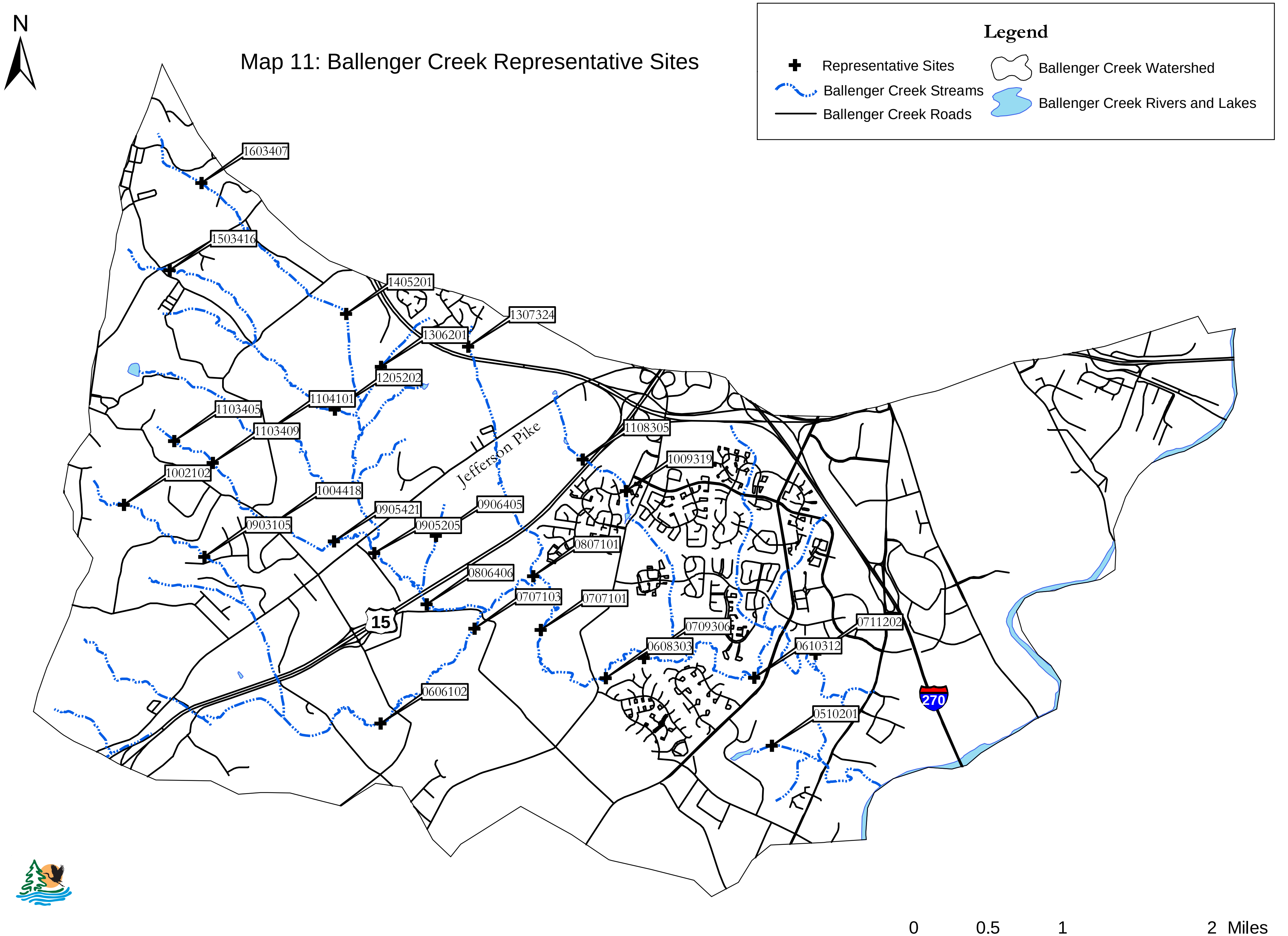


Stream, Roads and Rivers and Lakes layers provided by Frederick County DPW GIS

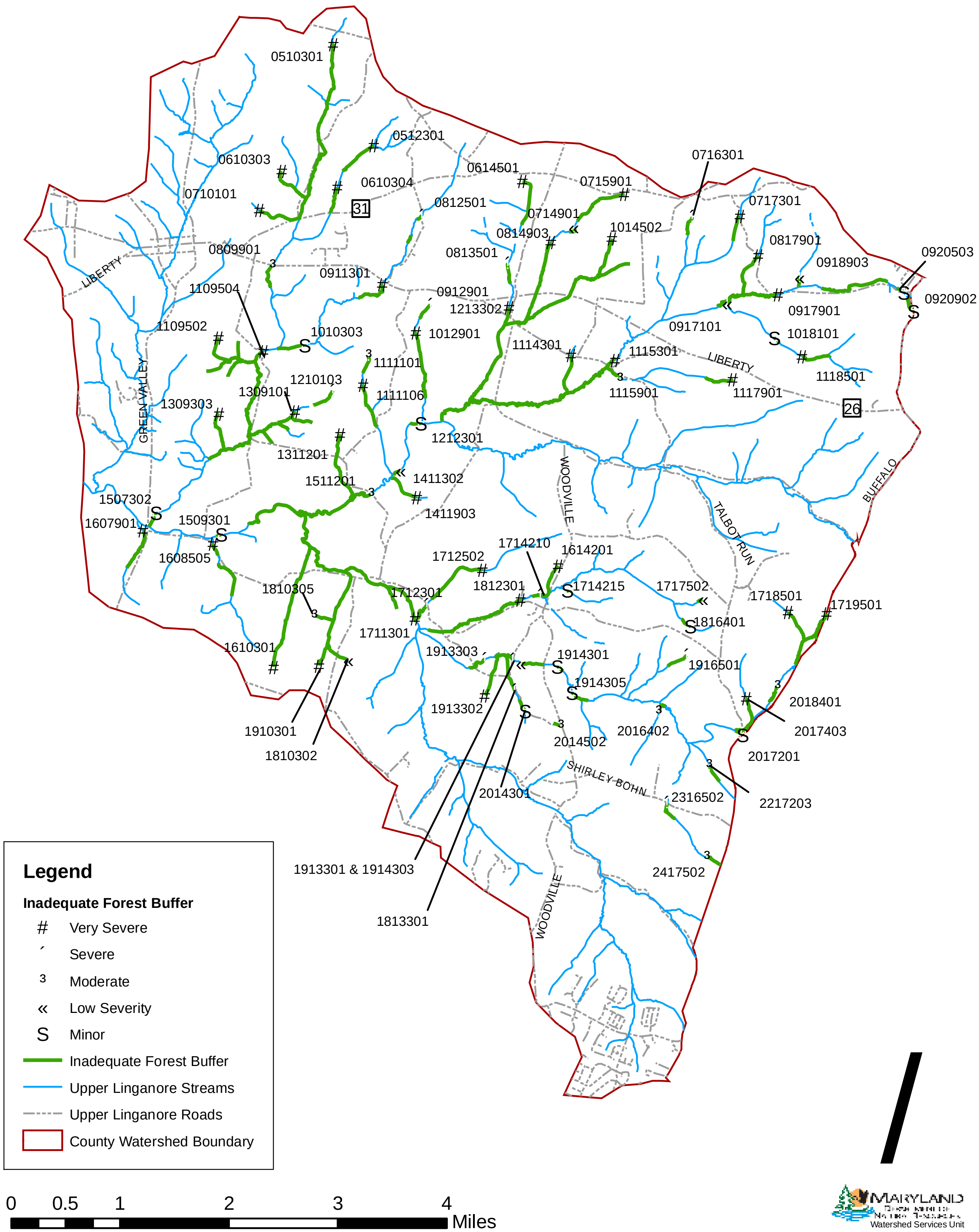


Stream, Roads and Rivers and Lakes layers provided by Frederick County DPW GIS

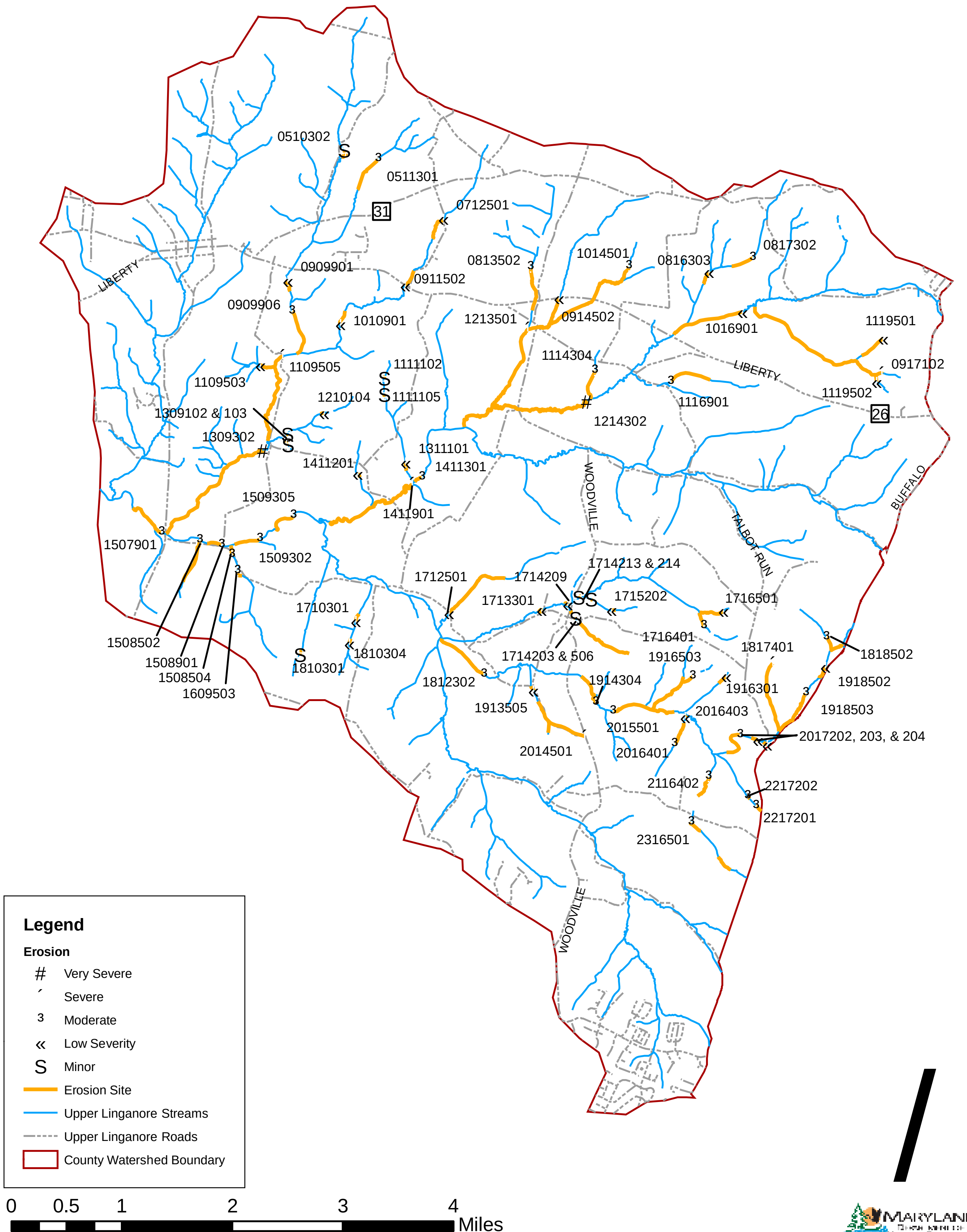
Map 11: Ballenger Creek Representative Sites



Stream, Roads and Rivers and Lakes layers provided by Frederick County DPW GIS



Map 12: Inadequate forest buffers in the Frederick County portion of the Upper Linganore Watershed.



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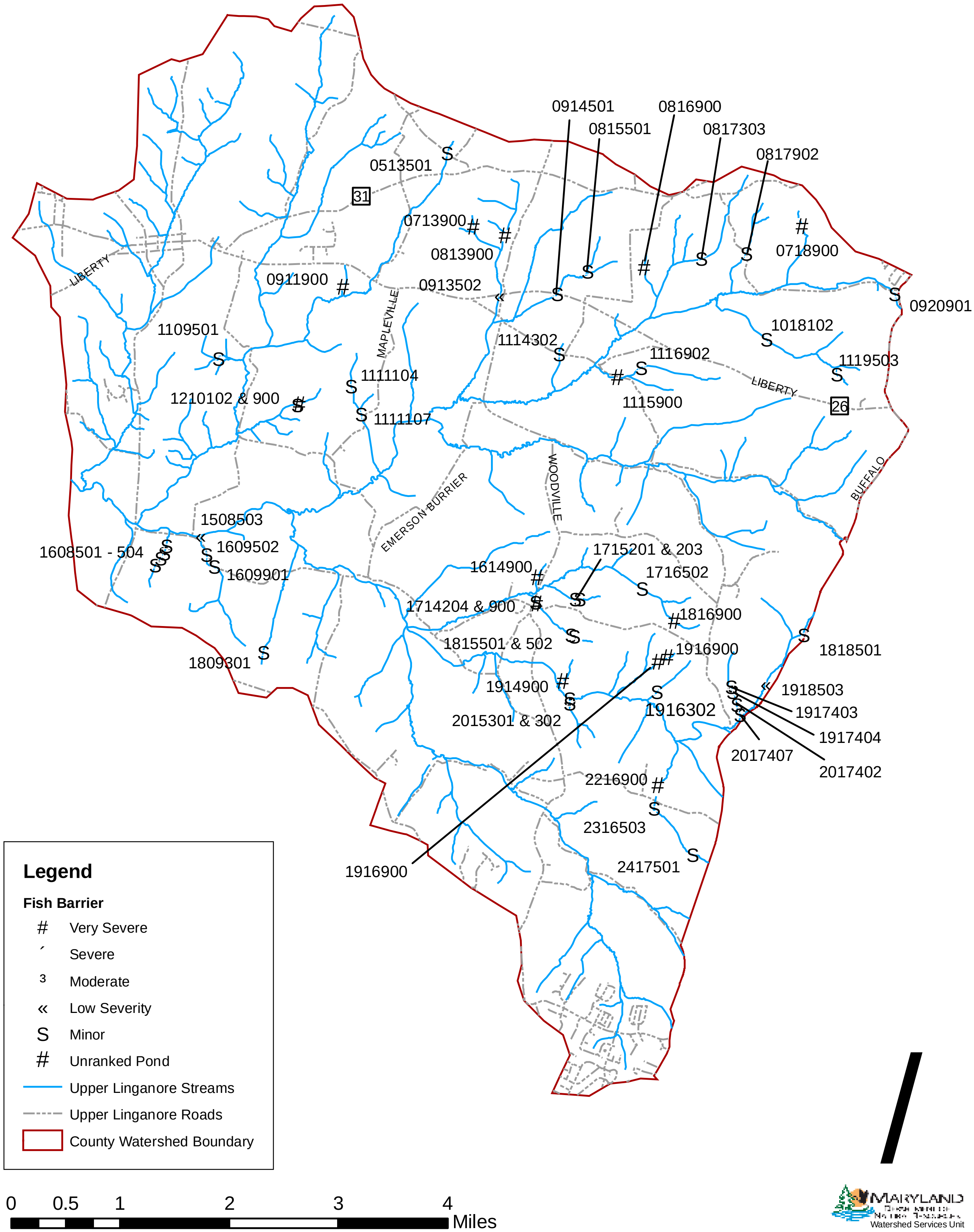
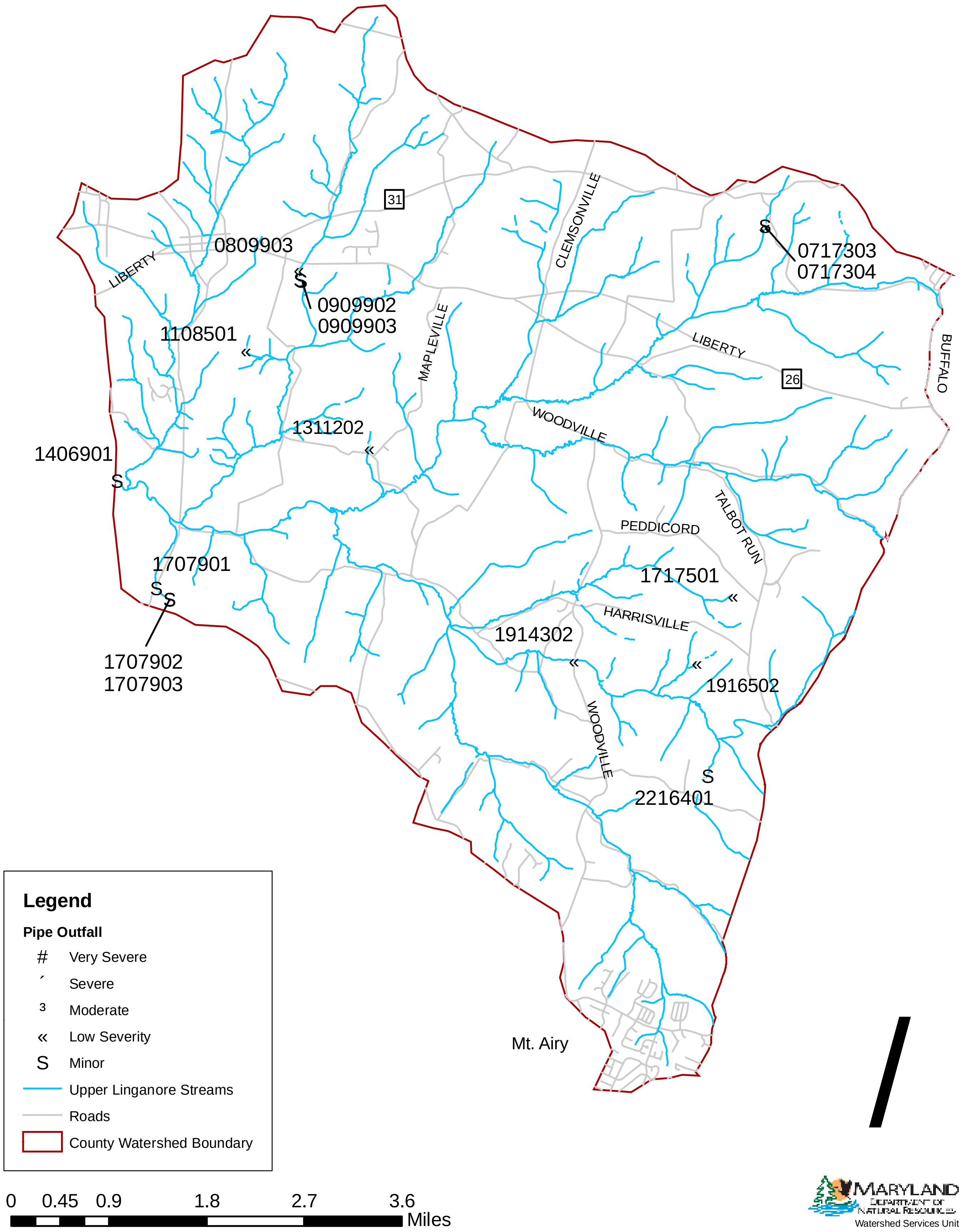
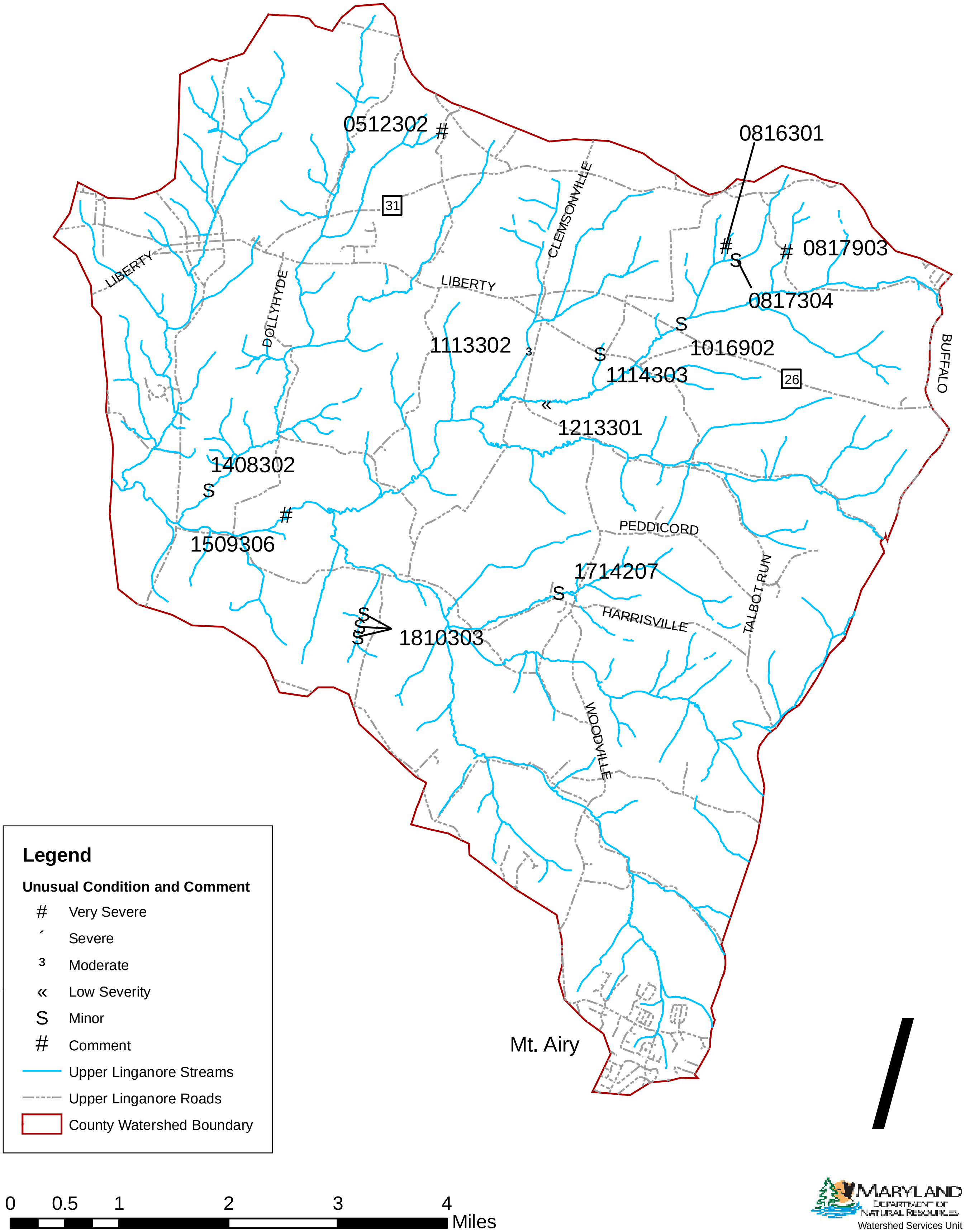
Map 13: Erosion sites in the Frederick County portion of the Upper Linganore Watershed.



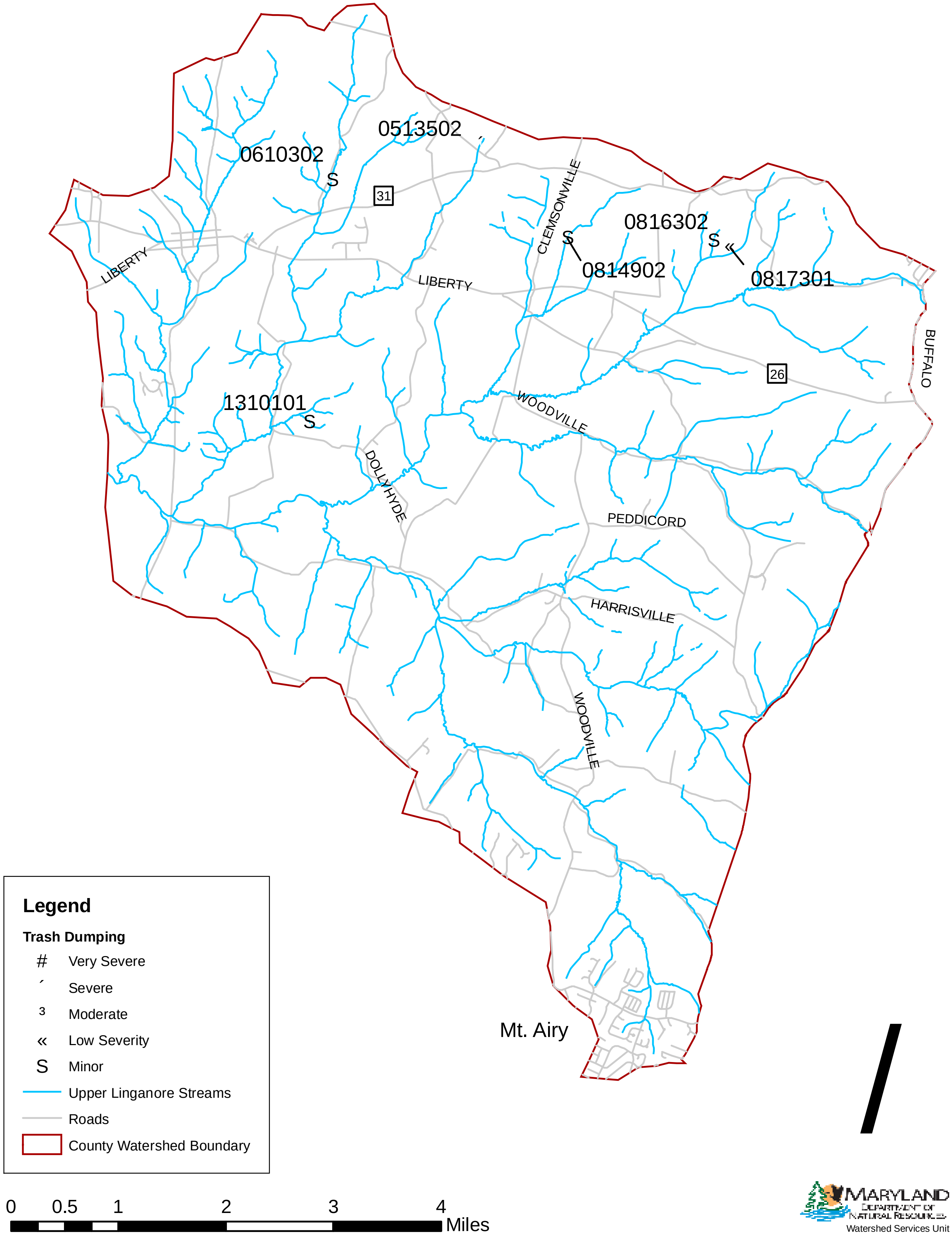
Map 14: Fish barriers in the Frederick County portion of the Upper Linganore Watershed.



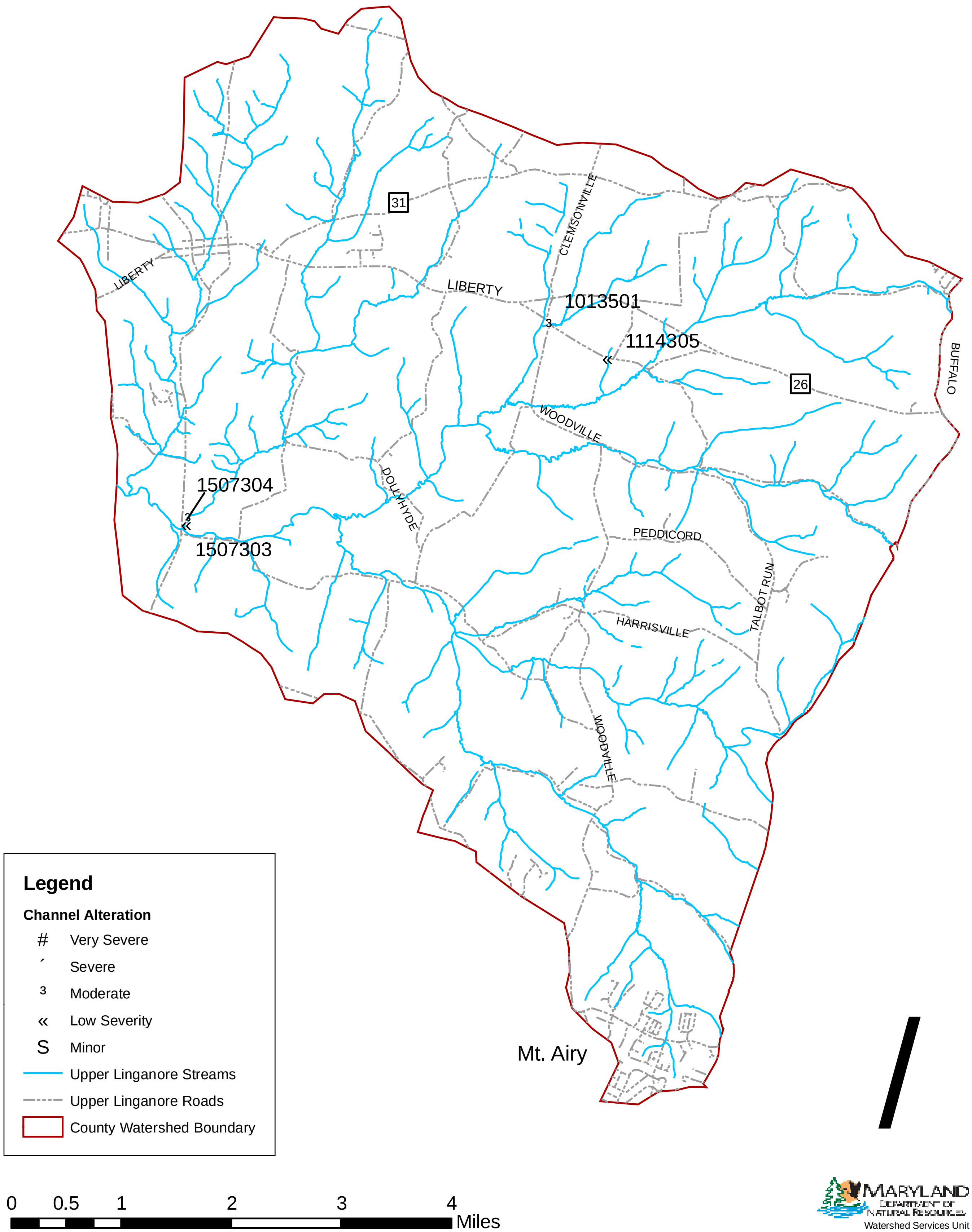
Map 15: Pipe outfall sites in the Frederick County portion of the Upper Linganore Watershed.



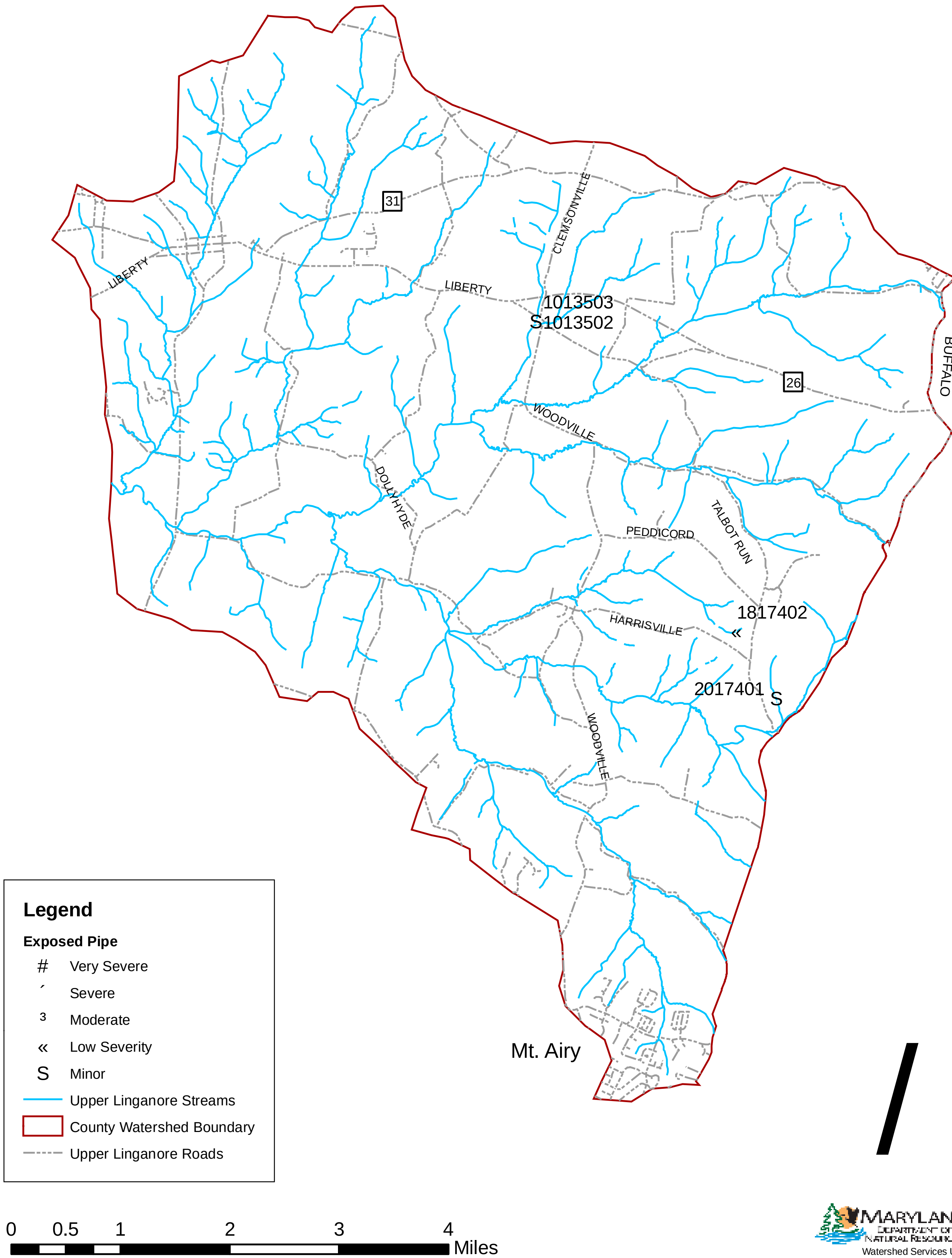
Map 16: Unusual condition and comment sites in the Frederick County portion of the Upper Linganore Watershed.



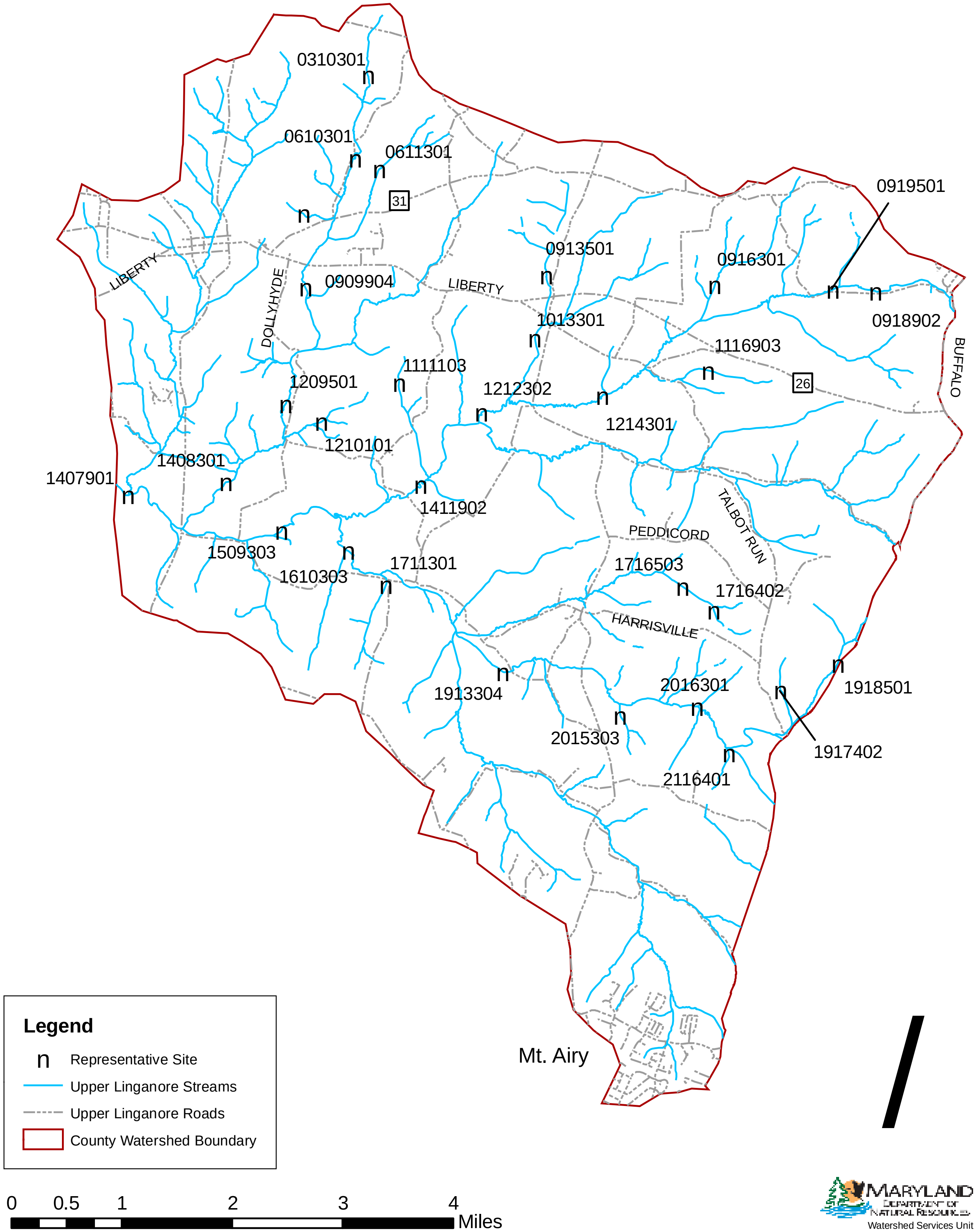
Map 17: Trash dumping sites in the Frederick County portion of the Upper Linganore Watershed.



Map 18: Channel alteration sites in the Frederick County portion of the Upper Linganore Watershed.



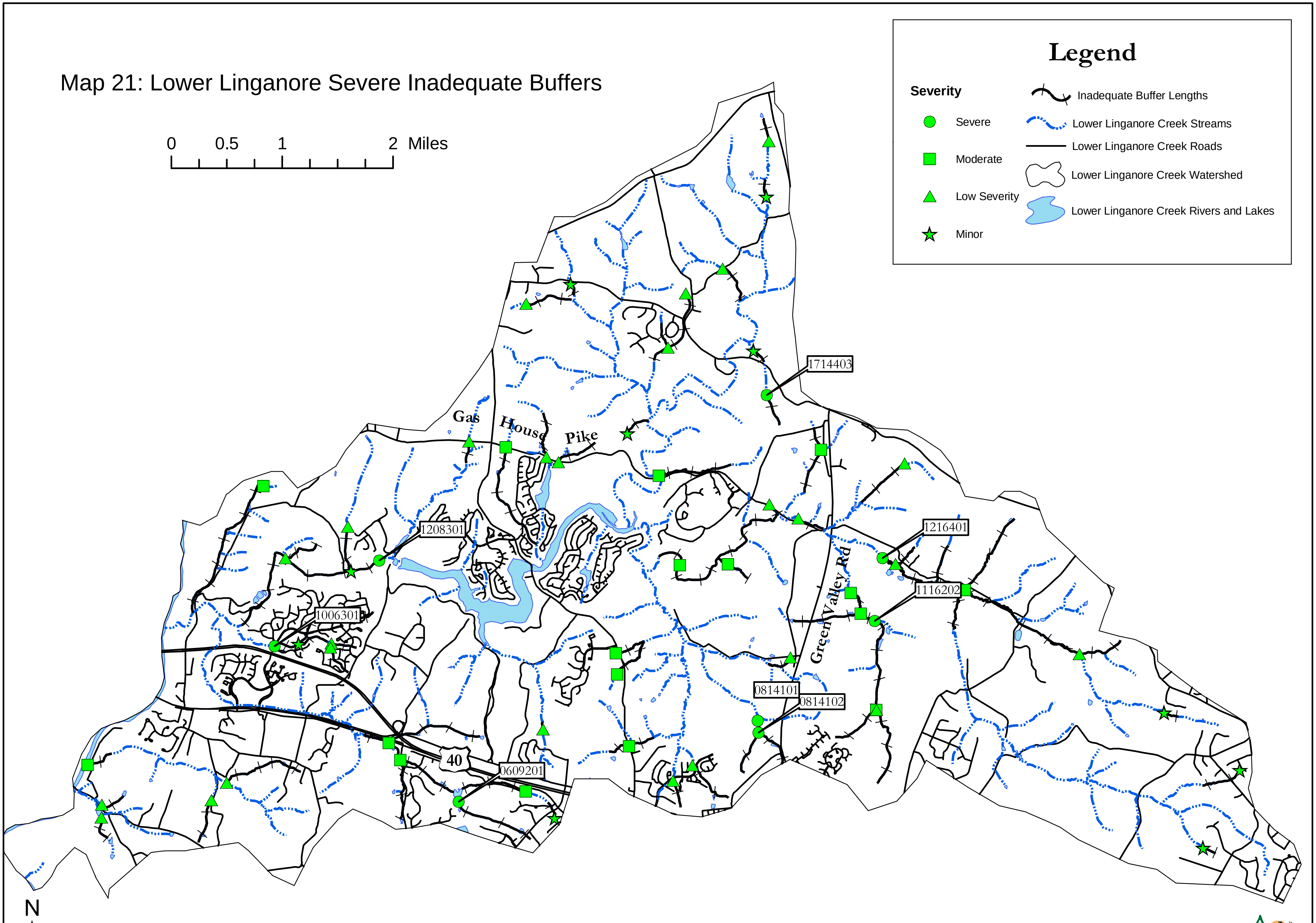
Map 19: Exposed pipe sites in the Frederick County portion of the Upper Linganore Watershed.



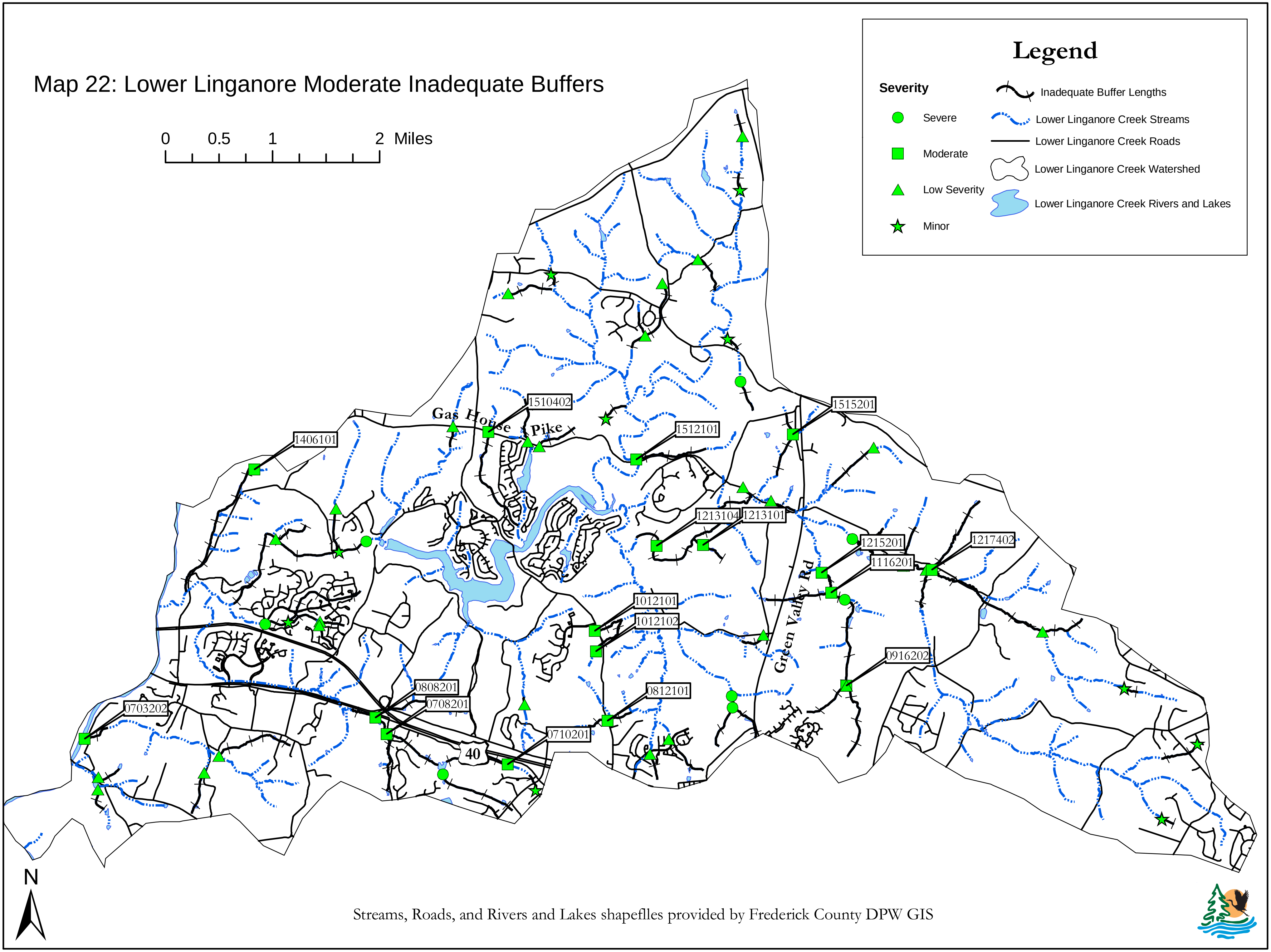
MARYLAND Department of Natural Resources
Watershed Services Unit

Map 20: Representative sites in the Frederick County portion of the Upper Linganore Watershed.

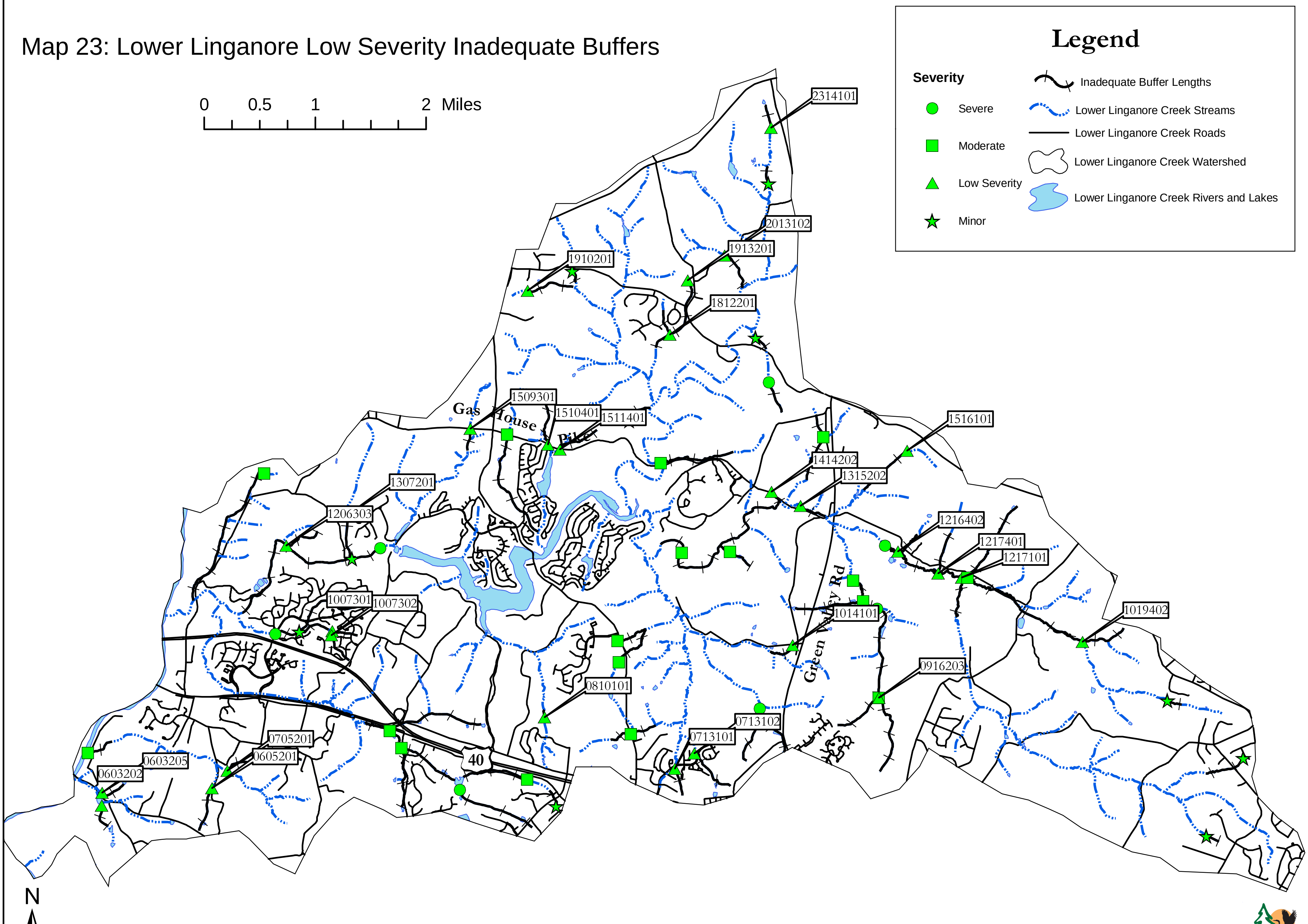
Map 21: Lower Linganore Severe Inadequate Buffers



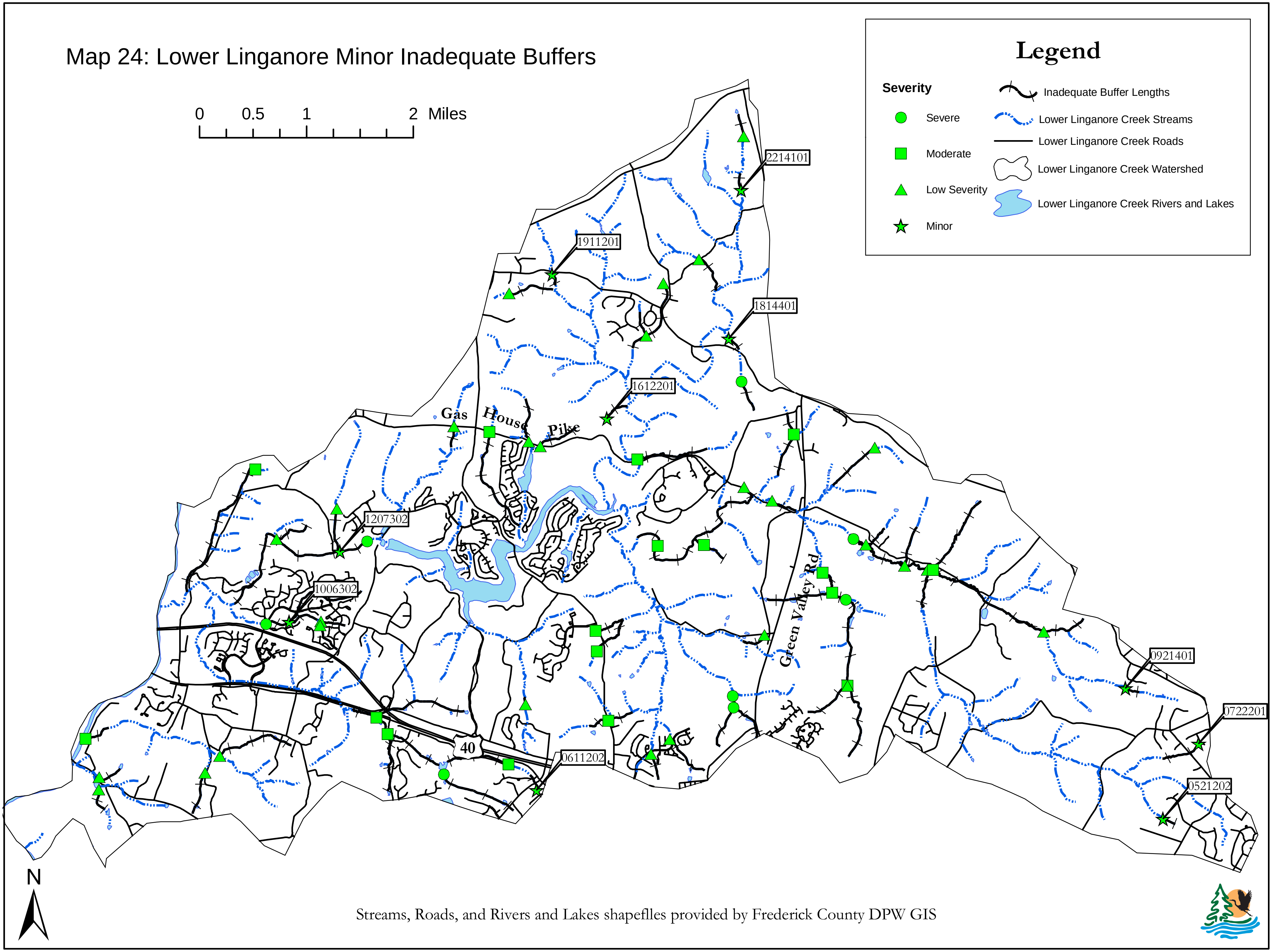
Streams, Roads, and Rivers and Lakes shapeflles provided by Frederick County DPW GIS


Map 22: Lower Linganore Moderate Inadequate Buffers
0
0.5
1
2
Miles
Legend
Severity
Severe
Moderate
Low Severity
Minor
Inadequate Buffer Lengths
Lower Linganore Creek Streams
Lower Linganore Creek Roads
Lower Linganore Creek Watershed
Lower Linganore Creek Rivers and Lakes
Gas House Pike
Green Valley Rd
40
1510402
1515201
1512101
1406101
1213104
1213101
1215201
1217402
1116201
1012101
1012102
0916202
0808201
0708201
0703202
0812101
0710201
N
Streams, Roads, and Rivers and Lakes shapeflles provided by Frederick County DPW GIS

Map 23: Lower Linganore Low Severity Inadequate Buffers

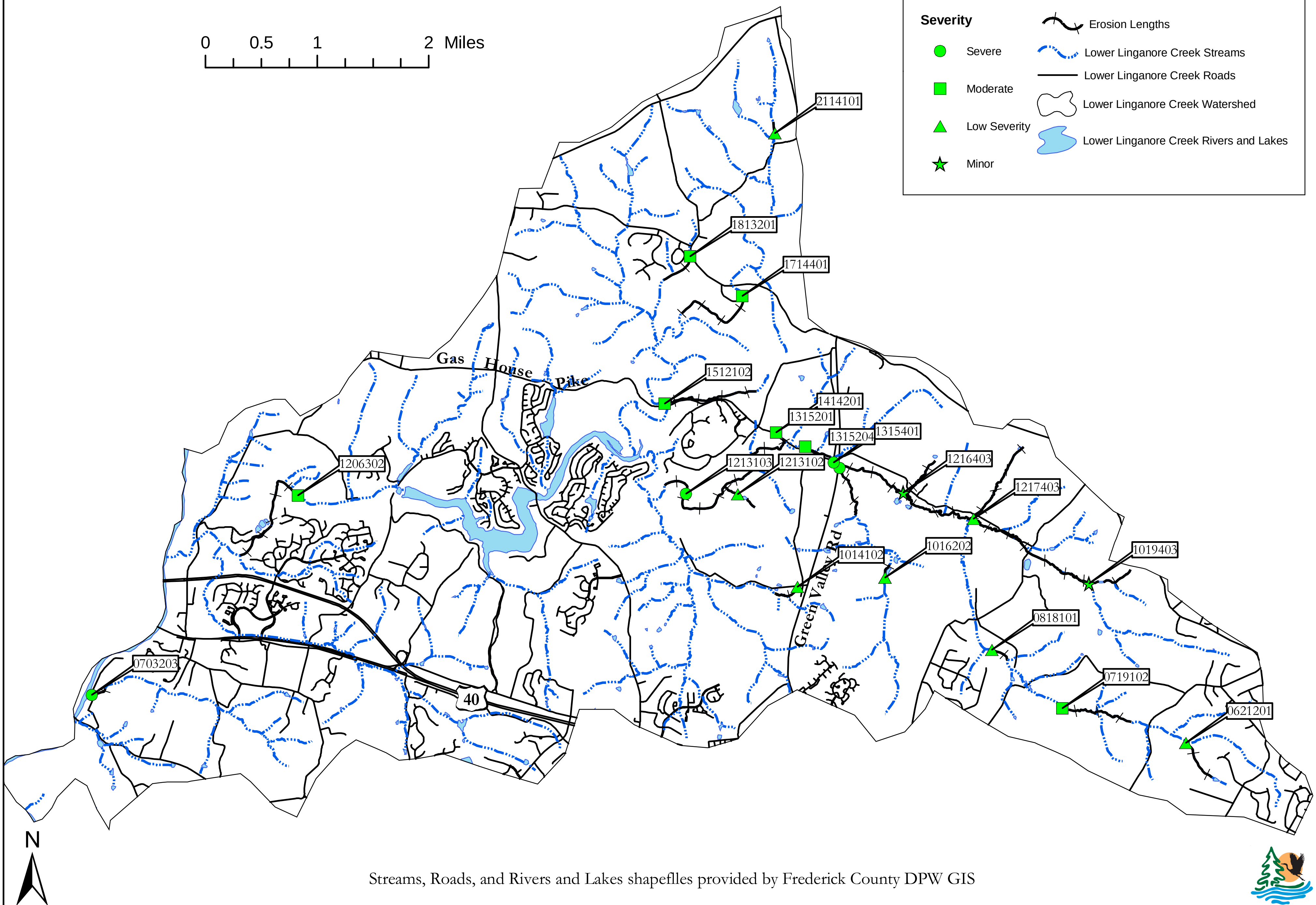


Streams, Roads, and Rivers and Lakes shapeflles provided by Frederick County DPW GIS



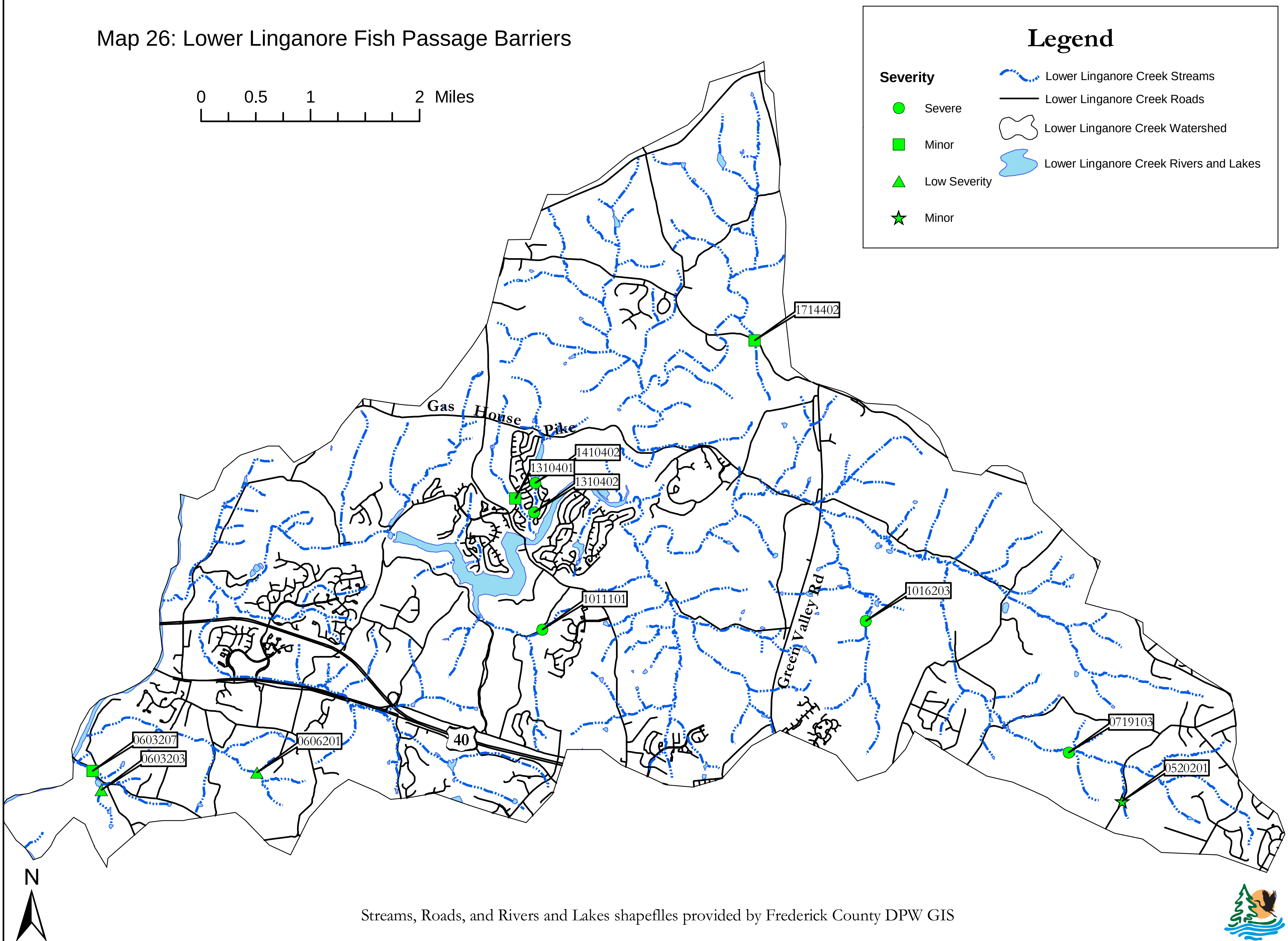
Map 24: Lower Linganore Minor Inadequate Buffers
0
0.5
1
2 Miles
Legend
Severity
Severe
Moderate
Low Severity
Minor
Inadequate Buffer Lengths
Lower Linganore Creek Streams
Lower Linganore Creek Roads
Lower Linganore Creek Watershed
Lower Linganore Creek Rivers and Lakes
2214101
1911201
1814401
1612201
1207302
1006302
0611202
0921401
0722201
0521202
Gas House Pike
Green Valley Rd
40
N
Streams, Roads, and Rivers and Lakes shapeflles provided by Frederick County DPW GIS

Map 25: Lower Linganore Erosion Sites

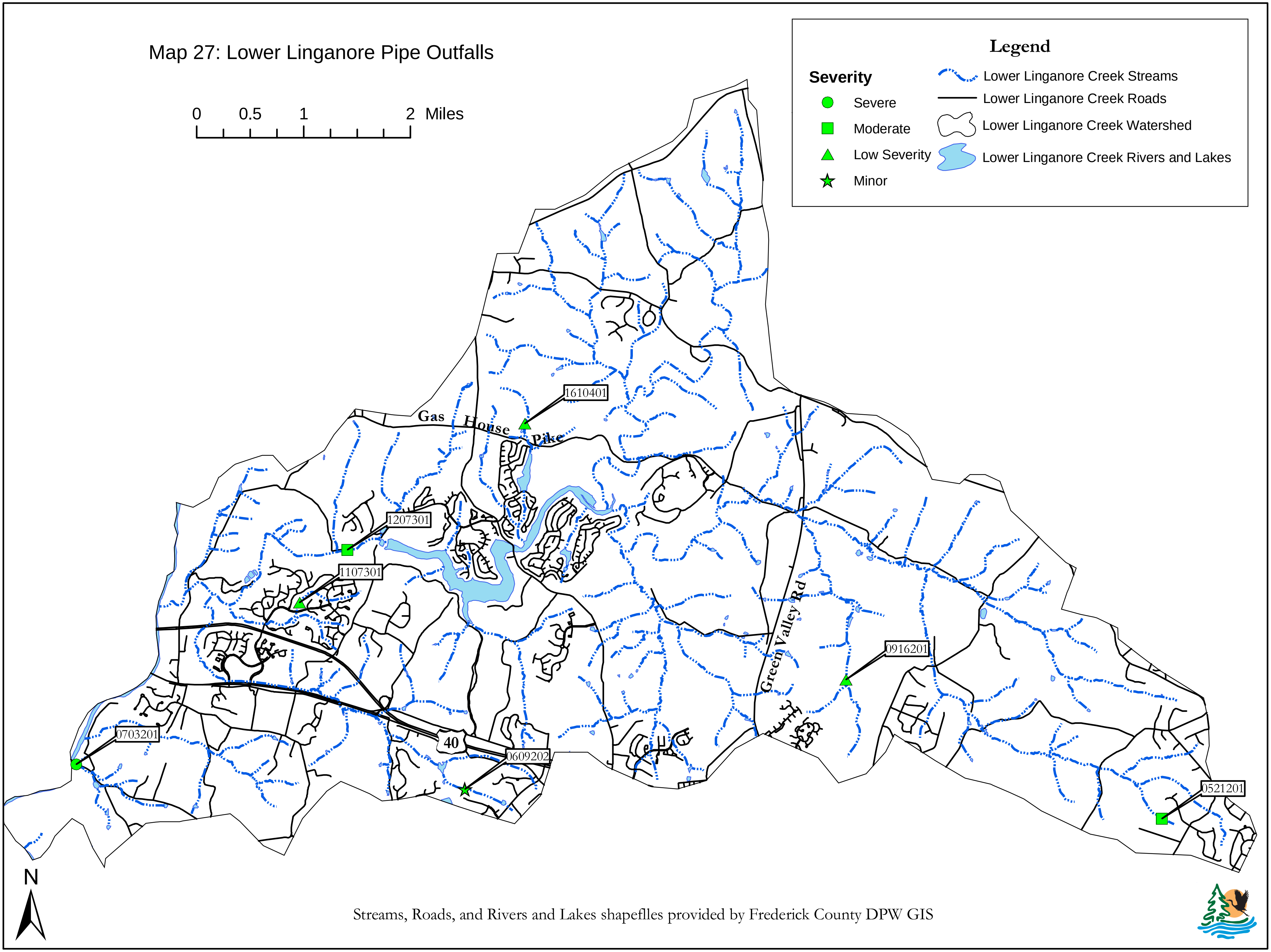


Streams, Roads, and Rivers and Lakes shapeflles provided by Frederick County DPW GIS

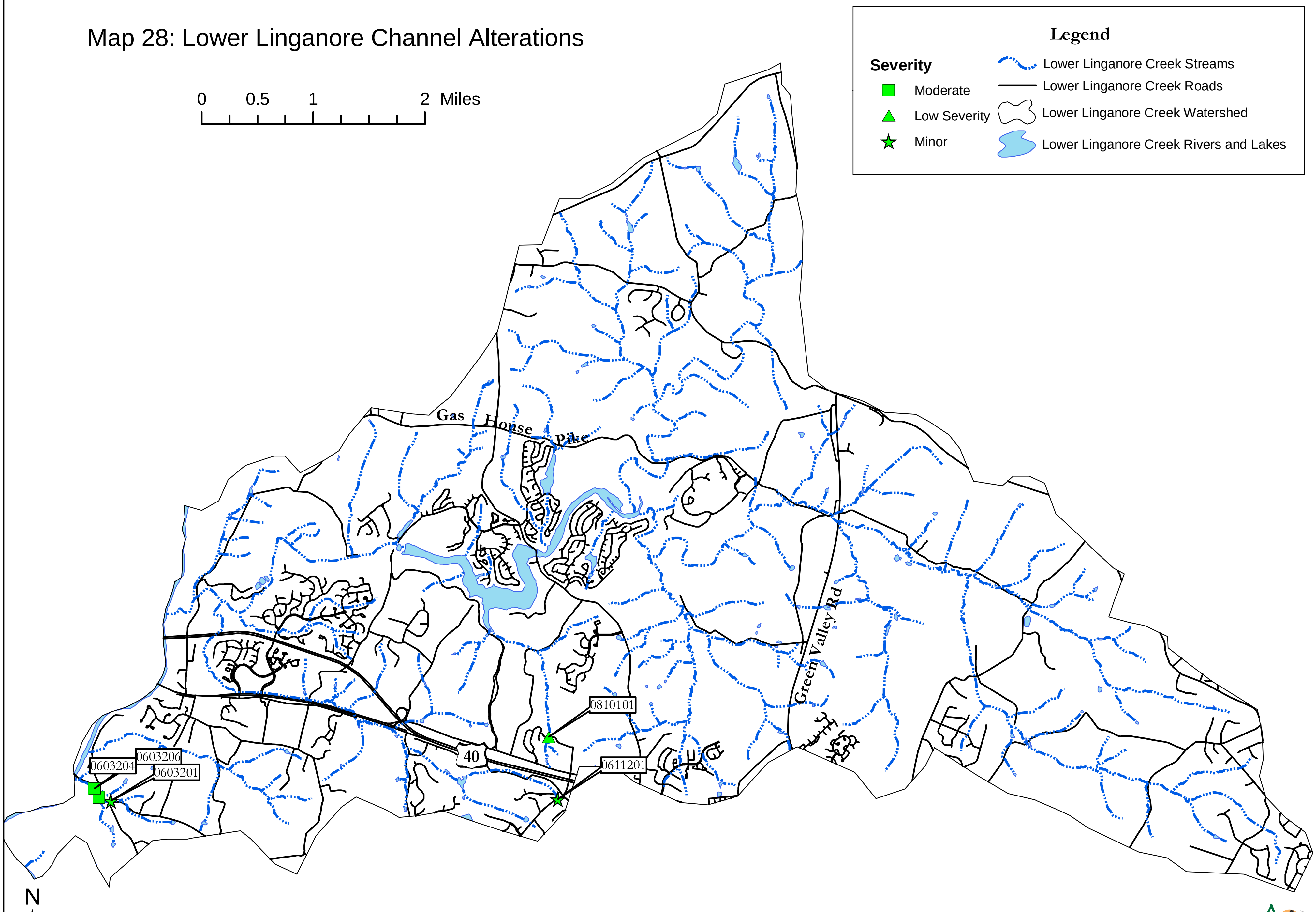
Map 26: Lower Linganore Fish Passage Barriers



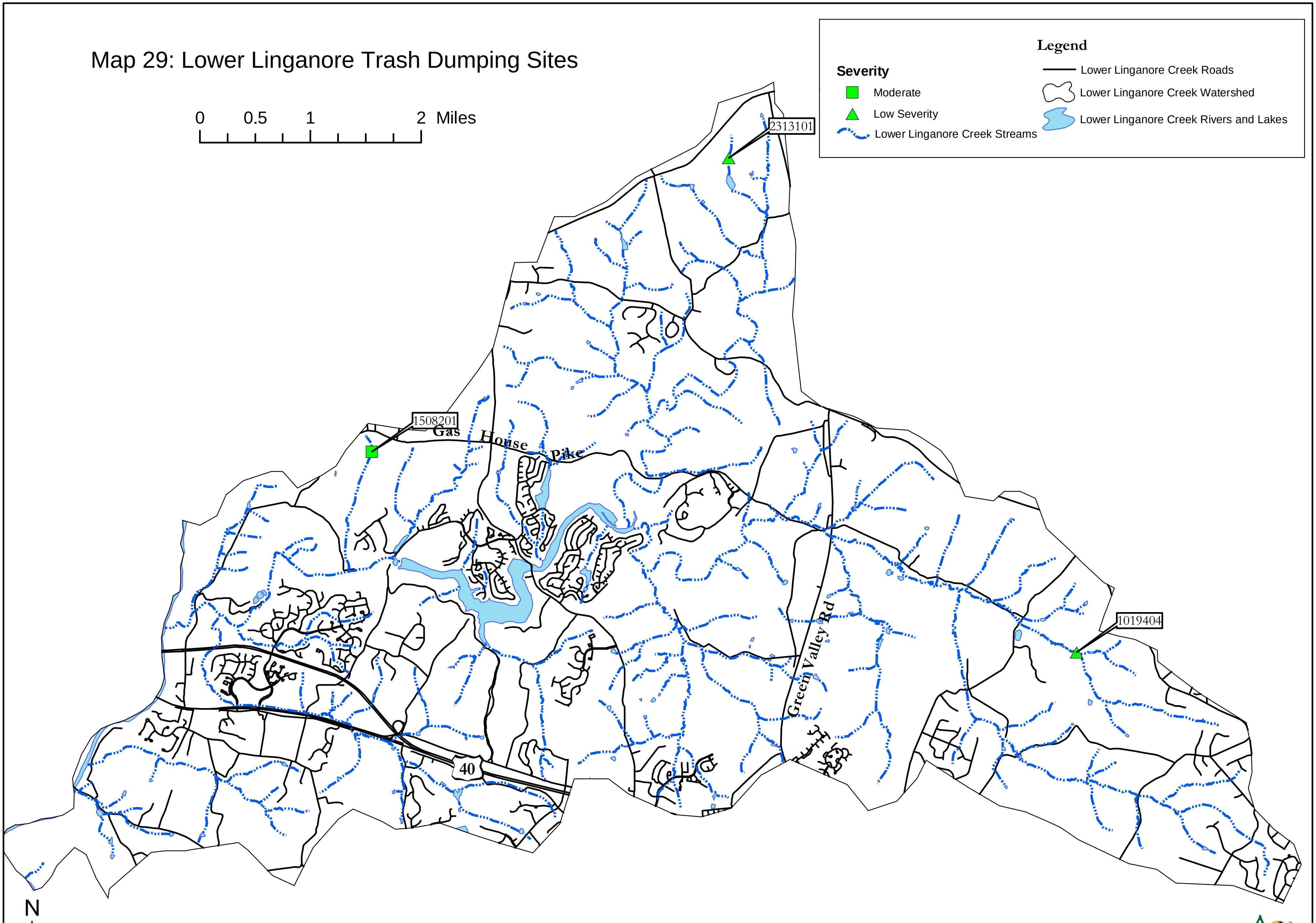
Streams, Roads, and Rivers and Lakes shapeflles provided by Frederick County DPW GIS


Map 27: Lower Linganore Pipe Outfalls
0 0.5 1 2 Miles
Legend
Severity
Severe
Moderate
Low Severity
Minor
Lower Linganore Creek Streams
Lower Linganore Creek Roads
Lower Linganore Creek Watershed
Lower Linganore Creek Rivers and Lakes
Gas House Pike
Green Valley Rd
40
1610401
1207301
1107301
0916201
0703201
0609202
0521201
N
Streams, Roads, and Rivers and Lakes shapeflles provided by Frederick County DPW GIS

Map 28: Lower Linganore Channel Alterations

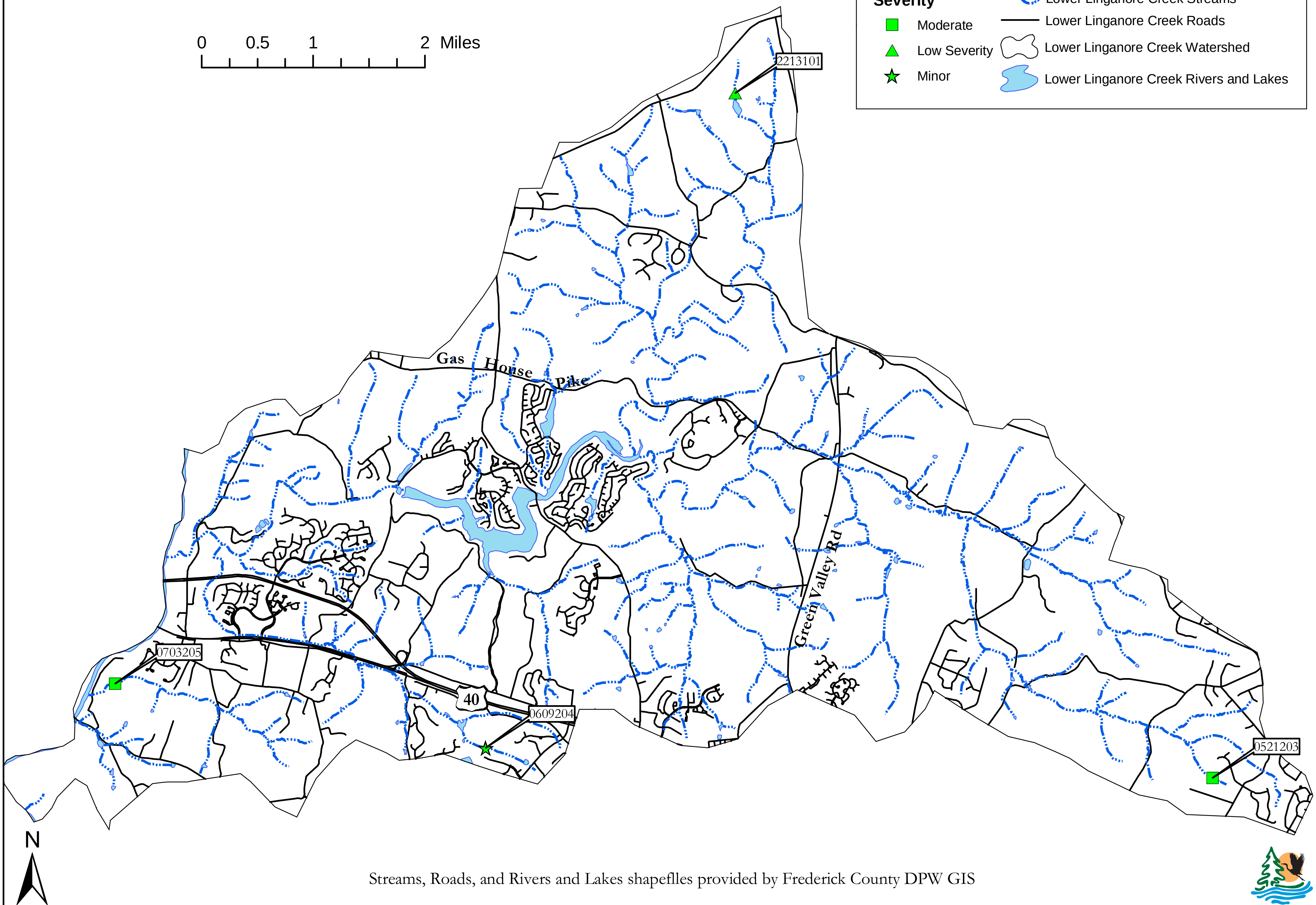


Streams, Roads, and Rivers and Lakes shapeflles provided by Frederick County DPW GIS

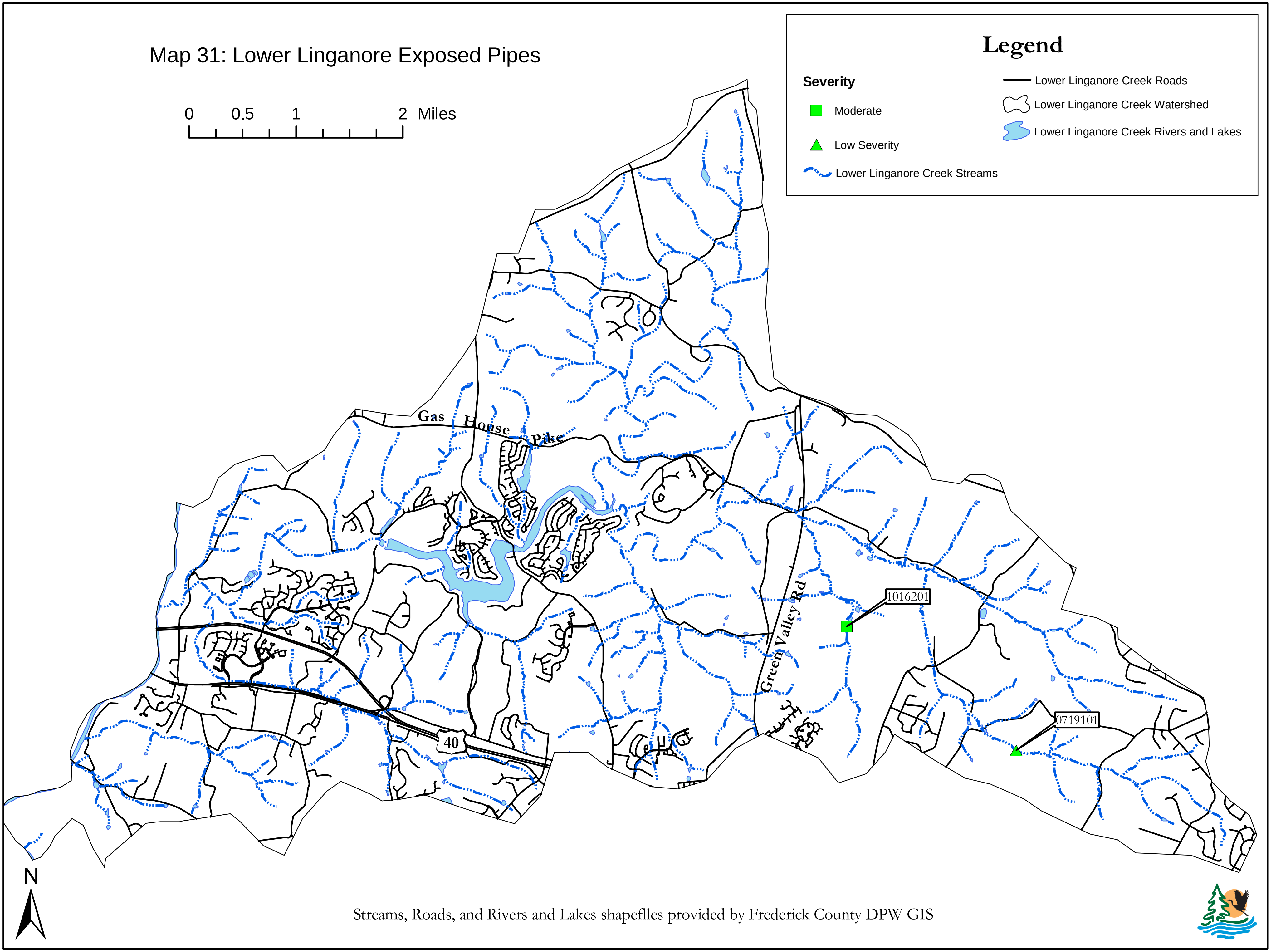


Streams, Roads, and Rivers and Lakes shapeflles provided by Frederick County DPW GIS

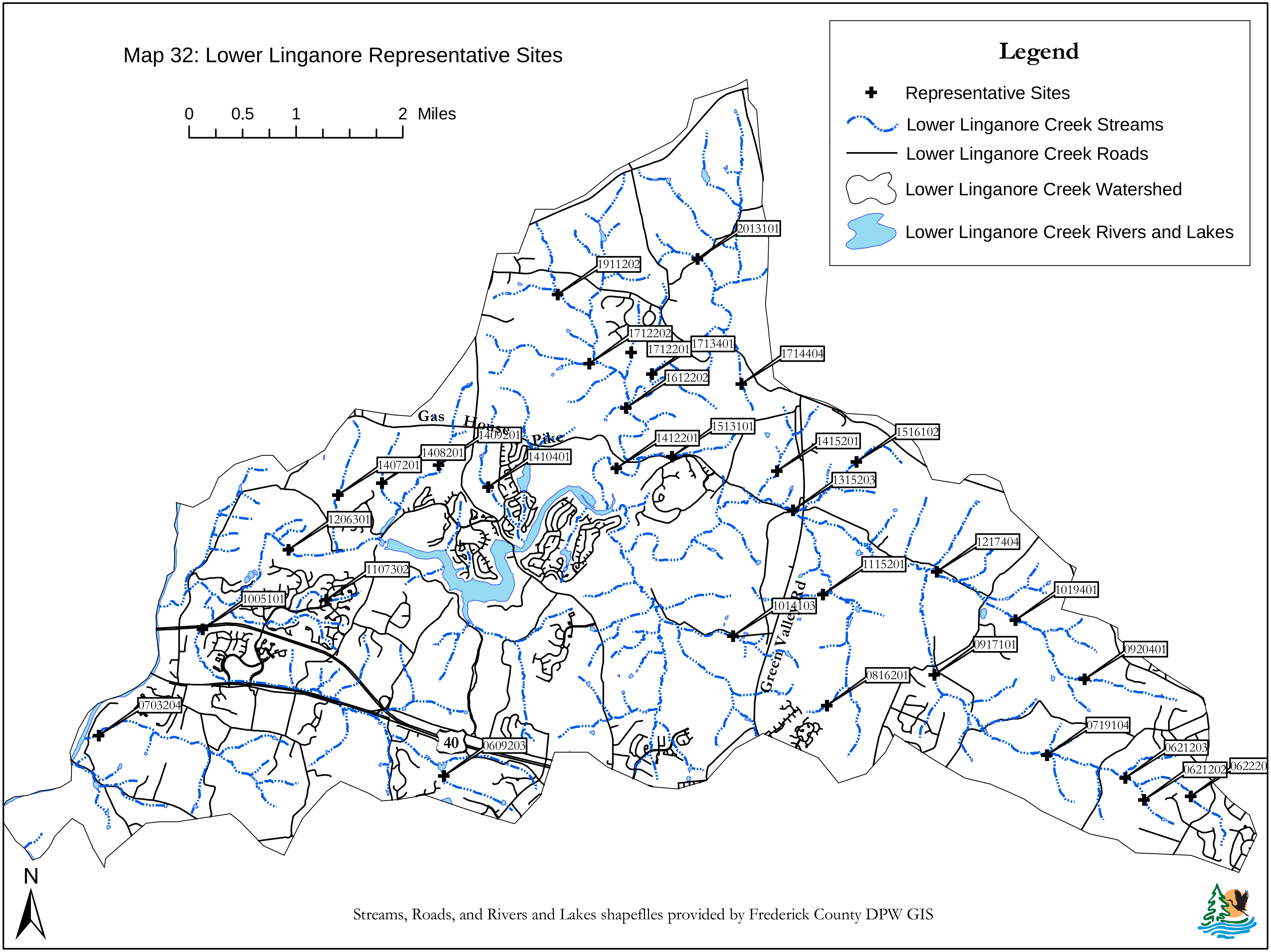
Map 30: Lower Linganore Unusual Conditions/Comments



Streams, Roads, and Rivers and Lakes shapeflles provided by Frederick County DPW GIS



Map 31: Lower Linganore Exposed Pipes
0
0.5
1
2 Miles
Legend
Severity
Moderate
Low Severity
Lower Linganore Creek Streams
Lower Linganore Creek Roads
Lower Linganore Creek Watershed
Lower Linganore Creek Rivers and Lakes
Gas House Pike
Green Valley Rd
40
1016201
0719101
N
Streams, Roads, and Rivers and Lakes shapeflles provided by Frederick County DPW GIS


Map 32: Lower Linganore Representative Sites
0 0.5 1 2 Miles
Legend
Representative Sites
Lower Linganore Creek Streams
Lower Linganore Creek Roads
Lower Linganore Creek Watershed
Lower Linganore Creek Rivers and Lakes
Gas House Pike
Green Valley Rd
40
2013101
1911202
1712202
1712201
1713401
1714404
1612202
1513101
1412201
1409201
1410401
1408201
1407201
1415201
1516102
1315203
1206301
1107302
1005101
1217404
1115201
1019401
1014103
0917101
0920401
0816201
0703204
0609203
0719104
0621203
0621202
062220
N
Streams, Roads, and Rivers and Lakes shapeflles provided by Frederick County DPW GIS

Map 33: Inadequate Buffer

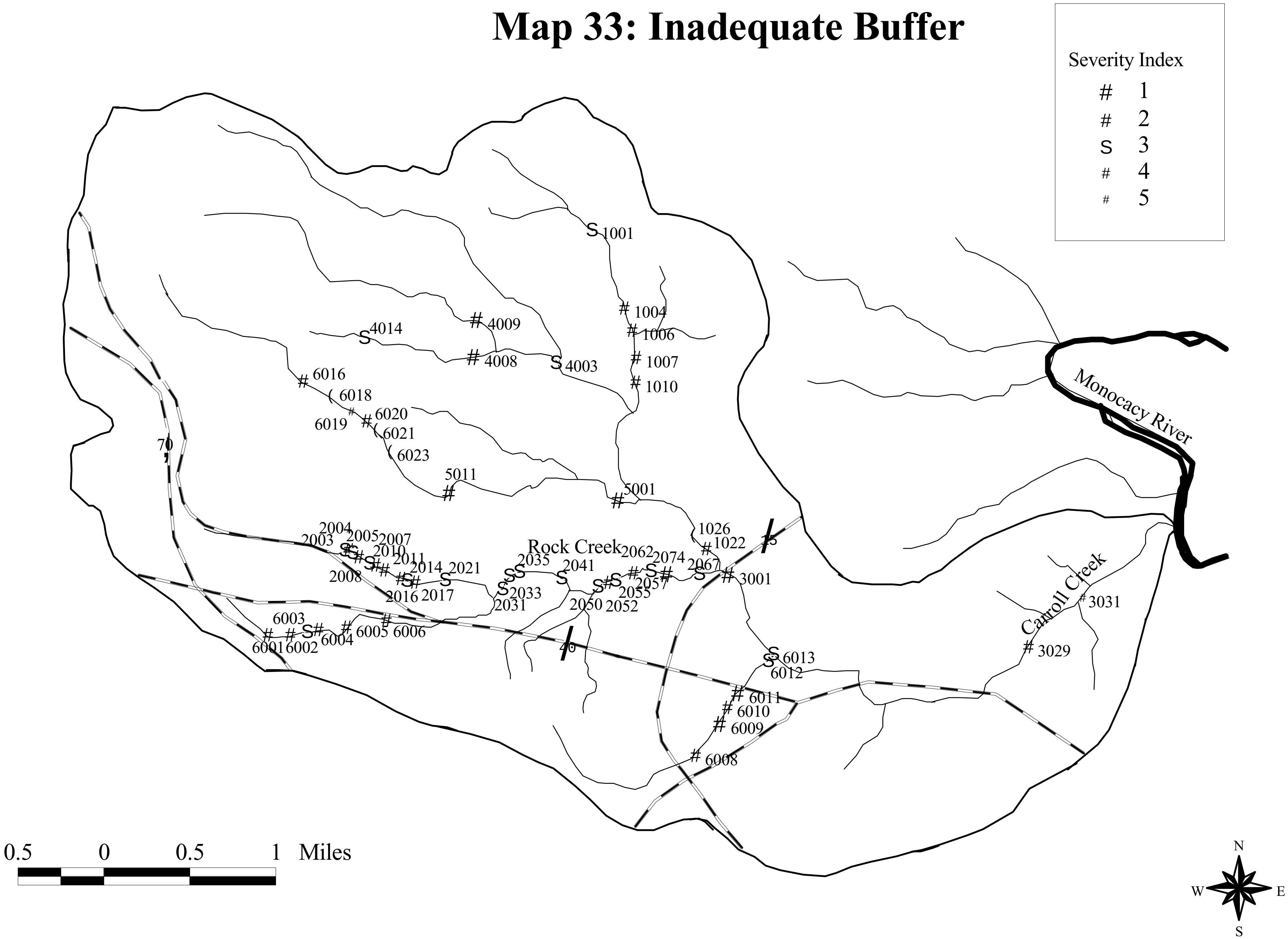


Figure 4b: Map of Carroll/Rock Creeks Inadequate Buffer Sites

Map 34: Pipe Outfalls

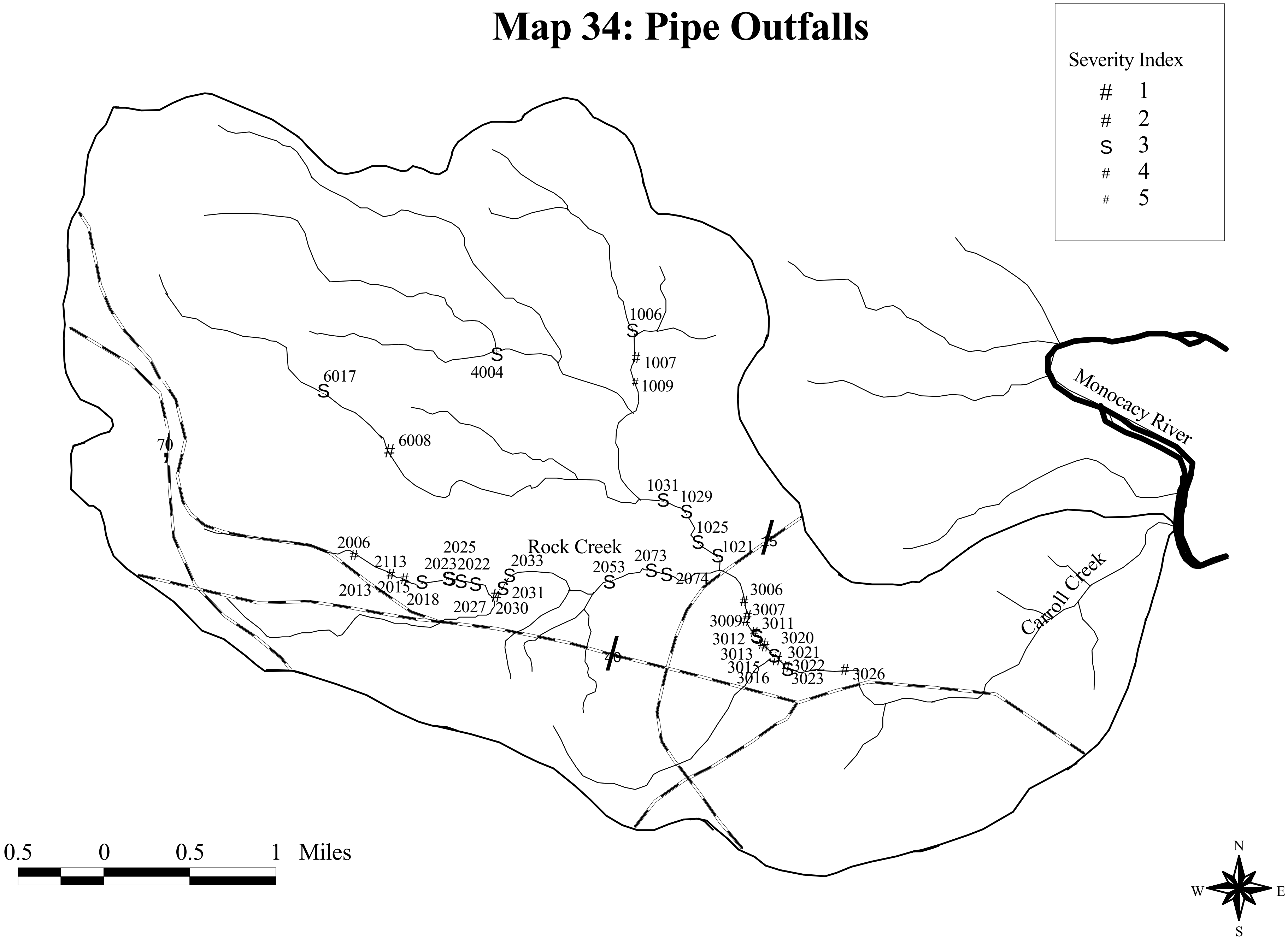


Figure 5b: Map of Carroll/Rock Creeks Pipe Outfalls

Map 35: Erosion

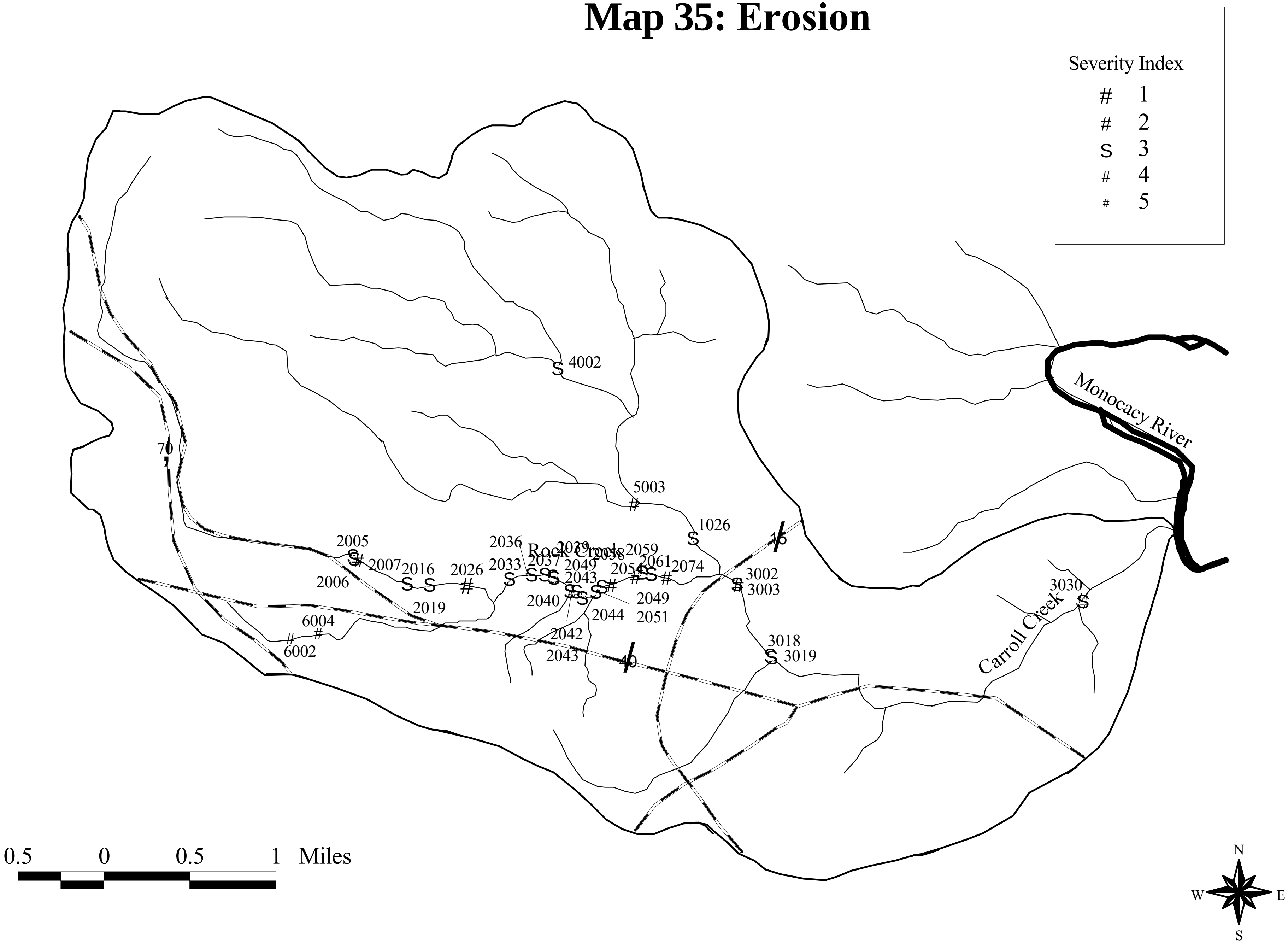


Figure 6b: Map of Carroll/Rock Creeks Erosion Sites

Map 36: Fish Barrier

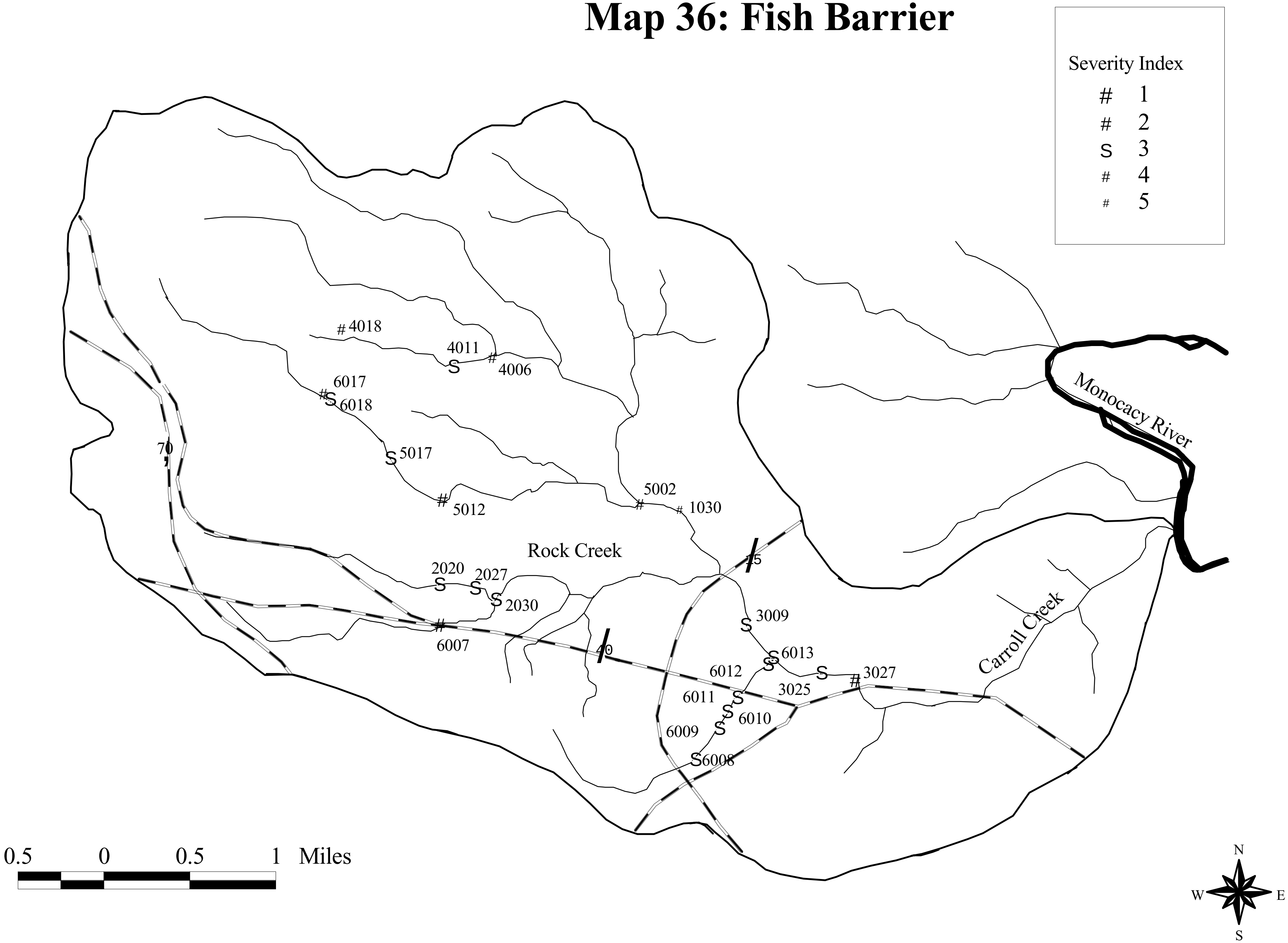


Figure 7b: Map of Carroll/Rock Creeks Fish Barrier Sites

Map 37: Channel Alteration

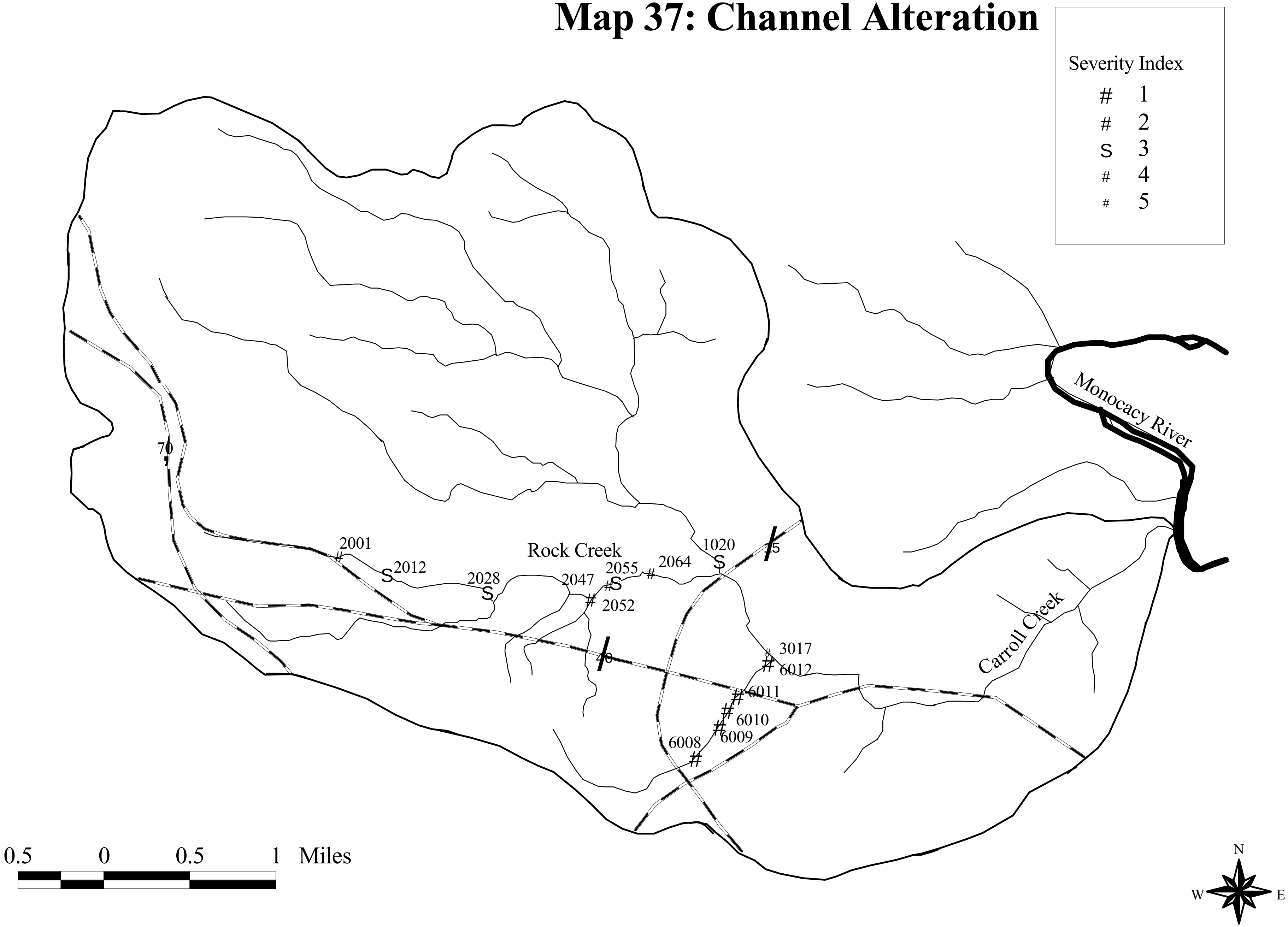


Figure 8b: Map of Carroll/Rock Creeks Channel Alteration Sites

Map 38: **Exposed Pipes**

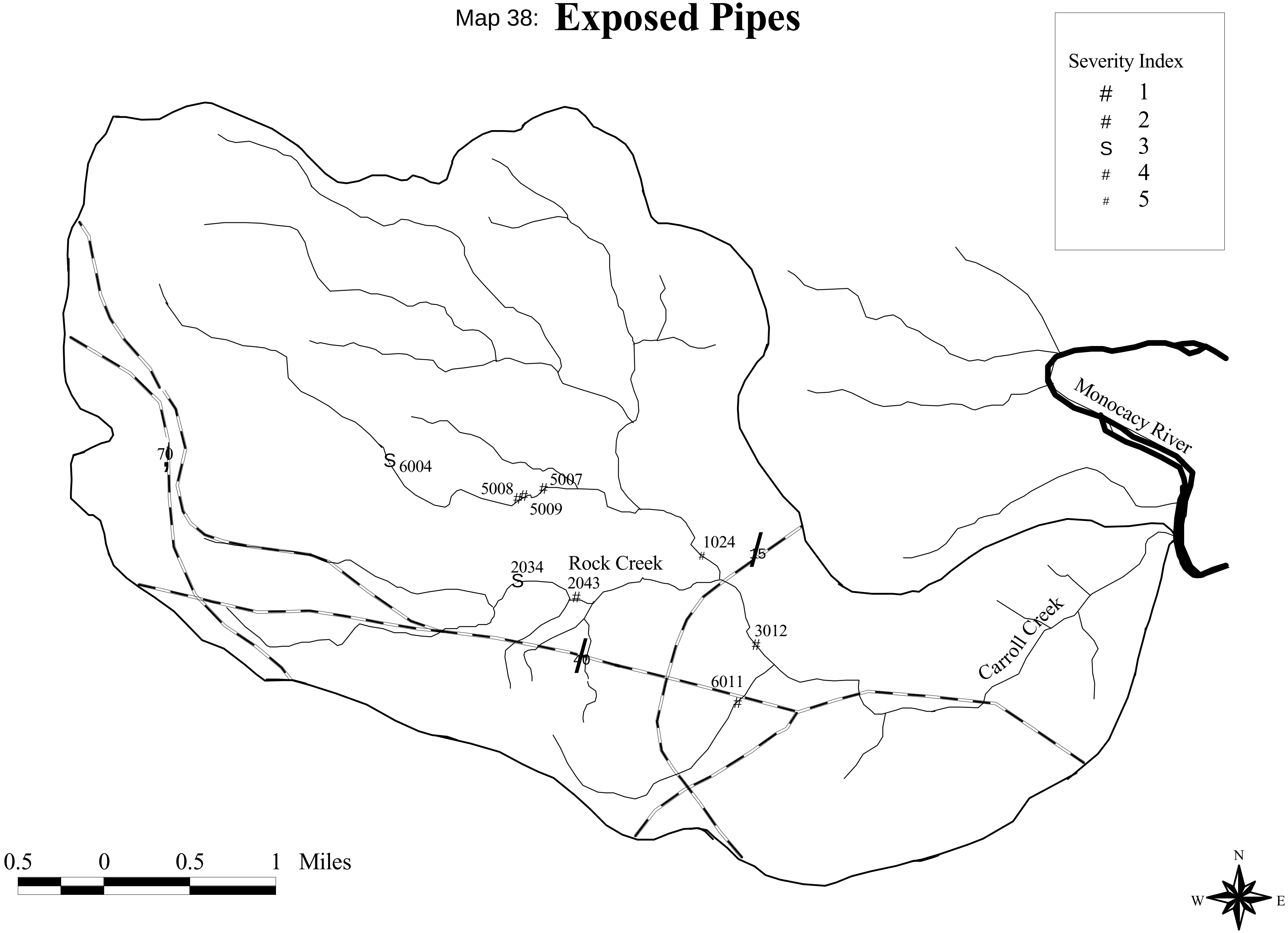


Figure 9b: Map of Carroll/Rock Creeks Exposed Pipes

Map 39: **Unusual Condition**

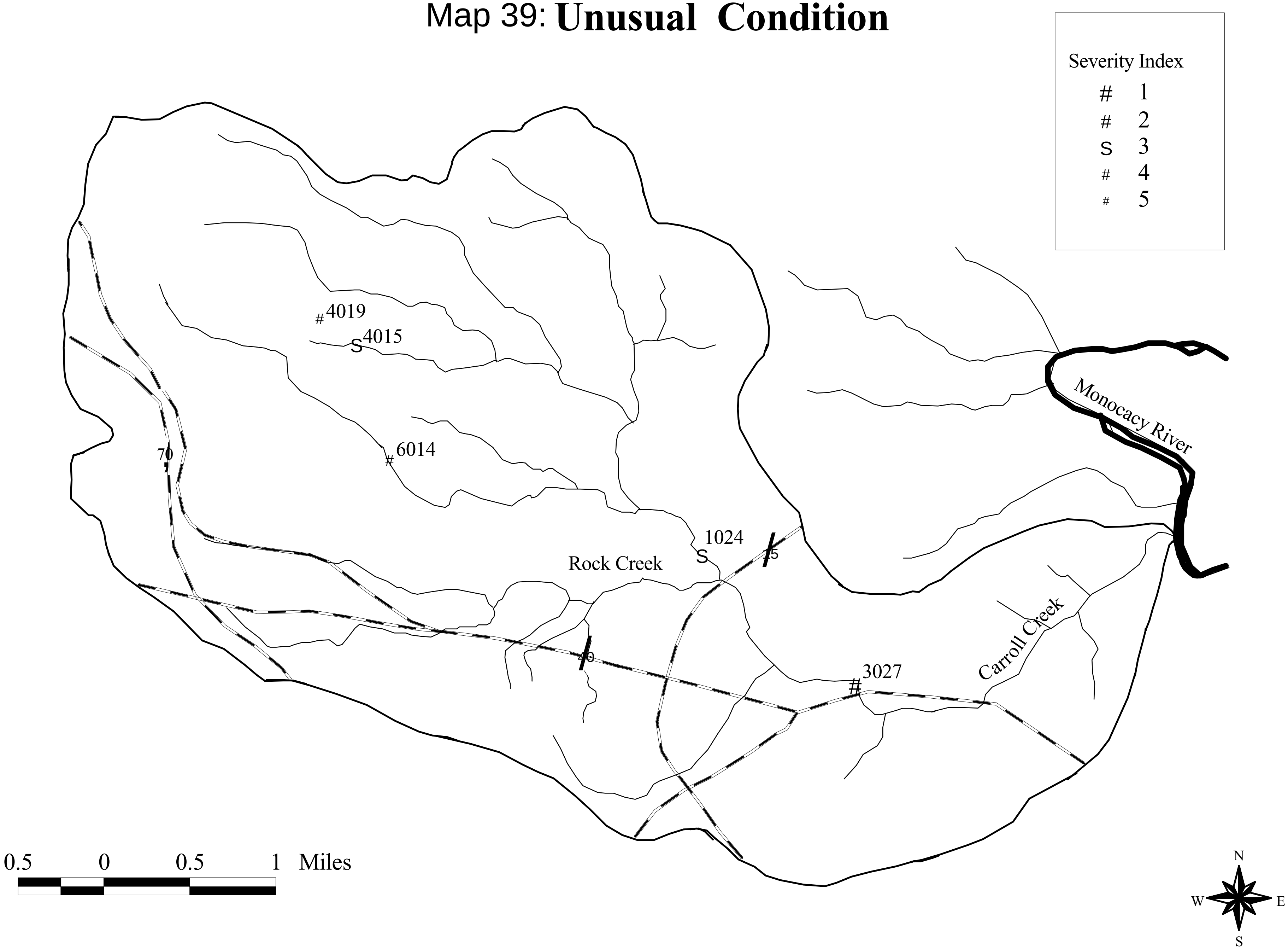


Figure 10b: Map of Carroll/Rock Creeks Unusual Condition Sites

Map 40: **Livestock**

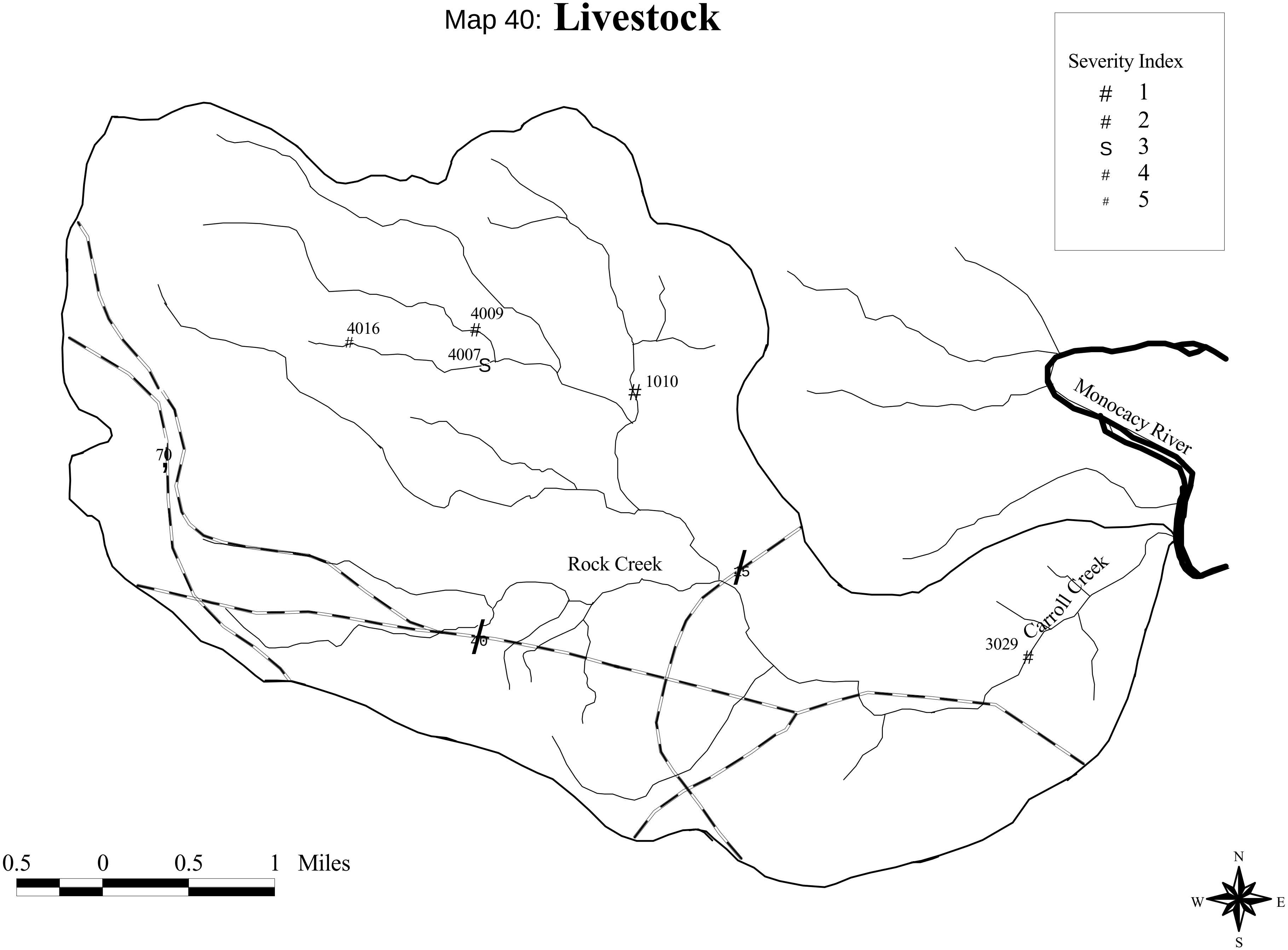


Figure 11b: Map of Carroll/Rock Creeks Livestock Sites

Map 41: **Representative Sites**

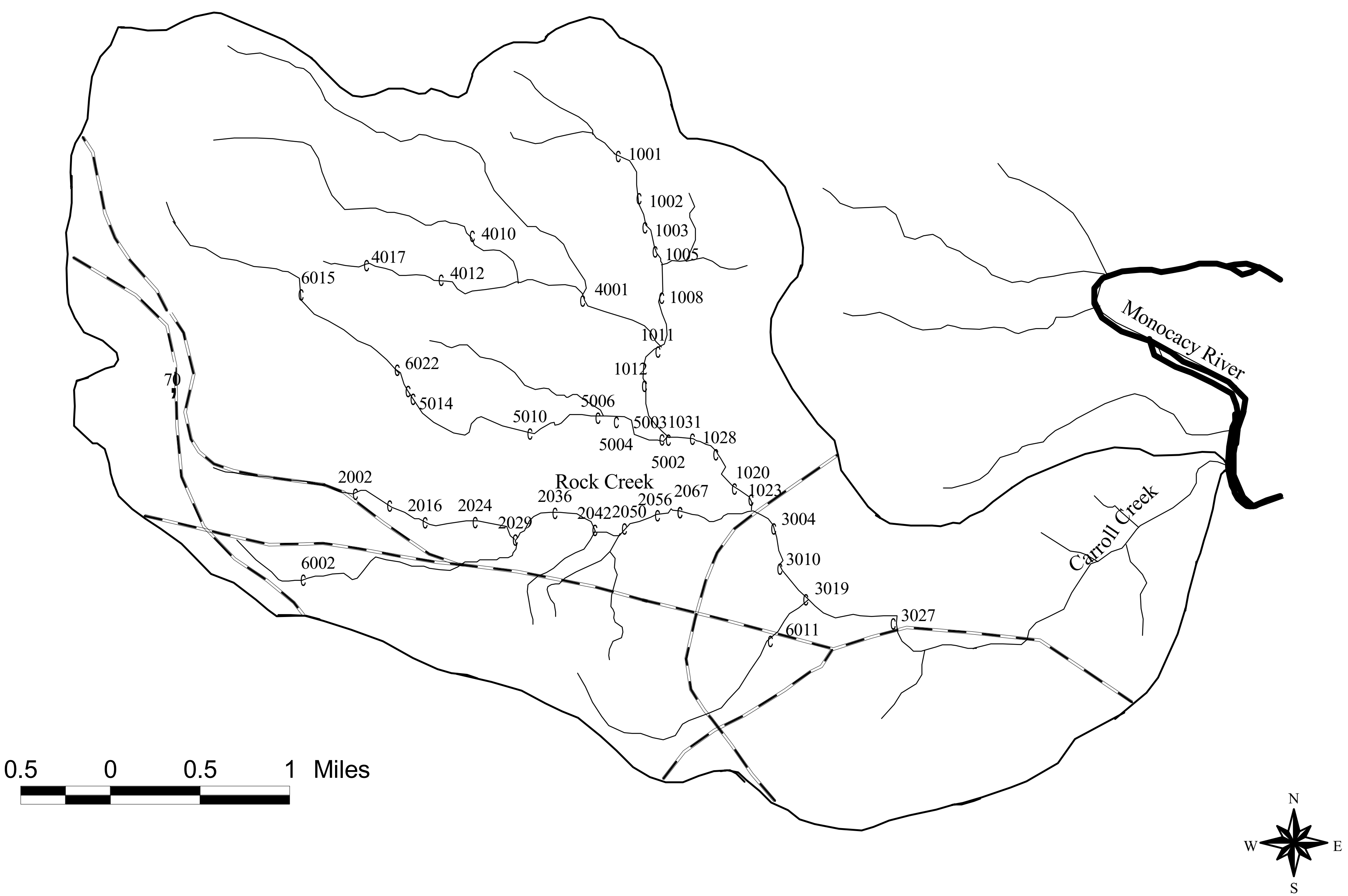
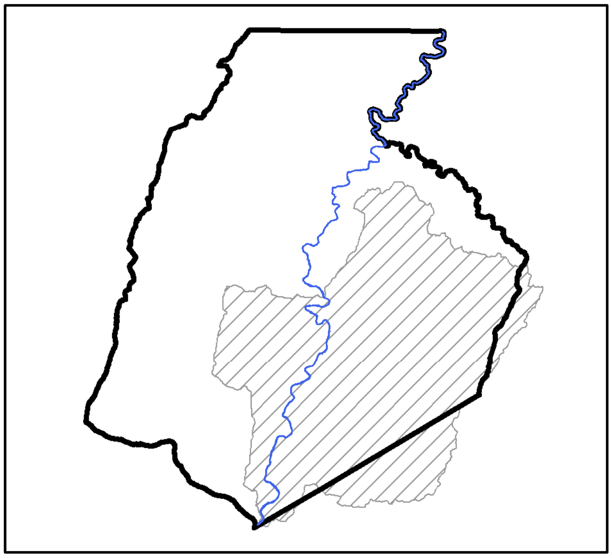


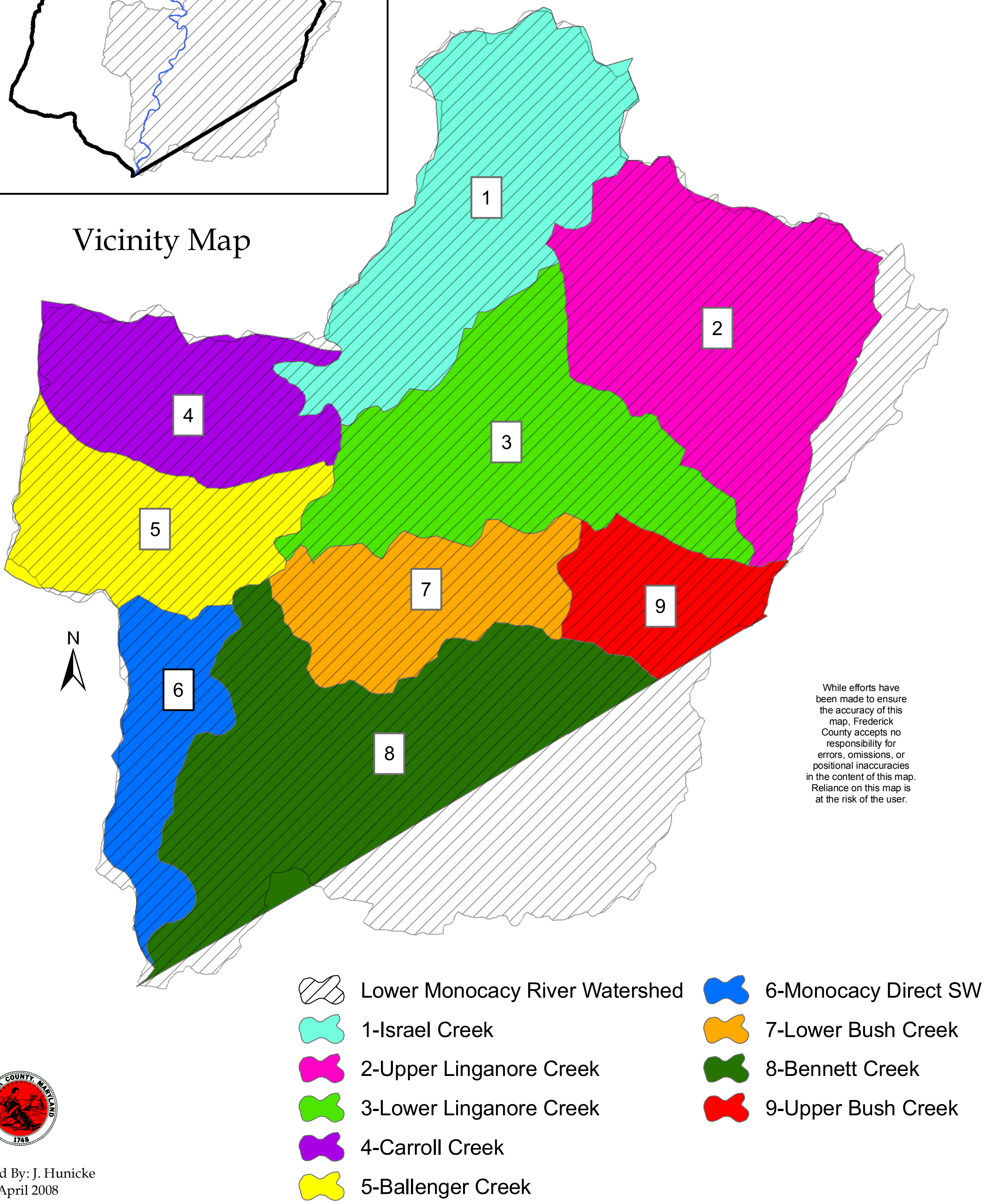
Figure 13: Map of Carroll/Rock Creeks Representative Sites

Appendix B: Lower Monocacy River Watershed Maps and Pollutant Loading Estimates

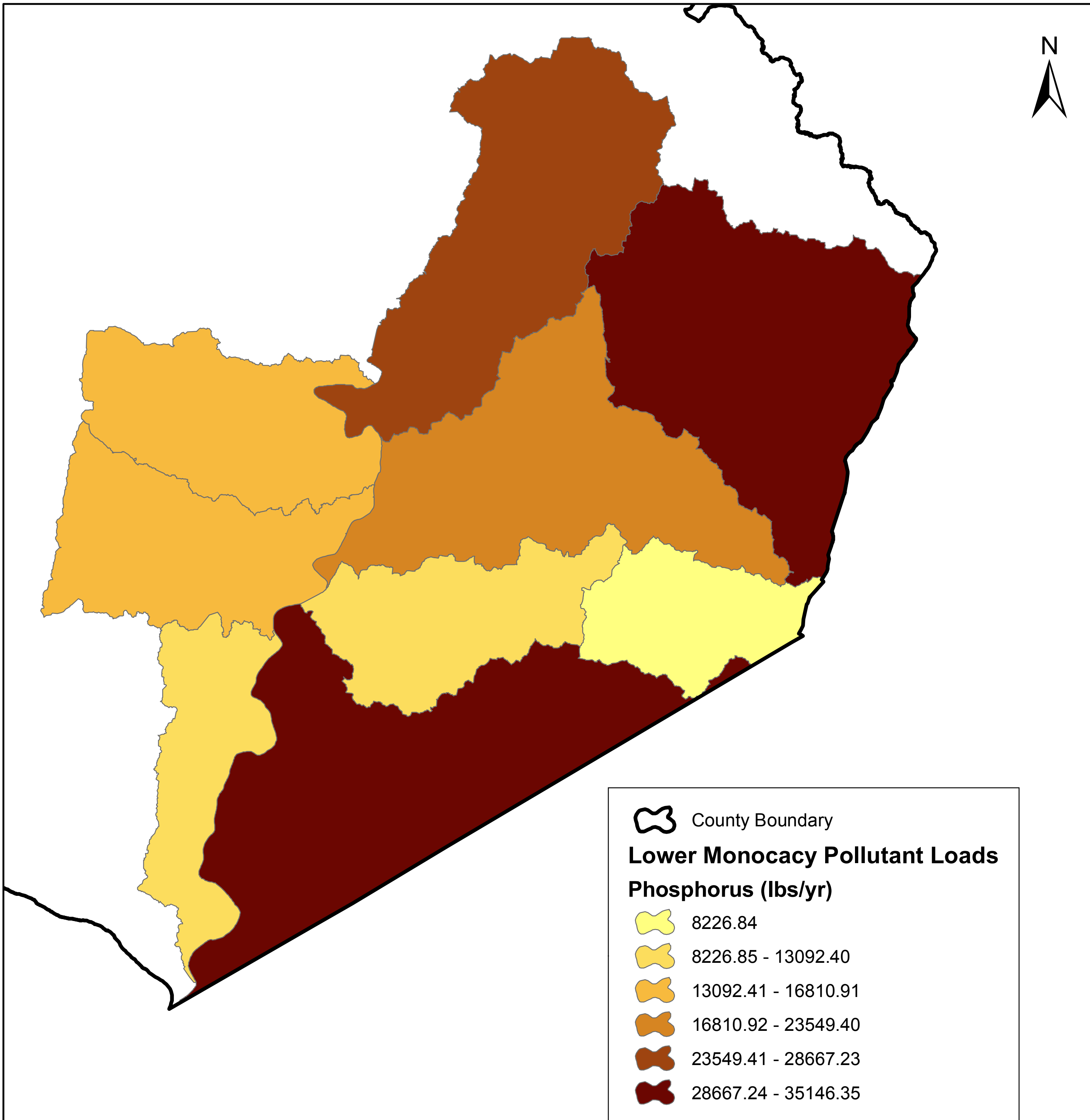
Map 42: Lower Monocacy River Subwatersheds



Vicinity Map



Created By: J. Hunicke
April 2008



Map 43: Lower Monocacy Pollutant Loads by Watershed Phosphorus (lbs/yr)

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J. Hunicke
April 2008

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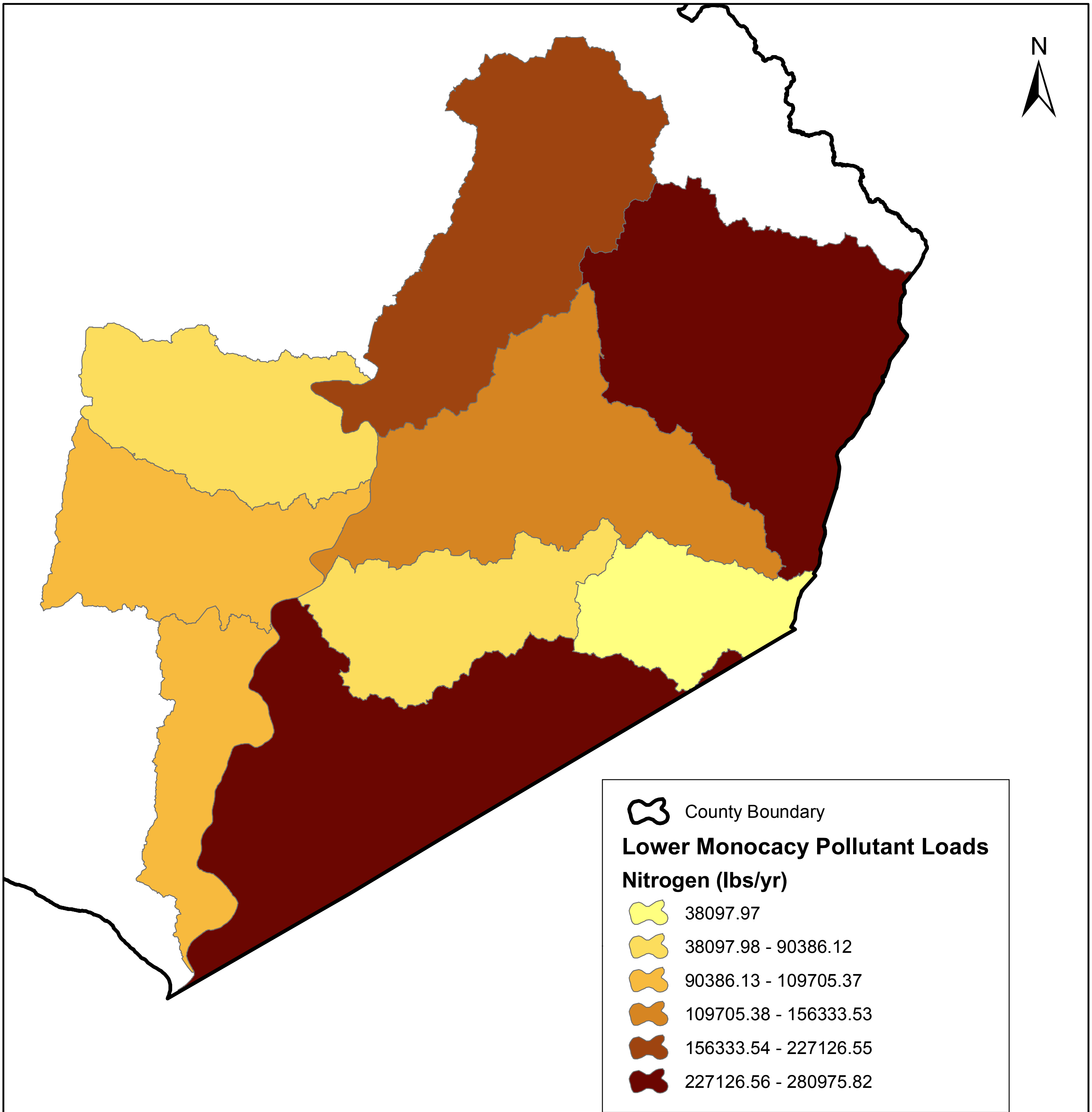

Map 44: Lower Monocacy Pollutant Loads by Watershed Nitrogen (lbs/yr)

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April 2008

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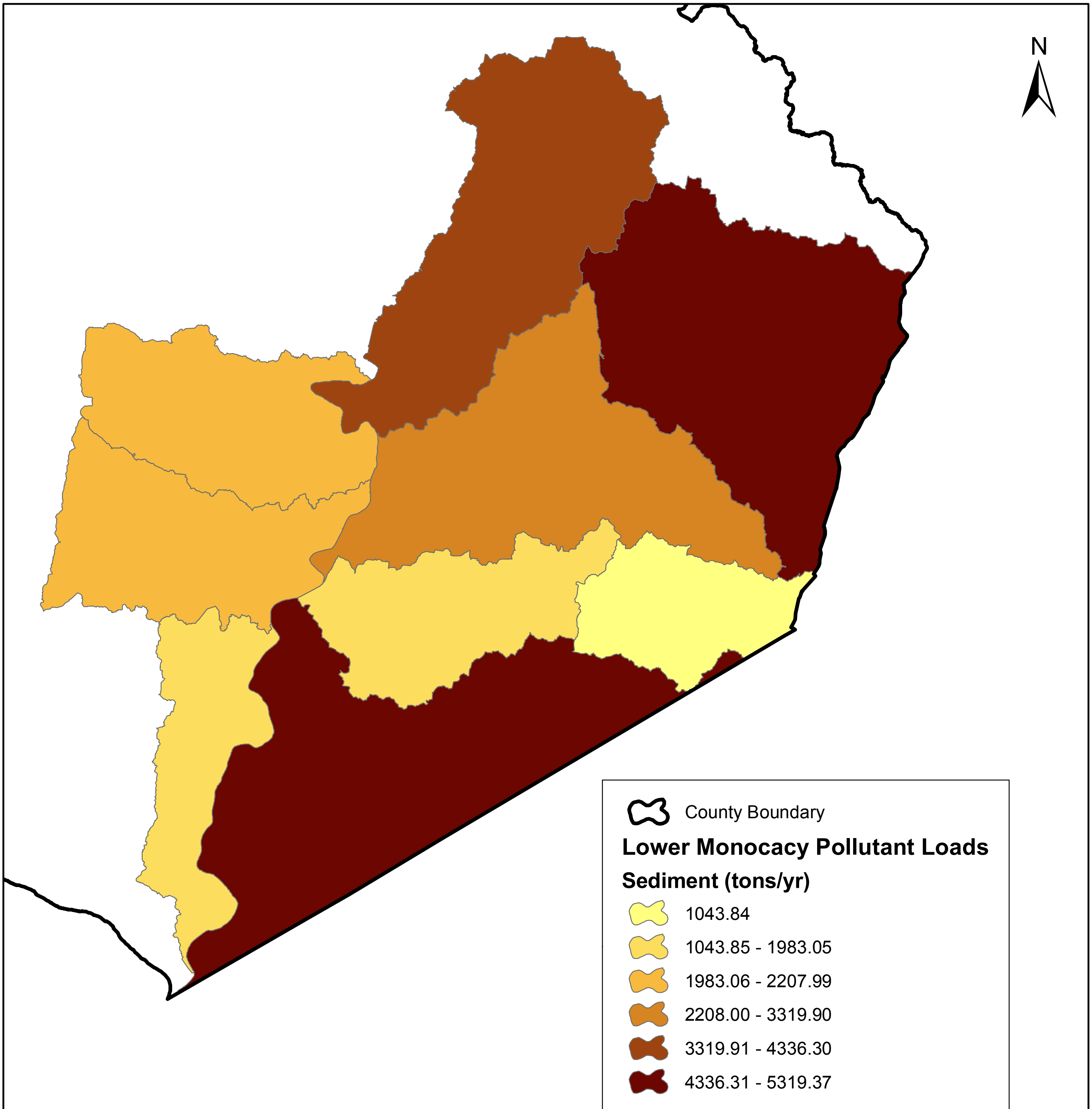

Map 45: Lower Monocacy Pollutant Loads by Watershed Sediment (tons/yr)

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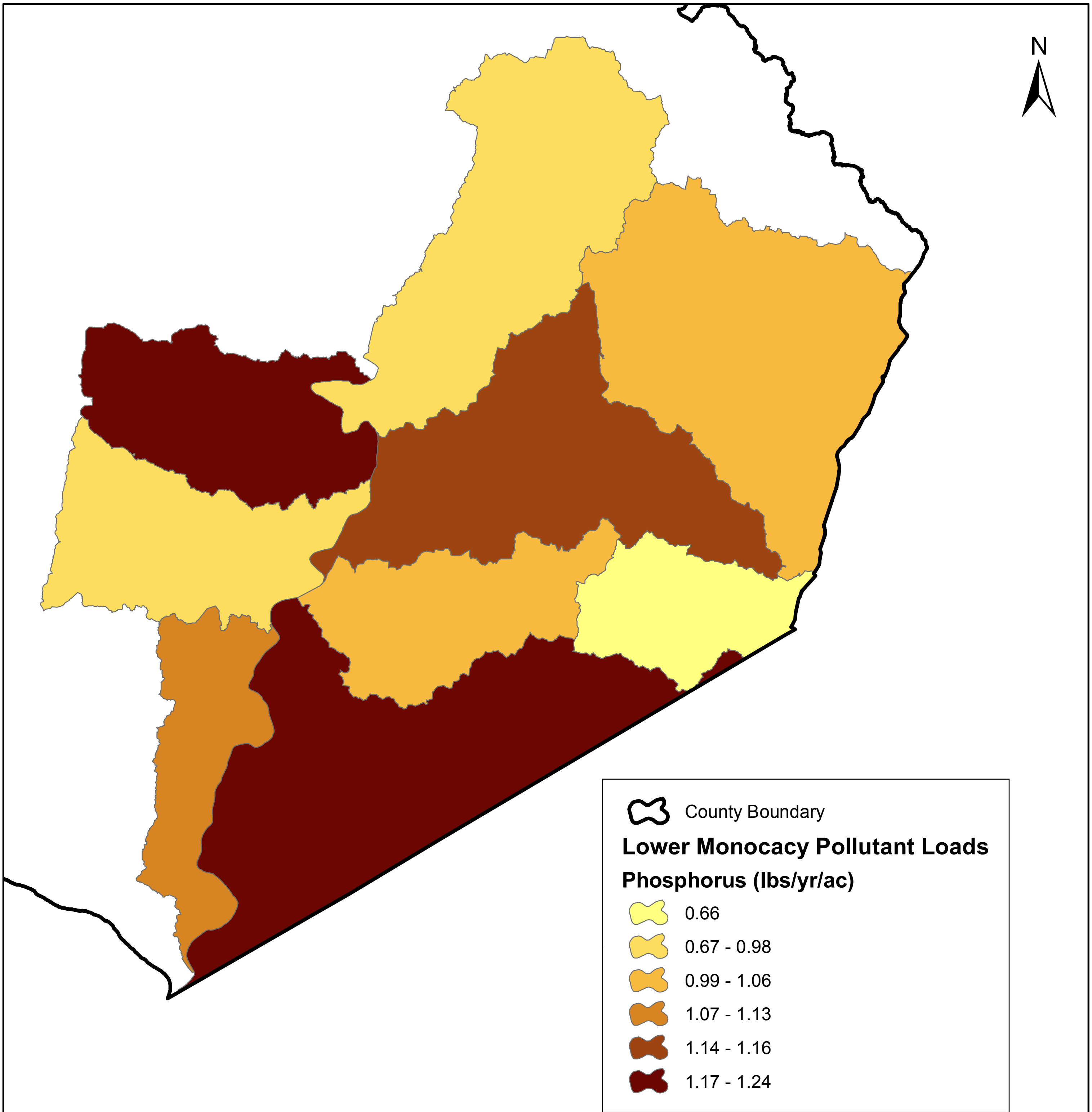
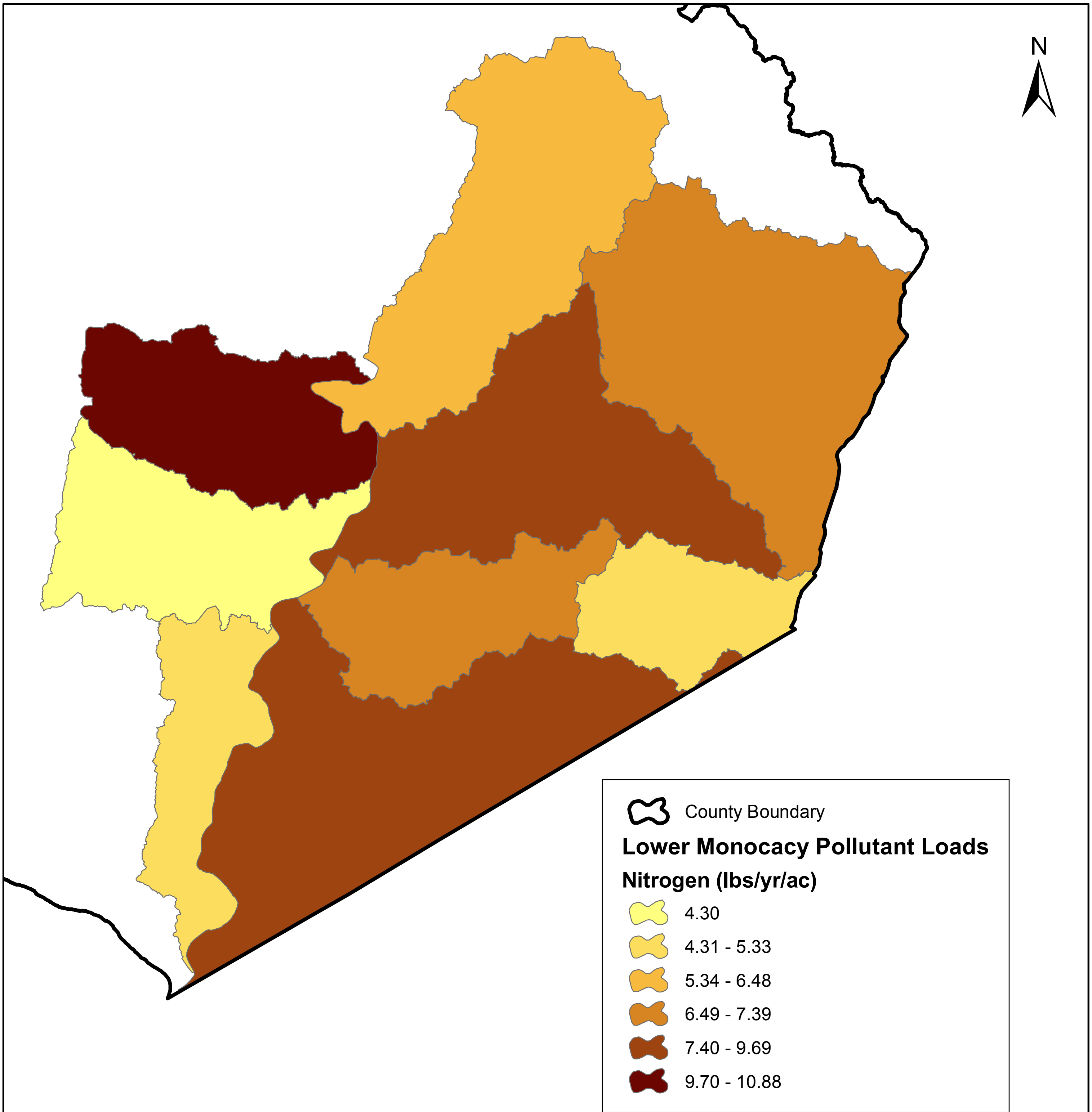


Map 46: Lower Monocacy Pollutant Loads Per Acre by Watershed Phosphorus (lbs/yr/ac)

Created by:
J. Hunicke
April 2008

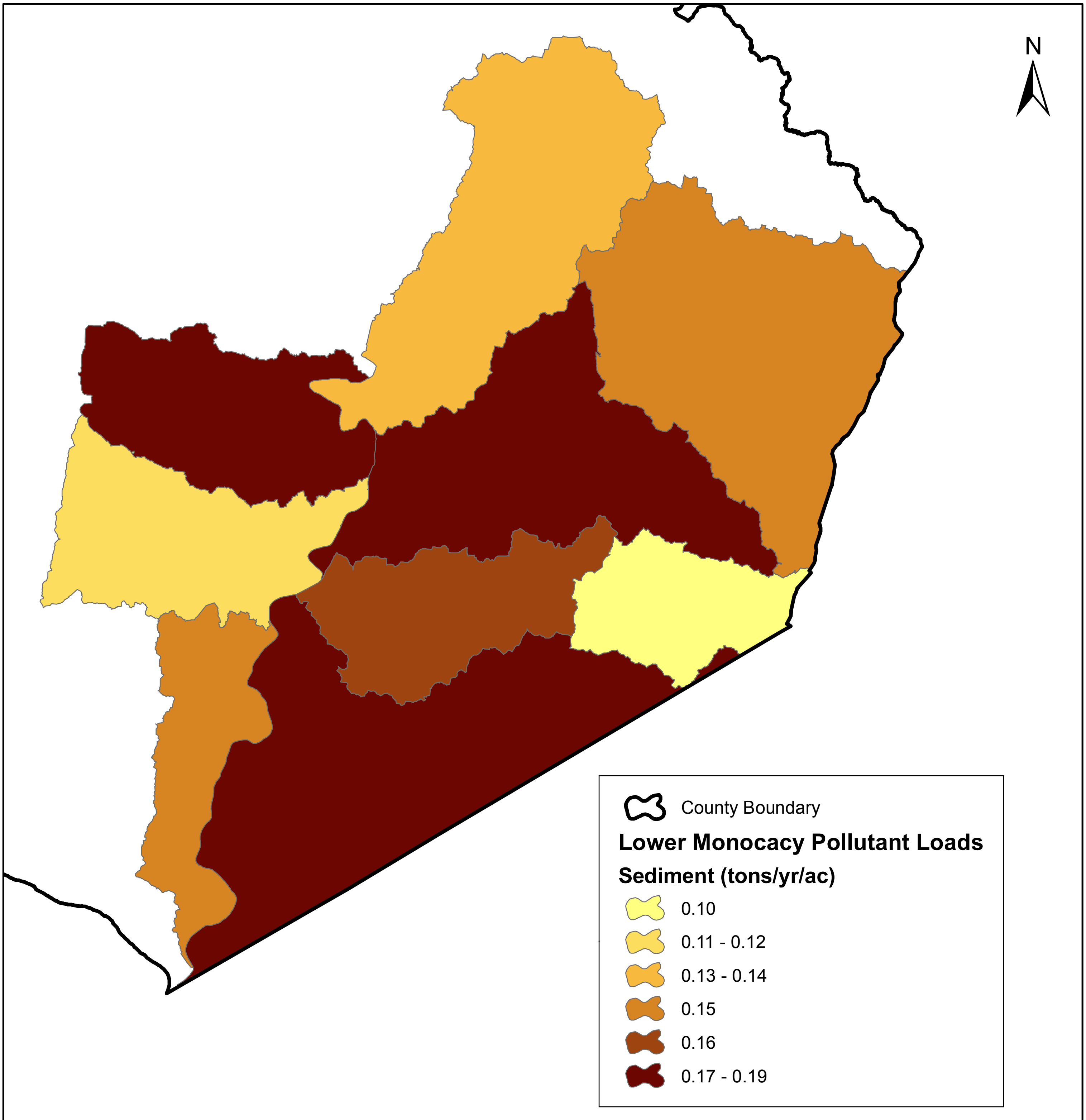
FREDERICK COUNTY, MARYLAND
1748



Map 47: Lower Monocacy Pollutant Loads Per Acre by Watershed Nitrogen (lbs/yr/ac)

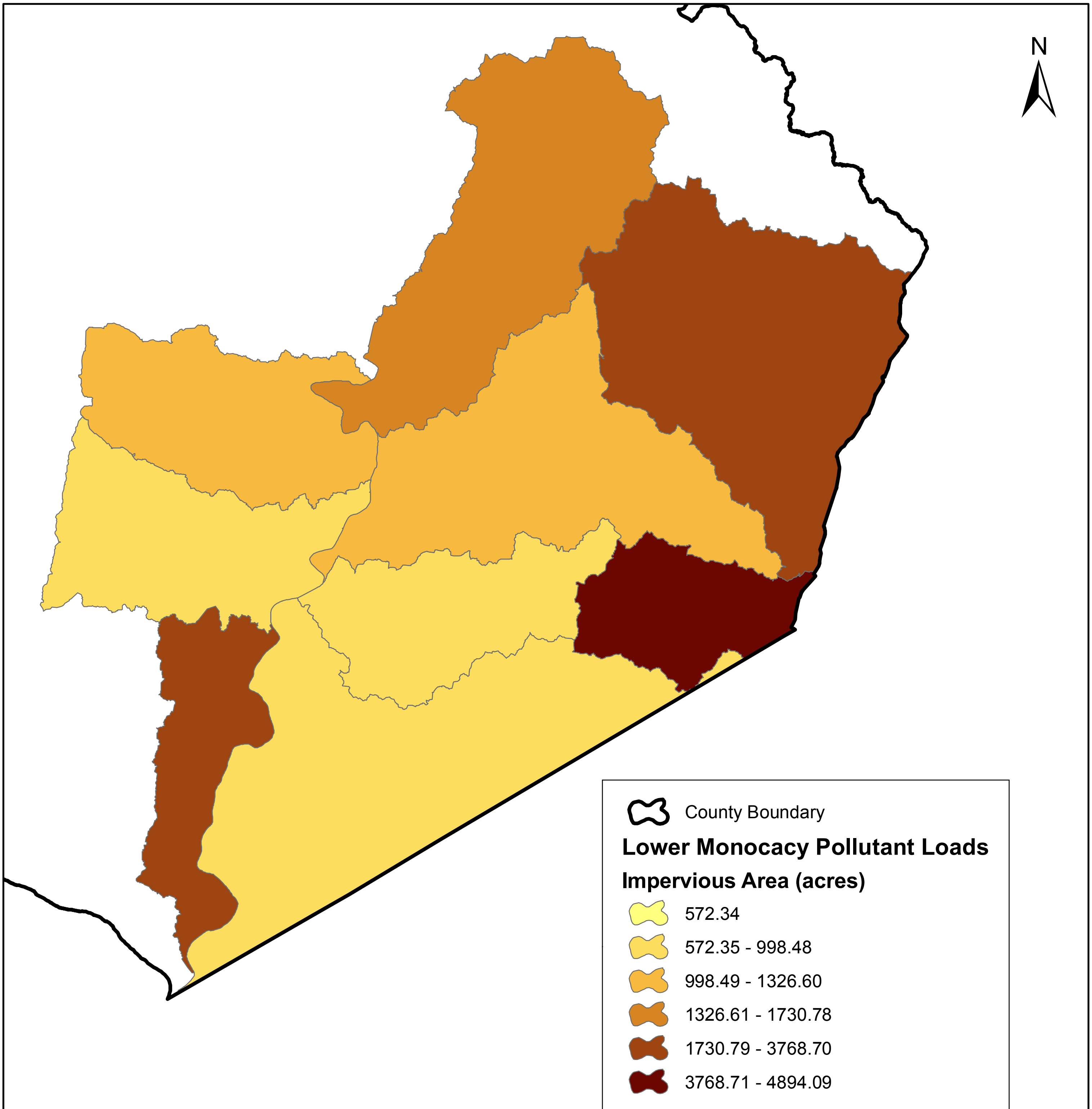
Created by:
J. Hunicke
April 2008

FREDERICK COUNTY, MARYLAND 1748



Map 48: Lower Monocacy Pollutant Loads Per Acre by Watershed Sediment (tons/yr)

Created by:
J. Hunicke
April 2008



Map 49: Lower Monocacy Impervious Area by Watershed (acres)

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April 2008

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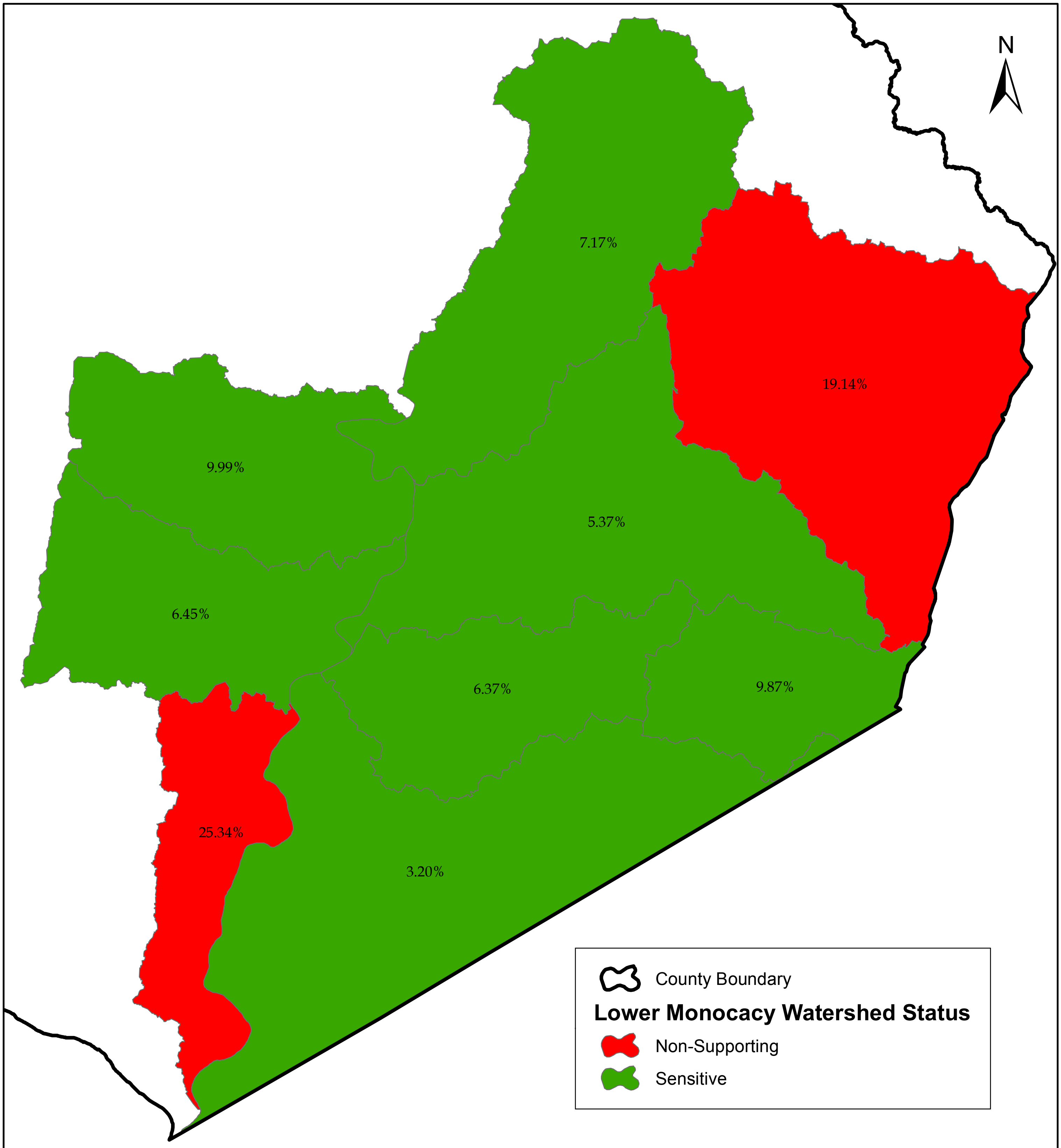

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April 2008

Map 50: Lower Monocacy Watershed Status

Appendix C: Bennett Creek Watershed Pollutant Loading Estimates

Pollutant Loads by Subwatershed

Table B-1 lists the pollutant loads for phosphorus, sediment, and nitrogen; the total impervious area in acres; percent impervious; and the stream status of each subwatershed within Bennett Creek.

The Bennett Creek subwatersheds are illustrated in Map 51. Estimated pollutant loadings per year by subwatershed for phosphorus, nitrogen, and sediment are illustrated in Maps 52-54. Estimated pollutant loadings per year, per acre for phosphorus, nitrogen, and sediment are illustrated in Maps 55-57. The estimated impervious area for each subwatershed is illustrated in Map 58. The stream status based on impervious area for each subwatershed is illustrated in Map 59. Maps 51-59 are included below.

Table B-1: Pollutant Loads and Imperviousness for the Bennett Creek Watershed by Subwatershed

Subwatershed	Watershed Area (acres)	Phosphorus (lbs/yr)	Phosphorus (lbs/yr/ac)	Nitrogen (lbs/yr)	Nitrogen (lbs/yr/ac)	Sediment (tons/yr)	Sediment (tons/yr/ac)	Impervious Area (acres)	Percent Impervious	Stream Status
Bear Branch	890.68	116.28	0.13	1836.19	2.06	33.31	0.04	14.84	1.67%	Sensitive
Fahrney Branch	4416.22	4657.59	1.05	36831.51	8.34	676.03	0.15	233.51	5.29%	Sensitive
Furnace Branch	1267.66	268.56	0.21	3535.94	2.79	62.35	0.05	25.39	2.00%	Sensitive
Lilypons	1617.34	2096.28	1.30	12387.92	7.66	331.13	0.20	212.27	13.12%	Impacted
Little Bennett Creek	1408.85	1243.09	0.88	7667.21	5.44	196.70	0.14	80.29	5.70%	Sensitive
Little Monocacy River	417.1	201.64	0.48	1625.46	3.90	37.44	0.09	8.23	1.97%	Sensitive
Lower Mainstem	2534.81	1539.8	0.61	9688.72	3.82	263.38	0.10	56.57	2.23%	Sensitive
Middle Mainstem	3276.07	3506.11	1.07	24375.16	7.44	548.42	0.17	315.49	9.63%	Sensitive
Monocacy Direct North	3798.12	3672.92	0.97	29532.62	7.78	567.82	0.15	191.88	5.05%	Sensitive
Monocacy Direct South	2654.95	1459.61	0.55	14211	5.35	253.09	0.10	154.57	5.82%	Sensitive
North Branch	899.27	927.79	1.03	6871.5	7.64	136.41	0.15	39.68	4.41%	Sensitive
Pleasant Branch	1289.18	1162.67	0.90	6285.98	4.88	123.47	0.10	98.39	7.63%	Sensitive
Sugarloaf	1977.39	1681.85	0.85	9285.5	4.70	283.82	0.14	33.5	1.69%	Sensitive
Upper Mainstem	2975.71	2557.94	0.86	16986.39	5.71	335.38	0.11	150.59	5.06%	Sensitive
Upper Mainstem B	337.1	291.87	0.87	1857.11	5.51	33.20	0.10	19.62	5.82%	Sensitive
Urbana Branch	881.13	1274.12	1.45	8498.52	9.65	176.35	0.20	50.99	5.79%	Sensitive

Pollutant Loads by Catchment

Table B-2 lists the pollutant loads for phosphorus, sediment, and nitrogen; the total impervious area in acres; percent impervious; and the stream status of each catchment within Bennett Creek.

The Bennett Creek catchments are illustrated in Map 60. Estimated pollutant loadings per year by catchment for phosphorus, nitrogen, and sediment are illustrated in Maps 61-63. Estimated pollutant loadings per year, per acre for phosphorus, nitrogen, and sediment are illustrated in Maps 64-66. The estimated impervious area for each catchment is illustrated in Map 67. The stream status based on impervious area for each catchment is illustrated in Map 68. Maps 60-68 are included below.

Table B-2: Pollutant Loads and Imperviousness for the Bennett Creek Watershed by Catchment

Catchment	Subwatershed	Watershed Area (acres)	Phosphorus (lbs/yr)	Phosphorus (lbs/yr/ac)	Nitrogen (lbs/yr)	Nitrogen (lbs/yr/ac)	Sediment (tons/yr)	Sediment (tons/yr/ac)	Impervious Areas (acres)	Percent Impervious	Stream Status
Bear Branch - A	Bear Branch	370.32	102.75	0.28	861.035	2.33	20.82	0.06	7.03	1.90%	Sensitive
Bear Branch - B	Bear Branch	520.36	13.53	0.03	975.15	1.87	12.49	0.02	7.81	1.50%	Sensitive
Bennett Creek - Lower Mainstem - A	Bennett Creek - Lower Mainstem	301.65	302.57	1.00	1647.03	5.46	46.97	0.16	14.17	4.70%	Sensitive
Bennett Creek - Lower Mainstem - B	Bennett Creek - Lower Mainstem	535.45	473.87	0.88	2323.79	4.34	76.12	0.14	12.09	2.26%	Sensitive
Bennett Creek - Lower Mainstem - C	Bennett Creek - Lower Mainstem	217.03	236.47	1.09	1391.3	6.41	34.87	0.16	6.52	3.00%	Sensitive
Bennett Creek - Lower Mainstem - D	Bennett Creek - Lower Mainstem	215.79	50.73	0.24	708.76	3.28	11.57	0.05	3.34	1.55%	Sensitive
Bennett Creek - Lower Mainstem - E	Bennett Creek - Lower Mainstem	480.25	347.07	0.72	1731.24	3.60	59.31	0.12	8.5	1.77%	Sensitive
Bennett Creek - Lower Mainstem - F	Bennett Creek - Lower Mainstem	442.73	26.25	0.06	858.98	1.94	12.78	0.03	6.66	1.50%	Sensitive
Bennett Creek - Lower Mainstem - G	Bennett Creek - Lower Mainstem	341.92	102.87	0.30	1027.69	3.01	21.77	0.06	5.29	1.55%	Sensitive
Bennett Creek - Middle Mainstem - A	Bennett Creek - Middle Mainstem	345.31	399.04	1.16	1838.83	5.33	62.34	0.18	7.86	2.28%	Sensitive
Bennett Creek - Middle Mainstem - B	Bennett Creek - Middle Mainstem	164.63	212.31	1.29	876.66	5.33	34.26	0.21	2.77	1.68%	Sensitive
Bennett Creek - Middle Mainstem - C	Bennett Creek - Middle Mainstem	233.08	297.48	1.28	2049.66	8.79	47.22	0.20	4.08	1.75%	Sensitive
Bennett Creek - Middle Mainstem - D	Bennett Creek - Middle Mainstem	348.63	400.65	1.15	3442.33	9.87	62.71	0.18	29.86	8.57%	Sensitive
Bennett Creek - Middle Mainstem - E	Bennett Creek - Middle Mainstem	270.45	362.02	1.34	2206.91	8.16	56.3	0.21	12.53	4.63%	Sensitive
Bennett Creek - Middle Mainstem - F	Bennett Creek - Middle Mainstem	295.46	292.03	0.99	2151.04	7.28	46.58	0.16	31.68	10.72%	Impacted
Bennett Creek - Middle Mainstem - G	Bennett Creek - Middle Mainstem	295.18	203.75	0.69	1956.12	6.63	31.72	0.11	7.3	2.47%	Sensitive
Bennett Creek - Middle Mainstem - H	Bennett Creek - Middle Mainstem	472.97	399.82	0.85	3336.47	7.05	59.18	0.13	120.8	25.54%	Non-Supporting

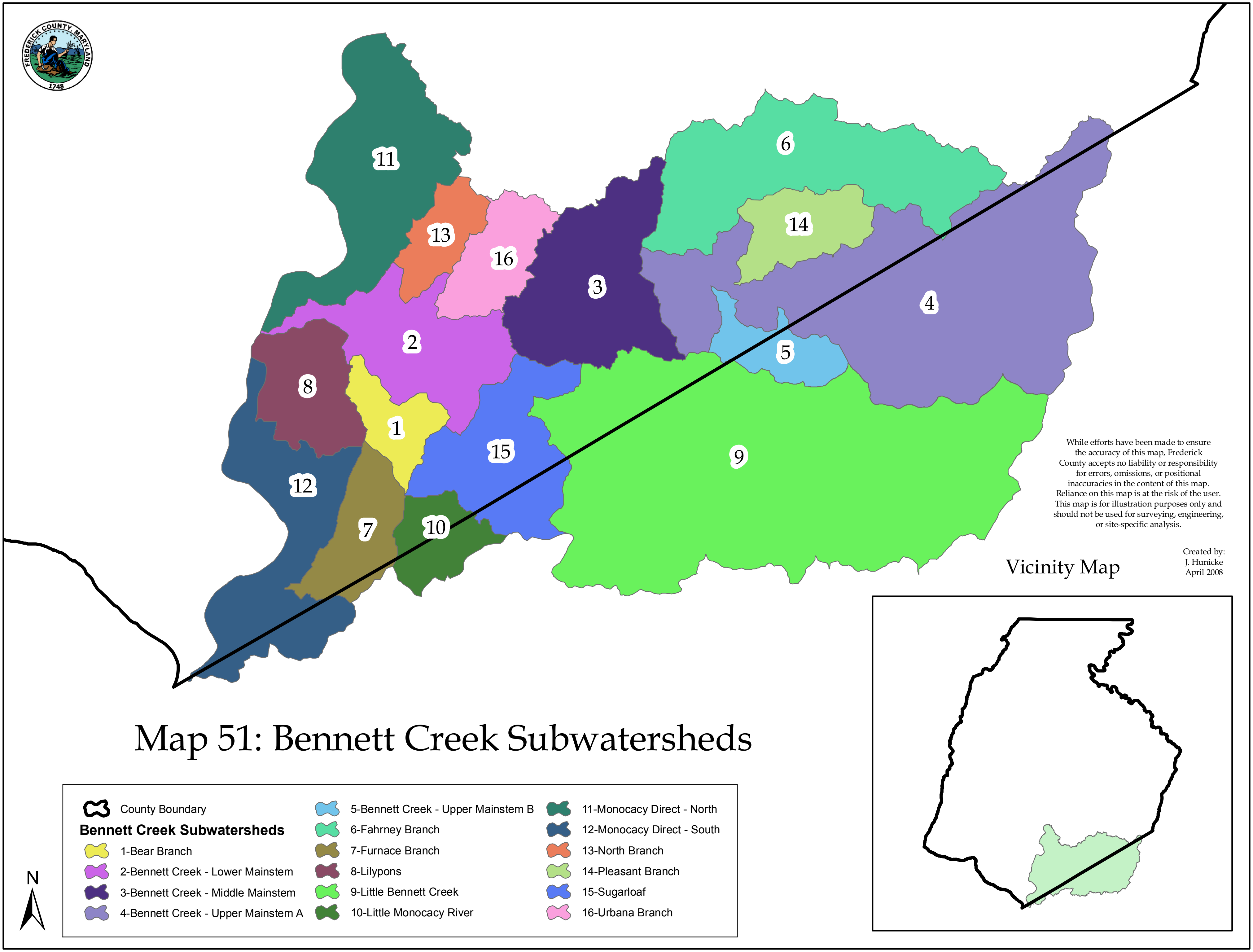
Catchment	Subwatershed	Watershed Area (acres)	Phosphorus (lbs/yr)	Phosphorus (lbs/yr/ac)	Nitrogen (lbs/yr)	Nitrogen (lbs/yr/ac)	Sediment (tons/yr)	Sediment (tons/yr/ac)	Impervious Areas (acres)	Percent Impervious	Stream Status
Bennett Creek - Middle Mainstem - I	Bennett Creek - Middle Mainstem	523.79	539.69	1.03	3947.36	7.54	85.26	0.16	91.02	17.38%	Non-Supporting
Bennett Creek - Middle Mainstem - J	Bennett Creek - Middle Mainstem	142.16	135.51	0.95	1243.59	8.75	21.33	0.15	2.97	2.09%	Sensitive
Bennett Creek - Middle Mainstem - k	Bennett Creek - Middle Mainstem	184.43	263.84	1.43	1326.43	7.19	41.51	0.23	4.61	2.50%	Sensitive
Bennett Creek - Upper Mainstem - A	Bennett Creek - Upper Mainstem	381.65	424.88	1.11	3444.01	9.02	67.96	0.18	6.98	1.83%	Sensitive
Bennett Creek - Upper Mainstem - B	Bennett Creek - Upper Mainstem	480.65	360.94	0.75	3222.54	6.70	53.34	0.11	18.47	3.84%	Sensitive
Bennett Creek - Upper Mainstem - C	Bennett Creek - Upper Mainstem	440.43	394.01	0.89	3507.45	7.96	58.73	0.13	12.18	2.76%	Sensitive
Bennett Creek - Upper Mainstem - D	Bennett Creek - Upper Mainstem	356.15	288.2	0.81	1437.91	4.04	33.06	0.09	21.12	5.93%	Sensitive
Bennett Creek - Upper Mainstem - E	Bennett Creek - Upper Mainstem	250.68	137.75	0.55	557.63	2.22	16.6	0.07	10.87	4.34%	Sensitive
Bennett Creek - Upper Mainstem - F	Bennett Creek - Upper Mainstem	343.76	255.99	0.74	1676.84	4.88	32.17	0.09	16.08	4.68%	Sensitive
Bennett Creek - Upper Mainstem - G	Bennett Creek - Upper Mainstem	336.34	313.55	0.93	1186.45	3.53	29.78	0.09	27.71	8.24%	Sensitive
Bennett Creek - Upper Mainstem - H	Bennett Creek - Upper Mainstem	160.53	144.97	0.90	1075.18	6.70	18.21	0.11	8.57	5.34%	Sensitive
Bennett Creek - Upper Mainstem - I	Bennett Creek - Upper Mainstem	47.62	76.67	1.61	223.46	4.69	10.28	0.22	9.31	19.54%	Non-Supporting
Bennett Creek - Upper Mainstem - J	Bennett Creek - Upper Mainstem	178.5	146.26	0.82	627.42	3.51	13.05	0.07	23.82	13.35%	Impacted
Bennett Creek - Upper Mainstem - K	Bennett Creek - Upper Mainstem	36.89	10.04	0.27	143.02	3.88	2.16	0.06	0.58	1.56%	Sensitive
Bennett Creek - Upper Mainstem - L	Bennett Creek - Upper Mainstem	300.36	281.92	0.94	1714.73	5.71	31.05	0.10	19.05	6.34%	Sensitive
Bennett Creek - Upper Mainstem - Z	Bennett Creek - Upper Mainstem	0.76	0.52	0.68	1.02	1.34	0.02	0.03	0.07	9.00%	Sensitive
Fahrney Branch - A	Fahrney Branch	306.75	300.3	0.98	2730	8.90	47.94	0.16	5.81	1.89%	Sensitive
Fahrney Branch - B	Fahrney Branch	427.43	509.21	1.19	4212.52	9.86	80.23	0.19	7.96	1.86%	Sensitive
Fahrney Branch - C	Fahrney Branch	294.66	281.73	0.96	2778.18	9.43	45.46	0.15	5.15	1.75%	Sensitive

Catchment	Subwatershed	Watershed Area (acres)	Phosphorus (lbs/yr)	Phosphorus (lbs/yr/ac)	Nitrogen (lbs/yr)	Nitrogen (lbs/yr/ac)	Sediment (tons/yr)	Sediment (tons/yr/ac)	Impervious Areas (acres)	Percent Impervious	Stream Status
Fahrney Branch - D	Fahrney Branch	215.59	353.43	1.64	2476.89	11.49	52.39	0.24	6.79	3.15%	Sensitive
Fahrney Branch - E	Fahrney Branch	228.61	286.54	1.25	2603.03	11.39	43.56	0.19	39.08	17.10%	Non-Supporting
Fahrney Branch - F	Fahrney Branch	533.4	434.2	0.81	3479.07	6.52	57.88	0.11	33.76	6.33%	Sensitive
Fahrney Branch - G	Fahrney Branch	376.25	307.99	0.82	1327.56	3.53	38.33	0.10	23.44	6.23%	Sensitive
Fahrney Branch - H	Fahrney Branch	374.82	270.18	0.72	1915.96	5.11	31.86	0.09	47.83	12.76%	Impacted
Fahrney Branch - I	Fahrney Branch	218.65	201.59	0.92	560.56	2.56	21.44	0.10	16.63	7.61%	Sensitive
Fahrney Branch - J	Fahrney Branch	251.64	310.94	1.24	2569.31	10.21	43.09	0.17	9.23	3.67%	Sensitive
Fahrney Branch - K	Fahrney Branch	189.04	216.96	1.15	1741.32	9.21	29.34	0.16	17.87	9.45%	Sensitive
Fahrney Branch - L	Fahrney Branch	270.02	256.62	0.95	2520.95	9.34	41.26	0.15	4.87	1.80%	Sensitive
Fahrney Branch - M	Fahrney Branch	384.7	493.83	1.28	4520.64	11.75	75.06	0.20	8.67	2.25%	Sensitive
Fahrney Branch - N	Fahrney Branch	344.66	434.06	1.26	3395.32	9.85	68.19	0.20	6.42	1.86%	Sensitive
Furnace Branch - A	Furnace Branch	166.14	24.84	0.15	478.27	2.88	6.87	0.04	2.54	1.53%	Sensitive
Furnace Branch - B	Furnace Branch	674.68	28.85	0.04	1245.67	1.85	16.01	0.02	16.05	2.38%	Sensitive
Furnace Branch - C	Furnace Branch	426.83	214.87	0.50	1811.98	4.25	39.47	0.09	6.79	1.59%	Sensitive
Lilypons - A	Lilypons	556.71	589.84	1.06	4979.09	8.94	91.63	0.16	193.76	34.80%	Non-Supporting
Lilypons - B	Lilypons	405.87	561.46	1.38	2169.96	5.35	90.09	0.22	7.05	1.74%	Sensitive
Lilypons - C	Lilypons	654.76	944.95	1.44	5238.8	8.00	149.4	0.23	11.46	1.75%	Sensitive
Little Bennett Creek - A	Little Bennett Creek	256.57	282.29	1.10	1273.67	4.96	45.52	0.18	4.85	1.89%	Sensitive
Little Bennett Creek - B	Little Bennett Creek	300.71	349.95	1.16	1604.81	5.34	54.7	0.18	6.81	2.27%	Sensitive

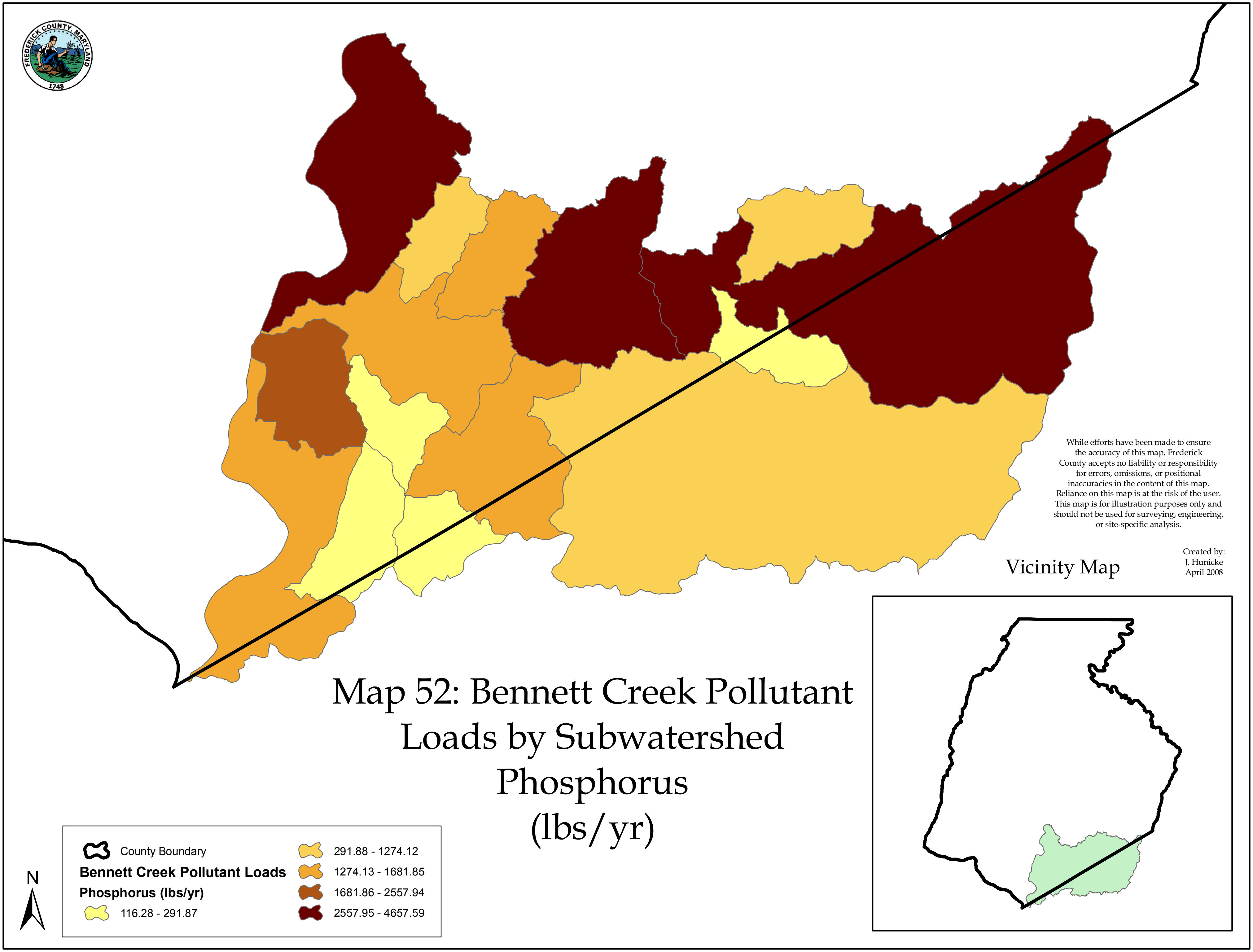
Catchment	Subwatershed	Watershed Area (acres)	Phosphorus (lbs/yr)	Phosphorus (lbs/yr/ac)	Nitrogen (lbs/yr)	Nitrogen (lbs/yr/ac)	Sediment (tons/yr)	Sediment (tons/yr/ac)	Impervious Areas (acres)	Percent Impervious	Stream Status
Little Bennett Creek - C	Little Bennett Creek	486.1	339.52	0.70	2430.43	5.00	53.8	0.11	30.46	6.27%	Sensitive
Little Bennett Creek - D	Little Bennett Creek	142.9	170.49	1.19	1536.06	10.75	25.76	0.18	29.54	20.68%	Non-Supporting
Little Bennett Creek - E	Little Bennett Creek	134	91.4	0.68	663	4.95	14.77	0.11	6.5	4.85%	Sensitive
Little Bennett Creek - F	Little Bennett Creek	79.6	9.44	0.12	143.21	1.80	1.96	0.02	2.03	2.55%	Sensitive
Little Bennett Creek - G	Little Bennett Creek	9.44	0.25	0.03	17.69	1.87	0.23	0.02	0.14	1.50%	Sensitive
Little Monocacy River - A	Little Monocacy River	162.37	119.08	0.73	530.33	3.27	20.68	0.13	4.22	2.60%	Sensitive
Little Monocacy River - B	Little Monocacy River	33.23	0.86	0.03	62.27	1.87	0.8	0.02	0.5	1.50%	Sensitive
Little Monocacy River - C	Little Monocacy River	221.6	81.76	0.37	1033.36	4.66	15.98	0.07	3.52	1.59%	Sensitive
Monocacy Direct - North - A	Monocacy Direct - North	419.32	455.52	1.09	3579.02	8.54	69.94	0.17	33.25	7.93%	Sensitive
Monocacy Direct - North - B	Monocacy Direct - North	431.86	183.67	0.43	1108.76	2.57	28.07	0.06	20.65	4.78%	Sensitive
Monocacy Direct - North - C	Monocacy Direct - North	340.15	435.29	1.28	1957.71	5.76	64.06	0.19	17.95	5.28%	Sensitive
Monocacy Direct - North - D	Monocacy Direct - North	241.42	192.17	0.80	1840.82	7.62	31.82	0.13	10.97	4.54%	Sensitive
Monocacy Direct - North - E	Monocacy Direct - North	197.4	28.77	0.15	566.51	2.87	7.23	0.04	38.3	19.40%	Non-Supporting
Monocacy Direct - North - F	Monocacy Direct - North	185.14	180.95	0.98	1553.99	8.39	28.85	0.16	25.52	13.79%	Impacted
Monocacy Direct - North - G	Monocacy Direct - North	362.38	434.01	1.20	4131.93	11.40	68.23	0.19	6.89	1.90%	Sensitive
Monocacy Direct - North - H	Monocacy Direct - North	429.44	408.09	0.95	3962.77	9.23	65.26	0.15	8.05	1.87%	Sensitive
Monocacy Direct - North - I	Monocacy Direct - North	336.13	460.36	1.37	4131.61	12.29	71.55	0.21	6.16	1.83%	Sensitive
Monocacy Direct - North - J	Monocacy Direct - North	324.5	166.54	0.51	1455.22	4.48	23.64	0.07	10.55	3.25%	Sensitive
Monocacy Direct - North - K	Monocacy Direct - North	242.43	350.1	1.44	1979.21	8.16	52.23	0.22	6.69	2.76%	Sensitive

Catchment	Subwatershed	Watershed Area (acres)	Phosphorus (lbs/yr)	Phosphorus (lbs/yr/ac)	Nitrogen (lbs/yr)	Nitrogen (lbs/yr/ac)	Sediment (tons/yr)	Sediment (tons/yr/ac)	Impervious Areas (acres)	Percent Impervious	Stream Status
Monocacy Direct - North - L	Monocacy Direct - North	287.96	377.44	1.31	3265.29	11.34	56.94	0.20	6.89	2.39%	Sensitive
Monocacy Direct - South - A	Monocacy Direct - South	124.4	82.28	0.66	629.1	5.06	13.89	0.11	20.41	16.40%	Non-Supporting
Monocacy Direct - South - B	Monocacy Direct - South	176.16	235.78	1.34	2210.46	12.55	36.65	0.21	3.23	1.83%	Sensitive
Monocacy Direct - South - C	Monocacy Direct - South	245.38	228.86	0.93	2271.91	9.26	36.68	0.15	21.77	8.87%	Sensitive
Monocacy Direct - South - D	Monocacy Direct - South	157.36	118.57	0.75	930.93	5.92	20.13	0.13	2.59	1.65%	Sensitive
Monocacy Direct - South - E	Monocacy Direct - South	162.28	-0.86	-0.01	266.17	1.64	2.67	0.02	24.13	14.87%	Impacted
Monocacy Direct - South - F	Monocacy Direct - South	474.18	178.46	0.38	1612.39	3.40	34.48	0.07	9.31	1.96%	Sensitive
Monocacy Direct - South - G	Monocacy Direct - South	415.49	288.21	0.69	2691.29	6.48	44.61	0.11	18.86	4.54%	Sensitive
Monocacy Direct - South - H	Monocacy Direct - South	340.86	101.83	0.30	1400.93	4.11	20.29	0.06	44.94	13.18%	Impacted
Monocacy Direct - South - I	Monocacy Direct - South	401.9	181.09	0.45	1591.53	3.96	34.13	0.08	6.35	1.58%	Sensitive
Monocacy Direct - South - J	Monocacy Direct - South	156.46	45.56	0.29	606.86	3.88	9.6	0.06	2.45	1.56%	Sensitive
North Branch - A	North Branch	267.04	236.43	0.89	1107.93	4.15	32.62	0.12	10.06	3.77%	Sensitive
North Branch - B	North Branch	261.61	267.61	1.02	2251.05	8.60	40.12	0.15	8.02	3.07%	Sensitive
North Branch - C	North Branch	229.7	233.91	1.02	2477.01	10.78	35.86	0.16	14.58	6.35%	Sensitive
North Branch - D	North Branch	140.9	189.82	1.35	1035.27	7.35	27.81	0.20	7.02	4.98%	Sensitive
Pleasant Branch - A	Pleasant Branch	437.86	434.32	0.99	2879.36	6.58	54.67	0.12	22.99	5.25%	Sensitive
Pleasant Branch - B	Pleasant Branch	398.14	372.49	0.94	1493.29	3.75	35.6	0.09	43.17	10.84%	Impacted
Pleasant Branch - C	Pleasant Branch	453.19	355.88	0.79	1913.27	4.22	33.2	0.07	32.23	7.11%	Sensitive
Sugarloaf - A	Sugarloaf	328.45	371.1	1.13	1470.99	4.48	60.03	0.18	6.06	1.85%	Sensitive

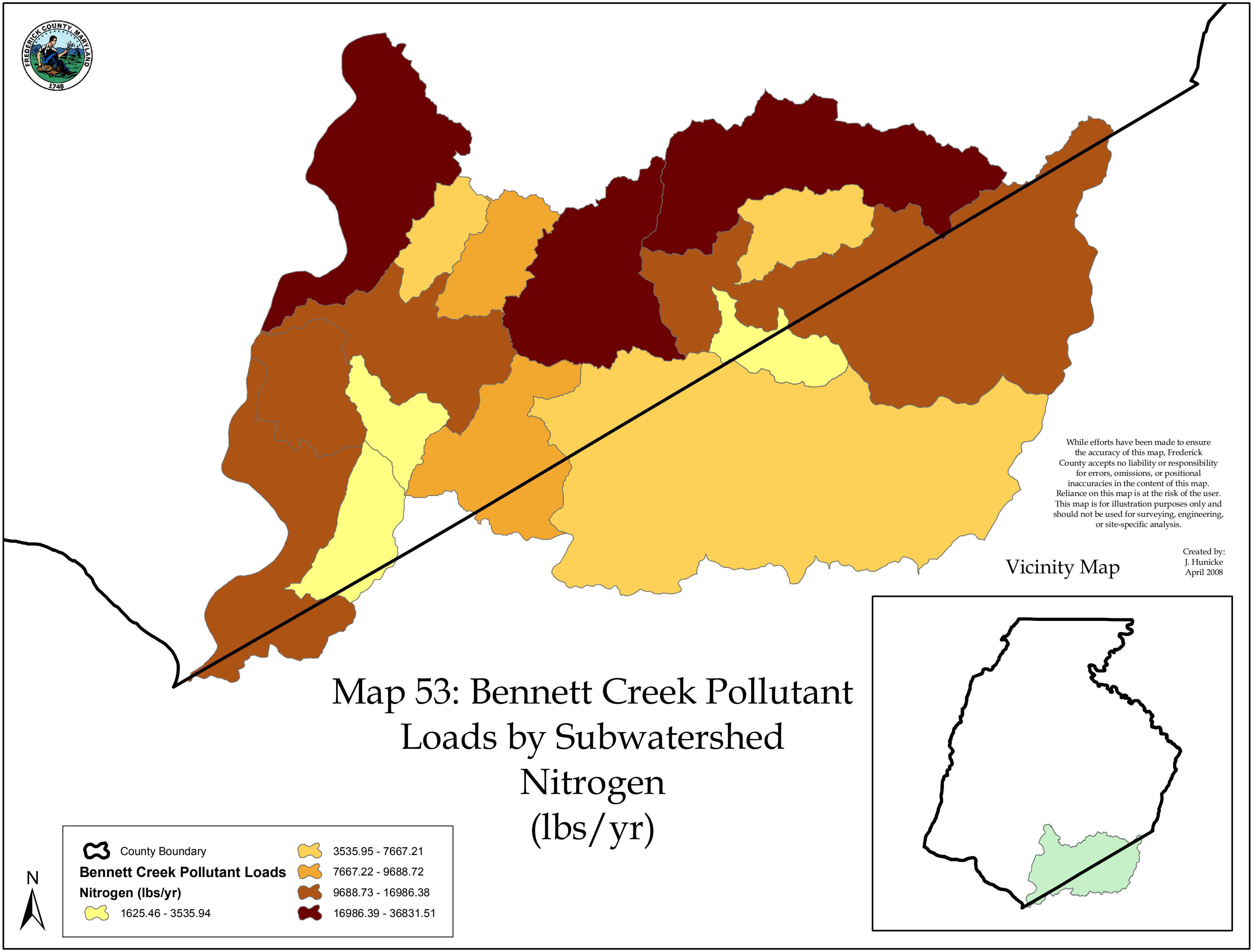
Catchment	Subwatershed	Watershed Area (acres)	Phosphorus (lbs/yr)	Phosphorus (lbs/yr/ac)	Nitrogen (lbs/yr)	Nitrogen (lbs/yr/ac)	Sediment (tons/yr)	Sediment (tons/yr/ac)	Impervious Areas (acres)	Percent Impervious	Stream Status
Sugarloaf - B	Sugarloaf	389.56	167.23	0.43	1203.83	3.09	31.8	0.08	7.63	1.96%	Sensitive
Sugarloaf - C	Sugarloaf	388.57	470.55	1.21	2154.85	5.55	76.23	0.20	6.53	1.68%	Sensitive
Sugarloaf - D	Sugarloaf	237.87	282.66	1.19	1410.01	5.93	42.93	0.18	6.27	2.63%	Sensitive
Sugarloaf - E	Sugarloaf	113.75	234.1	2.06	730.86	6.43	36.52	0.32	2.02	1.77%	Sensitive
Sugarloaf - F	Sugarloaf	113.71	149.54	1.32	1332	11.71	23.36	0.21	2.06	1.81%	Sensitive
Sugarloaf - G	Sugarloaf	448.56	36.53	0.08	1042.86	2.32	14.25	0.03	6.79	1.51%	Sensitive
Urbana Branch - A	Urbana Branch	191.16	55.01	0.29	475.52	2.49	8.19	0.04	5.87	3.07%	Sensitive
Urbana Branch - B	Urbana Branch	219.52	213.47	0.97	1206.2	5.49	26.42	0.12	10.68	4.86%	Sensitive
Urbana Branch - C	Urbana Branch	533.11	649.58	1.22	5161.47	9.68	95.34	0.18	32.01	6.00%	Sensitive
Urbana Branch - D	Urbana Branch	330.12	366.25	1.11	2391.27	7.24	55.82	0.17	8.32	2.52%	Sensitive



Map 51: Bennett Creek Subwatersheds



Map 52: Bennett Creek Pollutant Loads by Subwatershed Phosphorus (lbs/yr)


FREDERICK COUNTY MARYLAND
1748
Map 53: Bennett Creek Pollutant Loads by Subwatershed Nitrogen (lbs/yr)
County Boundary
Bennett Creek Pollutant Loads
Nitrogen (lbs/yr)
1625.46 - 3535.94
3535.95 - 7667.21
7667.22 - 9688.72
9688.73 - 16986.38
16986.39 - 36831.51
N
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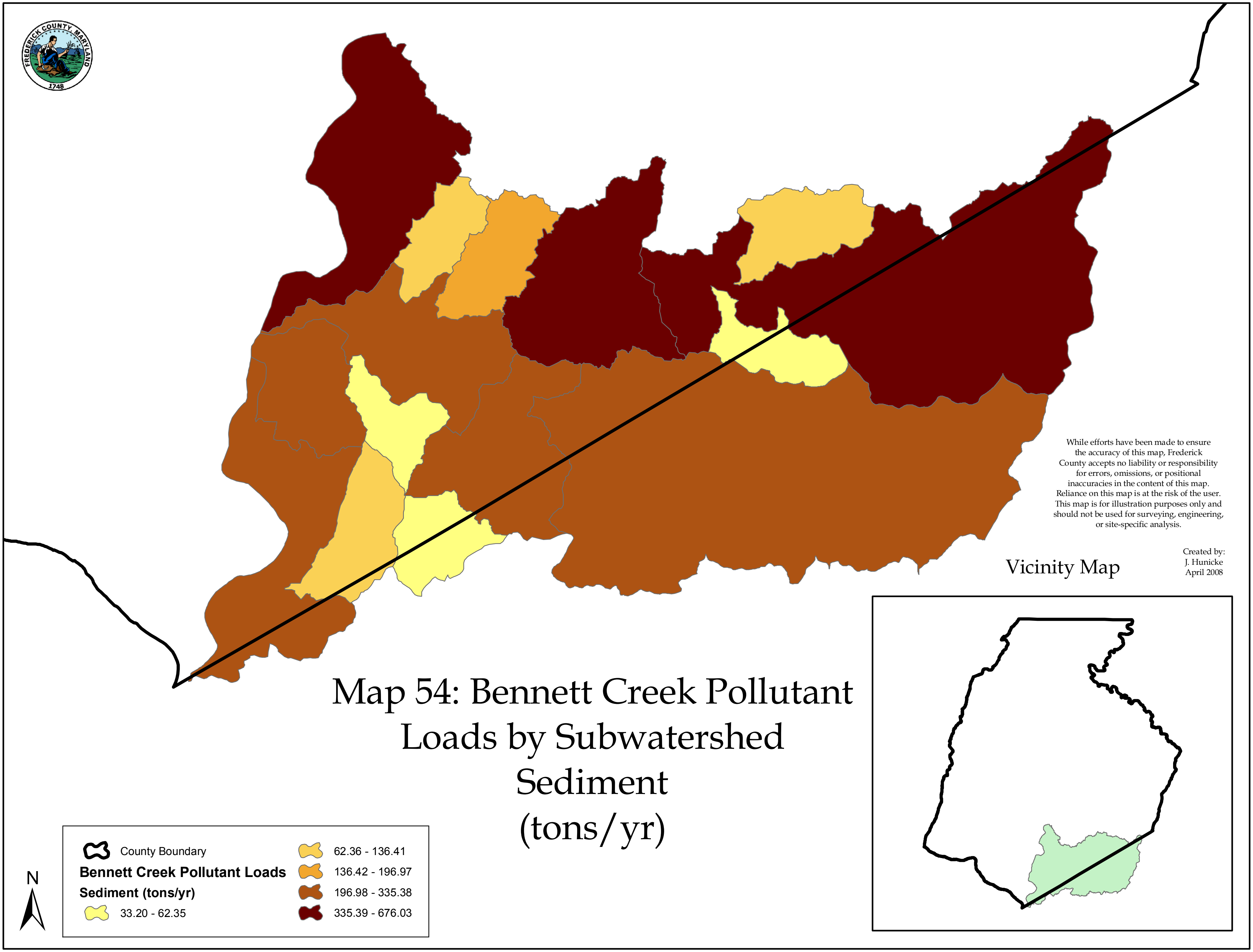
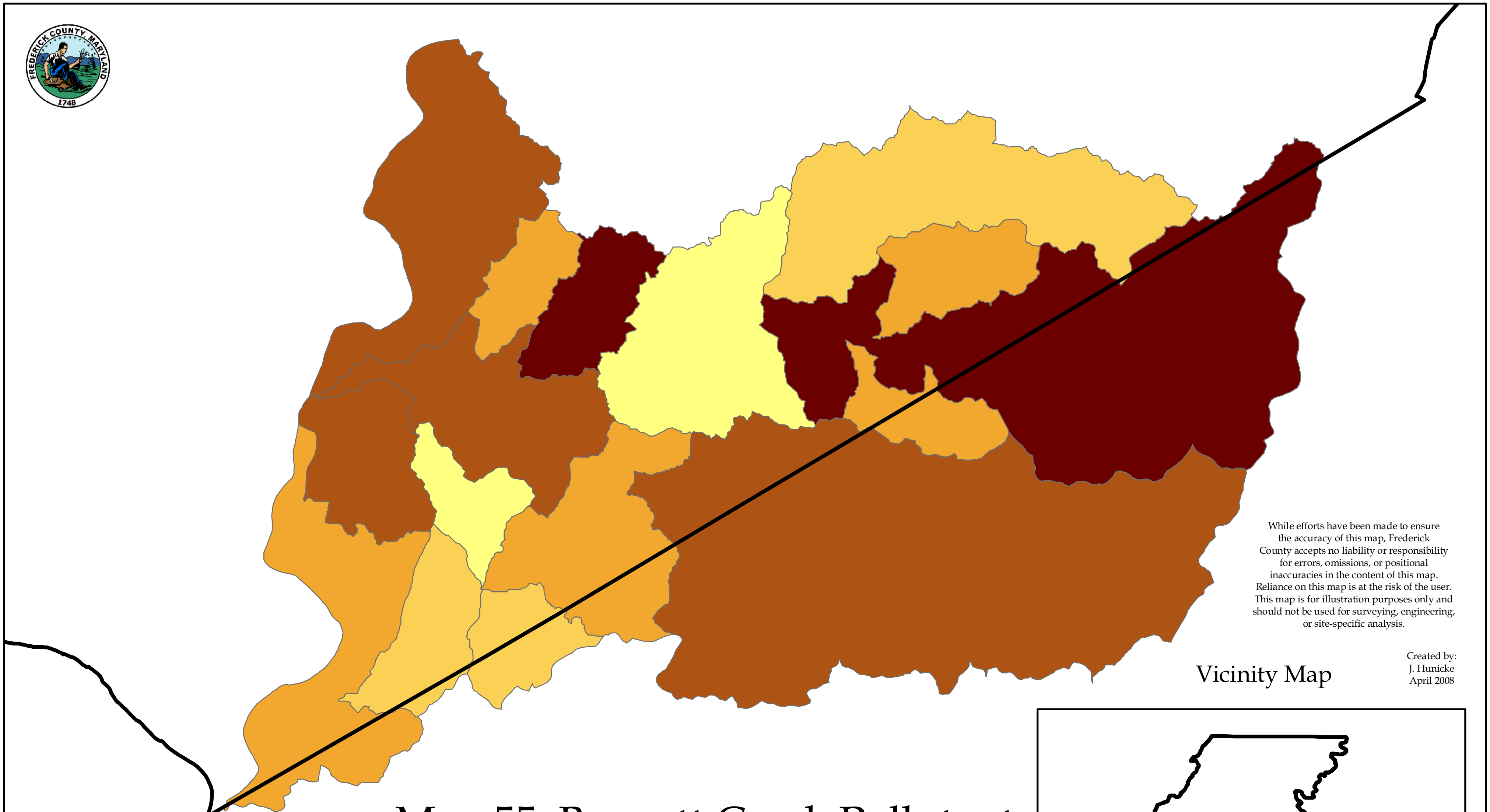
Vicinity Map
Created by:
J. Hunicke
April 2008



Map 54: Bennett Creek Pollutant Loads by Subwatershed Sediment (tons/yr)



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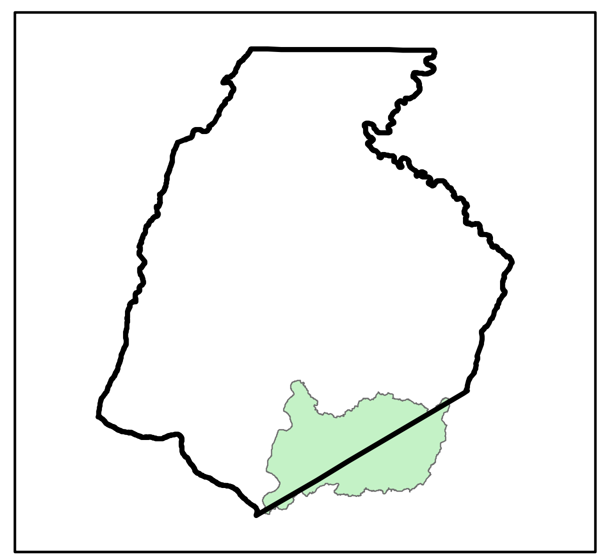
Created by:
J. Hunicke
April 2008

Vicinity Map



Map 55: Bennett Creek Pollutant Loads Per Acre by Subwatershed Phosphorus (lbs/yr/ac)

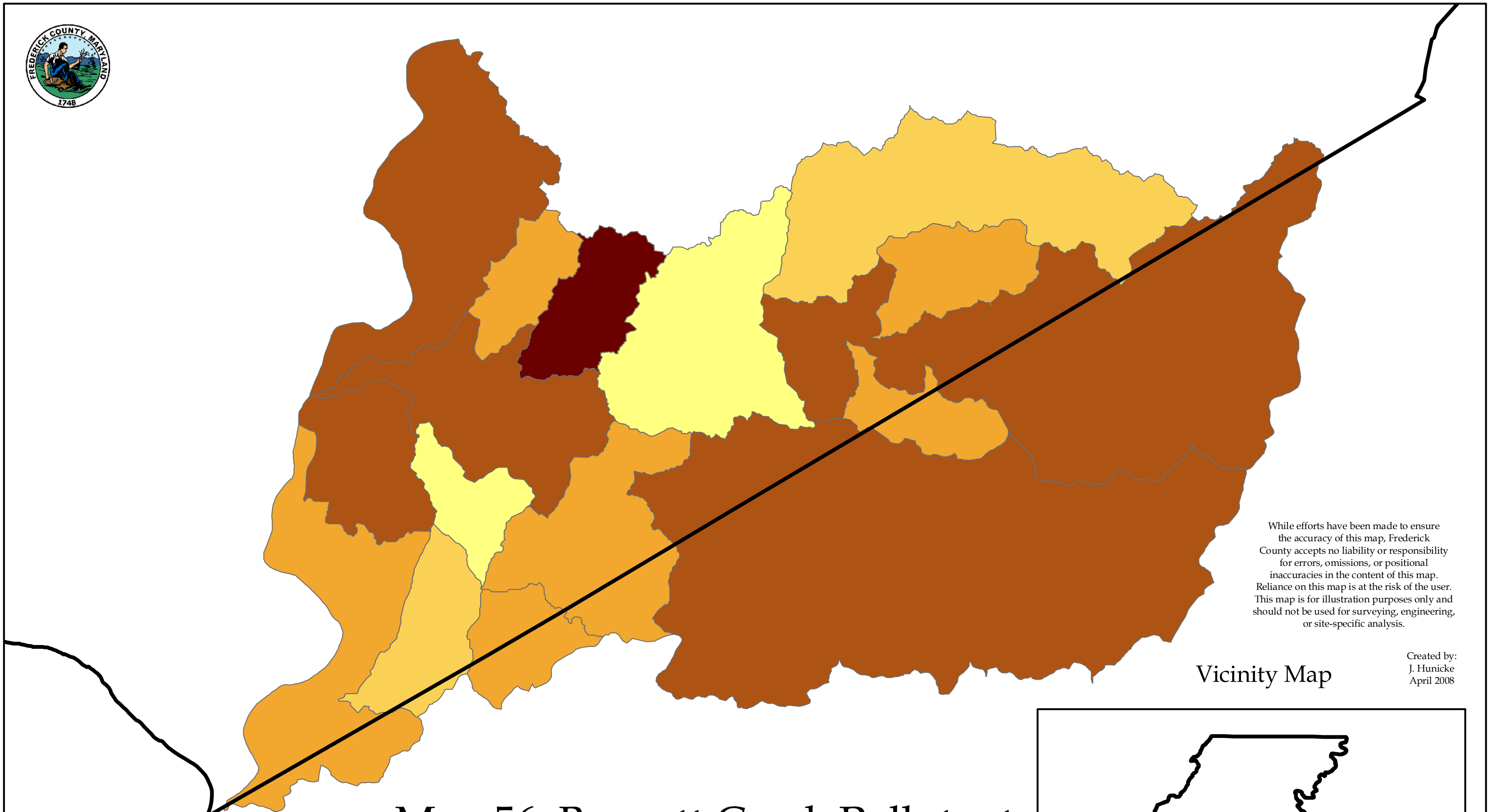
County Boundary

Bennett Creek Pollutant Loads

Phosphorus (lbs/yr/ac)

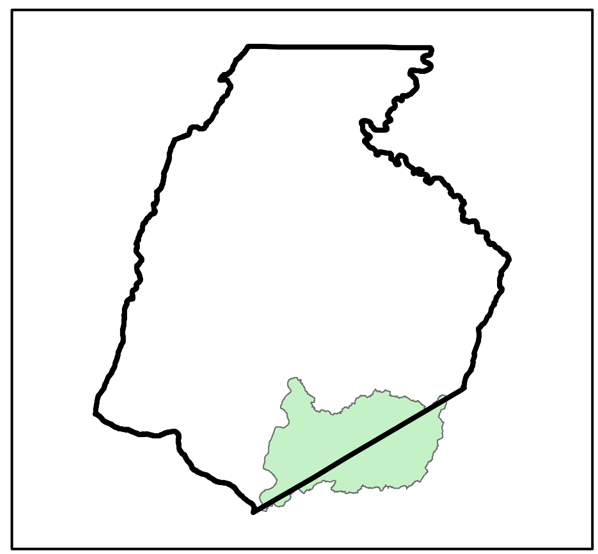
- 0.13 - 0.21
- 0.22 - 0.61
- 0.62 - 0.90
- 0.91 - 1.07
- 1.08 - 1.45

N



Map 56: Bennett Creek Pollutant Loads Per Acre by Subwatershed Nitrogen (lbs/yr/ac)

Vicinity Map

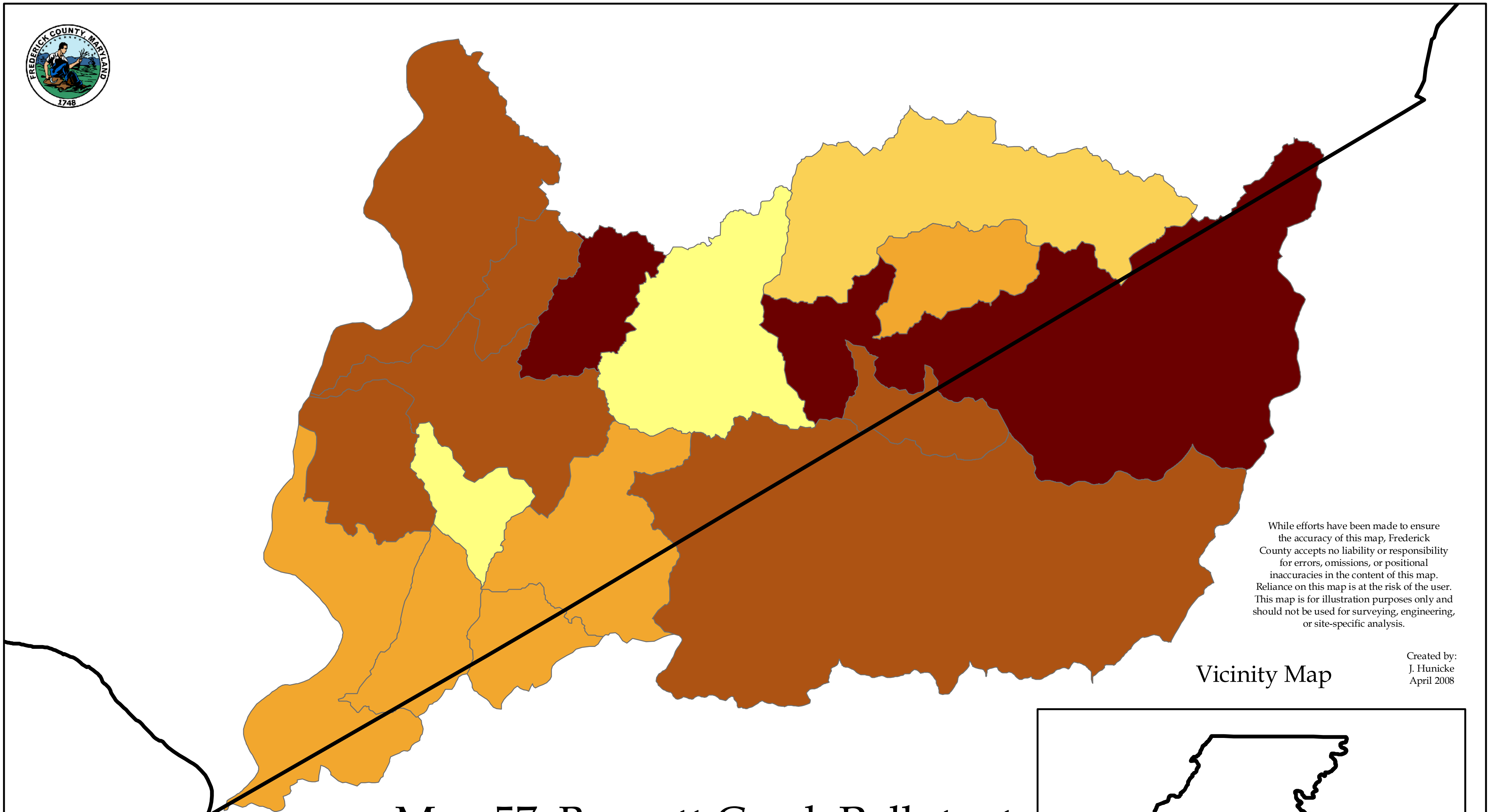


County Boundary

Bennett Creek Pollutant Loads Nitrogen (lbs/yr/ac)

- 2.06 - 2.79
- 2.80 - 3.90
- 3.91 - 5.71
- 5.72 - 8.34
- 8.35 - 9.65

N



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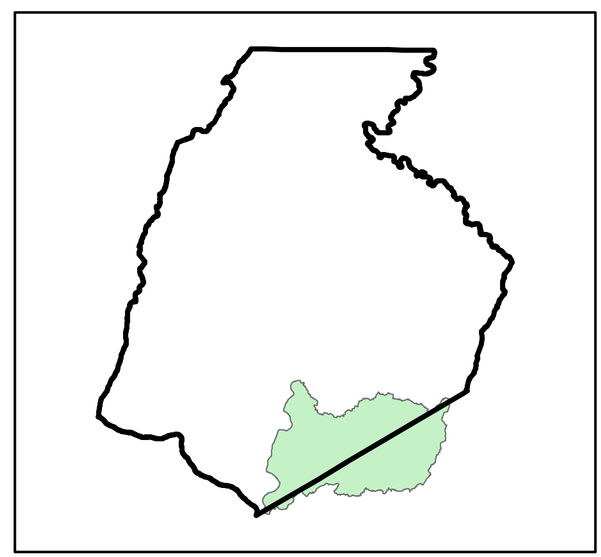
Vicinity Map



Created by:
J. Hunicke
April 2008

Map 57: Bennett Creek Pollutant Loads Per Acre by Subwatershed Sediment (tons/yr/ac)

County Boundary

Bennett Creek Pollutant Loads

Sediment (tons/yr/ac)

0.04 - 0.05

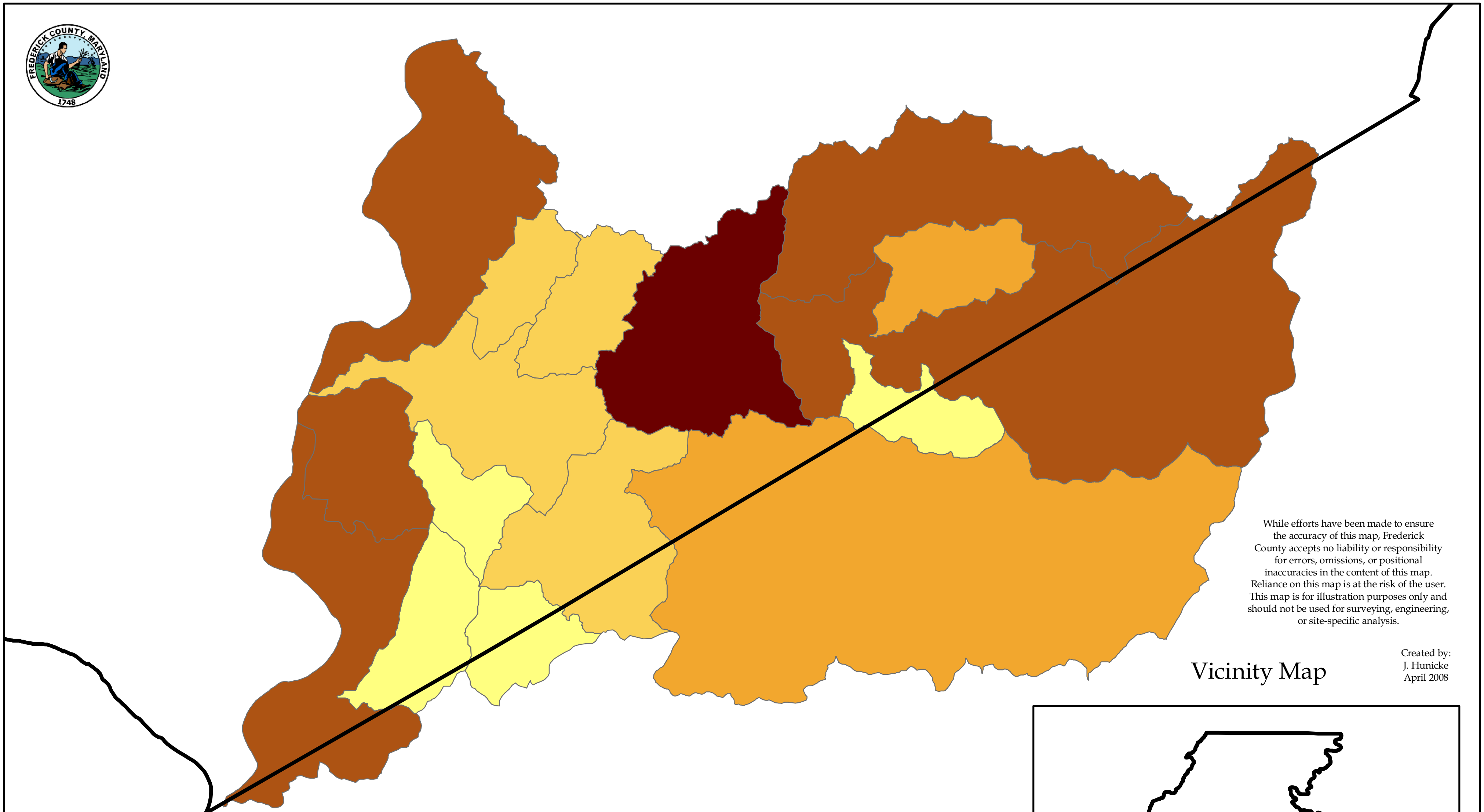
0.06 - 0.09

0.10 - 0.11

0.12 - 0.17

0.18 - 0.20

N



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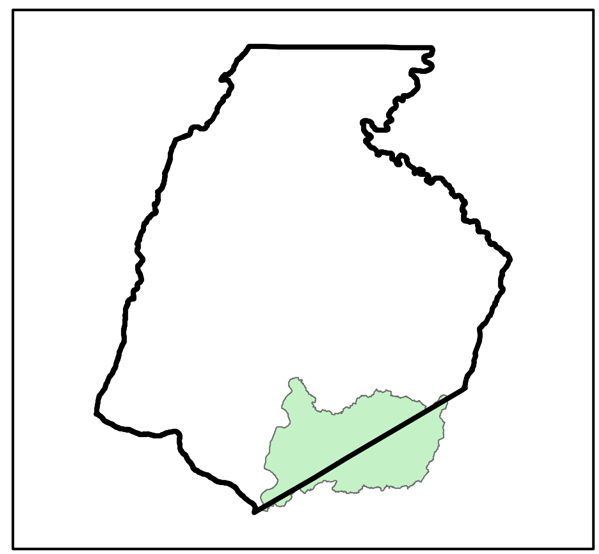
Vicinity Map



Map 58: Bennett Creek Impervious Area by Subwatershed (acres)

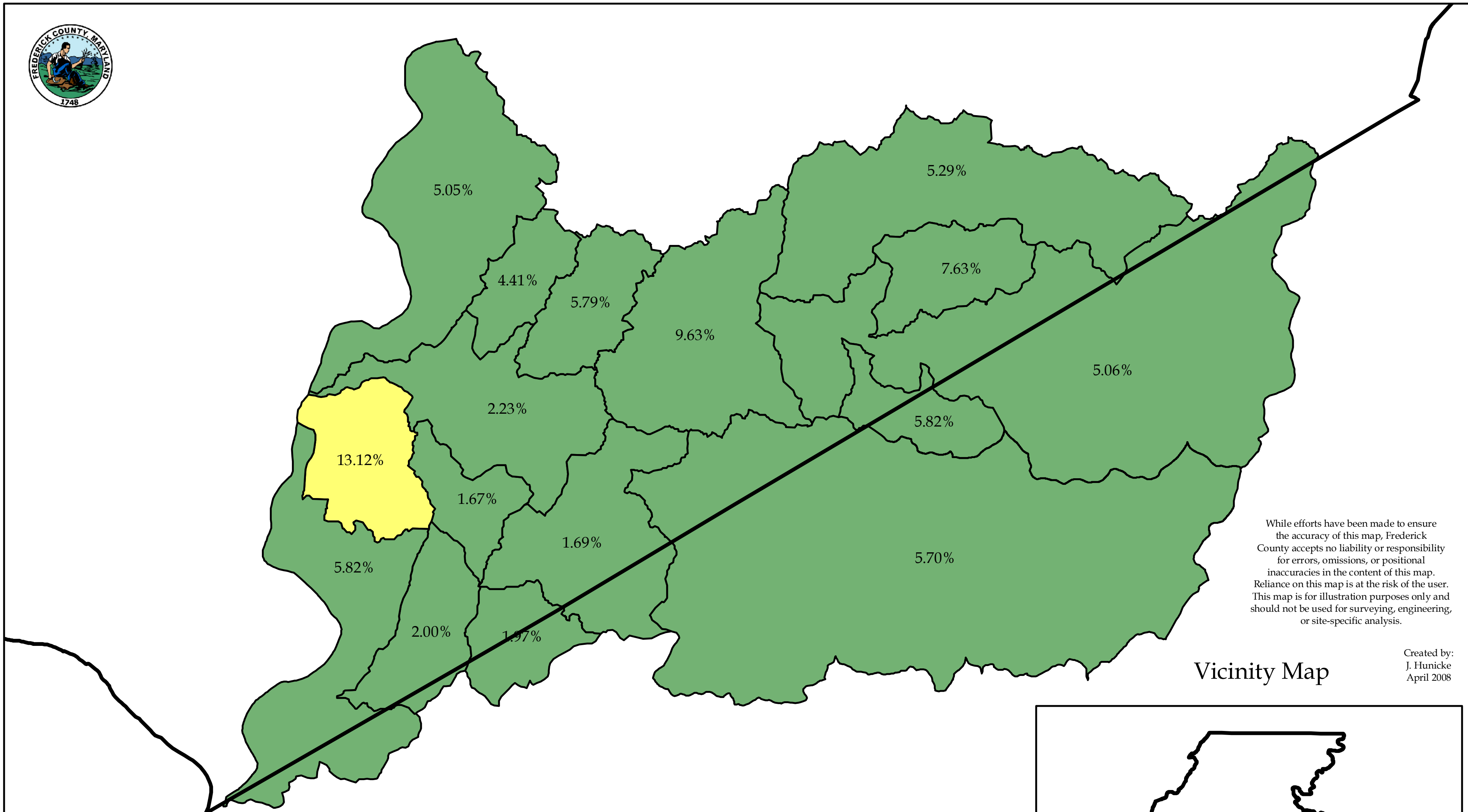
County Boundary

Bennett Creek Pollutant Loads

Impervious Area (acres)

- 8.23 - 25.39
- 25.40 - 56.57
- 56.58 - 98.39
- 98.40 - 233.51
- 233.52 - 315.49

N



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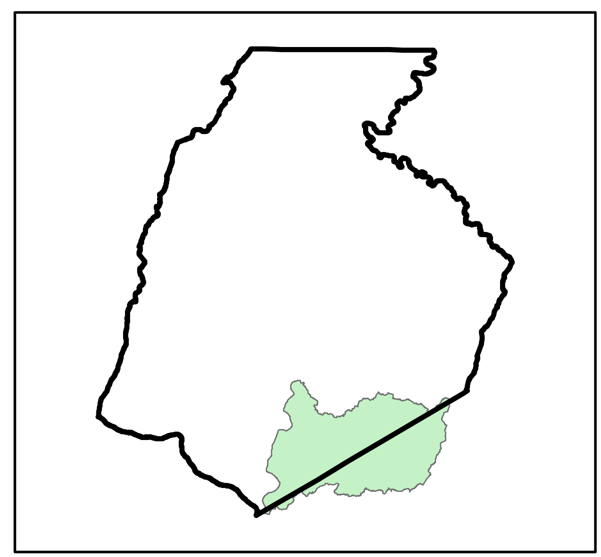
Vicinity Map

Created by:
J. Hunicke
April 2008



Map 59: Bennett Creek Subwatershed Status

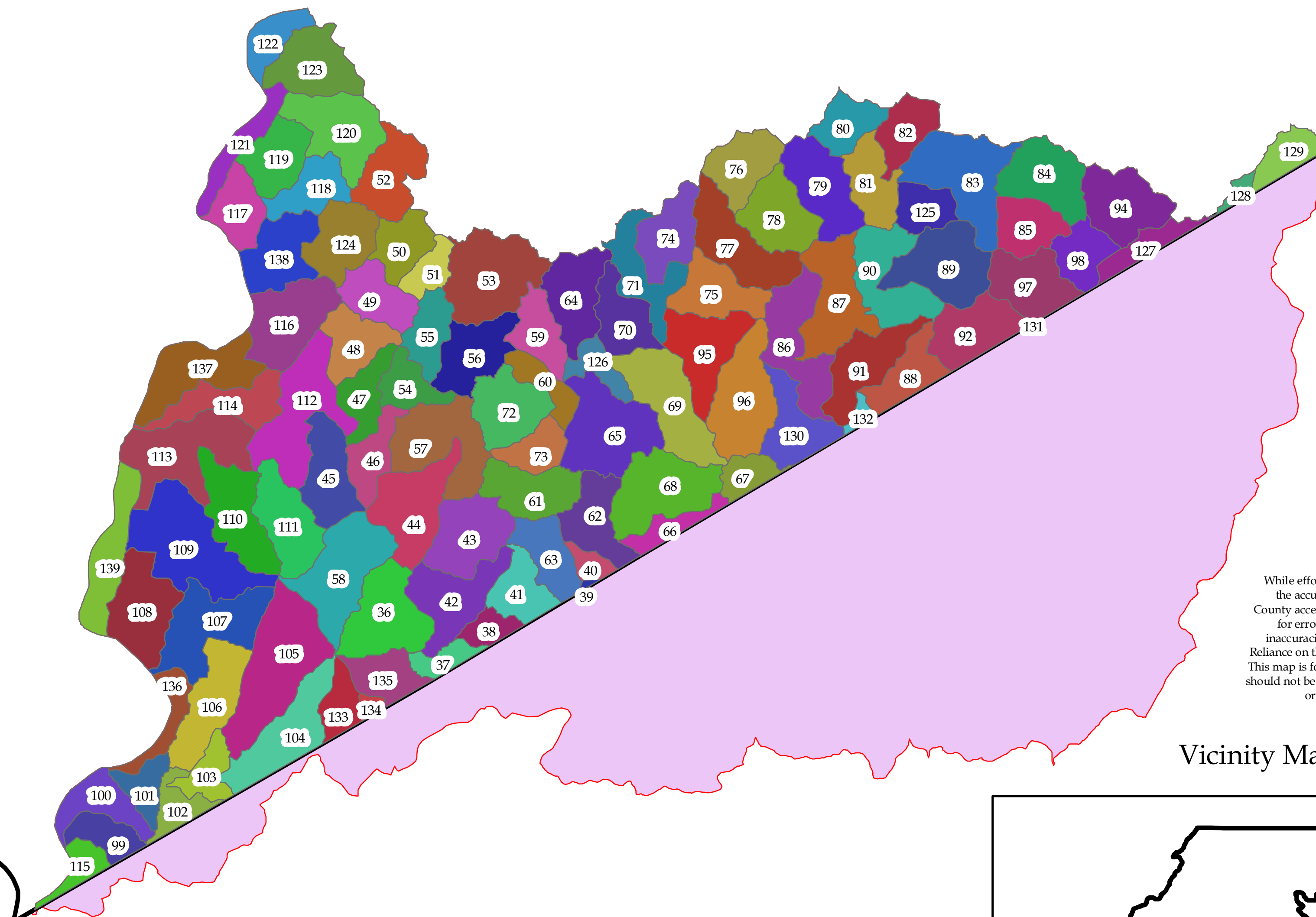
N

County Boundary

Bennett Creek Subwatershed Status

Impacted

Sensitive



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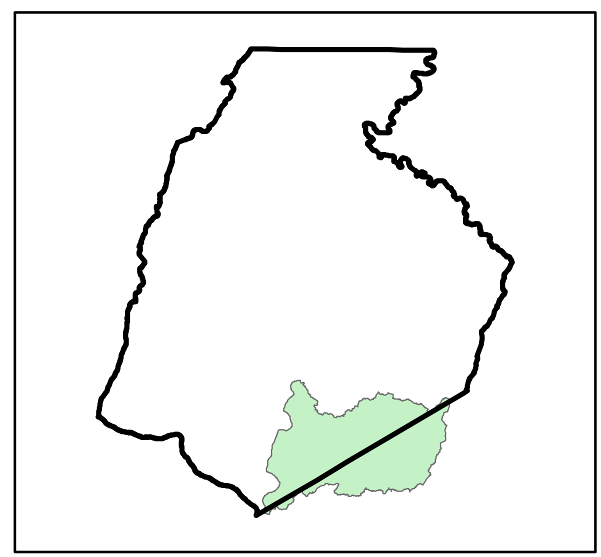
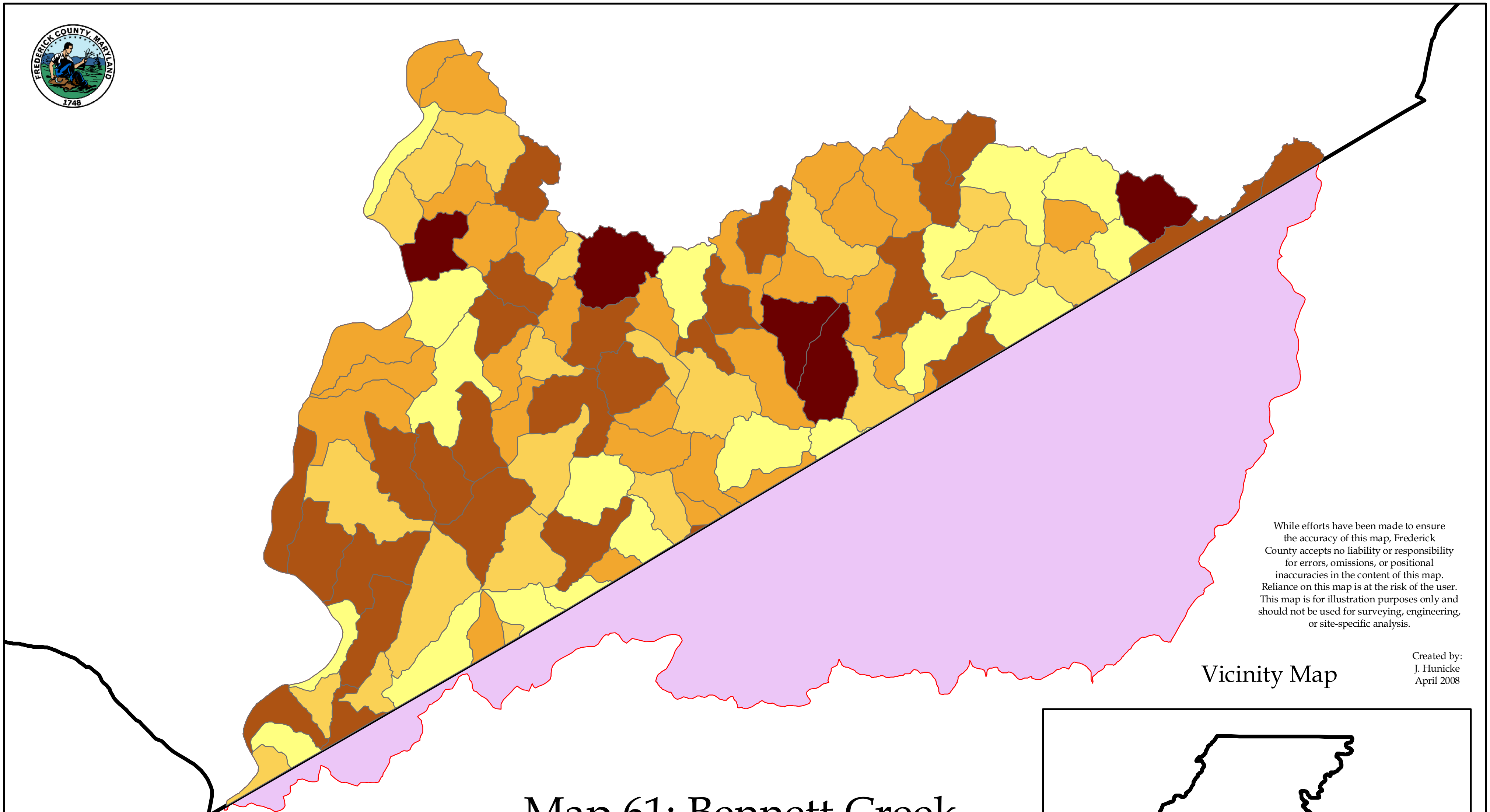
Vicinity Map

Created by:
J. Hunicke
April 2008



Map 60: Bennett Creek Catchments

N



Map 61: Bennett Creek Pollutant Loads by Catchment Phosphorus (lbs/yr)

County Boundary
Bennett Creek Outside of Frederick County

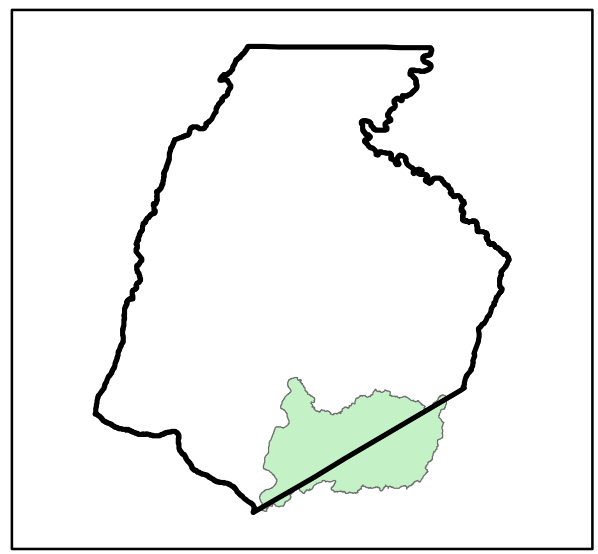
Bennett Creek Pollutant Loads

Phosphorus (lbs/yr)

- -0.86 - 91.40
- 91.41 - 203.75
- 203.76 - 313.55
- 313.56 - 509.21
- 509.22 - 944.95

N

Vicinity Map



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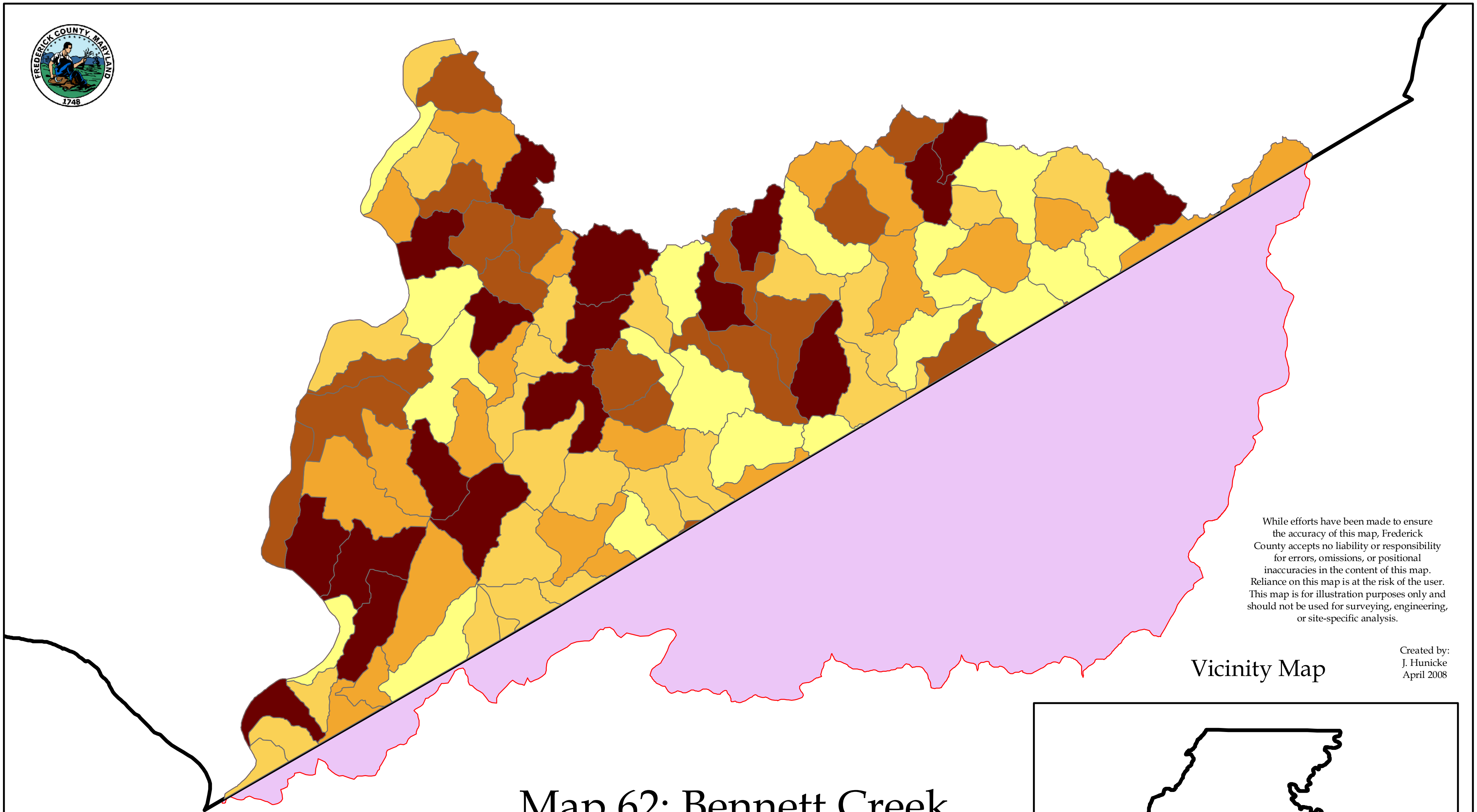

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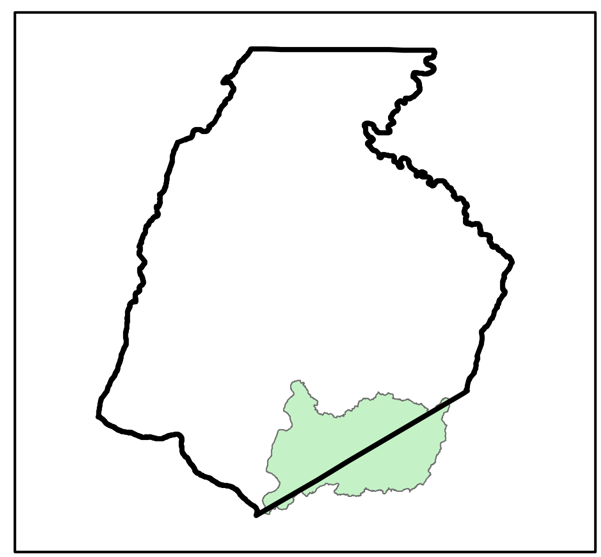


Map 62: Bennett Creek Pollutant Loads by Catchment Nitrogen (lbs/yr)

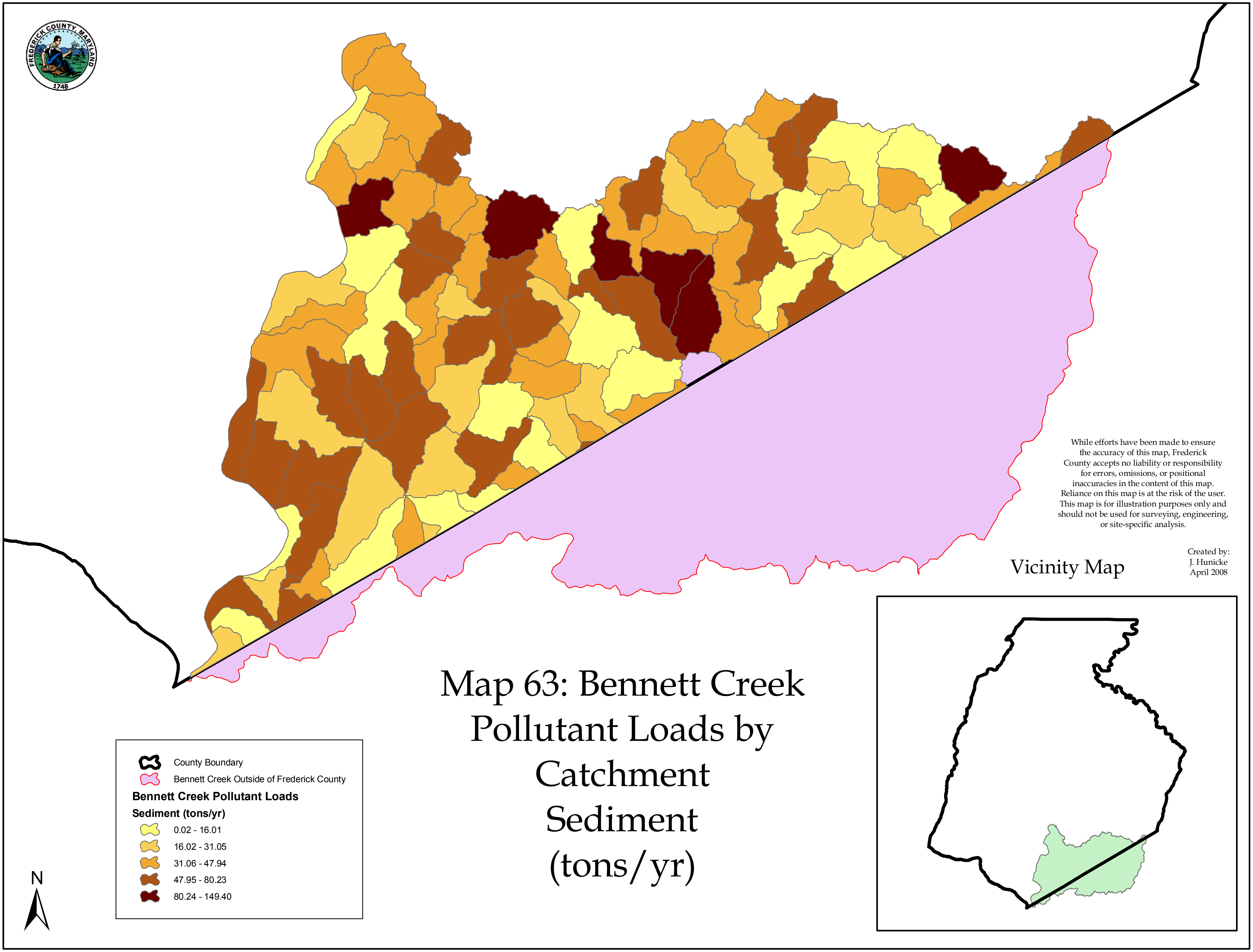
County Boundary
Bennett Creek Outside of Frederick County

Bennett Creek Pollutant Loads

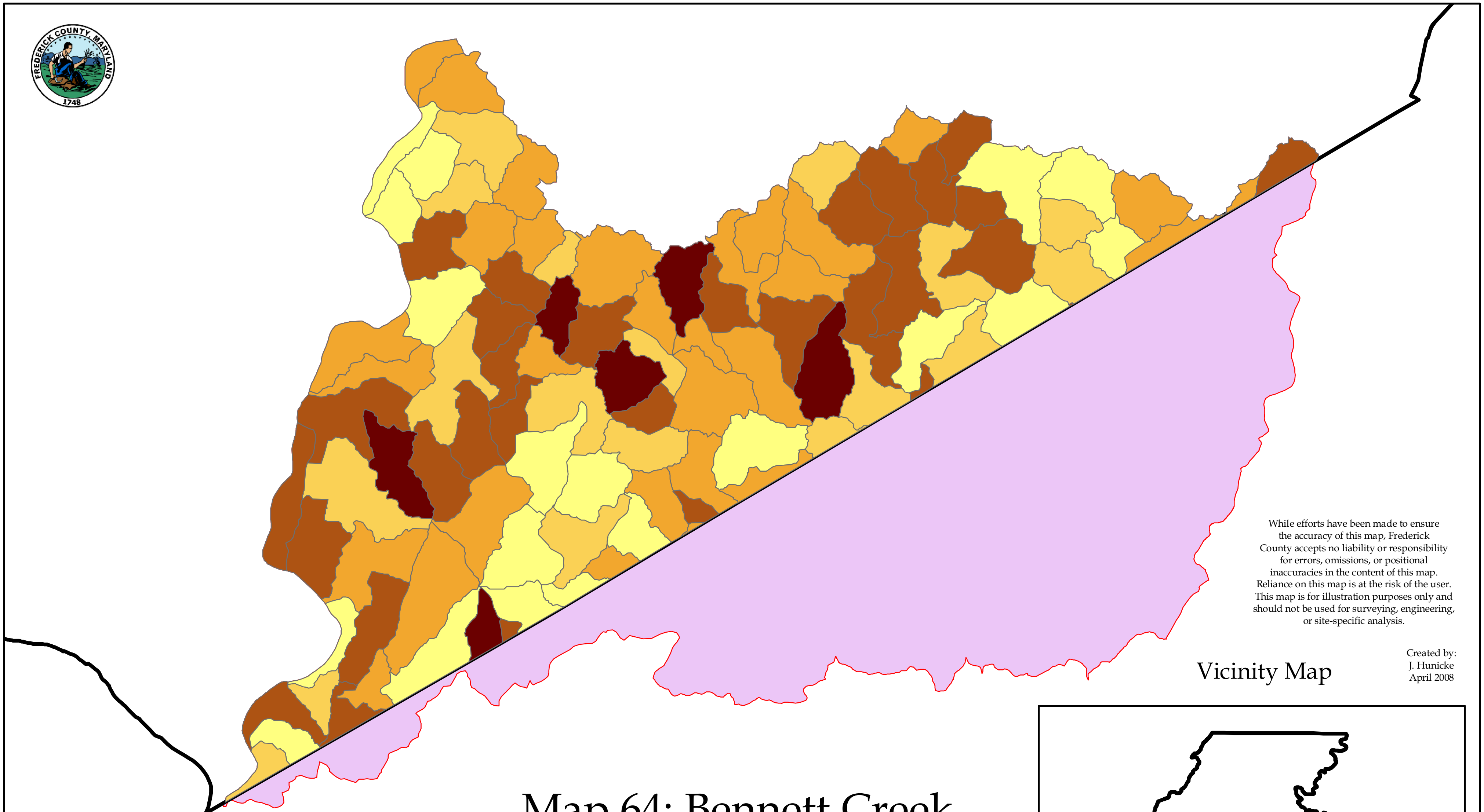
Nitrogen (lbs/yr)

- 1.02 - 730.86
- 730.87 - 1437.91
- 1437.92 - 2049.66
- 2049.67 - 2879.36
- 2879.37 - 5238.80

N



Map 63: Bennett Creek Pollutant Loads by Catchment Sediment (tons/yr)



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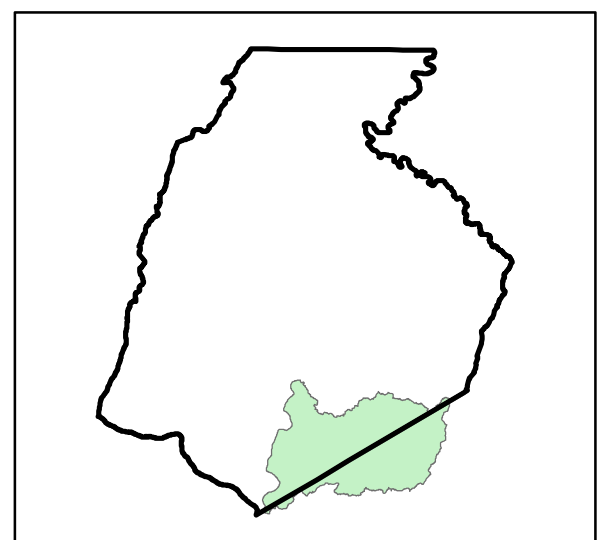
Vicinity Map



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Map 64: Bennett Creek Pollutant Loads Per Acre by Catchment Phosphorus (lbs/yr/ac)

County Boundary

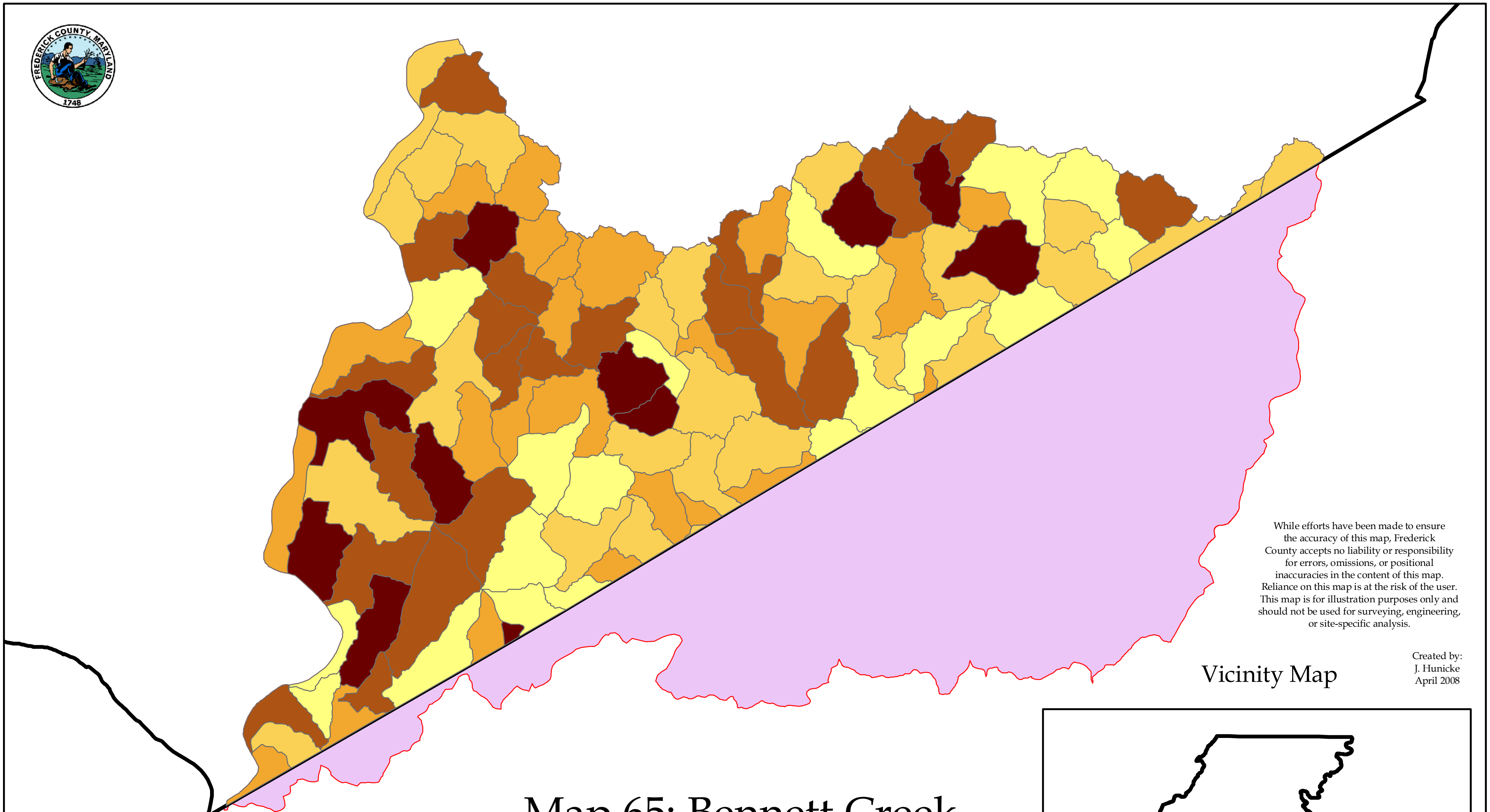
Bennett Creek Outside of Frederick County

Bennett Creek Pollutant Loads

Phosphorus (lbs/yr/ac)

- -0.01 - 0.38
- 0.39 - 0.75
- 0.76 - 1.06
- 1.07 - 1.38
- 1.39 - 2.06

N



Map 65: Bennett Creek Pollutant Loads Per Acre by Catchment Nitrogen (lbs/yr/ac)

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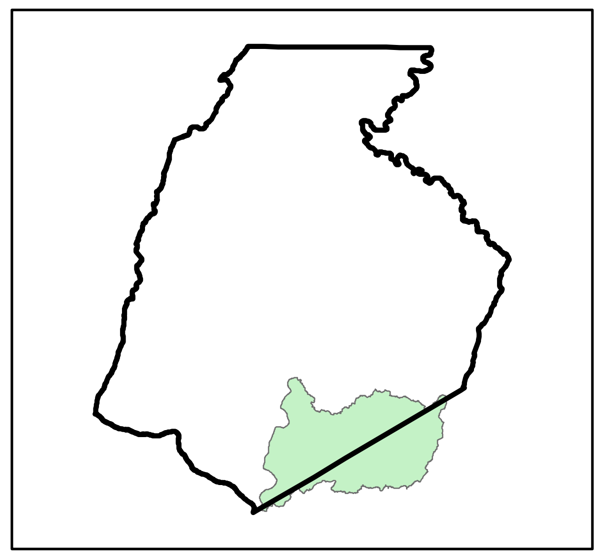
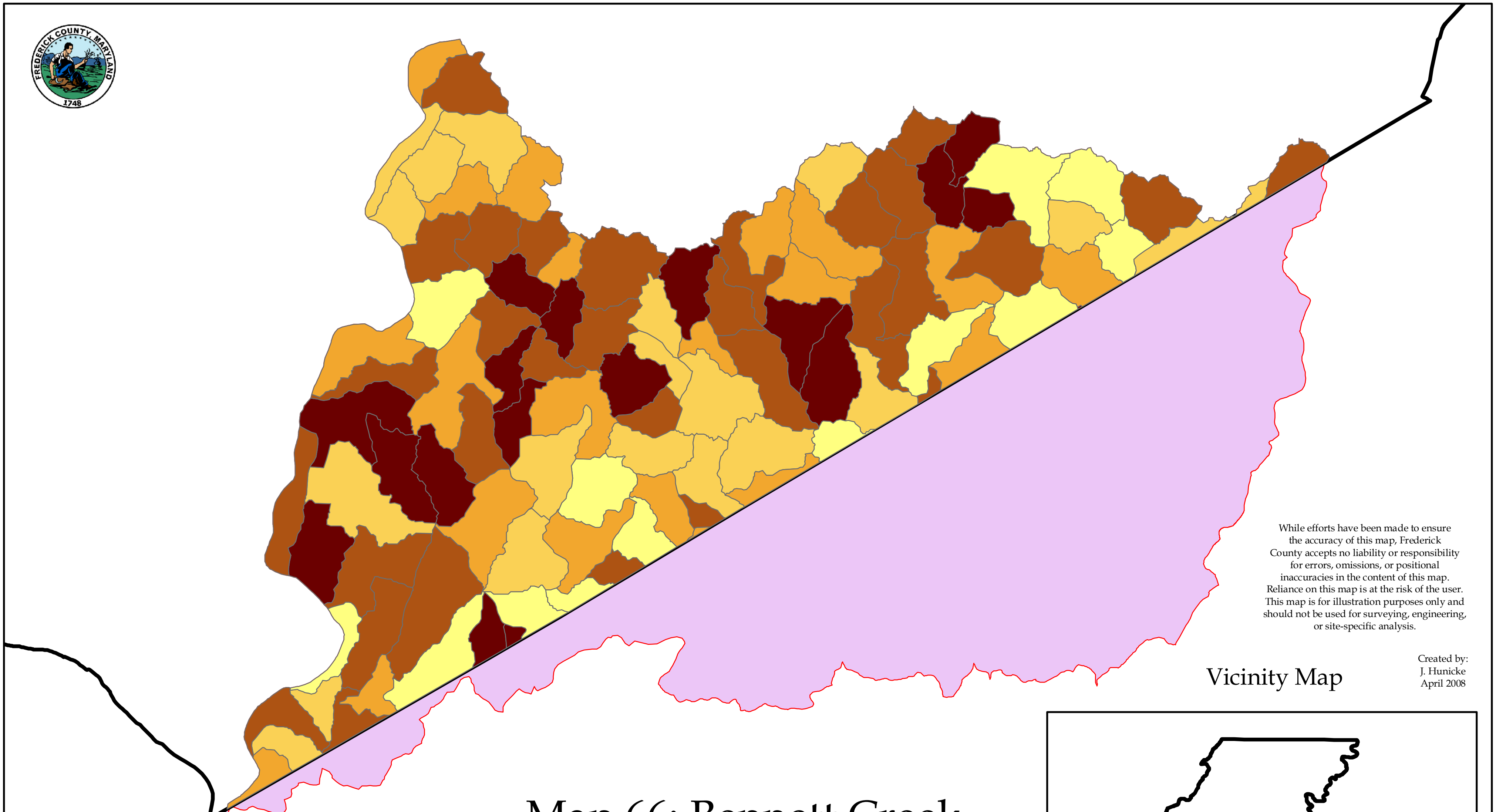
Vicinity Map



Map 66: Bennett Creek Pollutant Loads Per Acre by Catchment Sediment (tons/yr/ac)



County Boundary
Bennett Creek Outside of Frederick County

Bennett Creek Pollutant Loads

Sediment (tons/yr/ac)

- 0.02 - 0.05
- 0.06 - 0.09
- 0.10 - 0.14
- 0.15 - 0.19
- 0.20 - 0.32

N

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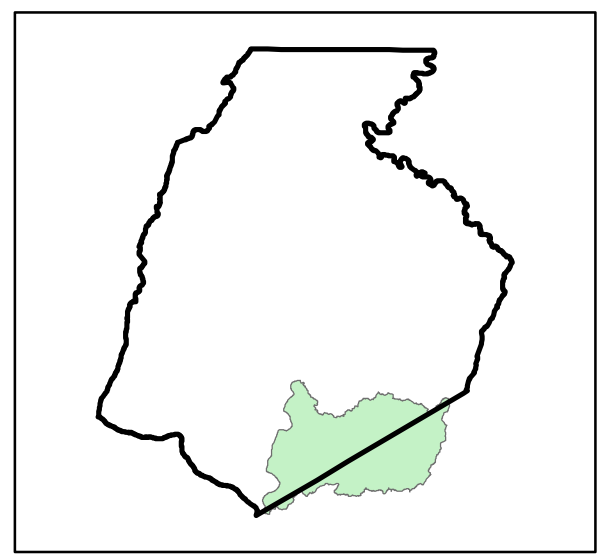
Vicinity Map



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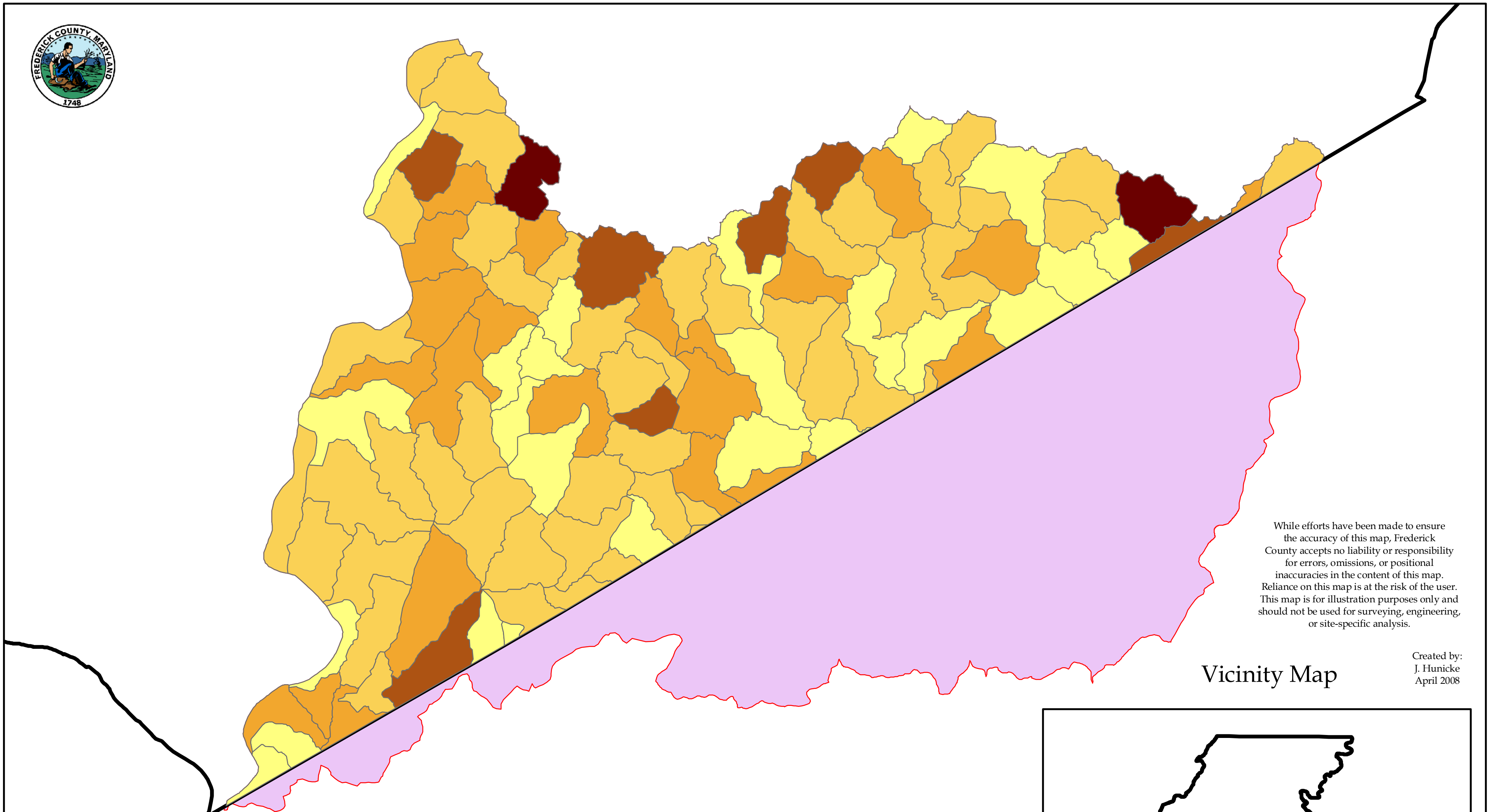

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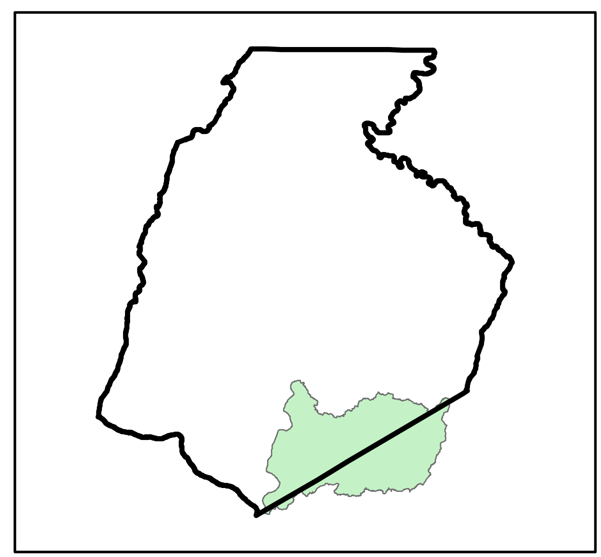
Vicinity Map



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J. Hunicke
April 2008

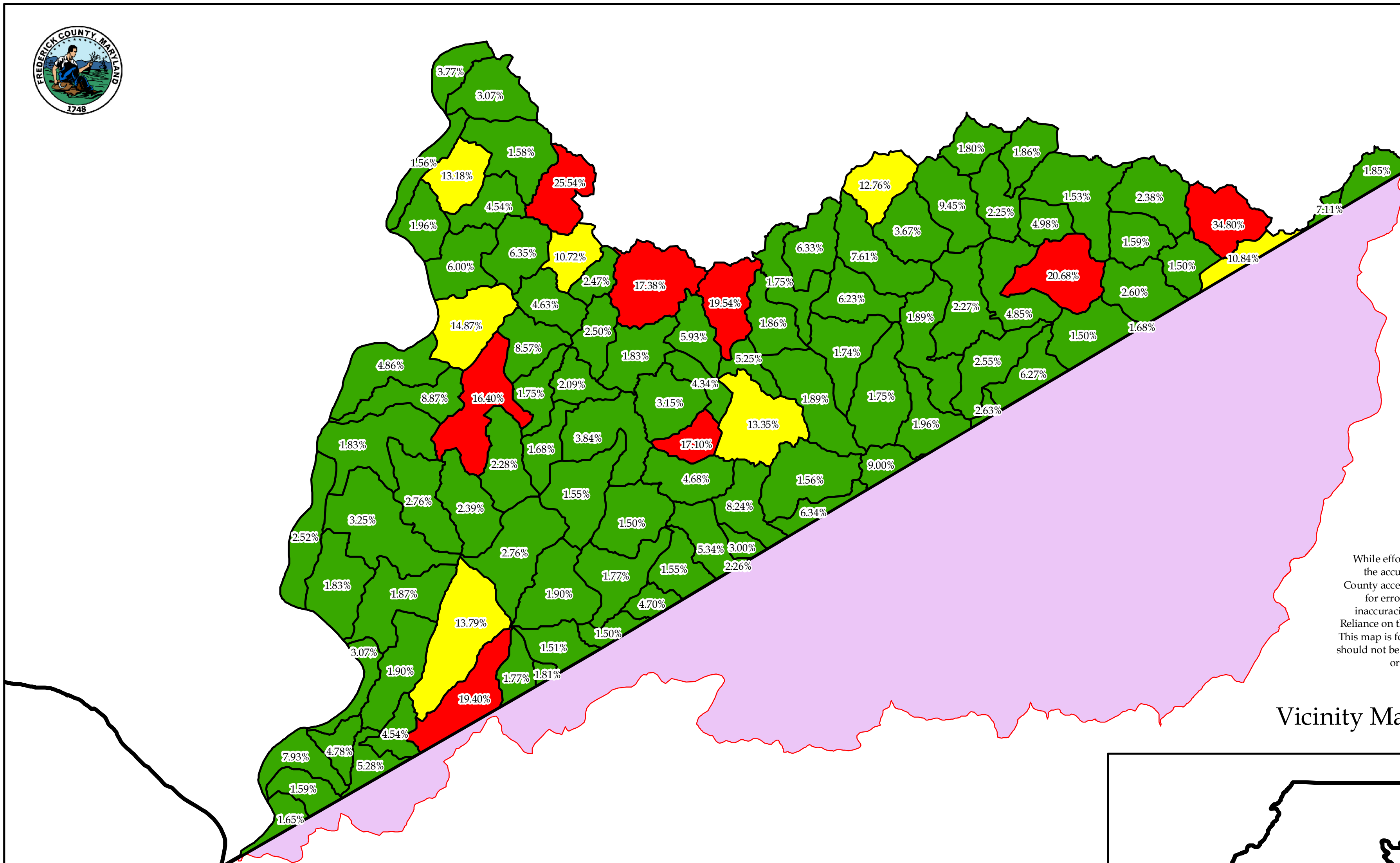
Map 67: Bennett Creek Impervious Area by Catchment (acres)

County Boundary
Bennett Creek Outside of Frederick County

Bennett Creek Pollutant Loads

Impervious Area (acres)

0.07 - 5.87
5.88 - 16.63
16.64 - 33.76
33.77 - 91.02
91.03 - 193.76



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Vicinity Map

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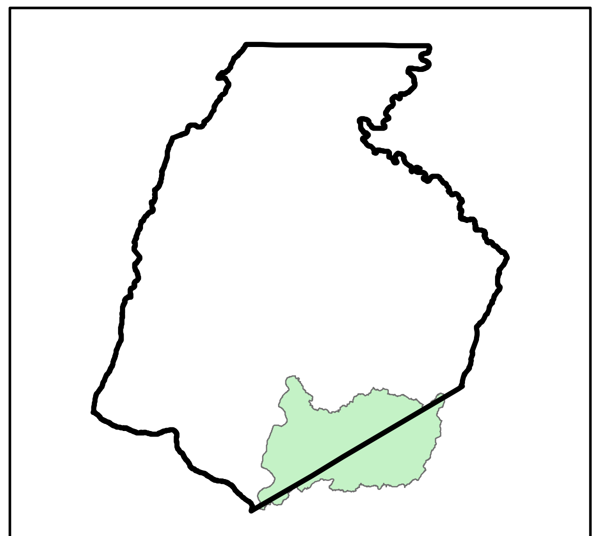

Map 68: Bennett Creek Catchment Status

County Boundary
Bennett Creek Outside of Frederick County

Bennett Creek Pollutant Loads

STATUS

Non-Supporting
Impacted
Sensitive

N

Appendix D: Linganore Creek Watershed Pollutant Loading Estimates

STORMWATER POLLUTANT MODEL FOR LINGANORE CREEK WATERSHED FREDERICK COUNTY, MARYLAND

Prepared for

Frederick County
Division of Public Works
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Frederick, Maryland 21701-5422

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July 2006

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1.0 INTRODUCTION

As part of the Linganore Creek Stormwater Retrofit and Stream Restoration Study, Versar developed stormwater pollutant loading estimates for Linganore Creek watershed (Figure 1-1). This effort updated previous modeling efforts for Lower Linganore Creek watershed (Perot et al. 2002) using more recent land use data, and extended the modeling into the Upper Linganore Creek watershed, including those portions located in Carroll County. The modeling method, input data, and assumptions used in Perot et al. (2002) were used in this effort, and they are documented in the following sections, along with results for Linganore Creek watershed.

For this simulation, we used version 4.4h of USEPA's Stormwater Management Model (SWMM). This model incorporates hydrological, topographical, and land use data from the watershed, and uses this information to calculate pollutant loads. SWMM is made up of different modules, or "blocks". For the Linganore Creek simulation, only the RUNOFF block was used. RUNOFF is used to calculate the amount of runoff and pollutants that flow off the land during storm events. The goal of this study was to simulate the pollutant contributions of the land surface to the surface waters; therefore the transport of flow and pollutants downstream of each subwatershed was not simulated.

SWMM was used to model ten pollutants: total nitrogen (TN), total phosphorus (TP), orthophosphorus (OP), total suspended solids (TSS), biological oxygen demand (BOD), chemical oxygen demand (COD), lead (Pb), cadmium (Cd), copper (Cu), and zinc (Zn). Ten land uses can be simulated within SWMM, and land uses were grouped accordingly. Event Mean Concentrations (EMCs) were calculated for each pollutant for each land use. These EMCs were used to calibrate the parameters of the model.

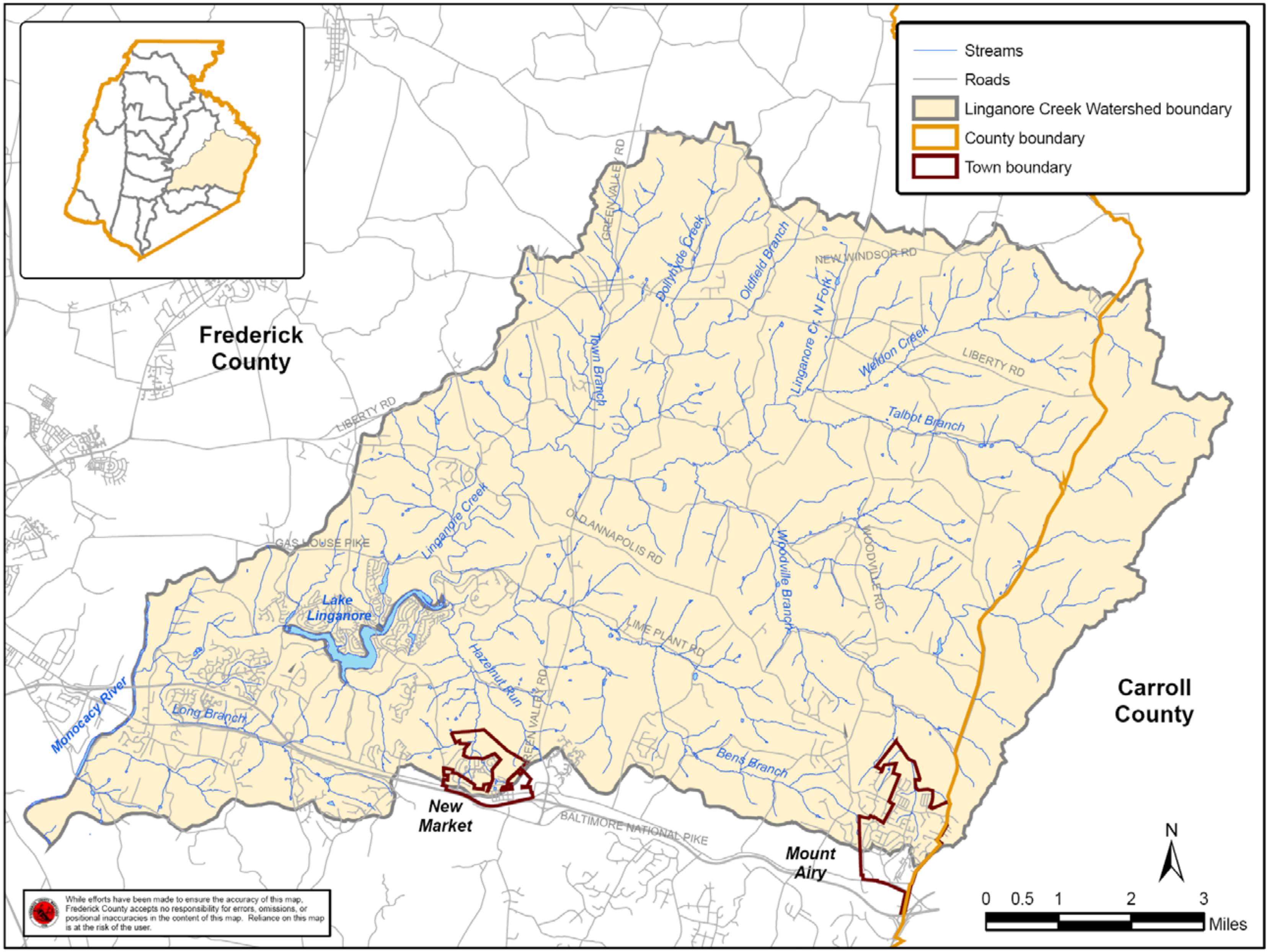

Figure 1-1. Linganore Creek watershed

2.0 METHODS AND INPUT DATA

2.1 HYDROLOGICAL DATA

Historical rain information from BWI Airport for the period from 1980 to 1992 was examined. Simulations were run with 1992 rainfall data, which represents an average year during that period. Monthly rainfall totals used in the simulations are summarized in Table 2-1. Rainfall data collected at BWI Airport were used because this rain gauge was the closest to the study area that contained hourly rainfall data for the simulation period.

Monthly evaporation rates (Table 2-2) were calculated from both BWI and National Airport data, as well as National Oceanic and Atmospheric Association (NOAA) Technical Report 34. These data have been used in similar studies in Maryland (Tetra Tech 2000, Versar 2001).

Table 2-1. Summary of monthly rainfall totals (inches) from BWI Airport used for the Linganore Creek SWMM simulation period. Simulations were run for an average (1992) year.

	1980	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**
Jan	2.58	0.49	3.37	2.21	1.96	2.03	2.16	5.85	3.24	3.07	3.71	3.54	1.27
Feb	1.06	2.93	4.04	4.81	3.9	3.03	3.78	2.22	3.25	3.36	1.48	0.73	2.49
Mar	5.46	1.14	3.03	6.8	5.79	2.37	0.96	0.99	2.35	4.24	2.54	5.65	4.58
Apr	4.24	2.04	3.61	6.55	2.95	0.39	2.64	1.86	2.44	3.16	4.23	1.68	1.76
May	3.58	3.63	1.85	5.47	4.29	6.01	0.37	4.16	4.37	8.71	4.92	1.16	2.92
Jun	3.04	5.4	5.7	5.23	1.65	2.44	1.46	2.63	0.84	5.98	2.55	1.08	1.89
Jul	3.25	4.59	2.16	1.31	3.27	2.53	4.12	5.05	3.78	7.35	5.68	1.76	5.07
Aug	4	1.93	0.95	1.57	4.11	3.72	4.26	1.61	2.64	3.38	6.17	2.54	2.19
Sep	1	2.89	3.63	1.76	2.38	6.22	0.58	7.34	2.05	3.64	1.07	3.05	5.96
Oct	3.08	2.57	2.31	3.58	1.94	2.48	1.86	2.25	1.59	4.9	2.57	3.2	2.19
Nov	2.72	0.31	3.13	5.02	3.01	4.71	5.96	5.05	4.78	1.97	2.1	1.69	3.44
Dec	0.7	3.3	2.39	6.72	1.71	0.84	5.52	2.07	0.97	2.12	4.86	4.08	4.63
TOTAL	34.71	31.22	36.17	51.03	36.96	36.77	33.67	41.08	32.3	51.88	41.88	30.16	38.39

Table 2-2. Monthly evaporation (in/day) for Central Maryland (Tetra Tech 2000)

Month	**Evaporation**	**Month**	**Evaporation**
Jan	0.0526	Jul	0.2442
Feb	0.0693	Aug	0.2233
Mar	0.1065	Sep	0.164
Apr	0.1627	Oct	0.1148
May	0.2023	Nov	0.0803
Jun	0.2326	Dec	0.0542

2.2 TOPOGRAPHICAL DATA

There are approximately 23,911 acres in the Lower Linganore Creek watershed and 34,758 acres in the Upper Linganore watershed. To improve the resolution of the model, the watershed was divided into subwatersheds, which were then subdivided in smaller catchments. The Lower Linganore Creek watershed had been divided into subwatershed and model catchments during the previous SWMM simulations, and these boundaries were utilized again for this simulation. Using the previous methodology as a guide, new subwatershed and model catchment boundaries were developed through a semi-automated process via geographic information systems (GIS; ArcGIS and the Spatial Analyst extension) and the County's digital elevation model (DEM). The Linganore Creek watershed was divided into 10 subwatersheds in the lower portion and 10 subwatersheds in the upper portion (as shown in Figure 2-1); these subwatersheds were then subdivided into 52 and 55 catchments, respectively.

GIS was used to calculate the area and flow length of each catchment. A central flow length was established that followed the stream network in the catchments. If there were no significant streams, a flow path was derived from elevation data. Once the flow length was determined, the width and slope of each catchment were calculated. Table 2-3 shows the width, area, and slope of each of the model catchments.

Table 2-3. Topographical data for Linganore Watershed catchments

Lower Linganore Watershed					**Upper Linganore Watershed**				
Sub-watershed	**Catch-ment**	**Width (feet)**	**Area (acres)**	**Slope (ft/ft)**	**Sub-watershed**	**Catch-ment**	**Width (feet)**	**Area (acres)**	**Slope (ft/ft)**
Bartonsville	BART-A	12,602	419	0.0184	Coppermine Branch	CB-A	17,934	915	0.0136
	BART-B	7,218	135	0.0266		CB-B	17,051	836	0.0096
	BART-C	12,833	541	0.0210	Dollyhyde Creek	DC-A	11,025	460	0.0147
	BART-D	9,439	449	0.0309		DC-B	13,685	680	0.0144
Bens Branch	BB-A	16,025	307	0.0141		DC-C	10,741	402	0.0158
	BB-B	11,720	341	0.0200		DC-D	18,966	1,008	0.0099
	BB-C	15,743	690	0.0185		DC-E	17,173	598	0.0108
	BB-D	13,205	263	0.0177	Mainstem Linganore Creek Upper	MLCU-A	12,625	669	0.0208
	BB-E	6,448	159	0.0347		MLCU-B	10,656	398	0.0155
	BB-F	12,039	527	0.0182		MLCU-C	13,124	480	0.0158
Chestnut Grove	CG-A	18,862	749	0.0153	North Fork	NF-A	17,000	1,094	0.0161
	CG-B	14,280	504	0.0193		NF-B	13,052	440	0.0175
Detrick	DET-A	13,277	758	0.0151		NF-C	15,759	608	0.0128
	DET-B	13,853	476	0.0159		NF-D	14,857	676	0.0138
	DET-C	14,975	607	0.0186		NF-E	11,993	450	0.0133
Hazelnut Run	HR-A	20,326	273	0.0171		NF-F	10,707	356	0.0172
	HR-B	16,368	154	0.0170	Oldfield Branch	OB-A	12,236	556	0.0164
	HR-C	9,168	679	0.0254		OB-B	13,567	655	0.0114

Table 2-3. (Continued)

Lower Linganore Watershed

Sub-watershed	Catch-ment	Width (feet)	Area (acres)	Slope (ft/ft)
Hazelnut Run (Cont.)	HR-D	6,480	442	0.0309
	HR-E	13,327	417	0.0175
	HR-F	13,173	333	0.0162
Horseshoe Farms	HF-A	11,799	986	0.0170
	HF-B	10,854	1,037	0.0151
Long Branch	LB-A	10,634	450	0.0201
	LB-B	10,931	432	0.0159
	LB-C	16,385	454	0.0196
	LB-D	10,709	373	0.0273
	LB-E	13,017	593	0.0198
	LB-F	8,473	231	0.0235
Mainstem Linganore Creek	MLC-A	12,861	565	0.0180
	MLC-B	15,300	691	0.0214
	MLC-C	15,317	665	0.0253
	MLC-D	14,398	629	0.0185
	MLC-E	7,659	110	0.0296
	MLC-F	12,110	298	0.0287
	MLC-G	8,555	207	0.0289
	MLC-H	10,911	216	0.0245
	MLC-I	14,639	892	0.0187
	MLC-J	6,859	131	0.0554
	MLC-K	4,762	57	0.0720
	MLC-L	17,200	349	0.0252
	MLC-M	14,188	568	0.0303
New London	NL-A	15,521	804	0.0182
	NL-B	10,324	318	0.0242
	NL-C	11,662	506	0.0186
	NL-D	11,653	494	0.0174
	NL-E	14,316	593	0.0158
	NL-F	15,688	789	0.0127
Westwinds	WW-A	8,461	256	0.0238
	WW-B	10,708	308	0.0229
	WW-C	9,540	287	0.0267
	WW-D	12,820	399	0.0211

Upper Linganore Watershed

Sub-watershed	Catch-ment	Width (feet)	Area (acres)	Slope (ft/ft)
South Fork	SF-A	15,658	406	0.0127
	SF-B	8,887	304	0.0289
	SF-C	16,552	464	0.0147
	SF-D	18,754	631	0.0164
	SF-E	15,428	596	0.0178
	SF-F	22,781	1,206	0.0155
	SF-G	15,516	833	0.0189
	SF-H	10,447	400	0.0213
	SF-I	6,546	146	0.0283
	SF-J	12,440	297	0.0208
	SF-K	15,857	888	0.0186
	SF-L	15,129	987	0.0195
	SF-M	12,699	628	0.0183
	SF-N	10,542	318	0.0149
	SF-O	12,725	365	0.0144
Talbot Branch	TAB-A	11,192	600	0.0191
	TAB-B	10,297	570	0.0223
	TAB-C	15,077	428	0.0201
	TAB-D	18,397	1,008	0.0198
	TAB-E	16,228	890	0.0185
	TAB-F	17,270	1,065	0.0144
	TAB-G	11,461	436	0.0277
	TAB-H	8,499	258	0.0254
Town Branch	TOB-A	15,012	857	0.0218
	TOB-B	12,657	558	0.0236
Weldon Creek	WC-A	16,798	522	0.0143
	WC-B	16,872	420	0.0160
	WC-C	13,663	599	0.0217
	WC-D	13,310	1,687	0.0192
	WC-E	13,703	623	0.0158
	WC-F	13,347	335	0.0221
Woodville Branch	WB-A	13,066	599	0.0172
	WB-B	12,378	865	0.0216
	WB-C	13,973	661	0.0200
	WB-D	23,561	748	0.0162
	WB-E	14,569	734	0.0260
	WB-F	12,817	545	0.0217

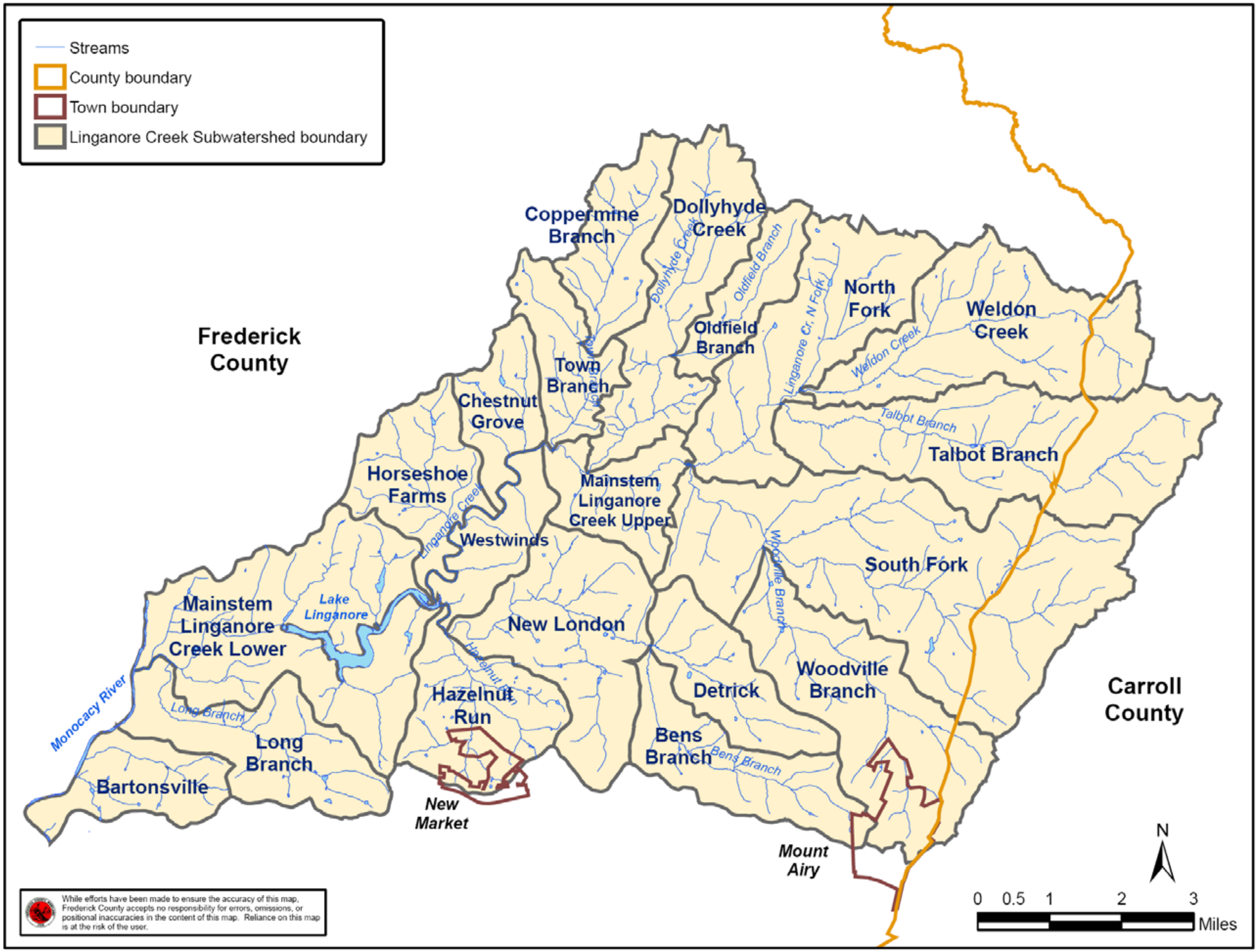

Figure 2-1. Subwatersheds within Linganore Creek watershed

2.3 LAND USE

Current land uses (MDP 2003a, 2003b) represent a mixture of residential, agriculture, and forest types, varying by subwatershed (Table 2-4, Table 2-5). SWMM used land use percentages directly to calculate the pollutant buildup within a catchment. Land use percentages were also used to determine the amount of impervious area and Manning roughness coefficients for each catchment, which were then used by SWMM to calculate the total runoff flow.

The directly connected impervious area (DCIA) is the amount of impervious area that is directly connected to a sewer system or water body. SWMM uses DCIA rather than the total impervious area in a subwatershed. SWMM employs two different Manning coefficients: the roughness of the pervious area and that of the impervious area. DCIA values for each land use were obtained from a recent assessment of the Patapsco River (Tetra Tech 2000). Manning coefficients for pervious and impervious surfaces were obtained from the Back River study (CDM 1997). DCIA and Manning coefficients assigned to each land use are shown in Table 2-6. The estimated percent DCIA and pervious and impervious Manning coefficients in each Linganore catchment are listed in Table 2-7.

Depression storage is a measure of the amount of low points in a watershed that must be filled before runoff can occur. Without further study, it was not possible to determine the actual depression storage within each subwatershed, therefore, literature values of 0.02 inches for impervious and 0.1 inches for pervious depression storage, as used in previous SWMM studies in central Maryland, were used (Tetra Tech 2000). These values do not account for existing SWM facilities.

Table 2-4. Percentages of land use by subwatershed in Lower Linganore watershed

	Low-Density Residential	Medium-Density Residential	High-Density Residential	Commercial	Open Urban Land	Cropland	Pasture	Forested Land	Barren	Water
Bartonsville	26.4	1.2	0.0	0.0	6.9	14.8	15.3	33.1	0.0	2.3
Bens Branch	29.2	2.4	0.0	6.0	0.0	11.0	11.9	39.5	0.0	0.0
Chestnut Grove	4.5	0.0	0.0	1.5	0.0	61.3	0.3	32.0	0.3	0.1
Detrick	14.2	0.0	0.0	0.0	0.0	51.0	9.1	25.6	0.0	0.1
Hazelnut Run	6.7	8.2	0.0	0.5	0.0	46.9	8.2	29.3	0.0	0.3
Horseshoe Farms	16.2	1.3	0.0	0.0	0.0	40.1	7.0	35.4	0.0	0.0
Long Branch	33.3	3.9	0.6	2.8	14.1	9.4	12.1	23.3	0.0	0.6
Mainstem Linganore Creek	7.0	26.7	0.6	0.2	0.0	18.2	7.1	38.3	0.0	1.9
New London	6.1	3.1	0.0	0.0	0.7	53.9	10.9	25.2	0.0	0.1
Westwinds	0.6	13.2	0.0	0.0	5.8	26.4	0.4	53.1	0.1	0.5

Table 2-5 Percentages of land use by subwatershed in Upper Linganore watershed

	Low-Density Residential	Medium-Density Residential	High-Density Residential	Commercial	Open Urban Land	Cropland	Pasture	Forested Land	Barren	Water
Coppermine Branch	2.4	4.2	0.3	1.0	5.1	58.4	4.9	21.9	0.0	1.9
Dollyhyde Creek	4.6	0.0	0.0	0.0	0.6	75.7	12.5	6.7	0.0	0.0
Mainstem Linganore Creek Upper	2.6	0.0	0.0	0.0	0.0	65.1	6.2	26.0	0.0	0.1
North Fork	6.6	0.5	0.0	0.0	0.0	82.2	4.8	5.8	0.0	0.0
Oldfield Branch	5.6	0.4	0.0	0.0	0.0	81.5	0.6	11.9	0.0	0.0
South Fork	19.4	0.1	0.0	0.0	0.0	40.6	5.6	34.3	0.0	0.1
Talbot Branch	7.9	0.4	0.0	2.0	0.0	51.3	3.9	34.3	0.0	0.3
Town Branch	7.7	0.2	0.0	0.2	0.2	59.4	3.6	28.8	0.0	0.0
Weldon Creek	15.2	0.0	0.0	0.0	0.0	49.7	6.9	28.1	0.0	0.0
Woodville Branch	13.5	13.6	0.0	1.0	0.3	32.1	8.4	30.7	0.4	0.0

Table 2-6. Directly Connected Impervious Area (DCIA) and Manning Coefficients for each land use category

Land Use	DCIA (%)	Manning Coefficients	
		Impervious	Pervious
Low Density Residential (LDR)	15.0%	0.015	0.250
Medium Density Residential (MDR)	25.0%	0.015	0.250
High Density Residential (HDR)	60.0%	0.015	0.250
Commercial/Industrial	90.0%	0.015	0.250
Open Urban	4.0%	0.015	0.300
Croplands	3.0%	0.015	0.400
Pasture	5.0%	0.015	0.400
Forest	1.5%	0.015	0.300
Barren	1.5%	0.015	0.300
Water/Wetlands	100.0%	0.100	0.400

Table 2-7. DCIA percentages and Manning Coefficients for Linganore Watershed catchments

Lower Linganore watershed					Upper Linganore watershed				
Sub-watershed	Catch-ment	% DCIA	Impervious Manning Coefficient	Pervious Manning Coefficient	Sub-watershed	Catch-ment	% DCIA	Impervious Manning Coefficient	Pervious Manning Coefficient
Bartonsville	BART-A	11.0	0.0215	0.3585	Coppermine Branch	CB-A	7.0	0.0150	0.3458
	BART-B	9.8	0.0150	0.3202		CB-B	6.7	0.0183	0.3782
	BART-C	8.5	0.0157	0.2956	Dollyhyde Creek	DC-A	3.2	0.0150	0.3803
	BART-D	6.0	0.0150	0.3088		DC-B	3.3	0.0150	0.3956
Bens Branch	BB-A	9.1	0.0150	0.2909		DC-C	4.8	0.0150	0.3697
	BB-B	4.8	0.0150	0.3359		DC-D	3.3	0.0150	0.3915
	BB-C	19.2	0.0150	0.3170		DC-E	4.4	0.0150	0.3810
	BB-D	10.9	0.0150	0.2901	Mainstem Linganore Creek Upper	MLCU-A	3.3	0.0150	0.3537
	BB-E	3.2	0.0150	0.3427		MLCU-B	3.1	0.0152	0.3781
	BB-F	11.6	0.0150	0.2696		MLCU-C	2.9	0.0150	0.3861
Chestnut Grove	CG-A	3.4	0.0152	0.3516	North Fork	NF-A	4.0	0.0151	0.3746
	CG-B	6.1	0.0150	0.3694		NF-B	3.8	0.0150	0.3909
Detrick	DET-A	3.6	0.0150	0.3751		NF-C	4.2	0.0150	0.3885
	DET-B	4.1	0.0155	0.3495		NF-D	3.5	0.0150	0.3936
	DET-C	6.5	0.0150	0.3283		NF-E	3.8	0.0150	0.3907
Hazelnut Run	HR-A	4.0	0.0156	0.3304		NF-F	4.7	0.0150	0.3647
	HR-B	5.6	0.0150	0.3652	Oldfield Branch	OB-A	3.3	0.0150	0.3753
	HR-C	5.4	0.0150	0.3537		OB-B	3.9	0.0150	0.3824
	HR-D	3.5	0.0153	0.3655	South Fork	SF-A	3.0	0.0150	0.3809
	HR-E	4.1	0.0150	0.3673		SF-B	3.2	0.0150	0.3611
	HR-F	3.7	0.0156	0.2929		SF-C	3.1	0.0150	0.3768

Table 2-7. (Continued)

Lower Linganore watershed					**Upper Linganore watershed**				
Sub-watershed	**Catch-ment**	**% DCIA**	**Impervious Manning Coefficient**	**Pervious Manning Coefficient**	**Sub-watershed**	**Catch-ment**	**% DCIA**	**Impervious Manning Coefficient**	**Pervious Manning Coefficient**
Horseshoe Farms	HF-A	3.5	0.0150	0.3345	South Fork (Cont.)	SF-D	7.2	0.0150	0.3094
	HF-B	17.8	0.0150	0.3420		SF-E	2.9	0.0150	0.3344
Long Branch	LB-A	13.4	0.0178	0.2811		SF-F	4.9	0.0150	0.3338
	LB-B	22.4	0.0150	0.2863		SF-G	7.3	0.0150	0.3106
	LB-C	5.5	0.0150	0.3155		SF-H	14.9	0.0153	0.2603
	LB-D	6.8	0.0150	0.3397		SF-I	7.2	0.0150	0.2921
	LB-E	10.4	0.0151	0.2883		SF-J	4.1	0.0150	0.3417
	LB-F	7.2	0.0151	0.3183		SF-K	7.2	0.0156	0.3333
Mainstem Linganore Creek	MLC-A	5.6	0.0176	0.3585		SF-L	2.4	0.0151	0.3359
	MLC-B	5.8	0.0152	0.3140		SF-M	2.8	0.0151	0.3482
	MLC-C	7.0	0.0158	0.3307		SF-N	3.2	0.0150	0.3745
	MLC-D	12.2	0.0179	0.3407		SF-O	2.9	0.0150	0.3872
	MLC-E	9.4	0.0157	0.2950	Talbot Branch	TAB-A	2.9	0.0150	0.3918
	MLC-F	27.0	0.0192	0.2669		TAB-B	3.6	0.0150	0.3687
	MLC-G	26.4	0.0197	0.2673		TAB-C	3.6	0.0150	0.3521
	MLC-H	24.9	0.0264	0.2938		TAB-D	2.8	0.0150	0.3352
	MLC-I	7.5	0.0150	0.3133		TAB-E	4.9	0.0163	0.3464
	MLC-J	7.5	0.0150	0.2886		TAB-F	13.1	0.0150	0.3421
	MLC-K	4.0	0.0150	0.2908		TAB-G	4.6	0.0150	0.3299
	MLC-L	8.7	0.0150	0.2842		TAB-H	4.5	0.0150	0.3515
	MLC-M	21.5	0.0151	0.2630	Town Branch	TOB-A	3.3	0.0150	0.3662
New London	NL-A	4.5	0.0152	0.3429		TOB-B	4.5	0.0150	0.3478
	NL-B	4.7	0.0150	0.3723	Weldon Creek	WC-A	4.0	0.0150	0.3843
	NL-C	4.3	0.0150	0.3694		WC-B	3.6	0.0150	0.3517
	NL-D	3.6	0.0150	0.3647		WC-C	7.8	0.0150	0.3717
	NL-E	4.3	0.0150	0.3612		WC-D	21.1	0.0150	0.3426
	NL-F	4.6	0.0150	0.3638		WC-E	5.8	0.0150	0.3217
Westwinds	WW-A	15.9	0.0169	0.2783		WC-F	6.1	0.0150	0.3334
	WW-B	4.9	0.0150	0.3113	Woodville Branch	WB-A	3.7	0.0150	0.3463
	WW-C	2.1	0.0150	0.3412		WB-B	3.7	0.0150	0.3226
	WW-D	2.4	0.0150	0.3393		WB-C	3.2	0.0150	0.3510
						WB-D	5.3	0.0150	0.2811
						WB-E	5.3	0.0150	0.3434
						WB-F	4.2	0.0150	0.3208

2.4 SOILS

Digital hydrologic soil group data, obtained from the NRCS (2004, 2005), were also used in GIS to generate input data for the model. Each hydrologic soil group has a different infiltration rate. By determining the percentages of each group within a catchment, the maximum and minimum infiltration rates were calculated. Using the Horton infiltration method in SWMM, a constant decay rate of 0.00115 per second was set. The infiltration rates for each hydrologic soil group are shown in Table 2-8. The maximum and minimum infiltration rates calculated for each Linganore catchment are listed in Table 2-9.

Table 2-8. Infiltration rates for NRCS hydrologic soil groups

Soil Group	Maximum Infiltration Rate (in/hr)	Minimum Infiltration Rate (in/hr)
A	2	0.065
B	1.5	0.05
C	1	0.035
D	0.5	0.02

Table 2-9. Maximum and minimum infiltration rates for Linganore Watershed catchments

Lower Linganore watershed				Upper Linganore watershed			
Sub-watershed	**Catch-ment**	**Maximum Infiltration (in/hr)**	**Minimum Infiltration (in/hr)**	**Sub-watershed**	**Catch-ment**	**Maximum Infiltration (in/hr)**	**Minimum Infiltration (in/hr)**
Bartonsville	BART-A	1.351	0.046	Coppermine Branch	CB-A	1.388	0.047
	BART-B	1.395	0.047		CB-B	1.387	0.047
	BART-C	1.359	0.046	Dollyhyde Creek	DC-A	1.283	0.043
	BART-D	1.318	0.045		DC-B	1.351	0.046
Bens Branch	BB-A	1.375	0.046		DC-C	1.395	0.047
	BB-B	1.426	0.048		DC-D	1.273	0.043
	BB-C	1.524	0.051		DC-E	1.182	0.040
	BB-D	1.484	0.050	Mainstem Linganore Creek Upper	MLCU-A	1.398	0.047
	BB-E	1.327	0.045		MLCU-B	1.305	0.044
	BB-F	1.453	0.049		MLCU-C	1.390	0.047
Chestnut Grove	CG-A	1.410	0.047	North Fork	NF-A	1.345	0.045
	CG-B	1.333	0.045		NF-B	1.398	0.047
Detrick	DET-A	1.320	0.045		NF-C	1.154	0.040
	DET-B	1.440	0.048		NF-D	1.398	0.047
	DET-C	1.474	0.049		NF-E	1.442	0.048
Hazelnut Run	HF-A	1.286	0.044		NF-F	1.256	0.043
	HF-B	1.453	0.049	Oldfield Branch	OB-A	1.462	0.049
	HR-A	1.206	0.041		OB-B	1.135	0.039

Table 2-9. (Continued)

Lower Linganore watershed				Upper Linganore watershed			
Sub-watershed	**Catch-ment**	**Maximum Infiltration (in/hr)**	**Minimum Infiltration (in/hr)**	**Sub-watershed**	**Catch-ment**	**Maximum Infiltration (in/hr)**	**Minimum Infiltration (in/hr)**
Hazelnut Run (Cont.)	HR-B	1.265	0.043	South Fork	SF-A	1.319	0.045
	HR-C	1.169	0.040		SF-B	1.307	0.044
	HR-D	1.310	0.044		SF-C	1.415	0.047
Horseshoe Farms	HR-E	1.331	0.045		SF-D	1.439	0.048
	HR-F	1.329	0.045		SF-E	1.529	0.051
Long Branch	LB-A	1.277	0.043		SF-F	1.368	0.046
	LB-B	1.456	0.049		SF-G	1.521	0.051
	LB-C	1.393	0.047		SF-H	1.571	0.052
	LB-D	1.348	0.045		SF-I	1.478	0.049
	LB-E	1.298	0.044		SF-J	1.551	0.052
	LB-F	1.310	0.044		SF-K	1.392	0.047
Mainstem Linganore Creek	MLC-A	1.310	0.044		SF-L	1.336	0.045
	MLC-B	1.405	0.047		SF-M	1.341	0.045
	MLC-C	1.457	0.049		SF-N	1.348	0.045
	MLC-D	1.442	0.048		SF-O	1.349	0.045
	MLC-E	1.357	0.046	Talbot Branch	TAB-A	1.395	0.047
	MLC-F	1.346	0.045		TAB-B	1.466	0.049
	MLC-G	1.357	0.046		TAB-C	1.426	0.048
	MLC-H	1.346	0.045		TAB-D	1.550	0.052
	MLC-I	1.208	0.041		TAB-E	1.472	0.049
	MLC-J	1.467	0.049		TAB-F	1.571	0.052
	MLC-K	1.500	0.050		TAB-G	1.411	0.047
	MLC-L	1.407	0.047		TAB-H	1.325	0.045
	MLC-M	1.479	0.049	Town Branch	TOB-A	1.302	0.044
New London	NL-A	1.373	0.046		TOB-B	1.417	0.048
	NL-B	1.500	0.050	Weldon Creek	WB-A	1.386	0.047
	NL-C	1.371	0.046		WB-B	1.461	0.049
	NL-D	1.357	0.046		WB-C	1.347	0.045
	NL-E	1.382	0.046		WB-D	1.374	0.046
	NL-F	1.370	0.046		WB-E	1.390	0.047
Westwinds	WW-A	1.274	0.043		WB-F	1.519	0.051
	WW-B	1.304	0.044	Woodville Branch	WC-A	1.398	0.047
	WW-C	1.148	0.039		WC-B	1.500	0.050
	WW-D	1.368	0.046		WC-C	1.511	0.050
					WC-D	1.438	0.048
					WC-E	1.500	0.050
					WC-F	1.524	0.051

2.5 BUILDUP AND WASHOFF

SWMM uses buildup and washoff algorithms to determine how much pollution will be washed off the land surface during a storm. Each pollutant has a land use specific buildup rate. Initial maximum pollutant accumulation values from the Back River study were calibrated using the EMCs selected for the Linganore Creek watershed. This algorithm uses the following equation:

PSHED = QFACT(1)*(1.0-exp(-QFACT(2)*t))

PSHED	=	pollutant mass available for washoff at time “t,” pounds per acre
QFACT(1)	=	maximum pollutant accumulation, pounds per acre
QFACT(2)	=	daily pollutant accumulation growth rate, per day
t	=	time, days

The washoff algorithm used constant values, with the washoff coefficient set to 4.6 per inch and the power exponent for runoff rate at 1.0. The following equation was used by SWMM:

POFF = PSHED0*(1.0-exp(-K*t))

K = RCOEFF*(r^WASHPO)

POFF	=	cumulative pollutant load washed off at time t, lbs/ac
K	=	first order decay rate
RCOEFF	=	washoff coefficient, per inch
WASHPO	=	power exponent for runoff rate
PSHED0	=	pollutant mass available for washoff, lbs/ac
r	=	runoff rate during time interval, in/hr
t	=	time interval, hr

Calibrated QFACT(1) values are shown in Table 2-10.

2.6 EVENT MEAN CONCENTRATIONS

EMCs are the mean pollutant loads that can be expected to run off from an average sized storm. The EMCs used in calibration of the Linganore Creek simulation (Table 2-11) were taken from the Patapsco study and adjusted according to Winer (2000).

Table 2-10. Calibrated QFACT(1) values for each land use and pollutant unit (lbs/acre)

	TN	TP	OP	BOD	COD	TSS	Pb	Cu	Zn	Cd
LDR	0.3183	0.0459	0.02524	1.423	6.812	13.658	0.002065	0.005565	0.00909	0.000416
MDR	0.3578	0.0582	0.03201	2.9245	9.875	20.563	0.00328	0.002523	0.01741	0.000582
HDR	0.3888	0.0622	0.0342	4.456	11.299	25.528	0.006142	0.00324	0.02637	0.000804
Comm/Ind	0.6744	0.06745	0.03711	5.911	14.439	25.286	0.01255	0.01875	0.06117	0.000877
Open	0.3391	0.04915	0.02703	0.8165	6.281	26.078	0.000479	0.01041	0.00566	0.000353
Crop	0.9647	0.1009	0.0555	1.646	6.143	52.556	0.000603	0.02182	0.004713	0.000295
Pasture	0.4458	0.05205	0.02863	1.064	4.108	42.797	0.000534	0.01556	0.003885	0.000334
Forest	0.2857	0.02857	0.01571	0.8885	3.884	14.285	0.000443	0.01714	0.003414	0.000229
Barren	0.3532	0.0718	0.0395	0.6964	5.727	49.103	0.000718	0.02182	0.005084	0.000488
Water	0.1965	0.00728	0.004	0.3128	1.371	7.533	0.004	0.00542	0.00895	0.000146

Table 2-11. Event Mean Concentrations (EMCs) used for the Lower Linganore Creek watershed SWMM model (EMCs were from Tetra Tech (2000), adjusted according to Winer (2000)).

	TN	TP	OP	BOD	COD	TSS	Pb	Cu	Zn	Cd
LDR	2.22	0.32	0.176	9.92	47.5	95.22	0.0144	0.0388	0.0634	0.0029
MDR	2.03	0.33	0.1815	16.58	55.99	116.63	0.0186	0.0143	0.0987	0.0033
HDR	1.5	0.24	0.132	17.19	43.6	98.46	0.0237	0.0125	0.1018	0.0031
Comm/Ind	2	0.2	0.11	17.53	42.81	75	0.0372	0.0556	0.1814	0.0026
Open	2.69	0.39	0.2145	6.48	49.85	206.91	0.0038	0.0826	0.0449	0.0028
Crop	7.84	0.82	0.451	13.38	49.92	427	0.0049	0.1774	0.0383	0.0024
Pasture	3.34	0.39	0.2145	7.97	30.78	320.52	0.004	0.1166	0.0291	0.0025
Forest	2	0.2	0.11	6.22	27.2	100	0.0031	0.12	0.0239	0.0016
Barren	2.46	0.5	0.275	4.85	39.87	342.17	0.005	0.152	0.0354	0.0034
Water	0.54	0.02	0.011	0.86	3.77	20.71	0.011	0.0149	0.0246	0.0004

2.7 CALIBRATION

Calibration was performed using the Lower Linganore Creek model simulation and rainfall data from 1980 to 1986. One simulation was created, incorporating all seven years of rainfall data. For this simulation, ten watersheds, each with an identical area, slope, and width, were created. A different land use was assigned to each watershed, and was used to calculate an infiltration value specific to that type of land use. The infiltration values for each land use were calculated by overlaying the soils map on the land use map. The proportion of soil types to land use was then used to determine an infiltration rate for each land use. Thus, each watershed had a unique land use and infiltration rate, but was otherwise identical to all the other watersheds.

The SWMM model uses QFACT(1) to define how much of each pollutant will run off during a storm event. SWMM uses these variables to determine the mean pollutant loads, in mg/L. These mean pollutant loads are the EMCs for that watershed. Initially, QFACT(1) values from the Back River study were used in SWMM to calculate the mean pollutant loads for each of the calibration watersheds. Since each calibration watershed was made up of a single land use, mean pollutant loads were compared to the Linganore Creek EMCs for that land use. After running the calibration, the loads were compared to the Linganore Creek EMCs, and QFACT(1) values were adjusted as necessary. This process was repeated until the difference between the mean pollutant loads and the EMCs was 0.0%[Perot1]. The calibrated QFACT(1) values were then used for the simulations for the Lower and Upper Linganore Creek watershed.

2.8 POLLUTANT REMOVAL BY STORMWATER FACILITIES

Currently, there are 87 stormwater facilities in the Linganore Creek watershed, with 64 of these located in Frederick County. Each SWM pond was analyzed separately in SWMM to determine the impact it had on its subwatershed. First, a variety of data sources, including topographic maps, aerial photographs, storm drain networks, and drainage area values reported in each County's SWM facility databases were used to delineate and digitize a drainage area polygon for each facility. These polygons were then overlaid onto land use maps to find the type and amount of land draining into each pond. Slopes for each drainage area polygon were calculated using the topographic map, and the land use data were used to calculate imperviousness and Manning coefficients for each facility. Once these values were determined, SWMM simulations were run under the assumption that each drainage area was a separate subwatershed; areas controlled by smaller stormwater management facilities nested within larger facilities were not analyzed to prevent "double-counting" areas treated and pollutant removals.

Once the pollutant loadings flowing into each pond were calculated, removal efficiencies were used to calculate loading removals by each facility. Each type of facility had different removal efficiencies, based on values from Winer (2000) and Schueler (1997).

3.0 RESULTS

3.1 MODELED POLLUTANT LOADS

Once all the simulations had been run, the total yearly pollutant loads expressed in pounds per acre to examine loadings independently of size were analyzed and mapped for the average rainfall year. As described in Section 1.8, pollutant removals provided by existing SWM facilities have been factored into these pollutant load estimates. Annual catchment loadings for total nitrogen, total phosphorus, BOD, TSS, copper, cadmium, lead, and zinc, along with peak flow estimates are shown in Figures 3-1 through 3-9. Since total and ortho phosphorus have similar results, as do BOD and COD, only figures for TP and BOD are included. Table 3-1 lists catchment load model results for all parameters. For comparison purposes, model output has also been calculated in terms of pounds per year, and is presented in Tables 1-3 in the Appendix. In general, modeled cadmium, lead, and zinc loads tended to be highest for urban catchments, while copper loads were more evenly distributed throughout the watershed.

To facilitate overall comparison of the subwatersheds, pollutant loads were calculated on a per acre basis. Subwatersheds were ranked by average-year pollutant loadings, with larger loadings receiving a higher rank (Table 3-2). For example, an area with the highest loadings would be ranked 10 and an area with the lowest loadings would be ranked 1. To simplify comparisons, individual pollutants were grouped into agricultural or urban pollutant categories. Average rankings for both agricultural and urban pollutants were then calculated for each subwatershed. These averages were used to provide an overview of which subwatersheds are the greatest sources of nonpoint pollutants.

As shown in Table 3-2, subwatersheds with the highest agricultural rankings are located in the upper portion of the Linganore Creek watershed, with North Fork, Oldfield Branch, and Dollyhyde Creek having the three highest agricultural pollutant loads. Urban rankings are generally higher in the southern, more developed portion of the watershed, with Woodville Branch, Bens Branch, and Long Branch having the three highest urban pollutant loads.

Separate subwatershed rankings for the lower and upper portions of Linganore Creek, which represent two of the County's watershed management units, have also been included (Tables 3-3 and 3-4). The following discussion focuses on these management units. The three lower subwatersheds that contain the highest agricultural pollutant loadings are Chestnut Grove, New London, and Hazelnut Run. In Upper Linganore watershed, North Fork, Oldfield Branch, and Dollyhyde Creek had the highest agricultural pollutant loadings. As shown in the land use data (Tables 2-3 and 2-4), these subwatersheds have the highest amounts of agricultural lands.

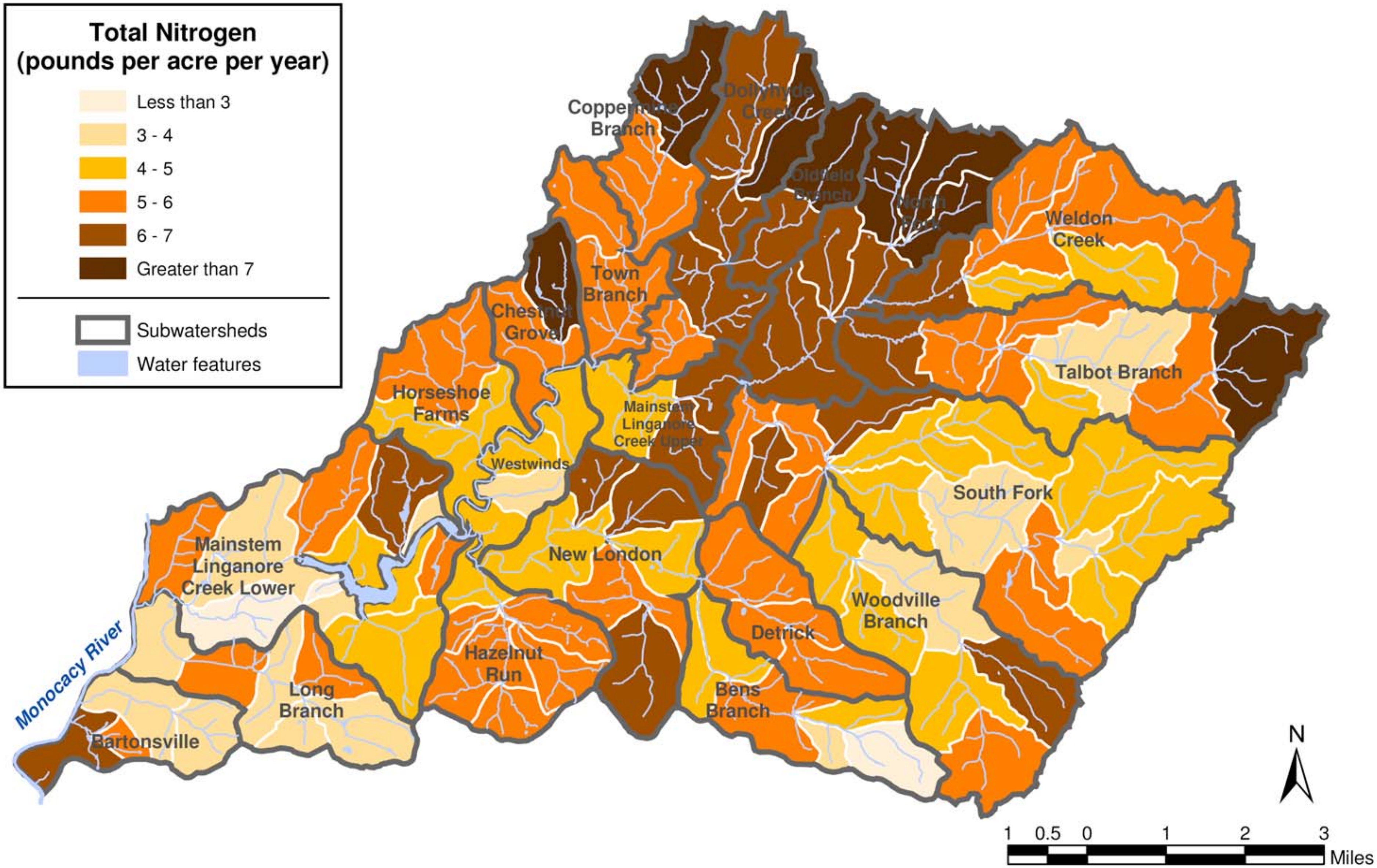

Figure 3-1. Annual pollutant loadings (lbs/ac) for TN in the Linganore Creek watershed, for an average rainfall year

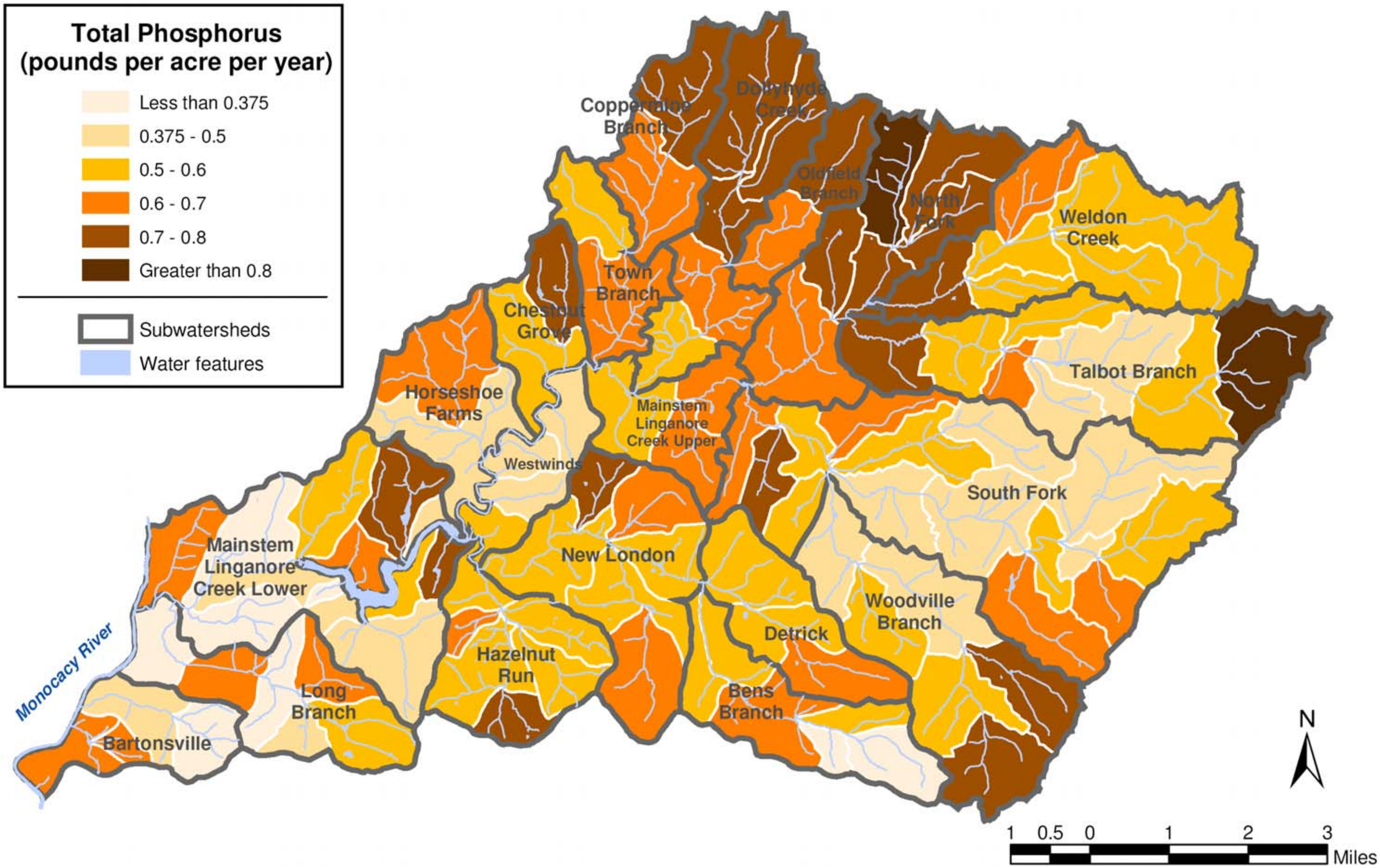

Figure 3-2. Annual pollutant loadings (lbs/ac) for TP in the Linganore Creek watershed, for an average rainfall year

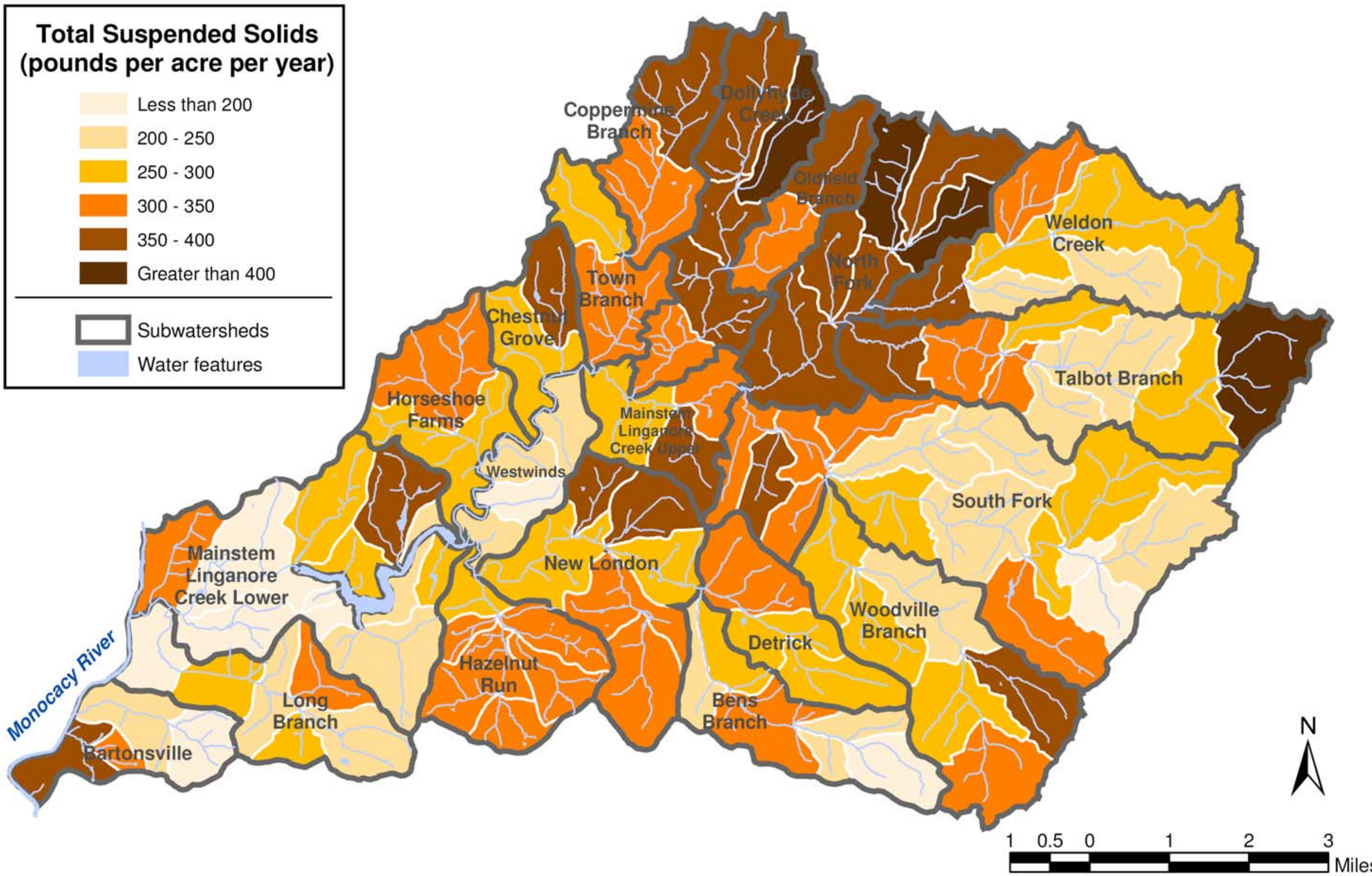

Figure 3-3. Annual pollutant loadings (lbs/ac) for TSS in the Linganore Creek watershed, for an average rainfall year

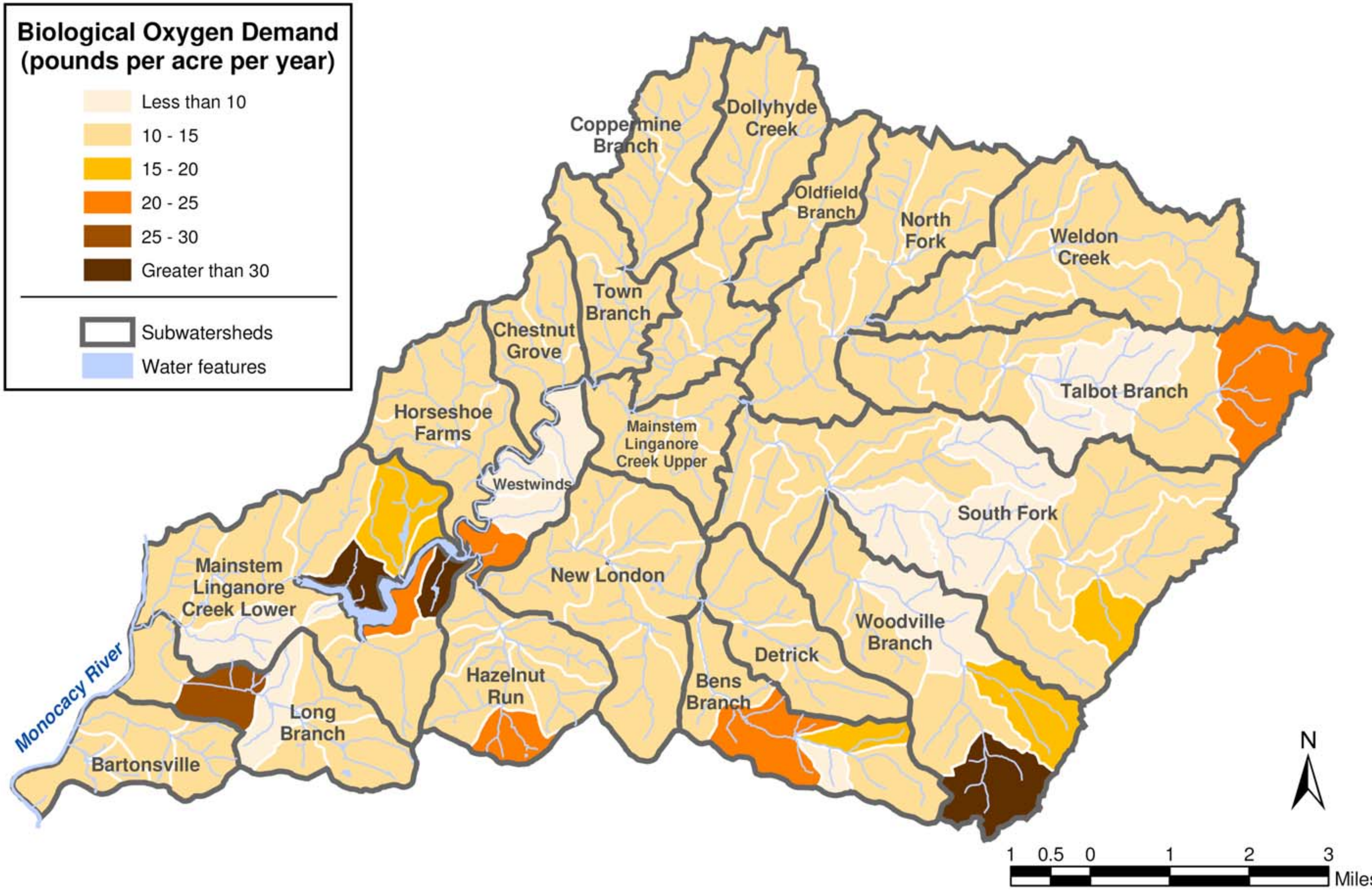

Figure 3-4. Annual pollutant loadings (lbs/ac) for BOD in the Linganore Creek watershed, for an average rainfall year

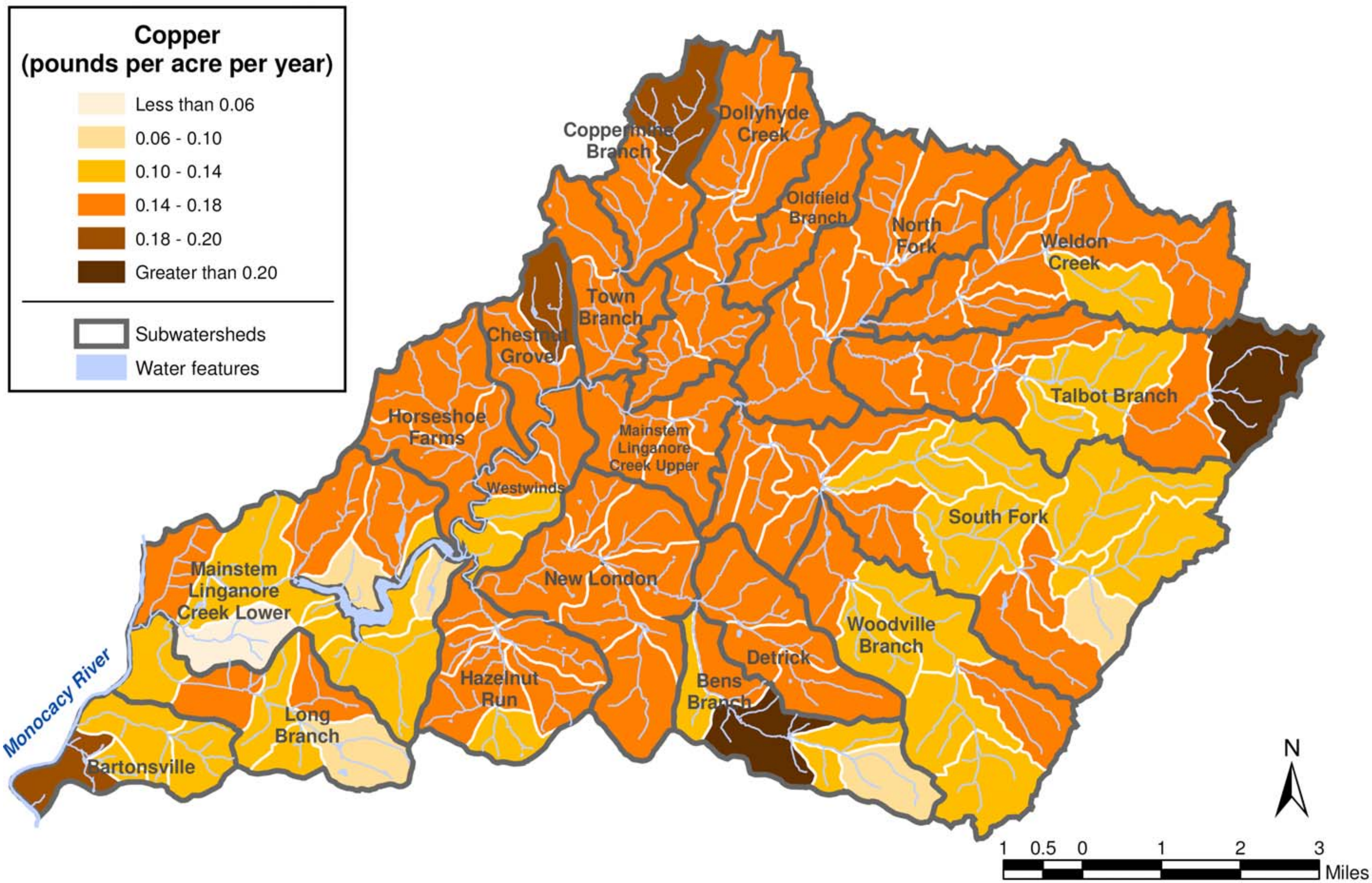

Figure 3-5. Annual pollutant loadings (lbs/ac) for copper in the Linganore Creek watershed, for an average rainfall year

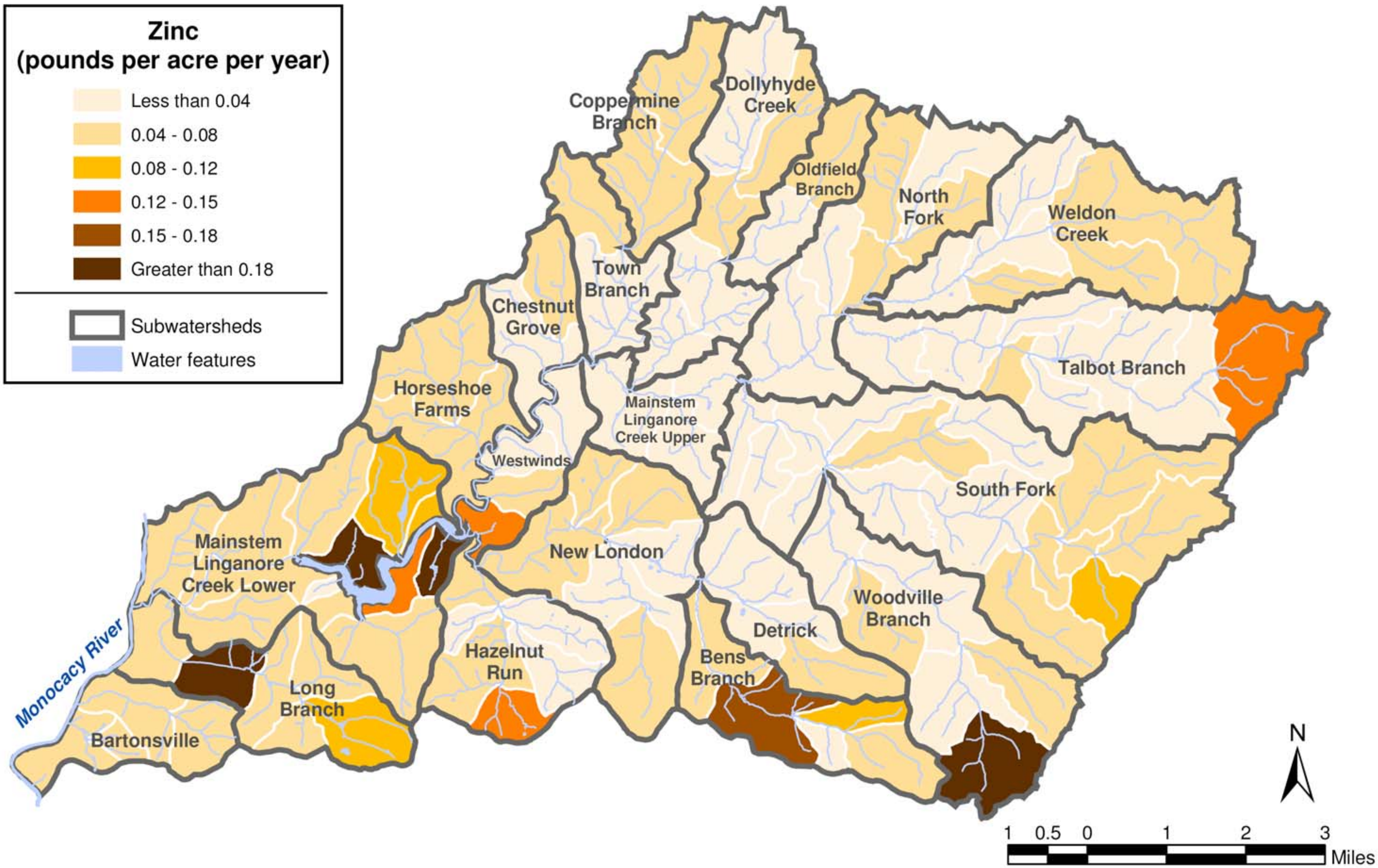

Figure 3-6. Annual pollutant loadings (lbs/ac) for zinc in the Linganore Creek watershed, for an average rainfall year

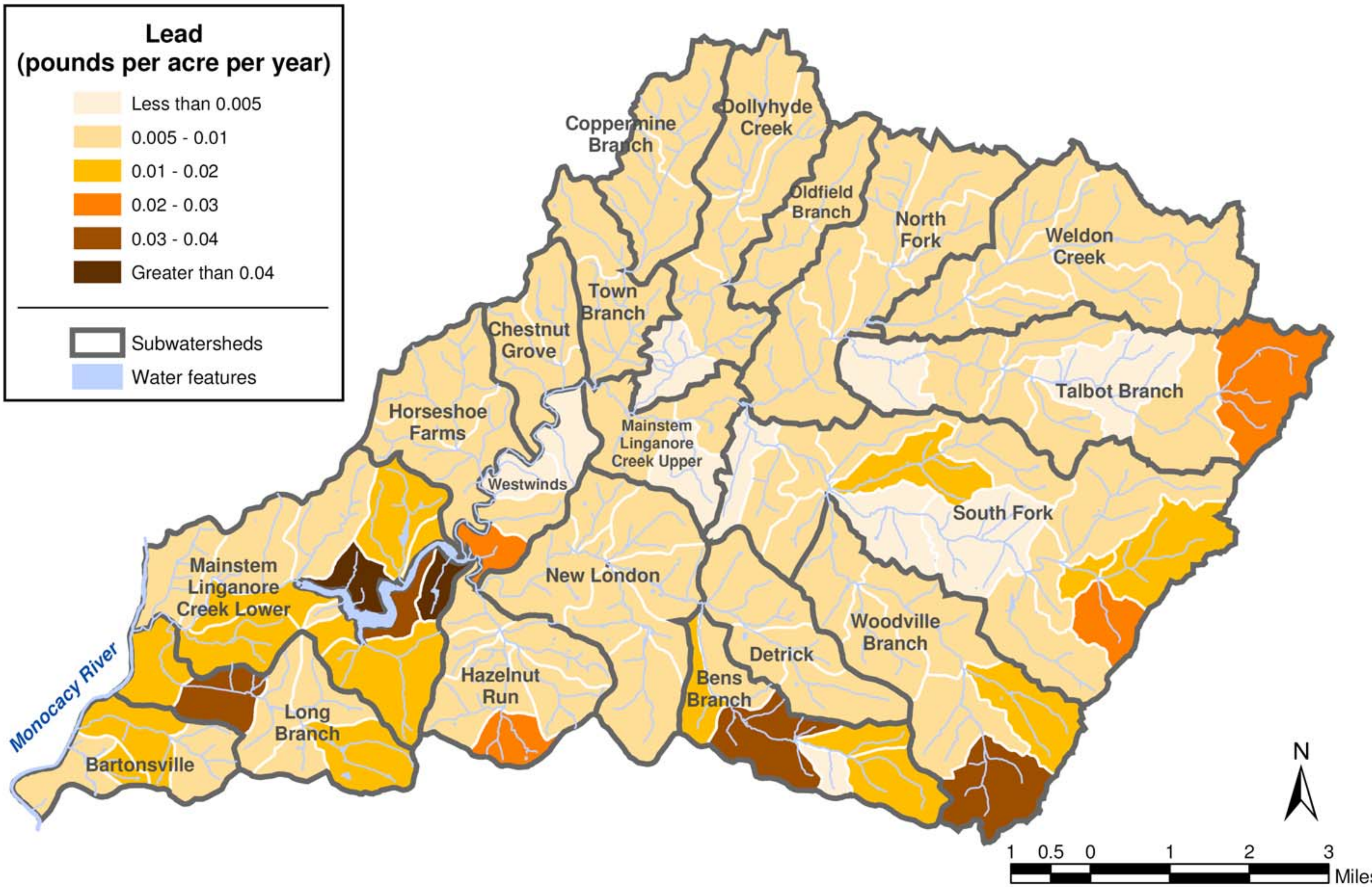

Figure 3-7. Annual pollutant loadings (lbs/ac) for lead in the Linganore Creek watershed, for an average rainfall year

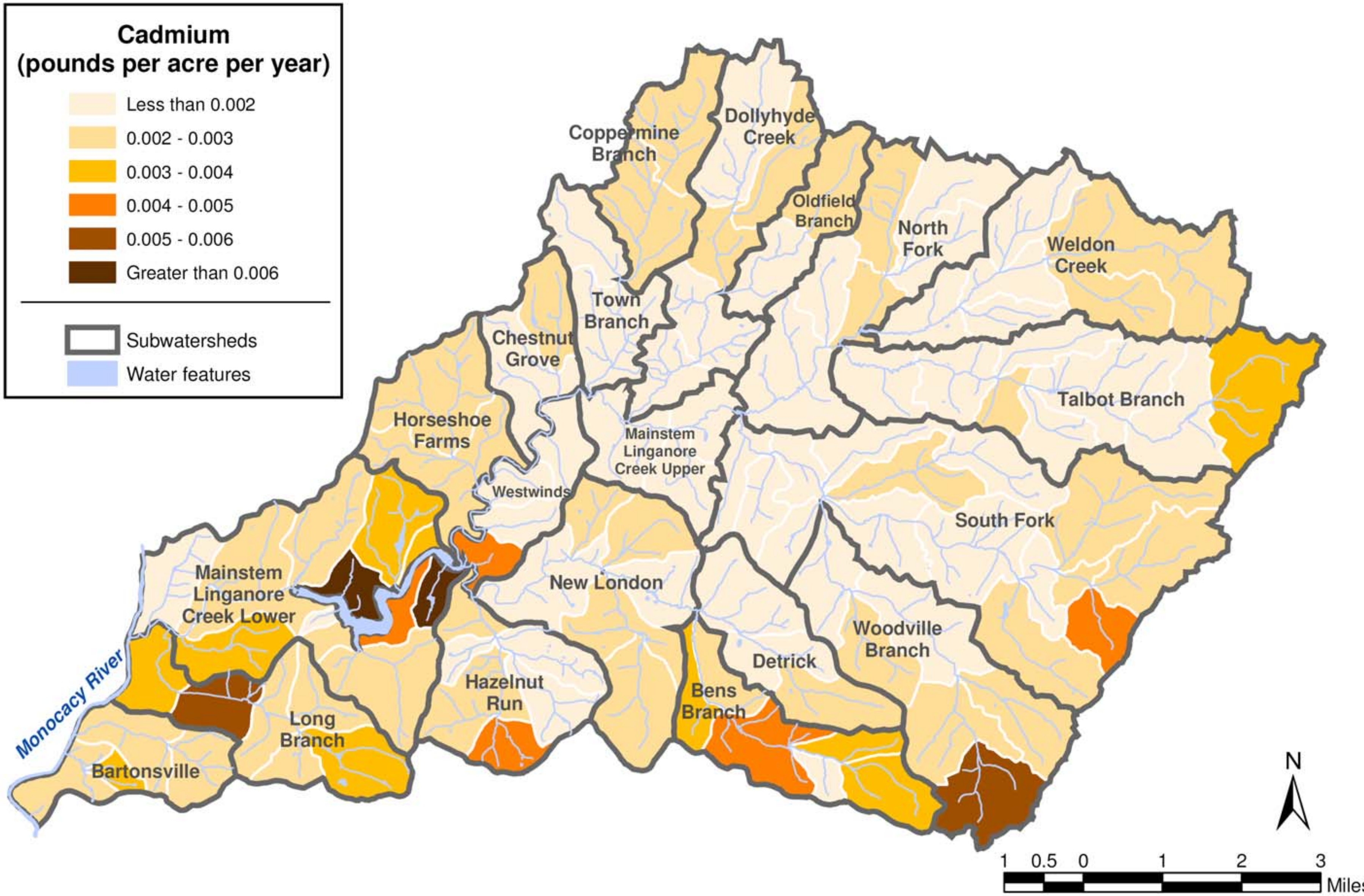

Figure 3-8. Annual pollutant loadings (lbs/ac) for cadmium in the Linganore Creek watershed, for an average rainfall year

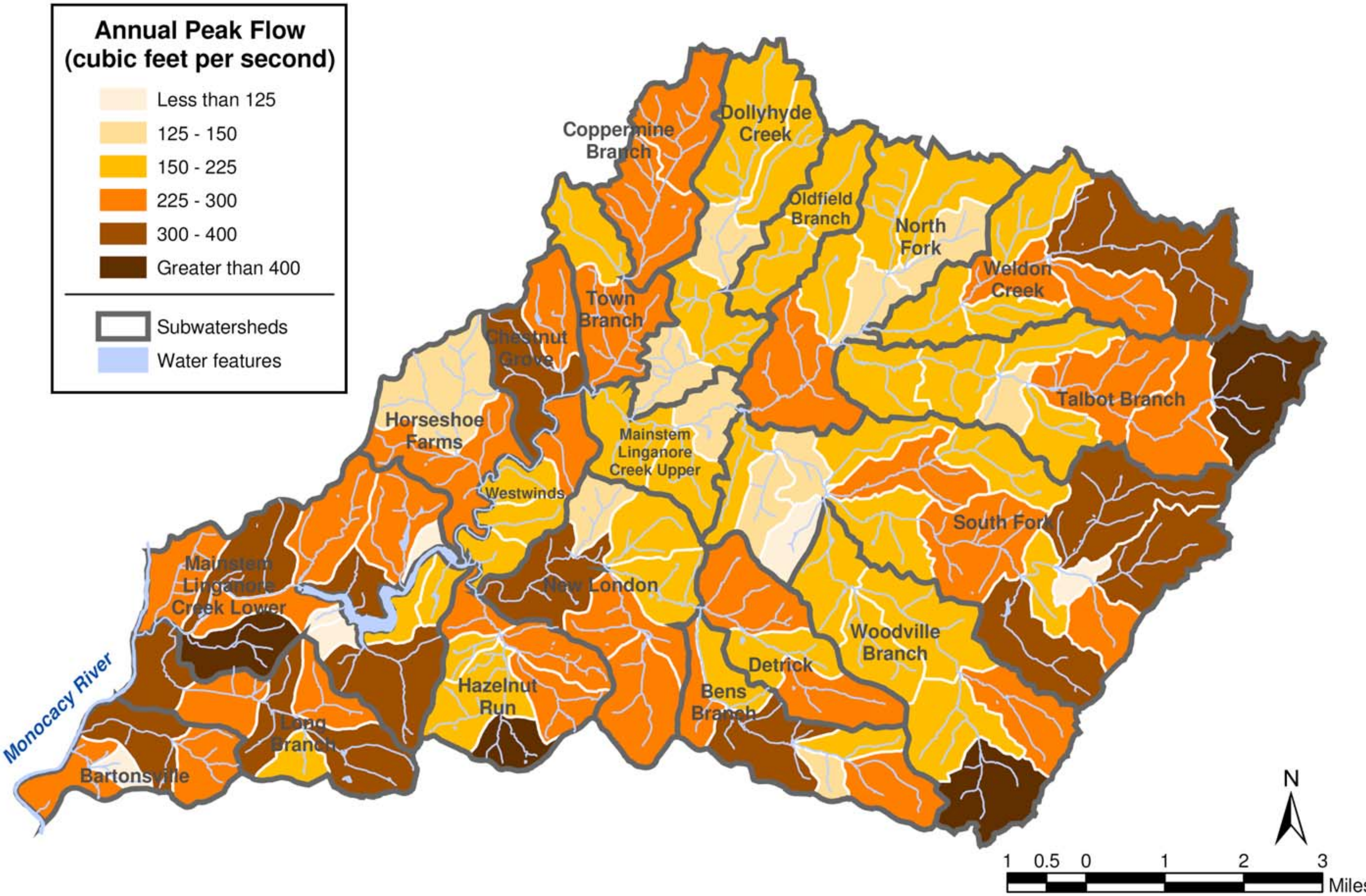

Figure 3-9. Annual peak flows (cfs) in the Linganore Creek watershed, for an average rainfall year

Table 3-1. SWMM model results for Linganore Creek catchments, annual results for an average rainfall year

Subwatershed	Catchment	Total annual loads, after SWM pond removals (pounds per acre)										Peak Flow (cfs)
		TN	TP	OP	BOD	COD	TSS	PB	CU	ZN	CD	
Bartonsville	BART-A	6.2	0.664	0.367	12.9	53.0	369.4	0.010	0.182	0.054	0.003	261.2
	BART-B	5.1	0.624	0.343	14.7	64.0	314.9	0.015	0.125	0.073	0.004	106.7
	BART-C	3.7	0.450	0.243	11.4	54.9	210.8	0.011	0.117	0.061	0.003	322.1
	BART-D	3.1	0.360	0.198	10.4	44.6	191.8	0.009	0.129	0.049	0.003	257.3
Bens Branch	BB-A	4.2	0.512	0.282	13.6	61.1	214.9	0.014	0.121	0.071	0.004	263.5
	BB-B	4.7	0.509	0.280	10.9	45.1	264.0	0.007	0.145	0.043	0.003	165.6
	BB-C	5.7	0.605	0.329	22.6	74.1	331.1	0.034	0.218	0.169	0.005	399.7
	BB-D	4.4	0.520	0.287	15.3	64.9	219.8	0.018	0.134	0.089	0.004	190.3
	BB-E	3.0	0.324	0.178	8.1	33.4	221.3	0.004	0.136	0.031	0.002	126.7
	BB-F	2.9	0.365	0.177	11.9	53.4	155.2	0.015	0.088	0.068	0.004	268.6
Chestnut Grove	CG-A	5.2	0.550	0.303	10.6	42.1	280.0	0.005	0.150	0.036	0.002	322.1
	CG-B	7.2	0.758	0.416	14.3	53.2	390.5	0.009	0.188	0.053	0.003	268.7
Detrick	DET-A	5.5	0.591	0.325	10.8	41.9	329.2	0.005	0.150	0.035	0.002	239.0
	DET-B	5.4	0.569	0.313	11.1	44.2	287.4	0.006	0.154	0.039	0.002	180.8
	DET-C	5.5	0.608	0.334	12.9	53.9	287.5	0.010	0.144	0.054	0.003	246.1
Horseshoe Farms	HF-A	4.6	0.496	0.273	11.0	44.5	256.5	0.006	0.152	0.042	0.003	259.9
	HF-B	5.9	0.640	0.352	13.0	53.0	319.2	0.008	0.155	0.051	0.003	132.0
Hazelnut Run	HR-A	4.8	0.513	0.282	12.1	47.4	255.1	0.007	0.153	0.048	0.003	243.1
	HR-B	5.8	0.603	0.324	11.2	43.4	317.2	0.005	0.151	0.037	0.002	162.1
	HR-C	5.5	0.593	0.326	11.8	46.7	313.2	0.006	0.158	0.042	0.003	223.8
	HR-D	5.6	0.597	0.328	11.3	44.2	326.7	0.005	0.160	0.037	0.002	229.8
	HR-E	5.4	0.568	0.312	10.7	41.0	306.7	0.005	0.148	0.035	0.002	265.2
	HR-F	5.4	0.701	0.387	23.8	84.9	315.0	0.028	0.110	0.146	0.005	471.0
Long Branch	LB-A	3.2	0.371	0.187	12.5	54.4	165.2	0.015	0.129	0.068	0.004	304.1
	LB-B	5.9	0.668	0.353	25.5	90.5	292.2	0.039	0.168	0.188	0.006	287.1
	LB-C	3.0	0.346	0.023	9.2	42.7	205.7	0.007	0.123	0.044	0.003	309.8
	LB-D	6.0	0.675	0.371	13.6	57.3	335.9	0.010	0.148	0.057	0.003	240.5
	LB-E	3.9	0.542	0.298	13.8	71.2	248.4	0.015	0.094	0.085	0.004	353.0
	LB-F	3.7	0.468	0.205	10.7	54.5	267.3	0.009	0.114	0.058	0.003	173.5
Mainstem Linganore Creek	MLC-A	6.0	0.619	0.340	11.8	46.3	322.5	0.006	0.174	0.040	0.002	255.2
	MLC-B	3.3	0.370	0.203	11.1	44.5	198.8	0.008	0.135	0.050	0.003	355.9
	MLC-C	5.2	0.569	0.313	14.2	54.1	283.8	0.010	0.154	0.060	0.003	289.1
	MLC-D	6.6	0.756	0.416	19.4	71.5	387.6	0.016	0.163	0.089	0.004	292.5
	MLC-E	3.5	0.424	0.233	16.2	61.0	201.0	0.014	0.138	0.082	0.004	104.6
	MLC-F	4.5	0.661	0.343	33.6	112.1	268.1	0.042	0.065	0.205	0.007	341.6
	MLC-G	5.2	0.790	0.435	37.1	128.1	297.1	0.044	0.065	0.223	0.008	203.4
	MLC-H	4.5	0.564	0.310	24.5	88.9	240.9	0.031	0.134	0.148	0.005	210.3
	MLC-I	4.2	0.484	0.266	13.9	54.9	242.2	0.011	0.138	0.065	0.003	385.3
	MLC-J	3.7	0.438	0.241	12.1	54.2	180.5	0.012	0.127	0.060	0.003	121.2
	MLC-K	2.6	0.279	0.154	8.7	38.9	124.7	0.007	0.132	0.039	0.002	61.5

Table 3-1. (Continued)

Subwatershed	Catchment	Total annual loads, after SWM pond removals (pounds per acre)										Peak Flow (cfs)
		TN	TP	OP	BOD	COD	TSS	PB	CU	ZN	CD	
Mainstem Linganore Creek (Cont.)	MLC-L	3.1	0.376	0.202	14.5	56.3	166.0	0.013	0.129	0.074	0.003	271.0
	MLC-M	1.5	0.260	0.073	5.6	22.5	83.2	0.020	0.040	0.043	0.004	429.6
New London	NL-A	4.9	0.528	0.292	10.9	43.5	276.3	0.006	0.146	0.041	0.002	322.1
	NL-B	7.0	0.750	0.413	13.7	52.4	381.4	0.007	0.165	0.046	0.003	145.0
	NL-C	6.5	0.689	0.379	12.8	49.1	356.1	0.006	0.162	0.044	0.003	218.6
	NL-D	4.7	0.508	0.280	10.0	39.3	296.9	0.005	0.145	0.034	0.002	208.3
	NL-E	5.1	0.551	0.303	10.8	43.2	310.6	0.006	0.147	0.039	0.003	253.6
	NL-F	6.3	0.674	0.371	13.1	49.7	343.7	0.007	0.159	0.046	0.003	274.0
Westwinds	WW-A	4.2	0.592	0.327	23.6	91.2	247.8	0.024	0.106	0.137	0.005	224.8
	WW-B	3.4	0.382	0.215	9.5	39.5	197.3	0.007	0.135	0.045	0.002	215.4
	WW-C	4.5	0.469	0.258	9.6	38.7	241.4	0.004	0.153	0.032	0.002	182.9
	WW-D	4.3	0.445	0.245	9.2	37.1	228.1	0.004	0.144	0.031	0.002	228.7
Coppermine Branch	CB-A	5.7	0.628	0.343	13.9	54.5	330.6	0.010	0.157	0.062	0.003	295.4
	CB-B	7.4	0.767	0.422	13.4	51.5	398.0	0.007	0.185	0.044	0.003	233.5
Dollyhyde Creek	DC-A	5.5	0.586	0.322	10.7	41.0	337.4	0.004	0.153	0.034	0.002	139.9
	DC-B	6.5	0.693	0.381	11.7	44.4	383.1	0.005	0.158	0.035	0.002	173.9
	DC-C	6.6	0.711	0.391	12.9	50.7	370.6	0.007	0.159	0.045	0.003	144.5
	DC-D	6.7	0.703	0.387	11.9	44.9	375.2	0.005	0.160	0.036	0.002	219.4
	DC-E	7.5	0.798	0.439	13.8	53.2	409.9	0.007	0.171	0.045	0.003	200.8
Mainstem Linganore Creek Upper	MLCU-A	5.0	0.531	0.292	10.3	40.8	276.5	0.005	0.146	0.035	0.002	198.8
	MLCU-B	6.1	0.642	0.353	11.3	43.3	342.5	0.005	0.160	0.035	0.002	132.5
	MLCU-C	6.4	0.675	0.371	11.6	43.8	358.5	0.004	0.160	0.034	0.002	156.4
North Fork	NF-A	6.4	0.677	0.372	12.0	46.6	352.7	0.006	0.157	0.039	0.002	262.8
	NF-B	6.9	0.732	0.403	12.5	47.6	397.0	0.005	0.164	0.039	0.002	162.3
	NF-C	7.6	0.801	0.441	13.9	52.3	420.1	0.006	0.173	0.044	0.003	197.8
	NF-D	7.3	0.766	0.422	12.8	47.9	397.5	0.005	0.166	0.038	0.002	181.0
	NF-E	7.4	0.783	0.431	13.2	49.7	403.1	0.006	0.168	0.041	0.002	138.4
	NF-F	6.9	0.740	0.407	13.4	52.8	370.5	0.007	0.166	0.046	0.003	148.0
Oldfield Branch	OB-A	6.2	0.650	0.357	11.4	44.0	336.0	0.005	0.155	0.036	0.002	159.6
	OB-B	7.3	0.769	0.423	13.3	50.6	394.2	0.006	0.169	0.042	0.003	212.9
South Fork	SF-A	6.0	0.633	0.349	11.2	43.0	348.5	0.004	0.159	0.035	0.002	162.1
	SF-B	5.4	0.574	0.316	10.9	42.7	306.3	0.005	0.156	0.036	0.002	139.8
	SF-C	6.4	0.675	0.371	11.8	45.3	350.0	0.005	0.161	0.036	0.002	182.4
	SF-D	4.4	0.511	0.281	12.4	53.6	236.5	0.011	0.133	0.057	0.003	296.2
	SF-E	4.1	0.426	0.234	9.1	37.0	215.6	0.005	0.137	0.032	0.002	208.1
	SF-F	4.5	0.495	0.272	10.8	44.5	254.6	0.007	0.140	0.043	0.003	367.7
	SF-G	4.7	0.529	0.290	12.4	53.4	242.2	0.011	0.132	0.057	0.003	302.0
	SF-H	4.4	0.602	0.331	17.8	82.7	198.0	0.025	0.080	0.109	0.005	245.8
	SF-I	3.8	0.443	0.243	11.9	53.1	186.3	0.011	0.128	0.058	0.003	105.1
	SF-J	5.2	0.552	0.303	11.1	45.1	274.4	0.006	0.149	0.040	0.002	156.1

Table 3-1. (Continued)												
Subwatershed	Catchment	Total annual loads, after SWM pond removals (pounds per acre)										Peak Flow (cfs)
		TN	TP	OP	BOD	COD	TSS	PB	CU	ZN	CD	
South Fork (Cont.)	SF-K	5.8	0.641	0.353	13.4	55.7	309.0	0.010	0.148	0.056	0.003	306.3
	SF-L	3.8	0.398	0.219	8.5	34.5	205.8	0.004	0.136	0.029	0.002	246.6
	SF-M	4.6	0.485	0.267	9.6	38.4	251.8	0.004	0.145	0.032	0.002	187.5
	SF-N	5.6	0.589	0.324	10.8	41.9	330.2	0.005	0.155	0.035	0.002	122.3
	SF-O	6.7	0.701	0.385	12.0	45.2	371.0	0.005	0.164	0.035	0.002	138.5
Talbot Branch	TAB-A	6.8	0.712	0.392	11.9	44.7	370.3	0.004	0.161	0.035	0.002	155.9
	TAB-B	5.4	0.579	0.318	10.7	41.9	314.2	0.005	0.148	0.035	0.002	163.1
	TAB-C	5.4	0.573	0.315	11.1	44.2	293.2	0.006	0.153	0.038	0.002	197.9
	TAB-D	3.7	0.392	0.216	8.5	34.6	204.5	0.004	0.132	0.030	0.002	278.5
	TAB-E	5.2	0.545	0.300	10.9	43.7	277.3	0.006	0.154	0.039	0.002	266.9
	TAB-F	8.0	0.849	0.467	21.8	75.8	414.9	0.023	0.211	0.124	0.004	403.2
	TAB-G	4.1	0.427	0.217	9.0	36.7	233.1	0.006	0.123	0.033	0.002	199.3
	TAB-H	5.7	0.606	0.333	11.8	46.7	323.2	0.006	0.159	0.041	0.003	130.2
Town Branch	TOB-A	6.0	0.628	0.345	11.4	44.3	321.7	0.005	0.156	0.037	0.002	245.7
	TOB-B	5.2	0.557	0.306	11.4	45.3	290.0	0.007	0.151	0.043	0.002	210.1
Woodville Branch	WB-A	4.4	0.474	0.261	10.0	40.6	263.2	0.006	0.142	0.037	0.002	193.9
	WB-B	3.8	0.411	0.226	9.3	39.5	207.4	0.006	0.139	0.036	0.002	194.4
	WB-C	6.8	0.753	0.387	16.3	61.7	386.2	0.011	0.160	0.064	0.003	243.1
	WB-D	5.7	0.765	0.411	32.0	108.4	321.9	0.037	0.110	0.198	0.006	746.7
	WB-E	4.8	0.523	0.281	10.1	39.5	282.6	0.007	0.140	0.037	0.003	223.7
	WB-F	4.6	0.518	0.285	11.8	50.1	250.6	0.009	0.139	0.051	0.003	187.9
Weldon Creek	WC-A	7.0	0.739	0.407	12.6	48.2	382.0	0.005	0.164	0.039	0.002	191.0
	WC-B	5.1	0.536	0.295	10.4	41.6	275.6	0.005	0.144	0.036	0.002	226.9
	WC-C	5.9	0.615	0.338	11.0	42.6	321.9	0.005	0.152	0.035	0.002	204.4
	WC-D	5.2	0.569	0.313	11.8	48.3	296.3	0.008	0.147	0.046	0.003	363.3
	WC-E	4.6	0.502	0.276	11.2	47.0	237.3	0.008	0.139	0.046	0.003	266.2
	WC-F	4.7	0.501	0.276	10.5	43.3	246.1	0.006	0.142	0.040	0.002	207.0

Table 3-2. Relative subwatershed rankings, by pollutant loads, for the entire Linganore Creek watershed (20 = highest loads; 1 = lowest loads)

		Agriculture Pollutant Ranking							**Urban Pollutant Rankings**						
	Subwatershed	**TN**	**TP**	**OP**	**TSS**	**CU**	**Average Agricultural Score**	**Agriculture Rank**	**BOD**	**COD**	**PB**	**ZN**	**CD**	**Average Urban Score**	**Urban Rank**
Lower	Bartonsville	4	3	5	5	6	4.6	5	8	14	15	15	15	13.4	14
	Bens Branch	5	2	3	2	9	4.2	4	17	18	19	19	17	18	18.5
	Chestnut Grove	16	15	16	16	19	16.4	16	9	7	8	9	6	7.8	8
	Detrick	11	9	9	10	10	9.8	9	5	6	9	8	10	7.6	7
	Hazelnut Run	10	14	15	13	5	11.4	11	19	17	16	16	16	16.8	16
	Horseshoe Farms	7	7	7	7	11	7.8	7	6	5	10	10	9	8	9
	Long Branch	2	5	1	4	2	2.8	2	16	19	18	18	19	18	18.5
	Mainstem Linganore Creek	3	4	4	3	1	3	3	18	16	17	17	18	17.2	17
	New London	13	13	13	15	12	13.2	14	7	4	6	7	8	6.4	6
	Westwinds	1	1	2	1	4	1.8	1	11	13	14	14	13	13	13
Upper	Coppermine Branch	17	17	17	17	20	17.6	17	15	15	12	13	14	13.8	15
	Dollyhyde Creek	18	18	18	19	16	17.8	18	10	8	2	2	5	5.4	4
	Mainstem Linganore Creek Upper	15	12	12	14	14	13.4	15	1	1	1	1	1	1	1
	North Fork	20	20	20	20	18	19.6	20	14	12	5	6	7	8.8	10
	Oldfield Branch	19	19	19	18	17	18.4	19	12	10	3	3	3	6.2	5
	South Fork	6	6	6	6	7	6.2	6	3	9	11	11	12	9.2	11
	Talbot Branch	12	10	10	11	15	11.6	12	13	11	13	12	11	12	12
	Town Branch	14	11	11	12	13	12.2	13	4	2	4	4	2	3.2	2
	Weldon Creek	9	8	8	8	8	8.2	8	2	3	7	5	4	4.2	3
	Woodville Branch	8	16	14	9	3	10	10	20	20	20	20	20	20	20

Table 3-3. Relative subwatershed rankings, by pollutant loads, in Lower Linganore Creek (10 = highest loads; 1 = lowest loads)

	Agricultural Pollutant Rankings					**Average Agricultural Score**	**Agricultural Rank**	**Urban Pollutant Rankings**					**Average Urban Score**	**Urban Rank**
	TN	**TP**	**OP**	**TSS**	**CU**			**BOD**	**COD**	**PB**	**ZN**	**CD**		
Bartonsville	4	3	5	5	5	4.4	5	4	6	6	6	6	5.6	6
Bens Branch	5	2	3	2	6	3.6	4	8	9	10	10	8	9.0	9.5
Chestnut Grove	10	10	10	10	10	10.0	10	5	4	2	3	1	3.0	3.5
Detrick	8	7	7	7	7	7.2	7	1	3	3	2	4	2.6	2
Hazelnut Run	7	9	9	8	4	7.4	8	10	8	7	7	7	7.8	7
Horseshoe Farms	6	6	6	6	8	6.4	6	2	2	4	4	3	3.0	3.5
Long Branch	2	5	1	4	2	2.8	2	7	10	9	9	10	9.0	9.5
Mainstem Linganore Creek	3	4	4	3	1	3.0	3	9	7	8	8	9	8.2	8
New London	9	8	8	9	9	8.6	9	3	1	1	1	2	1.6	1
Westwinds	1	1	2	1	3	1.6	1	6	5	5	5	5	5.2	5

Table 3-4. Relative subwatershed rankings by pollutant loads, in Upper Linganore Creek (10 = highest loads; 1 = lowest loads)

	Agricultural Pollutant Rankings					**Average Agricultural Score**	**Agricultural Rank**	**Urban Pollutant Rankings**					**Average Urban Score**	**Urban Rank**
	TN	**TP**	**OP**	**TSS**	**CU**			**BOD**	**COD**	**PB**	**ZN**	**CD**		
Coppermine Branch	7	7	7	7	10	7.6	7	9	9	8	9	9	8.8	9
Dollyhyde Creek	8	8	8	9	7	8.0	8	5	4	2	2	5	3.6	3
Mainstem Linganore Creek Upper	6	5	5	6	5	5.4	6	1	1	1	1	1	1.0	1
North Fork	10	10	10	10	9	9.8	10	8	8	5	6	6	6.6	7
Oldfield Branch	9	9	9	8	8	8.6	9	6	6	3	3	3	4.2	5
South Fork	1	1	1	1	2	1.2	1	3	5	7	7	8	6.0	6
Talbot Branch	4	3	3	4	6	4.0	4	7	7	9	8	7	7.6	8
Town Branch	5	4	4	5	4	4.4	5	4	2	4	4	2	3.2	2
Weldon Creek	3	2	2	2	3	2.4	2	2	3	6	5	4	4.0	4
Woodville Branch	2	6	6	3	1	3.6	3	10	10	10	10	10	10.0	10

Forested areas produce relatively smaller agricultural pollutant loads, and as such, subwatersheds with larger proportions of forest were ranked lower. The three lower subwatersheds with the least agricultural pollutant loadings are Westwinds, Long Branch, and Mainstem Linganore Creek. With the exception of Long Branch, these subwatersheds have more forested than agricultural land, so the low rankings were expected. In the upper watershed, South Fork, Weldon Creek, and Woodville Branch have the least agriculture loadings.

Urban pollutant rankings were highest in the Lower Linganore watershed for the Bens Branch, Long Branch, and Mainstem Linganore Creek subwatersheds. Woodville Branch, Coppermine Branch, and Talbot Branch had the highest urban pollutants loadings in the Upper Linganore watershed. In general, if a subwatershed has a high ranking for one group of pollutants, it has a lower matching ranking for the other group of pollutants. For example, Long Branch may have the highest urban loadings, but has lowest agricultural loadings.

3.2 USE OF BASELINE POLLUTANT LOADINGS

SWMM modeling provides useful results for comparing nonpoint pollutant loadings originating from various areas within Lower and Upper Linganore watershed. These SWMM results have been integrated with other watershed assessment findings to provide valuable information for targeting areas (catchments) where water quality improvement opportunities would be most effective. This information was used to aid in identifying potential areas for implementing new structural BMPs, retrofits to existing structures, stream restoration projects, or other site-specific improvements.

3.3 ADDITIONAL MODELING TO EVALUATE BENEFIT OF CANDIDATE RESTORATION PROJECTS

Annual stormwater pollutant loadings from the 15 proposed Tier 1 candidate watershed restoration projects and their drainage areas (Perot et al. 2006) were calculated using SWMM for each pollutant of interest, in a manner similar to the overall catchment loadings for the Linganore watershed. Drainage areas for each project were estimated from topographic maps, aerial photos, and visits to the project sites in the field. These drainage areas were mapped into GIS and the sub-drainage areas to the various project elements were estimated. Land use percentages within each project drainage were calculated in GIS using the 2002 land use data. Directly-connected impervious area for each project area were estimated from the land use percentages as described in Section 2.3. Physical parameters for each project drainage area subcatchment were the same as those for the catchment in which the project would be located, except for the subcatchment width, which was adjusted by the percent of the total catchment area.

BMP pollutant removal efficiency values were taken from Schueler (1987), Schueler (1997a), Schueler (1997b) and Winer (2000) (Table 3-5). Note that in a few cases, removal efficiencies are negative values, indicating that these BMPs result in a release of some constituents. Winer (2000) explains that in the case of dissolved phosphorus, organic or sediment bound forms of the nutrient are transformed within certain structural BMPs and flushed out during subsequent storm events. A project composite pollutant removal efficiency was calculated based on the proportion of each project element type within the overall project. Rain barrels were assumed not to remove any water quality constituents.

Table 3-5. Percent removal of pollutants by stormwater management structure type

	TSS	TP	TN	COD	BOD	Cd	Cu	Pb	Zn	TKN	TDS	Diss. Phos.
Infiltration Trench (IT)	87	**100**	**42**	66	66	ND	34	71	80	ND	ND	**100**
Wet Pond (WP)	**79**	**49**	**32**	45	45	24	**58**	73	**65**	ND	ND	**62**
Dry Pond (DP)	**3**	**19**	**5**	-1	-1	54	**10**	43	**5**	ND	ND	**0**
Extended Wet Detention Pond (EDSW)	**80**	**55**	**35**	27	27	24	**44**	73	**69**	ND	ND	**67**
Extended Dry Detention Pond (EDSD)	**61**	**20**	**31**	25	25	54	**26**	43	**26**	ND	ND	**-11**
Infiltration Basin, Rain Garden (IB) [(a)]	80	55	55	80	80	75	75	75	75	ND	ND	ND
Oil/Grit Separator (OGS) [(b)]	**-8**	**-41**	15	ND	ND	ND	**-11**	10	**17**	21	ND	**40**
Shallow Marsh (SM)	**83**	**43**	**26**	21	21	69	**33**	63	**42**	ND	ND	**29**
Swale (SW)	**81**	**34**	**84**	67	67	42	**51**	67	**71**	ND	ND	**38**
Sand Filter (SF)	**86**	**59**	**38**	67	67	ND	**49**	ND	**88**	ND	ND	**3**

All bold information from:
Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Prepared by Center for Watershed Protection for USEPA Office of Science and Technology.
Other (non-bold) information from:
Schueler, T. R. Technical Note 95. Comparative Pollutant Removal Capability of Urban BMPs: A Reanalysis. Watershed Protection Techniques. Vol. 2, No. 4. June 1997 except as noted below:
(a) Schueler, T. R. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Department of Environmental Programs Metropolitan Washington Council of Governments. July, 1987 Washington Metropolitan Water Resources Planning Board.
(b) Schueler, T. R. Technical Note 101. Performance of Oil-Grit Separators in Removing Pollutants at Small Sites. Watershed Protection Techniques. Vol. 2, No. 4. June 1997.
ND = No data available.

The SWMM model produced total loads generated in each project area within each model catchment. Composite removal efficiencies were then used to calculate pollutant removals for projects within each catchment. Results are summarized in two ways: Total pollutants removed by each project (in pounds per year – Table 3-6) and percent removal of pollutants by projects for each model catchment that contained one or more projects (Table 3-7). Results show a wide range of pollutant reductions, depending on many variables, including project type and size relative to the size of the catchment in which it is located. Some land-use types vary widely in the amount of pollutant generated. For example, some metals are generated by higher intensity land-uses such as residential and commercial and not by less intense uses like open space and pasture, while other parameters are less affected by the type of land use. Thus, projects that treat a pocket of higher intensity land-use area located within a catchment that is overall, less developed, will show a greater percentage reduction in loadings.

Table 3-6. Pollutant removal by proposed projects (lbs/year) in Linganore Creek watershed										
Project	**TN**	**TP**	**OP**	**BOD**	**COD**	**TSS**	**PB**	**CU**	**ZN**	**CD**
BA101	22.2	2.2	(0.1)	55.1	215	3,785	0.0	0.8	0.2	0.0
BA102	77.2	11.1	-	270	2,064	8,574	0.2	3.3	1.8	0.1
BB102	3.2	0.5	-	20.8	99.7	200	0.0	0.1	0.1	0.0
BB104	104	14.9	-	671	3,207	6,514	0.9	2.6	4.0	0.2
CB101	42.3	6.0	-	166	1,141	4,597	0.1	1.8	1.1	0.1
CB107	81.6	10.2	-	614	2,032	6,295	0.7	2.5	3.6	0.1
HF107	125	18.0	-	814	3,876	7,814	1.1	3.0	4.9	0.2
HR101	88.9	8.9	(0.4)	249	927.0	7,575	0.1	2.5	0.9	0.1
HR102	66.7	10.7	-	755	2,613	5,425	0.8	0.7	4.2	0.1
HR103	18.0	3.3	0.4	218	716.4	1,535	0.3	0.2	1.3	0.0
LB102	67.8	11.2	0.5	812	2,667	5,605	0.9	0.9	4.9	0.1
NL102	154	19.7	0.4	889	3,104	13,484	0.8	3.9	4.2	0.2
TO105	42.9	5.1	-	210	734.9	3,421	0.2	1.2	1.0	0.0
WB111	33.2	4.8	-	216	1,034	2,074	0.3	0.8	1.3	0.1
WB113	43.5	6.3	-	281	1,345	2,752	0.4	1.0	1.7	0.1
Total	970	133	0.7	6,241	25,776	79,649	6.8	25.2	35.2	1.4

Table 3-7. Percent reduction in catchment loads from all Tier 1 projects

Basin	Catchment	% Removal of Pollutants by All Tier 1 Projects										
		TN	**TP**	**OP**	**BOD**	**COD**	**TSS**	**PB**	**CU**	**ZN**	**CD**	**Project(s) in catchment**
Lower	BART-A	1.2%	1.2%	-0.1%	1.6%	2.0%	3.2%	1.5%	1.6%	1.9%	3.0%	BA101, BA102
	BART-C	3.4%	3.9%	0.0%	3.7%	6.0%	6.7%	2.3%	4.4%	4.6%	5.3%	BA102
	BB-A	8.0%	9.5%	0.0%	16.1%	17.1%	9.9%	20.7%	7.0%	18.4%	16.4%	BB104
	BB-D	0.3%	0.3%	0.0%	0.5%	0.6%	0.3%	0.6%	0.2%	0.5%	0.6%	BB102
	HF-A	5.2%	7.0%	0.0%	14.3%	16.8%	5.9%	33.8%	3.8%	22.6%	17.1%	HF107
	HF-B	6.5%	8.6%	0.0%	19.3%	22.4%	7.5%	39.8%	5.8%	29.5%	23.3%	HF107
	HR-B	3.4%	3.2%	-0.3%	4.8%	4.7%	5.4%	6.3%	3.6%	5.2%	5.2%	HR101
	HR-F	1.4%	1.9%	0.1%	3.6%	3.4%	2.4%	3.8%	0.8%	3.7%	3.3%	HR102, HR103
	LB-A	3.4%	4.6%	0.4%	9.4%	7.5%	6.3%	9.8%	0.9%	9.8%	7.2%	LB102
	LB-B	0.6%	0.8%	0.1%	1.5%	1.4%	1.0%	1.4%	0.4%	1.4%	1.3%	LB102
	NL-B	1.6%	1.9%	0.1%	5.1%	4.6%	2.4%	8.9%	1.5%	7.4%	4.7%	NL102
	NL-C	3.6%	4.3%	0.1%	10.3%	9.4%	5.9%	17.3%	3.8%	14.3%	9.8%	NL102
Upper	CB-A	2.9%	3.3%	0.0%	6.8%	7.0%	4.3%	9.8%	3.5%	9.0%	6.8%	CB101, CB105, TO105
	TOB-B	0.5%	0.6%	0.0%	1.6%	1.3%	0.7%	2.6%	0.5%	2.2%	1.3%	TO105
	WB-E	1.0%	1.4%	0.0%	2.9%	3.4%	1.1%	6.8%	0.9%	4.4%	3.7%	WB113
	WB-F	2.8%	3.6%	0.0%	7.1%	8.0%	3.3%	12.6%	2.2%	9.9%	8.0%	WB111

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APPENDIX

SWMM Model Results for Linganore Creek Catchments in Pounds Per Year

Table 1. Total annual loads (pounds/year), before SWM facility removals, for an average rainfall year											
Basin	**Catchment**	**TN**	**TP**	**OP**	**BOD**	**COD**	**TSS**	**PB**	**CU**	**ZN**	**CD**
Bartonsville	BART-A	2,669	283.4	155.9	5,570	22,890	156,600	4.139	78.37	22.71	1.315
	BART-B	692	84.26	46.34	1,990	8,646	42,510	1.975	16.9	9.91	0.5409
	BART-C	2,056	254.4	139.9	6,500	31,210	115,600	6.39	64.66	34.84	1.865
	BART-D	1,386	161.5	88.83	4,649	20,040	86,100	3.838	57.7	21.89	1.278
Bens Branch	BB-A	1,296	157.2	86.47	4,173	18,750	65,960	4.363	37.25	21.67	1.117
	BB-B	1,594	173.6	95.46	3,733	15,390	90,030	2.336	49.38	14.53	0.8806
	BB-C	4,171	437.3	240.5	17,810	56,740	230,800	25.42	157.8	133.1	3.478
	BB-D	1,152	137.3	75.53	4,047	17,130	57,920	4.68	35.32	23.42	1.023
	BB-E	469.8	51.46	28.3	1,283	5,305	35,190	0.661	21.59	4.865	0.3651
	BB-F	1,886	250.2	137.6	8,339	36,530	91,340	9.766	54.16	47.79	2.211
Chestnut Grove	CG-A	3,914	412	226.6	7,927	31,530	209,700	3.819	112.6	26.77	1.651
	CG-B	3,704	386.6	212.6	7,649	27,940	198,800	4.85	95.84	30.92	1.43
Detrick	DET-A	4,206	447.7	246.3	8,205	31,770	249,500	3.652	113.9	26.61	1.762
	DET-B	2,566	270.7	148.9	5,277	21,060	136,800	2.733	73.15	18.33	1.108
	DET-C	3,324	369	202.9	7,828	32,700	174,500	5.806	87.48	32.67	1.801
Horseshoe Farms	HF-A	1,264	135.5	74.52	3,000	12,160	70,030	1.718	41.48	11.34	0.6838
	HF-B	901.1	98.6	54.23	2,002	8,163	49,160	1.308	23.85	7.805	0.4486
Hazelnut Run	HR-A	3,250	348.5	191.7	8,239	32,160	173,200	5.01	104.2	32.46	1.755
	HR-B	2,671	281.2	154.6	5,208	20,080	143,900	2.367	69.86	17	1.023
	HR-C	2,308	247.2	136	4,921	19,470	130,600	2.599	65.68	17.49	1.071
	HR-D	1,874	198.7	109.3	3,756	14,710	108,800	1.75	53.2	12.48	0.8122
	HR-E	5,330	563.8	310.1	10,730	41,140	302,800	4.807	146.6	35.35	2.202
	HR-F	6,533	823.3	452.8	28,590	102,400	345,300	31.38	131.2	164.7	5.879
Long Branch	LB-A	1,641	202.3	111.2	7,363	30,060	80,540	8.334	59.98	40.84	1.829
	LB-B	2,765	318.7	175.3	12,580	43,760	131,600	19.25	78.21	95.12	2.603
	LB-C	1,412	168.2	92.48	4,290	19,940	95,180	3.303	56.68	20.47	1.278
	LB-D	2,240	251.6	138.4	5,086	21,370	125,300	3.687	55.24	21.2	1.197
	LB-E	2,296	321.3	176.7	8,196	42,230	147,300	8.873	55.72	50.17	2.551
	LB-F	849.7	109.8	60.4	2,478	12,670	61,990	2.148	26.42	13.39	0.8063
Mainstem Linganore Creek	MLC-A	3,371	349.7	192.3	6,661	26,180	182,200	3.438	98.11	22.61	1.376
	MLC-B	2,250	255.4	140.5	7,658	30,730	137,400	5.598	93.13	34.52	1.897
	MLC-C	3,432	378.4	208.1	9,414	35,970	188,700	6.43	102.4	39.61	2.002
	MLC-D	4,161	475.5	261.5	12,200	44,950	243,800	10.04	102.8	56.07	2.583
	MLC-E	381.8	46.59	25.62	1,778	6,709	22,110	1.552	15.14	9.017	0.4052
	MLC-F	1,529	226.4	124.5	11,260	37,710	85,610	13.47	24.06	67.97	2.268
	MLC-G	1,086	163.6	89.97	7,677	26,520	61,490	9.083	13.41	46.19	1.577
	MLC-H	964.1	121.9	67.01	5,296	19,200	52,040	6.715	28.97	31.92	1.164
	MLC-I	3,715	432.1	237.6	12,400	49,010	216,000	9.971	123.1	58.04	2.926
	MLC-J	487	57.32	31.52	1,579	7,098	23,650	1.53	16.65	7.915	0.4174
	MLC-K	146.3	15.93	8.762	495.1	2,219	7,109	0.3718	7.531	2.237	0.1319
	MLC-L	1,141	139.6	76.74	5,436	20,900	59,460	4.801	45.99	27.78	1.232
	MLC-M	2,912	427.2	234.9	19,520	67,600	159,200	22.18	46.25	115.5	4.012
New London	NL-A	4,002	431.1	237.1	8,992	36,180	223,500	5.001	118.7	33.61	1.988
	NL-B	2,234	238.5	131.2	4,357	16,660	121,300	2.206	52.61	14.78	0.8479
	NL-C	3,282	348.7	191.8	6,497	24,820	180,200	3.213	82.12	22.08	1.283
	NL-D	2,342	251.1	138.1	4,951	19,480	146,700	2.344	71.96	16.95	1.154
	NL-E	3,016	326.7	179.7	6,433	25,590	184,200	3.417	87.27	22.92	1.494
	NL-F	4,984	532	292.6	10,330	39,200	271,200	5.287	125.4	36.02	2.023
Westwinds	WW-A	1,083	152.6	83.9	6,083	23,480	63,780	6.28	27.24	35.31	1.376
	WW-B	1,135	126.8	69.76	3,474	14,350	62,530	2.266	43.07	15.3	0.8157
	WW-C	1,303	134.5	74	2,768	11,100	69,270	1.173	43.97	9.106	0.5902
	WW-D	1,710	177.6	97.69	3,673	14,820	91,030	1.641	57.53	12.36	0.7931
Coppermine Branch	CB-A	5,326	587.9	323.4	13,180	51,330	307,100	9.192	146.3	58.58	2.848
	CB-B	6,169	641.4	352.8	11,240	43,080	332,700	5.711	155	36.69	2.169
Dollyhyde Creek	DC-A	2,536	269.5	148.3	4,911	18,870	155,200	2.023	70.38	15.5	1.069
	DC-B	4,446	471.5	259.3	7,949	30,210	260,500	3.083	107.4	24.02	1.592
	DC-C	2,653	285.8	157.2	5,188	20,400	149,000	2.765	63.97	17.99	1.085
	DC-D	6,731	708.5	389.7	11,990	45,290	378,200	4.727	161	35.9	2.3
	DC-E	4,481	477.1	262.4	8,258	31,790	245,100	3.983	102.2	26.86	1.608

Table 1. Total annual loads (pounds/year), before SWM facility removals, for an average rainfall year											
Basin	**Catchment**	**TN**	**TP**	**OP**	**BOD**	**COD**	**TSS**	**PB**	**CU**	**ZN**	**CD**
Mainstem Linganore Creek Upper	MLCU-A	3,371	355.4	195.5	6,887	27,310	185,000	3.272	97.93	23.2	1.458
	MLCU-B	2,439	255.4	140.5	4,509	17,250	136,300	1.796	63.82	13.77	0.8907
	MLCU-C	3,091	323.9	178.2	5,551	21,040	172,100	2.128	76.68	16.54	1.065
North Fork	NF-A	6,980	740.7	407.4	13,170	50,980	385,800	6.2	171.6	42.9	2.635
	NF-B	3,033	322.1	177.2	5,515	20,950	174,700	2.355	72.27	17.12	1.099
	NF-C	4,591	487.3	268	8,433	31,800	255,400	3.78	105.2	26.75	1.61
	NF-D	4,933	518.1	285	8,629	32,370	268,700	3.415	112.1	25.64	1.575
	NF-E	3,345	352.4	193.8	5,923	22,380	181,400	2.552	75.49	18.27	1.095
	NF-F	2,463	263.3	144.8	4,783	18,800	131,900	2.549	58.95	16.47	0.9624
Oldfield Branch	OB-A	3,439	361.3	198.7	6,360	24,460	186,800	2.708	86.23	19.84	1.232
	OB-B	4,772	504	277.2	8,688	33,140	258,200	3.869	110.9	27.34	1.643
South Fork	SF-A	2,440	257.2	141.5	4,565	17,460	141,500	1.818	64.58	14.03	0.9338
	SF-B	1,655	174.5	95.99	3,308	12,980	93,100	1.487	47.34	10.85	0.6985
	SF-C	2,986	313.1	172.2	5,479	21,010	162,400	2.264	74.87	16.87	1.055
	SF-D	2,805	322.5	177.4	7,798	33,840	149,200	6.779	83.74	36.23	1.977
	SF-E	2,420	253.6	139.5	5,411	22,060	128,500	2.72	81.71	19.15	1.199
	SF-F	5,465	597.2	328.5	12,970	53,720	307,000	8.376	169	51.28	3.078
	SF-G	3,913	447.1	245.9	10,530	45,340	202,800	9.037	110.6	48.33	2.59
	SF-H	1,753	240.8	132.4	7,105	33,080	79,180	9.805	32.13	43.63	2.002
	SF-I	555	64.63	35.54	1,736	7,746	27,200	1.627	18.73	8.519	0.4527
	SF-J	1,535	163.9	90.12	3,303	13,380	81,500	1.858	44.14	12.02	0.7148
	SF-K	5,130	569.5	313.2	11,890	49,420	274,400	8.963	131.6	49.72	2.739
	SF-L	3,795	393.1	216.2	8,405	34,090	203,100	3.831	134	28.71	1.855
	SF-M	2,917	304.4	167.4	6,053	24,110	158,100	2.732	90.92	20.15	1.286
	SF-N	1,768	187.4	103.1	3,445	13,320	105,000	1.462	49.14	11	0.7391
	SF-O	2,443	255.9	140.7	4,362	16,510	135,400	1.663	60.02	12.94	0.8292
Talbot Branch	TAB-A	4,087	427	234.9	7,122	26,790	222,200	2.652	96.39	20.71	1.303
	TAB-B	3,106	329.9	181.5	6,121	23,880	179,100	2.817	84.62	20.15	1.301
	TAB-C	2,313	245.1	134.8	4,748	18,900	125,500	2.392	65.3	16.35	1.003
	TAB-D	3,772	395.1	217.3	8,553	34,880	206,100	4.18	132.7	30.13	1.937
	TAB-E	4,617	485.4	267	9,698	38,910	246,800	5.325	137.5	34.59	2.077
	TAB-F	8,526	905.4	498	23,310	80,960	442,100	24.25	225.4	132.7	4.382
	TAB-G	2,076	224	123.2	4,815	19,930	109,600	3.03	63.36	18.71	1.095
	TAB-H	1,460	156.4	86.01	3,033	12,060	83,380	1.577	41	10.62	0.6662
Town Branch	TOB-A	5,121	538.2	296	9,765	37,990	275,700	4.367	133.6	31.37	1.934
	TOB-B	2,903	310.9	171	6,355	25,300	161,800	3.683	84.41	23.91	1.393
Woodville Branch	WB-A	2,292	247.4	136.1	5,220	21,190	137,400	2.871	74.15	19.22	1.245
	WB-B	1,602	172.7	95	3,926	16,590	87,090	2.339	58.23	15.28	0.9441
	WB-C	4,287	477	262.4	10,320	38,950	235,900	6.989	97.23	41.98	2.088
	WB-D	9,982	1,337	735.6	56,310	190,700	551,500	64.25	187.9	342.8	11.12
	WB-E	3,252	357.7	196.7	7,565	30,610	187,800	5.079	92.22	30.59	1.759
	WB-F	1,553	173.6	95.49	3,958	16,790	83,960	3.014	46.61	17.04	0.964
Weldon Creek	WC-A	4,196	442.7	243.5	7,573	28,900	228,800	3.285	98.2	23.53	1.441
	WC-B	4,375	464	255.2	9,025	35,970	238,400	4.575	124.2	31.2	1.919
	WC-C	3,870	406.7	223.7	7,292	28,170	212,800	3.12	100.7	22.98	1.448
	WC-D	3,882	425.8	234.2	8,829	36,140	221,600	5.67	110.2	34.44	2.061
	WC-E	3,367	368.4	202.6	8,200	34,480	174,200	5.74	102.2	33.68	1.908
	WC-F	2,554	273.1	150.2	5,746	23,590	134,100	3.389	77.65	21.59	1.276

Table 2. Total annual loads (pounds/year), after SWM facility removals, for an average rainfall year

Basin	Catchment	TN	TP	OP	BOD	COD	TSS	PB	CU	ZN	CD	Peak Flow (cfs)
Bartonsville	BART-A	2,633	276.9	151.5	5,505	22,637	149,335	4.053	76.79	22.11	1.298	261.2
	BART-B	692	84.3	46.3	1,990	8,646	42,510	1.975	16.90	9.91	0.541	106.7
	BART-C	2,026	251.4	140.7	6,384	30,653	113,036	6.113	64.20	34.04	1.801	322.1
	BART-D	1,386	161.5	88.8	4,649	20,040	86,100	3.838	57.70	21.89	1.278	257.3
Bens Branch	BB-A	1,296	157.2	86.5	4,173	18,750	65,960	4.363	37.25	21.67	1.117	263.5
	BB-B	1,594	173.6	95.5	3,733	15,390	90,030	2.336	49.38	14.53	0.881	165.6
	BB-C	4,080	422.2	234.9	17,221	55,241	219,412	21.814	154.09	121.30	3.180	399.7
	BB-D	1,152	137.4	75.5	4,047	17,130	57,928	4.678	35.32	23.41	1.023	190.3
	BB-E	470	51.5	28.3	1,283	5,305	35,190	0.661	21.59	4.87	0.365	126.7
	BB-F	1,730	235.7	142.0	7,652	33,728	76,413	8.329	51.51	43.52	1.848	268.6
Chestnut Grove	CG-A	3,914	412.0	226.6	7,927	31,530	209,700	3.819	112.60	26.77	1.651	322.1
	CG-B	3,701	385.4	212.6	7,654	27,952	198,734	4.428	95.69	30.68	1.389	268.7
Detrick	DET-A	4,206	447.7	246.3	8,205	31,770	249,500	3.652	113.90	26.61	1.762	239.0
	DET-B	2,566	270.7	148.9	5,277	21,060	136,800	2.733	73.15	18.33	1.108	180.8
	DET-C	3,324	369.0	202.9	7,828	32,700	174,500	5.806	87.48	32.67	1.801	246.1
Horseshoe Farms	HF-A	1,264	135.5	74.5	3,000	12,160	70,030	1.718	41.48	11.34	0.684	259.9
	HF-B	901	98.6	54.2	2,002	8,163	49,160	1.308	23.85	7.81	0.449	132.0
Hazelnut Run	HR-A	3,250	348.5	191.7	8,239	32,160	173,200	5.010	104.20	32.46	1.755	243.1
	HR-B	2,635	278.7	155.4	5,154	19,879	139,994	2.326	69.17	16.82	1.002	162.1
	HR-C	2,308	247.2	136.0	4,921	19,470	130,600	2.599	65.68	17.49	1.071	223.8
	HR-D	1,874	198.7	109.3	3,756	14,710	108,800	1.750	53.20	12.48	0.812	229.8
	HR-E	5,316	560.5	308.9	10,664	40,914	300,246	4.600	146.37	34.61	2.159	265.2
	HR-F	6,039	744.4	411.1	27,134	97,078	286,784	28.139	119.77	150.41	5.437	471.0
Long Branch	LB-A	1,548	192.8	114.1	6,747	28,066	70,176	7.017	59.19	37.01	1.559	304.1
	LB-B	2,637	309.2	178.2	11,927	41,786	120,925	17.153	75.72	88.99	2.347	287.1
	LB-C	1,411	168.5	92.3	4,290	19,940	95,195	3.300	56.69	20.45	1.278	309.8
	LB-D	2,240	251.6	138.4	5,086	21,370	125,300	3.687	55.24	21.20	1.197	240.5
	LB-E	537	76.7	99.0	1,977	8,996	33,648	2.390	12.95	11.28	0.585	353.0
	LB-F	423	53.6	42.5	1,075	5,250	36,319	0.643	14.75	5.02	0.361	173.5
Mainstem Linganore Creek	MLC-A	3,371	349.7	192.3	6,661	26,180	182,200	3.438	98.11	22.61	1.376	255.2
	MLC-B	2,250	255.4	140.5	7,658	30,730	137,400	5.598	93.13	34.52	1.897	355.9
	MLC-C	3,432	378.4	208.1	9,414	35,970	188,700	6.430	102.40	39.61	2.002	289.1
	MLC-D	4,161	475.5	261.5	12,200	44,950	243,800	10.040	102.80	56.07	2.583	292.5
	MLC-E	382	46.6	25.6	1,778	6,709	22,110	1.552	15.14	9.02	0.405	104.6
	MLC-F	1,467	220.8	126.2	10,944	36,618	78,839	12.905	22.84	66.13	2.127	341.6
	MLC-G	1,086	163.6	90.0	7,677	26,520	61,490	9.083	13.41	46.19	1.577	203.4
	MLC-H	964	121.9	67.0	5,296	19,200	52,040	6.715	28.97	31.92	1.164	210.3
	MLC-I	3,569	417.3	242.1	11,494	45,928	199,347	8.252	121.83	52.49	2.533	385.3
	MLC-J	487	57.3	31.5	1,579	7,098	23,650	1.530	16.65	7.92	0.417	121.2
	MLC-K	146	15.9	8.8	495	2,219	7,109	0.372	7.53	2.24	0.132	61.5
	MLC-L	1,118	137.4	77.4	5,308	20,454	56,936	4.571	45.58	27.02	1.175	271.0
	MLC-M	2,706	361.6	238.4	18,932	65,628	143,472	14.088	43.00	106.83	2.208	429.6
New London	NL-A	3,970	424.3	232.5	8,920	35,790	218,535	4.860	117.68	32.55	1.969	322.1
	NL-B	2,234	238.5	131.2	4,357	16,660	121,300	2.206	52.61	14.78	0.848	145.0
	NL-C	3,282	348.7	191.8	6,497	24,820	180,200	3.213	82.12	22.08	1.283	218.6
	NL-D	2,338	249.9	137.5	4,903	19,337	146,353	2.242	71.88	16.40	1.154	208.3
	NL-E	3,016	326.7	179.7	6,433	25,590	184,200	3.417	87.27	22.92	1.494	253.6
	NL-F	4,984	532.0	292.6	10,330	39,200	271,200	5.287	125.40	36.02	2.023	274.0
Westwinds	WW-A	1,082	152.8	83.8	6,083	23,480	63,798	6.278	27.25	35.29	1.376	224.8
	WW-B	1,089	116.5	62.7	3,276	13,568	56,135	1.728	41.85	12.32	0.775	215.4
	WW-C	1,303	134.5	74.0	2,768	11,100	69,270	1.173	43.97	9.11	0.590	182.9
	WW-D	1,710	177.6	97.7	3,673	14,820	91,030	1.641	57.53	12.36	0.793	228.7
Coppermine Branch	CB-A	5,291	584.3	323.3	13,081	50,940	303,732	8.966	145.54	57.82	2.804	295.4
	CB-B	6,169	641.4	352.8	11,240	43,080	332,700	5.711	155.00	36.69	2.169	233.5
Dollyhyde Creek	DC-A	2,536	269.5	148.3	4,911	18,870	155,200	2.023	70.38	15.50	1.069	139.9
	DC-B	4,446	471.5	259.3	7,949	30,210	260,500	3.083	107.40	24.02	1.592	173.9
	DC-C	2,653	285.8	157.2	5,188	20,400	149,000	2.765	63.97	17.99	1.085	144.5
	DC-D	6,731	708.5	389.7	11,990	45,290	378,200	4.727	161.00	35.90	2.300	219.4
	DC-E	4,481	477.1	262.4	8,258	31,790	245,100	3.983	102.20	26.86	1.608	200.8

Table 2. Total annual loads (pounds/year), after SWM facility removals, for an average rainfall year												
Basin	**Catchment**	**TN**	**TP**	**OP**	**BOD**	**COD**	**TSS**	**PB**	**CU**	**ZN**	**CD**	**Peak Flow** (cfs)
Mainstem Linganore Creek Upper	MLCU-A	3,371	355.4	195.5	6,887	27,310	185,000	3.272	97.93	23.20	1.458	198.8
	MLCU-B	2,439	255.4	140.5	4,509	17,250	136,300	1.796	63.82	13.77	0.891	132.5
	MLCU-C	3,091	323.9	178.2	5,551	21,040	172,100	2.128	76.68	16.54	1.065	156.4
North Fork	NF-A	6,980	740.7	407.4	13,170	50,980	385,800	6.200	171.60	42.90	2.635	262.8
	NF-B	3,033	322.1	177.2	5,515	20,950	174,700	2.355	72.27	17.12	1.099	162.3
	NF-C	4,591	487.3	268.0	8,433	31,800	255,400	3.780	105.20	26.75	1.610	197.8
	NF-D	4,933	518.1	285.0	8,629	32,370	268,700	3.415	112.10	25.64	1.575	181.0
	NF-E	3,345	352.4	193.8	5,923	22,380	181,400	2.552	75.49	18.27	1.095	138.4
	NF-F	2,463	263.3	144.8	4,783	18,800	131,900	2.549	58.95	16.47	0.962	148.0
Oldfield Branch	OB-A	3,439	361.3	198.7	6,360	24,460	186,800	2.708	86.23	19.84	1.232	159.6
	OB-B	4,772	504.0	277.2	8,688	33,140	258,200	3.869	110.90	27.34	1.643	212.9
South Fork	SF-A	2,440	257.2	141.5	4,565	17,460	141,500	1.818	64.58	14.03	0.934	162.1
	SF-B	1,655	174.5	96.0	3,308	12,980	93,100	1.487	47.34	10.85	0.699	139.8
	SF-C	2,986	313.1	172.2	5,479	21,010	162,400	2.264	74.87	16.87	1.055	182.4
	SF-D	2,805	322.5	177.4	7,798	33,840	149,200	6.779	83.74	36.23	1.977	296.2
	SF-E	2,420	253.6	139.5	5,411	22,060	128,500	2.720	81.71	19.15	1.199	208.1
	SF-F	5,465	597.2	328.5	12,970	53,720	307,000	8.376	169.00	51.28	3.078	367.7
	SF-G	3,894	445.4	246.4	10,454	45,020	201,005	8.879	110.24	47.86	2.549	302.0
	SF-H	1,753	240.8	132.4	7,105	33,080	79,180	9.805	32.13	43.63	2.002	245.8
	SF-I	555	64.6	35.5	1,736	7,746	27,200	1.627	18.73	8.52	0.453	105.1
	SF-J	1,535	163.9	90.1	3,303	13,380	81,500	1.858	44.14	12.02	0.715	156.1
	SF-K	5,130	569.5	313.2	11,890	49,420	274,400	8.963	131.60	49.72	2.739	306.3
	SF-L	3,795	393.1	216.2	8,405	34,090	203,100	3.831	134.00	28.71	1.855	246.6
	SF-M	2,917	304.4	167.4	6,053	24,110	158,100	2.732	90.92	20.15	1.286	187.5
	SF-N	1,768	187.4	103.1	3,445	13,320	105,000	1.462	49.14	11.00	0.739	122.3
	SF-O	2,443	255.9	140.7	4,362	16,510	135,400	1.663	60.02	12.94	0.829	138.5
Talbot Branch	TAB-A	4,087	427.0	234.9	7,122	26,790	222,200	2.652	96.39	20.71	1.303	155.9
	TAB-B	3,106	329.9	181.5	6,121	23,880	179,100	2.817	84.62	20.15	1.301	163.1
	TAB-C	2,313	245.1	134.8	4,748	18,900	125,500	2.392	65.30	16.35	1.003	197.9
	TAB-D	3,772	395.1	217.3	8,553	34,880	206,100	4.180	132.70	30.13	1.937	278.5
	TAB-E	4,617	485.4	267.0	9,698	38,910	246,800	5.325	137.50	34.59	2.077	266.9
	TAB-F	8,522	904.7	497.7	23,263	80,844	441,768	24.128	225.30	132.14	4.378	403.2
	TAB-G	1,996	218.1	125.0	4,626	19,100	101,755	2.739	61.24	17.78	0.992	199.3
	TAB-H	1,460	156.4	86.0	3,033	12,060	83,380	1.577	41.00	10.62	0.666	130.2
Town Branch	TOB-A	5,121	538.2	296.0	9,765	37,990	275,700	4.367	133.60	31.37	1.934	245.7
	TOB-B	2,903	310.9	171.0	6,355	25,300	161,800	3.683	84.41	23.91	1.393	210.1
Woodville Branch	WB-A	2,292	247.4	136.1	5,220	21,190	137,400	2.871	74.15	19.22	1.245	193.9
	WB-B	1,602	172.7	95.0	3,926	16,590	87,090	2.339	58.23	15.28	0.944	194.4
	WB-C	4,124	452.9	261.3	8,892	34,081	222,190	5.511	94.59	34.06	1.824	243.1
	WB-D	9,672	1,280	722.1	53,712	181,550	520,454	59.970	183.93	322.61	10.518	746.7
	WB-E	3,236	350.4	196.2	7,525	30,536	187,206	4.327	91.67	29.62	1.595	223.7
	WB-F	1,553	173.6	95.5	3,958	16,790	83,960	3.014	46.61	17.04	0.964	187.9
Weldon Creek	WC-A	4,196	442.7	243.5	7,573	28,900	228,800	3.285	98.20	23.53	1.441	191.0
	WC-B	4,375	464.0	255.2	9,025	35,970	238,400	4.575	124.20	31.20	1.919	226.9
	WC-C	3,870	406.7	223.7	7,292	28,170	212,800	3.120	100.70	22.98	1.448	204.4
	WC-D	3,882	425.8	234.2	8,829	36,140	221,600	5.670	110.20	34.44	2.061	363.3
	WC-E	3,367	368.4	202.6	8,200	34,480	174,200	5.740	102.20	33.68	1.908	266.2
	WC-F	2,554	273.1	150.2	5,746	23,590	134,100	3.389	77.65	21.59	1.276	207.0

Table 3. Total annual loads (pounds/year), after SWM facility and Tier 1 project removals, for an average rainfall year												
Basin	**Catchment**	**TN**	**TP**	**OP**	**BOD**	**COD**	**TSS**	**PB**	**CU**	**ZN**	**CD**	**Project(s)**
Bartonsville	BART-A	2,601	273.5	151.7	5,417	22,182	144,560	3.990	75.59	21.69	1.259	BA101, BA102
	BART-B	692	84.3	46.3	1,990	8,646	42,510	1.975	16.90	9.91	0.541	
	BART-C	1,958	241.5	140.7	6,146	28,828	105,452	5.970	61.36	32.47	1.705	BA102
	BART-D	1,386	161.5	88.8	4,649	20,040	86,100	3.838	57.70	21.89	1.278	
Bens Branch	BB-A	1,192	142.3	86.5	3,502	15,543	59,446	3.460	34.63	17.68	0.933	BB104
	BB-B	1,594	173.6	95.5	3,733	15,390	90,030	2.336	49.38	14.53	0.881	
	BB-C	4,080	422.2	234.9	17,221	55,241	219,412	21.814	154.09	121.30	3.180	
	BB-D	1,148	137.0	75.5	4,026	17,030	57,729	4.650	35.25	23.28	1.017	BB102
	BB-E	470	51.5	28.3	1,283	5,305	35,190	0.661	21.59	4.87	0.365	
	BB-F	1,730	235.7	142.0	7,652	33,728	76,413	8.329	51.51	43.52	1.848	
Chestnut Grove	CG-A	3,914	412.0	226.6	7,927	31,530	209,700	3.819	112.60	26.77	1.651	
	CG-B	3,701	385.4	212.6	7,654	27,952	198,734	4.428	95.69	30.68	1.389	
Detrick	DET-A	4,206	447.7	246.3	8,205	31,770	249,500	3.652	113.90	26.61	1.762	
	DET-B	2,566	270.7	148.9	5,277	21,060	136,800	2.733	73.15	18.33	1.108	
	DET-C	3,324	369.0	202.9	7,828	32,700	174,500	5.806	87.48	32.67	1.801	
Horseshoe Farms	HF-A	1,198	126.0	74.5	2,572	10,111	65,882	1.137	39.89	8.78	0.567	HF107
	HF-B	843	90.2	54.2	1,616	6,336	45,494	0.788	22.48	5.50	0.344	HF107
Hazelnut Run	HR-A	3,250	348.5	191.7	8,239	32,160	173,200	5.010	104.20	32.46	1.755	
	HR-B	2,546	269.9	155.8	4,905	18,952	132,419	2.178	66.66	15.95	0.949	HR101
	HR-C	2,308	247.2	136.0	4,921	19,470	130,600	2.599	65.68	17.49	1.071	
	HR-D	1,874	198.7	109.3	3,756	14,710	108,800	1.750	53.20	12.48	0.812	
	HR-E	5,316	560.5	308.9	10,664	40,914	300,246	4.600	146.37	34.61	2.159	
	HR-F	5,954	730.4	410.6	26,161	93,749	279,824	27.080	118.83	144.84	5.257	HR102, HR103
Long Branch	LB-A	1,496	184.0	113.7	6,116	25,969	65,761	6.328	58.65	33.38	1.447	LB102
	LB-B	2,622	306.8	178.1	11,745	41,215	119,735	16.917	75.40	87.77	2.316	LB102
	LB-C	1,411	168.5	92.3	4,290	19,940	95,195	3.300	56.69	20.45	1.278	
	LB-D	2,240	251.6	138.4	5,086	21,370	125,300	3.687	55.24	21.20	1.197	
	LB-E	537	76.7	99.0	1,977	8,996	33,648	2.390	12.95	11.28	0.585	
	LB-F	423	53.6	42.5	1,075	5,250	36,319	0.643	14.75	5.02	0.361	
Mainstem Linganore Creek	MLC-A	3,371	349.7	192.3	6,661	26,180	182,200	3.438	98.11	22.61	1.376	
	MLC-B	2,250	255.4	140.5	7,658	30,730	137,400	5.598	93.13	34.52	1.897	
	MLC-C	3,432	378.4	208.1	9,414	35,970	188,700	6.430	102.40	39.61	2.002	
	MLC-D	4,161	475.5	261.5	12,200	44,950	243,800	10.040	102.80	56.07	2.583	
	MLC-E	382	46.6	25.6	1,778	6,709	22,110	1.552	15.14	9.02	0.405	
	MLC-F	1,467	220.8	126.2	10,944	36,618	78,839	12.905	22.84	66.13	2.127	
	MLC-G	1,086	163.6	90.0	7,677	26,520	61,490	9.083	13.41	46.19	1.577	
	MLC-H	964	121.9	67.0	5,296	19,200	52,040	6.715	28.97	31.92	1.164	
	MLC-I	3,569	417.3	242.1	11,494	45,928	199,347	8.252	121.83	52.49	2.533	
	MLC-J	487	57.3	31.5	1,579	7,098	23,650	1.530	16.65	7.92	0.417	
	MLC-K	146	15.9	8.8	495	2,219	7,109	0.372	7.53	2.24	0.132	
	MLC-L	1,118	137.4	77.4	5,308	20,454	56,936	4.571	45.58	27.02	1.175	
	MLC-M	2,706	361.6	238.4	18,932	65,628	143,472	14.088	43.00	106.83	2.208	
New London	NL-A	3,970	424.3	232.5	8,920	35,790	218,535	4.860	117.68	32.55	1.969	
	NL-B	2,199	233.9	131.1	4,136	15,894	118,425	2.010	51.83	13.69	0.808	NL102
	NL-C	3,163	333.6	191.5	5,830	22,482	169,591	2.657	79.01	18.93	1.158	NL102
	NL-D	2,338	249.9	137.5	4,903	19,337	146,353	2.242	71.88	16.40	1.154	
	NL-E	3,016	326.7	179.7	6,433	25,590	184,200	3.417	87.27	22.92	1.494	
	NL-F	4,984	532.0	292.6	10,330	39,200	271,200	5.287	125.40	36.02	2.023	
Westwinds	WW-A	1,082	152.8	83.8	6,083	23,480	63,798	6.278	27.25	35.29	1.376	
	WW-B	1,089	116.5	62.7	3,276	13,568	56,135	1.728	41.85	12.32	0.775	
	WW-C	1,303	134.5	74.0	2,768	11,100	69,270	1.173	43.97	9.11	0.590	
	WW-D	1,710	177.6	97.7	3,673	14,820	91,030	1.641	57.53	12.36	0.793	
Coppermine Branch	CB-A	5,140	564.9	323.3	12,191	47,374	290,612	8.089	140.52	52.62	2.615	CB101, CB105, TO105
	CB-B	6,169	641.4	352.8	11,240	43,080	332,700	5.711	155.00	36.69	2.169	
Dollyhyde Creek	DC-A	2,536	269.5	148.3	4,911	18,870	155,200	2.023	70.38	15.50	1.069	
	DC-B	4,446	471.5	259.3	7,949	30,210	260,500	3.083	107.40	24.02	1.592	
	DC-C	2,653	285.8	157.2	5,188	20,400	149,000	2.765	63.97	17.99	1.085	
	DC-D	6,731	708.5	389.7	11,990	45,290	378,200	4.727	161.00	35.90	2.300	
	DC-E	4,481	477.1	262.4	8,258	31,790	245,100	3.983	102.20	26.86	1.608	
Mainstem Linganore Creek Upper	MLCU-A	3,371	355.4	195.5	6,887	27,310	185,000	3.272	97.93	23.20	1.458	
	MLCU-B	2,439	255.4	140.5	4,509	17,250	136,300	1.796	63.82	13.77	0.891	
	MLCU-C	3,091	323.9	178.2	5,551	21,040	172,100	2.128	76.68	16.54	1.065	

Table 3. Total annual loads (pounds/year), after SWM facility and Tier 1 project removals, for an average rainfall year

Basin	Catchment	TN	TP	OP	BOD	COD	TSS	PB	CU	ZN	CD	Project(s)
North Fork	NF-A	6,980	740.7	407.4	13,170	50,980	385,800	6.200	171.60	42.90	2.635	
	NF-B	3,033	322.1	177.2	5,515	20,950	174,700	2.355	72.27	17.12	1.099	
	NF-C	4,591	487.3	268.0	8,433	31,800	255,400	3.780	105.20	26.75	1.610	
	NF-D	4,933	518.1	285.0	8,629	32,370	268,700	3.415	112.10	25.64	1.575	
	NF-E	3,345	352.4	193.8	5,923	22,380	181,400	2.552	75.49	18.27	1.095	
	NF-F	2,463	263.3	144.8	4,783	18,800	131,900	2.549	58.95	16.47	0.962	
Oldfield Branch	OB-A	3,439	361.3	198.7	6,360	24,460	186,800	2.708	86.23	19.84	1.232	
	OB-B	4,772	504.0	277.2	8,688	33,140	258,200	3.869	110.90	27.34	1.643	
South Fork	SF-A	2,440	257.2	141.5	4,565	17,460	141,500	1.818	64.58	14.03	0.934	
	SF-B	1,655	174.5	96.0	3,308	12,980	93,100	1.487	47.34	10.85	0.699	
	SF-C	2,986	313.1	172.2	5,479	21,010	162,400	2.264	74.87	16.87	1.055	
	SF-D	2,805	322.5	177.4	7,798	33,840	149,200	6.779	83.74	36.23	1.977	
	SF-E	2,420	253.6	139.5	5,411	22,060	128,500	2.720	81.71	19.15	1.199	
	SF-F	5,465	597.2	328.5	12,970	53,720	307,000	8.376	169.00	51.28	3.078	
	SF-G	3,894	445.4	246.4	10,454	45,020	201,005	8.879	110.24	47.86	2.549	
	SF-H	1,753	240.8	132.4	7,105	33,080	79,180	9.805	32.13	43.63	2.002	
	SF-I	555	64.6	35.5	1,736	7,746	27,200	1.627	18.73	8.52	0.453	
	SF-J	1,535	163.9	90.1	3,303	13,380	81,500	1.858	44.14	12.02	0.715	
	SF-K	5,130	569.5	313.2	11,890	49,420	274,400	8.963	131.60	49.72	2.739	
	SF-L	3,795	393.1	216.2	8,405	34,090	203,100	3.831	134.00	28.71	1.855	
	SF-M	2,917	304.4	167.4	6,053	24,110	158,100	2.732	90.92	20.15	1.286	
	SF-N	1,768	187.4	103.1	3,445	13,320	105,000	1.462	49.14	11.00	0.739	
	SF-O	2,443	255.9	140.7	4,362	16,510	135,400	1.663	60.02	12.94	0.829	
Talbot Branch	TAB-A	4,087	427.0	234.9	7,122	26,790	222,200	2.652	96.39	20.71	1.303	
	TAB-B	3,106	329.9	181.5	6,121	23,880	179,100	2.817	84.62	20.15	1.301	
	TAB-C	2,313	245.1	134.8	4,748	18,900	125,500	2.392	65.30	16.35	1.003	
	TAB-D	3,772	395.1	217.3	8,553	34,880	206,100	4.180	132.70	30.13	1.937	
	TAB-E	4,617	485.4	267.0	9,698	38,910	246,800	5.325	137.50	34.59	2.077	
	TAB-F	8,522	904.7	497.7	23,263	80,844	441,768	24.128	225.30	132.14	4.378	
	TAB-G	1,996	218.1	125.0	4,626	19,100	101,755	2.739	61.24	17.78	0.992	
	TAB-H	1,460	156.4	86.0	3,033	12,060	83,380	1.577	41.00	10.62	0.666	
Town Branch	TOB-A	5,121	538.2	296.0	9,765	37,990	275,700	4.367	133.60	31.37	1.934	
	TOB-B	2,888	309.0	171.0	6,255	24,959	160,607	3.587	83.99	23.38	1.375	TO105
Woodville Branch	WB-A	2,292	247.4	136.1	5,220	21,190	137,400	2.871	74.15	19.22	1.245	
	WB-B	1,602	172.7	95.0	3,926	16,590	87,090	2.339	58.23	15.28	0.944	
	WB-C	4,124	452.9	261.3	8,892	34,081	222,190	5.511	94.59	34.06	1.824	
	WB-D	9,672	1,280	722.1	53,712	181,550	520,454	59.970	183.93	322.61	10.518	
	WB-E	3,203	345.6	196.2	7,309	29,501	185,131	4.033	90.88	28.33	1.536	WB113
	WB-F	1,510	167.3	95.5	3,677	15,445	81,208	2.633	45.56	15.36	0.887	WB111
Weldon Creek	WC-A	4,196	442.7	243.5	7,573	28,900	228,800	3.285	98.20	23.53	1.441	
	WC-B	4,375	464.0	255.2	9,025	35,970	238,400	4.575	124.20	31.20	1.919	
	WC-C	3,870	406.7	223.7	7,292	28,170	212,800	3.120	100.70	22.98	1.448	
	WC-D	3,882	425.8	234.2	8,829	36,140	221,600	5.670	110.20	34.44	2.061	
	WC-E	3,367	368.4	202.6	8,200	34,480	174,200	5.740	102.20	33.68	1.908	
	WC-F	2,554	273.1	150.2	5,746	23,590	134,100	3.389	77.65	21.59	1.276	

Appendix E: Impervious Cover Model

(excerpted from *The Impervious Cover Model*
http://www.stormwatercenter.net/monitoring%20and%20assessment/imp%20cover/impercovr%20model.htm)

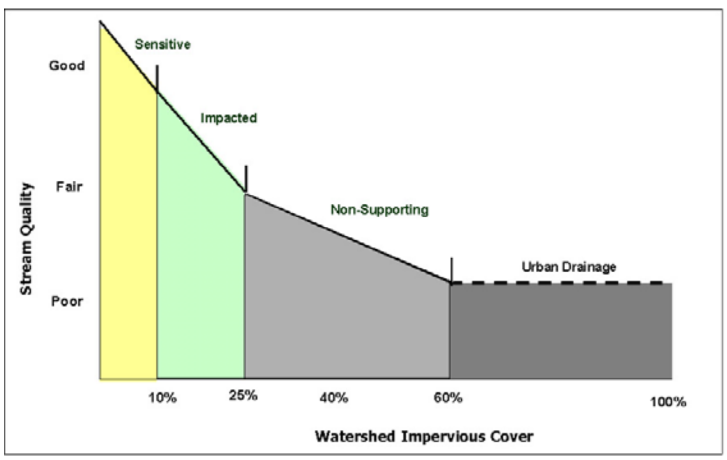
This simple classification system contains three stream categories, based on the percentage of impervious cover. Figure 1 illustrates this simple, yet powerful model that predicts the existing and future quality of streams based on the measurable change in impervious cover.

The model classifies streams into one of three categories: sensitive, impacted, and non-supporting. Each stream category can be expected to have unique characteristics as follows:

Sensitive Streams. These streams typically have a watershed impervious cover of zero to 10 percent. Consequently, sensitive streams are of high quality, and are typified by stable channels, excellent habitat structure, good to excellent water quality, and diverse communities of both fish and aquatic insects. Since impervious cover is so low, they do not experience frequent flooding and other hydrological changes that accompany urbanization. It should be noted that some sensitive streams located in rural areas may have been impacted by prior poor grazing and cropping practices that may have severely altered the riparian zone, and consequently, may not have all the properties of a sensitive stream. Once riparian management improves, however these streams are often expected to recover.

Impacted Streams. Streams in this category possess a watershed impervious cover ranging from 11 to 25 percent, and show clear signs of degradation due to watershed urbanization. The elevated storm flows begin to alter stream geometry. Both erosion and channel widening are clearly evident. Streams banks become unstable, and physical habitat in the stream declines noticeably. Stream water quality shifts into the fair/good category during both storms and dry weather periods. Stream biodiversity declines to fair levels, with most sensitive fish and aquatic insects disappearing from the stream.

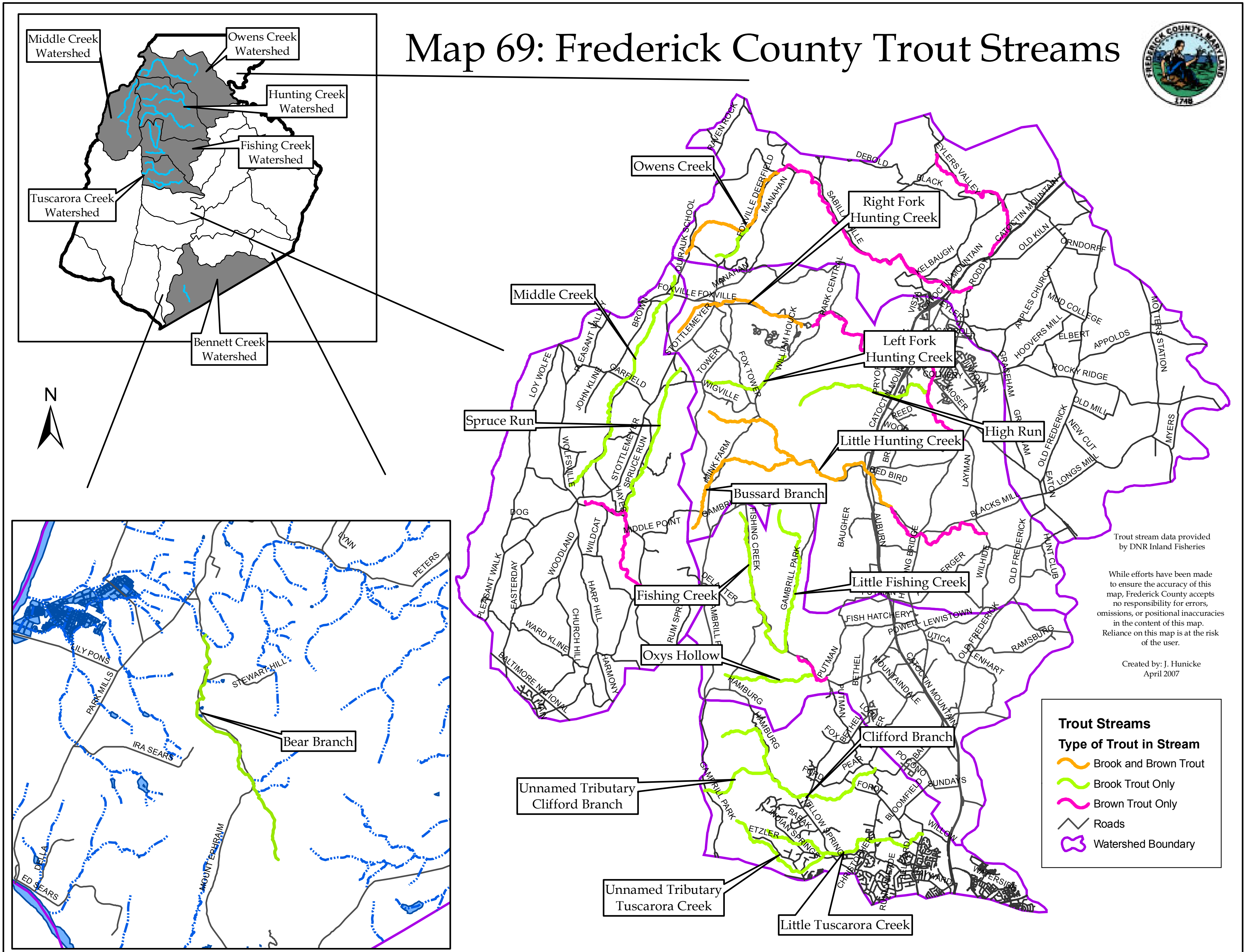
Figure 1: Stream Status



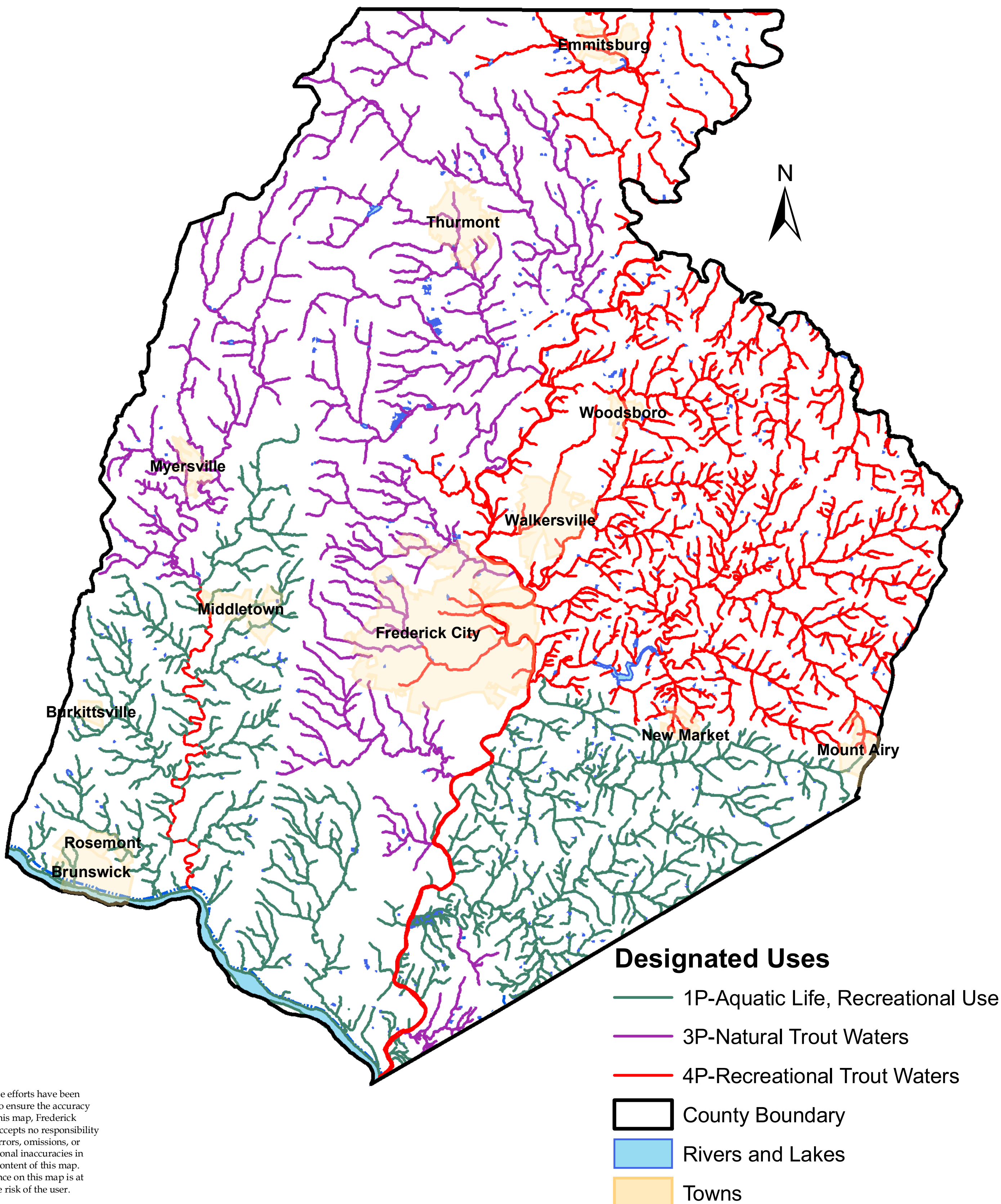
Non-Supporting Streams. Once watershed impervious cover exceeds 25%, stream quality crosses a second threshold. Streams in this category essentially become conduits for conveying stormwater flows, and can no longer support a diverse stream community. The stream channel becomes highly unstable, and many stream reaches experience severe widening, downcutting, and stream bank erosion. Pool and riffle structure needed to sustain fish is diminished or eliminated and the substrate can no longer provide habitat for aquatic insects, or spawning areas for fish. Water quality is consistently rated as fair to poor, and water recreation is no longer possible due to the presence of high bacterial levels. Subwatersheds in the non-supporting category will generally display increases in nutrient loads to downstream receiving waters, even if effective urban BMPs are installed and maintained. The biological quality of non-supporting streams is generally considered poor, and is dominated by pollution tolerant insects and fish.

Appendix F: Critical Area Maps

Map 69: Frederick County Trout Streams

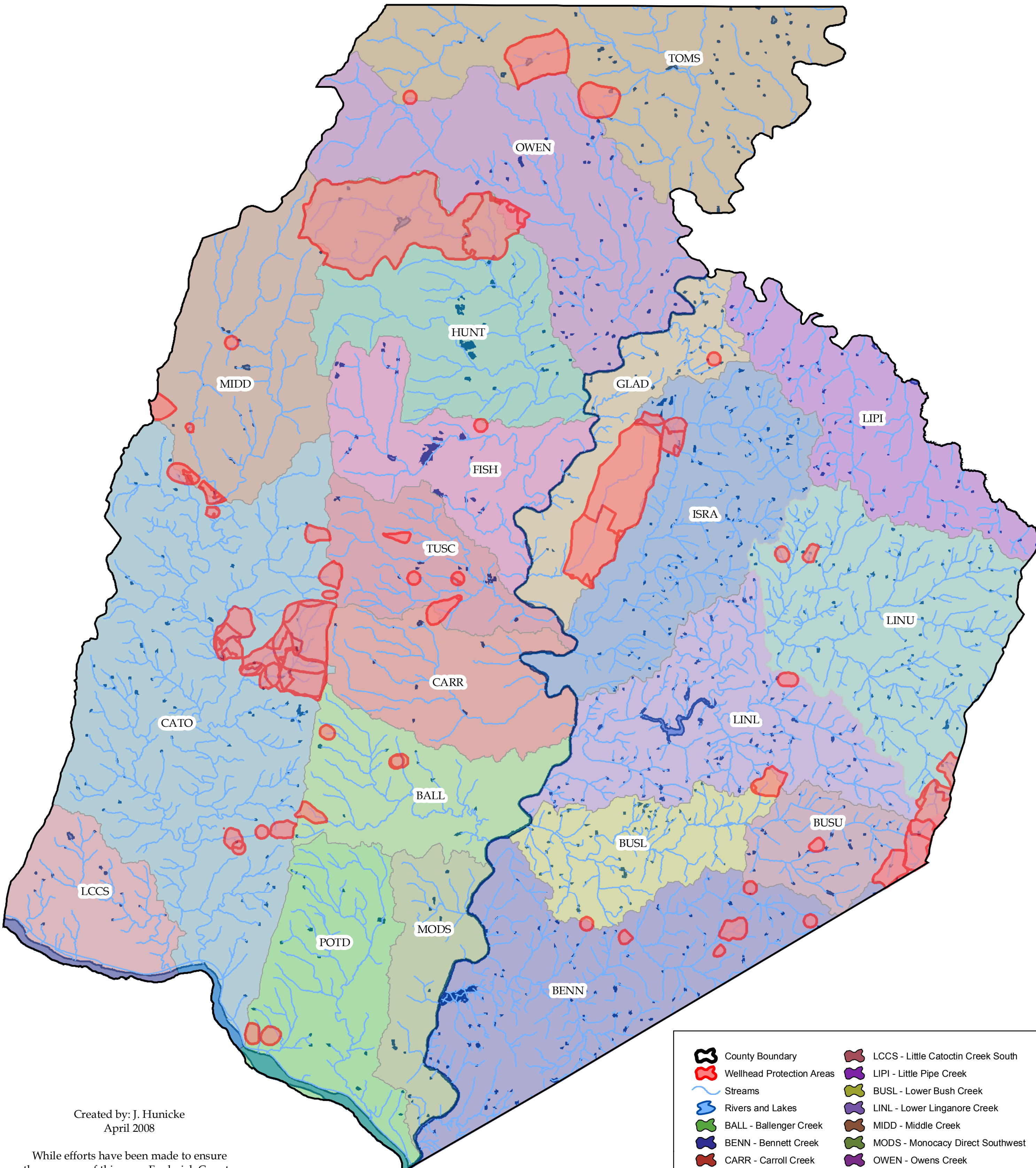


Map 70: Frederick County Stream Use Designations



While efforts have been made to ensure the accuracy of this map, Frederick County accepts no responsibility for errors, omissions, or positional inaccuracies in the content of this map. Reliance on this map is at the risk of the user.

Map 71: Frederick County Wellhead Protection Areas



Created by: J. Hunicke
April 2008

While efforts have been made to ensure the accuracy of this map, Frederick County accepts no liability or responsibility for errors, omissions, or positional inaccuracies in the content of this map. Reliance on this map is at the risk of the user. This map is for illustration purposes only and should not be used for surveying, engineering, or site-specific analysis.

- County Boundary
- Wellhead Protection Areas
- Streams
- Rivers and Lakes
- BALL - Ballenger Creek
- BENN - Bennett Creek
- CARR - Carroll Creek
- CATO - Catoctin Creek
- FISH - Fishing Creek
- GLAD - Glade Creek
- HUNT - Hunting Creek
- ISRA - Israel Creek
- LCCS - Little Catoctin Creek South
- LIPI - Little Pipe Creek
- BUSL - Lower Bush Creek
- LINL - Lower Linganore Creek
- MIDD - Middle Creek
- MODS - Monocacy Direct Southwest
- OWEN - Owens Creek
- POTD - Potomac Direct
- TOMS - Toms Creek
- TUSC - Tuscarora Creek
- BUSU - Upper Bush Creek
- LINU - Upper Linganore Creek

Appendix G: Monocacy & Catoctin Watershed Alliance Outreach Materials

Monocacy & Catoctin Watershed Alliance

WWW.WATERSHED-ALLIANCE.COM

THE WATERSHED STEWARD PROGRAM

Thanks to Bill McCall, pictured above, a 4,200 foot stretch of Israel Creek has a vigorous young forested buffer which helps to cleanse and improve the water for aquatic organisms, while providing habitat for wildlife in this "riparian" corridor.

The Watershed Steward Program was developed to recognize the efforts of community members to protect and restore the natural resources of the Monocacy and Catoctin watersheds by implementing voluntary conservation and best management practices on their property.

Watershed Steward

Improving Watershed Health Through Community Partnerships

Watershed Steward signs are available to community members who meet the criteria in one of eight different categories:

- Improving Watershed Health Through Community Partnerships
- Rain Gardens
- Forest Conservation Practice
- Agricultural Conservation Practice
- Forest Land Protection
- Farm Land Protection
- Tree Planting
- Wildlife Habitat Improvement

For more information about the Watershed Stewards Program please visit www.watershed-alliance.com/mcwa_stewards.html or email watershedalliance@fredco-md.net.

ALLIANCE PARTNERS

Audubon Naturalist Society of Central MD • Catoctin Land Trust • Catoctin Mountain Park • Chesapeake Wildlife Heritage • Citizen representatives • City of Frederick • Community Commons • Emmitsburg Business and Professional Association • Frederick County Government • Frederick Forestry Board • Friends of the Lake • Friends of Rural Roads • Friends of Waterford Park • Hood College • Interstate Commission on the Potomac River Basin • Lake Linganore Conservation Society • MD Chapter of American Chestnut Foundation • MD Forest Service • Natural Resource Conservation Service • New Forest Society • Potomac Conservancy • The Potomac Valley Fly Fishers • Strawberry Hill Nature Center • ThorpeWood • Town of Emmitsburg • Town of Mt. Airy • Western MD RC&D • and others.

This publication was funded in part by the National Fish and Wildlife Foundation, The Chesapeake Bay Program, The USDA Forest Service and The US Environmental Protection Agency through their support of The Chesapeake Bay Small Watershed Grants Program.

For more information call 301.600.1741 or visit www.watershed-alliance.com.

Printed with soy-based inks on recycled paper

WHAT IS A WATERSHED?

A watershed is an area of land that drains to a specific body of water – a stream, river, lake, bay, or wetland. It can be as small as a backyard or as large as the entire Chesapeake Bay watershed, 64,000 square miles, including parts of Maryland, Delaware, Virginia, West Virginia, Pennsylvania, the District of Columbia and New York. Watersheds are defined by natural topography (mountains, valleys) and hydrology (the water cycle), and often cross political or jurisdictional boundaries.

Common Eastern Box Turtle
Photo Courtesy of Kai Hagen

MISSION STATEMENT

The Monocacy & Catoctin Watershed Alliance coordinates the efforts of a diverse group of stakeholders dedicated to the protection and restoration of the natural resources in the Monocacy & Catoctin watersheds.

VISION STATEMENT

We envision a broadening and deepening stewardship ethic among an informed citizenry, which will help protect the County's agricultural heritage and rural character, maintain and improve the quality of life, protect and treasure our natural resources, and manage future growth more wisely. We envision healthy streams and rivers with forested buffers supplying clean drinking water and supporting healthy communities of aquatic and terrestrial life, as well as diverse and popular recreational uses. We envision a healthy and vibrant agricultural community built on links with citizens who support local agricultural and renewable forest products. We envision increasingly concentrated residential development using conservation design principles with access to collective transportation modes and a web of well-maintained trails. We envision watershed conservation folks from all sectors and communities collaborating to implement effective conservation and restoration practices and foster a creative stewardship consciousness.

Precious Barnes, a former student at TJ Middle school, examines stream life during National Water Monitoring Day.
Photo Courtesy of Shannon Moore

ABOUT US

The Monocacy & Catoctin Watershed Alliance (MCWA) is a mutual, collaborative, non-advocacy effort among individuals and organizations desiring to work together to improve the health of the Monocacy and Catoctin watersheds. Growing out of more than two years of planning for the Monocacy Watershed Restoration Action Strategy (WRAS), a Frederick County coordinated and State assisted local planning process, participants decided to continue their affiliation and cooperation at its conclusion in order to help foster WRAS plan implementation.

THE CHALLENGE

New development in the Monocacy Watershed can preserve its quality and character. How could this development have been designed to better protect the watershed? What can be done now that it is in place?
Photo Courtesy of USDA–NRCS

The Monocacy and Catoctin basins, located primarily in Frederick County's fertile agricultural region, are rich in history, cultural heritage, and natural resources. The areas are also confronted by complex water resource problems that negatively impact the quality of life for area residents and the health of the Chesapeake Bay. Some of the most challenging resource problems are poor water quality due to sediment and nutrients from agricultural lands, atmospheric deposition from fossil fuel burning engines, practices by residential, commercial, and municipal development, high proportions of soils that erode easily, the exploding population growth in the area and rapid land use conversion. For the past few decades, various groups have undertaken initiatives to address water quality issues, and although progress has been made, only partial success has been achieved.

The 1998 statewide assessment of watersheds determined that the Monocacy River and Catoctin Creek watersheds need both restoration and protection to meet water quality and habitat needs.

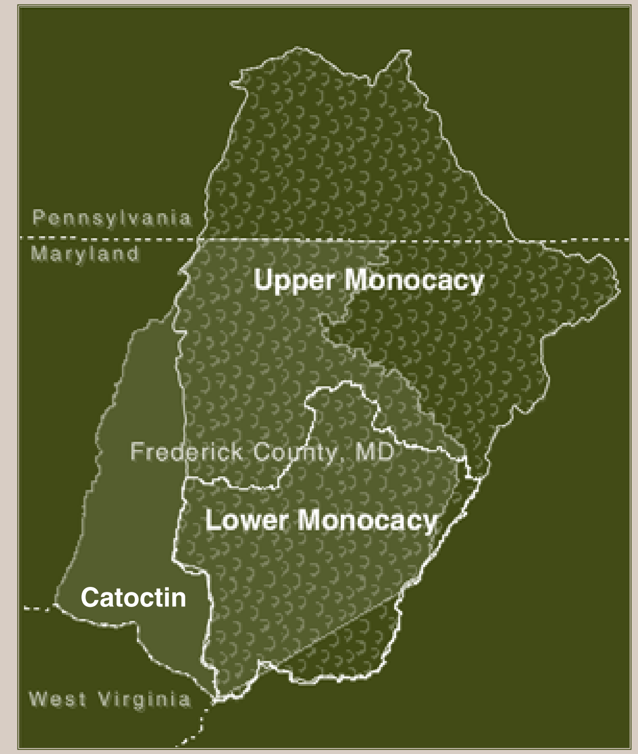
ALLIANCE PROJECTS

The Alliance has helped encourage and facilitate projects where several partners contribute expertise and resources, resulting in a community restoration project, a demonstration project, or an education and outreach event. Alliance projects that have occurred in the past or are currently underway include:

- The **Cloverhill Community Restoration Project** grew out of a Homeowner Association's interest to improve its stream corridor and involved at least four Alliance partners who wrote a grant application, developed a phased forest stewardship plan, arranged for a school group to plant trees and shrubs that the students had raised, and mobilized volunteers for community work days;
- The **Tree Growth Field Trial** at the Monocacy Natural Resource Management Area investigates four alternative methods of protecting newly planted trees from deer browse. The trial is sponsored by the Maryland Department of Natural Resources. Foresters were assisted by three Alliance partners during the fence installation, planting, measurement and public relation phases of the project;
- The **Libertytown Stewards Project** involves four community restoration projects in Libertytown and outreach and education to area citizens to encourage Bay Wise Landscaping;
- The **Bennett Creek Restoration Initiative** provides outreach and assistance in restoration to urban and agricultural owners along Pleasant and Fahrney Branches in the Bennett Creek watershed;
- The **Linganore TMDL Urban Demonstration Project** and the **Holding Our Ground Project** provide funds for outreach and demonstration projects in the Upper and Lower Linganore Creek watersheds;
- The **Watershed Road Sign Project** involved the installation of 50 signs along County roads in the Upper Monocacy watershed and educate drivers about which subwatershed they enter;
- The **Backyard Buffer Program** occurs each spring and offers 25 free tree and shrub seedlings to landowners with stream frontage; and
- The **Waterford Park Restoration Project** is sponsored by the Friends of Waterford Park. The efforts include invasive species management and the establishment of riparian buffer plantings along Rock and Carroll Creeks. Future plans include the establishment of a warm season grass meadow and butterfly area as well.

For more information about Alliance projects or to learn more about voluntary practices for your property, please visit www.watershed-alliance.com or contact the Community Restoration Coordinator at 301.600.1741 or watershedalliance@fredco-md.net.

WHY CARE ABOUT YOUR WATERSHED?



The Monocacy and Catoctin Watersheds

As the map illustrates, the Monocacy and Catoctin watersheds drain all of the land in Frederick County, along with portions of Carroll County, Montgomery County, and Adams County, PA. All of us who live and work on the land are interconnected. We have a common interest in healthy streams and rivers that support aquatic life and provide drinking water for many locally, as well as downstream. Good quality streams depend upon healthy vegetated stream corridors that limit erosion, provide shade, contribute leaves and woody debris for aquatic animals, and help filter out soil and pollutants from surrounding residential or agricultural lands. Water is for drink, for play, and for the survival of the aquatic community from the crayfish and mayflies in headwater streams, to the trout and bass in the streams and rivers, to the blue crabs and oysters in the Bay.

By protecting the Monocacy watershed, we also preserve the rural character treasured by new and old residents alike.
Photo Courtesy of Kai Hagen

Area resident joins others to clean up trash along a local stream.
Photo Courtesy of Shannon Moore

HOW DOES THE ALLIANCE WORK FOR THE COMMUNITY ?

Community groups with local problems and potential ideas for community restoration projects approach a member of the Alliance and request help. Requests are often referred to the Community Restoration Coordinator who alerts appropriate partners to the potential project and facilitates initial conversations or meetings to discern the best strategy for planning and securing the needed resources. Often, if several interested community groups are concentrated in a particular watershed, the funding and collaborative potential for the project increases.

If you have a project, need help finding volunteers or funding, are interested in volunteering, or would just like to receive more information about the Monocacy & Catoctin Watershed Alliance, please contact the Community Restoration Coordinator at 301.600.1741, send an email to watershedalliance@fredco-md.net or visit the website at www.watershed-alliance.com.

MONOCACY & CATOCTIN
WATERSHED ALLIANCE

Watershed Steward

Improving Watershed Health Through Community Partnerships

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Watershed Steward

Rain Garden

www.watershed-alliance.com

Appendix H: Draft Outline for Frederick County Biological Monitoring Report for Pilot Study Year of FCSS Program

1) Introduction

1.1) What and why (Purpose of study)

- What was done (generally – survey of biological, habitat and WQ) and where (Bennett & Catoctin)
- Assessment of stream conditions using biological, water chemistry, and physical indicators
- Assessment of the extent and severity of stream stressors, throughout the county and by watershed
- Pilot was prep for FCSS that will provide information on streams throughout the county and by watershed

1.2) Highlights of key findings

- Overall biological conditions in the two watersheds were rated as fair, affected by land use, habitat, and water quality
- Assessment of stressors and stream condition results will be highlighted in the next section:
  - Land Use
  - Habitat
  - Water quality
  - Biology

2) 2008 Pilot Study Results

For each of the 4 sections, text will first explain background – what is important about this topic and why are we looking at it. The 10 management questions and answers (with figures) will be in text boxes. Other figures will be interspersed in text.

2.1) Land Use

- Discuss ag, urban, impervious
- Maps – land use in Bennett and Catoctin watersheds, each with a pie chart showing breakdown of land use in 6 major categories (for the entire watershed)
- What is the relationship of different land uses to biotic condition (IBI scores) in Frederick County?
- What are the land cover/land use characteristics of streams in good and poor condition?

- What % of stream miles that is in good condition is near the thresholds of impervious surface likely to cause degradation (i.e. are most vulnerable)?

2.2) Habitat

- Discuss habitat, including riparian buffer, bank/channel erosion, sediment flow, PHI
- What % of stream miles lack vegetated riparian buffers?
- What % of stream miles exhibits substantial bank erosion?
- Countywide watershed map with Bennett and Catoctin watershed mean PHI results

2.3) Water quality

- Discuss nutrients, DO, sediment
- What % of stream miles has one-time dissolved oxygen less than the state water quality standard?
- What is the geographic distribution of streams with high amounts of TN?
- Countywide watershed map with Bennett and Catoctin watershed mean TN results

2.4) Stream Biological Community

- Discuss what benthic macroinvertebrates are and why we use them in monitoring, what is IBI?
- What % of stream miles is in poor, fair, or good condition according to the benthic IBI?
- What % of stream miles have suitable physical habitat and would be expected to have desired species if other stressors were absent (i.e. are good candidates for restoration)?

2.5) Stressor Analysis (using MDE screening approach)

- Use results to highlight the stressors affecting streams – if there are extensive problems, will provide support for county developing new management measures to reduce stressors
- What watersheds meet the MDE screening criteria for impairment by flow/sediment or nutrients (i.e. what subset of Frederick County watersheds within listed Maryland 8-digit watersheds are most appropriate for TMDL development)?

3) Future

- Discuss how results over the coming 4 years will provide even more detailed data for answering the questions of interest.
- Monitoring for 2008 is getting underway with 50 sites to be monitored countywide in 2008

- With results for 2008 and beyond, will be able to provide countywide results, also a breakdown into 8-digit watersheds
- When the four-year survey is complete, will have results for each of the 20 watersheds
- Impervious area data
- Results will help ID watersheds or specific sites/groups of sites that are in excellent condition, candidates for protection
- Results will help ID watersheds or specific sites/groups of sites that are degraded, would be priorities for restoration

4) Appendix – technical details: data tables, category cutoff thresholds

Appendix I: Long-Term Health of Chesapeake Bay Tributaries and Maryland's Streams

(excerpted from http://www.dnr.state.md.us/streams/status_trend/maps/maps.html)

Data collected by the Chesapeake Bay Water and Habitat Quality Monitoring Program since 1985 is used to assess the long-term health of the Chesapeake Bay tributaries and Maryland streams. Samples are analyzed for nutrients, such as total nitrogen and total phosphorus, and for physiochemical parameters, such as dissolved oxygen.

Status/trend information is available at: http://www.dnr.state.md.us/bay/tribstrat/upper_pot/up_status_treands.html.

Station MON0269

Monthly water chemistry samples at MON0269 are taken from the middle of the bridge over the Monocacy River at Biggs Ford Road. There is no USGS gauge at this station and Biggs Ford Rd. crosses the Monocacy above Frederick, MD. The benthos are sampled by Surber sampler at MON0269.

Total nitrogen and total phosphorus are both high at this station. Total organic carbon is, also, high suggesting a source of organic enrichment. None of these parameters exhibited a trend. Total alkalinity and pH are high. TALK increased since 1986. Conductivity is in the mid-tercile range and also increased. TALK and COND are correlated (PCC = 0.77, $p<0.001$). For a complete examination of the Water Quality Parameters concentrations and trends see Map #26 below.

An increasing trend in % EPT was weakly significant ($p<0.1$) but did not correlate with any of the WQ parameters. A graph of the number of taxa observed each year and a summary table of the Spearman Rank Coefficients and p-values for each benthic and water quality parameter measured is presented here: (Table 26- below)

Map 26 MON0269 Monocacy - Frederick County

Water Quality Parameter	Median Concentration 2002-2004	Linear Trend 1986-2004	% Change	Significant Quadratic Term
Chlorophyll a CHLA	1.79 µg/L (Lower)	NS	-16.9	NS
Conductivity COND	275.5 µmhos/cm (Middle)	Increasing	14.4	NS
Dissolved Oxygen DO	9.4 mg/L (Lower)	NS	-5.8	NS
Ammonium NH4	0.029 mg/L (Lower)	NS	0	NS

Nitrate NO3	2.10 mg/L (Middle)	Decreasing	-31.8	NS
Nitrite NO2	0.013 mg/L (Middle)	Decreasing	-25.6	NS
Nitrate + Nitrite NO23	2.11 mg/L ((Upper)	Decreasing	-33.8	NS
Total Kjeldahl Nitrogen TKN	0.60 mg/L (Middle)	NS	-15.8	NS
pH	7.75 (Upper)	NS	0	Concave Down
Orthophosphate PO4	0.065 mg/L (Upper)	NS	-22.6	NS
Sulfate SO4	NA	NA	NA	NA
Total Alkalinity TALK	68.5 mg/L (Upper)	Increasing	19.2	NS
Total organic carbon TOC	3.94 mg/L (Upper)	NS	-1.4	NS
Total nitrogen TN	2.80 mg/L (Upper)	NS	-25.8	NS
Total phosphorus TP	0.093 mg/L (Upper)	NS	-21.9	NS
Total suspended solids TSS	7 mg/L (Middle)	NS	0	NS
Turbidity TURB	7 NTU (Middle)	NS	-17.2	NS
Water temperature WATEMP	14.1° C (Upper)	NS	0	NS

NA = not available
NS = not significant
( ) = indicates station median concentration fall within benchmark data set concentration tercile

Table 26 MON0269 Monocacy - Frederick County

Correlations of Benthic Metrics with Water Quality variables for station MON0269 through 2004. The upper number is the Spearman Rank Correlation coefficient, the lower number is the p-value.

Water Quality Variable	Tatal Abundance	Tatal Taxa	Biotic Index	Diversity	Percent EPT	WQ parameter Trend
Chorophyll a (CHLA)	0.34 0.2212	0.38 0.1621	0.28 0.3143	0.18 0.5155	0.19 0.4907	-0.18 0.5159
Conductivity (COND)	0.37 0.1773	0.29 0.2974	0.22 0.435	-0.35 0.203	0.08 0.7757	0.41 0.132
Dissolved Oxygen (DO)	0.38 0.1684	0.13 0.6357	0.31 0.2621	-0.16 0.58	0.19 0.4948	-0.32 0.2427
Ammonium (NH4)	0 0	0.17 0.5462	-0.04 0.8843	0.17 0.5366	0.18 0.5113	0.12 0.6664
Nitrate (N03)	-0.07 0.8003	-0.28 0.3037	-0.18 0.5197	-0.41 0.1316	-0.26 0.3544	-0.73 0.0019
Nitrite (NO2)	0.14 0.6205	0.05 0.8733	0.22 0.4273	-0.54 0.0363	0.1 0.7322	-0.47 0.0786
Nitrite + Nitrate (NO23)	-0.05 0.8695	-0.29 0.288	-0.14 0.6293	-0.38 0.1637	-0.25 0.3684	-0.75 0.0014
Total Kjeldahl Nitrogen (TKN)	0.14 0.6296	-0.09 0.7398	-0.12 0.6661	-0.52 0.0478	-0.13 0.6568	-0.53 0.0445
Acidity (pH)	0.23 0.4201	0.22 0.4389	0.41 0.1261	-0.63 0.0111	-0.07 0.8149	0.19 0.5075
Orthophosphate (PO4)	-0.13 0.6571	-0.2 0.4789	-0.3 0.2739	-0.24 0.3791	-0.39 0.1491	-0.47 0.0786
Sulfate (SO4)	. .	. .	. .	. .	. .	. .
Total Alkalinity (TALK)	0.51 0.0517	0.46 0.0808	0.39 0.1491	-0.11 0.7084	0.26 0.3579	0.44 0.1014

Total Organic Carbon (TOC)	-0.41 0.1247	-0.27 0.3333	-0.5 0.0595	0.23 0.4197	-0.28 0.3078	-0.2 0.4829
Total Nitrogen (TN)	-0.01 0.9798	-0.27 0.3233	-0.08 0.7806	-0.4 0.1354	-0.21 0.4505	-0.71 0.003
Total Phosphorus (TP)	-0.1 0.7134	-0.14 0.6311	-0.05 0.8694	-0.28 0.3078	-0.25 0.3614	-0.39 0.1515
Total Suspended Solids (TSS)	-0.08 0.7905	-0.14 0.6219	0.13 0.6339	0.06 0.8346	0.09 0.7466	-0.35 0.1961
Turbidity (TURB)	-0.09 0.7613	-0.1 0.7157	-0.04 0.8944	0.2 0.4784	-0.27 0.3307	-0.5 0.0577
Water Temperature (WATEMP)	-0.16 0.576	-0.08 0.7788	-0.09 0.737	0.16 0.5668	-0.24 0.3899	0.08 0.7905
Benthic Index Trend	-0.02 0.9396	0.26 0.3469	0.26 0.3475	0.14 0.6112	0.45 0.0892	1 _

Station MON0020

Monthly water chemistry samples are taken from the middle of the MD 28 bridge over the Monocacy River. The bridge is 2.0 miles upstream of the confluence with the Potomac River. There is no stream gauge at this location. The benthos are sampled by Surber sampler.

Median concentration of total nitrogen and total phosphorus are high at MON0020. Both, however, have decreased since 1986. The trend for total phosphorus may be reversing as indicated by the significant quadratic term. Additionally, NH4, a reduced nitrogen component of TN may also be turning upward.

Median concentration of total alkalinity and pH are high and has increased since 1986. The downward concavity of the data as indicated by the quadratic term of the pH regression with time suggests that the upward trend is reversing. TALK and COND were correlated at MON0020. For a complete examination of the Water Quality Parameters concentrations and trends see Map #28, below.

None of the benthic indices had significant trends at MON0020. A graph of the number of taxa observed each year and a summary table of the Spearman Rank Coefficients and p-values for each benthic and water quality parameter measured is presented here: (Table 28, below)

Map 28 MON0020 Monocacy - Frederick County

Water Quality Parameter	Median Concentration 2002-2004	Linear Trend 1986-2004	% Change	Significant Quadratic Term
Chlorophyll a CHLA	2.39 µg/L (Lower)	NS	-17.5	NS
Conductivity COND	320 µmhos/cm (Upper)	Increasing	20.6	NS
Dissolved Oxygen DO	9.2 mg/L (Lower)	NS	-3.6	NS
Ammonium NH4	0.045 mg/L (Middle)	Decreasing	-14.1	Concave Up
Nitrate NO3	2.52 mg/L (Upper)	Decreasing	-25.6	NS
Nitrite NO2	0.15 mg/L (Middle)	Decreasing	-37.2	NS
Nitrate + Nitrite NO23	2.51 mg/L (Upper)	Decreasing	-27.5	NS
Total Kjeldahl Nitrogen TKN	0.59 mg/L (Middle)	Decreasing	-25.3	NS
pH	7.9 (Upper)	Increasing	5	Concave Down
Orthophosphate PO4	0.063 mg/L (Upper)	Decreasing	-33.9	NS
Sulfate SO4	NA	NA	NA	NA
Total Alkalinity TALK	82 mg/L (Upper)	Increasing	12.3	NS
Total organic carbon TOC	3.73 mg/L (Upper)	NS	3.7	Concave Down

Total nitrogen TN	3.04 mg/L (Upper)	Decreasing	-27	NS
Total phosphorus TP	0.106 mg/L (Upper)	Decreasing	-27.2	Concave Up
Total suspended solids TSS	10 mg/L (Upper)	NS	0	NS
Turbidity TURB	8 NTU (Middle)	NS	-19.4	NS
Water temperature WATEMP	14.1° C (Upper)	NS	0	NS

NA = not available
NS = not significant
( ) = indicates station median concentration fall within benchmark data set concentration tercile

Table 28 MON0020 Monocacy - Frederick County

Correlations of Benthic Metrics with Water Quality variables for station MON0020 through 2004. The upper number is the Spearman Rank Correlation coefficient, the lower number is the p-value.

Water Quality Variable	Tatal Abundance	Tatal Taxa	Biotic Index	Diversity	Percent EPT	WQ parameter Trend
Chorophyll a (CHLA)	0.3 0.2356	-0.13 0.6148	0.34 0.187	-0.37 0.1408	0.21 0.4245	-0.12 0.6461
Conductivity (COND)	-0.05 0.8445	0.12 0.6451	-0.09 0.7325	0.45 0.0727	-0.09 0.7431	0.41 0.1028
Dissolved Oxygen (DO)	0.32 0.2089	-0.23 0.3774	0.57 0.0159	-0.41 0.0983	-0.18 0.4975	-0.18 0.486
Ammonium (NH4)	-0.25 0.343	-0.08 0.7498	-0.31 0.2195	0.36 0.1585	-0.07 0.7969	-0.45 0.0727
Nitrate (N03)	-0.16 0.5351	-0.25 0.3268	-0.23 0.3705	0.02 0.9405	0.23 0.3653	-0.42 0.0919

Nitrite (NO2)	0.03 0.9034	-0.06 0.8257	-0.18 0.4885	0.13 0.6326	0.11 0.6731	-0.71 0.0015
Nitrite + Nitrate (NO23)	-0.15 0.5668	-0.25 0.3366	-0.2 0.433	0 0.9851	0.21 0.4106	-0.45 0.0727
Total Kjeldahl Nitrogen (TKN)	0.19 0.4623	0.1 0.6898	0.13 0.6255	0.11 0.6735	0.01 0.9776	-0.65 0.005
Acidity (pH)	-0.04 0.8812	0.09 0.7426	0.15 0.5599	0.21 0.4112	-0.19 0.4765	0.51 0.0345
Orthophosphate (PO4)	-0.15 0.554	0.01 0.9664	-0.43 0.0874	0.62 0.0076	0.1 0.7078	-0.37 0.1495
Sulfate (SO4)	. .	. .	. .	. .	. .	. .
Total Alkalinity (TALK)	0.39 0.1195	0.48 0.0529	0.2 0.453	0.4 0.1145	-0.33 0.1975	0.37 0.1495
Total Organic Carbon (TOC)	-0.09 0.7434	0.12 0.6383	-0.05 0.8479	0.36 0.1615	-0.14 0.5989	-0.04 0.8738
Total Nitrogen (TN)	-0.1 0.6942	-0.2 0.4321	-0.2 0.4358	0.01 0.9702	0.23 0.3731	-0.5 0.0398
Total Phosphorus (TP)	0.19 0.4623	0.35 0.1633	0.01 0.9553	0.53 0.028	-0.29 0.2596	-0.36 0.1554
Total Suspended Solids (TSS)	-0.01 0.9777	-0.23 0.38	0.3 0.237	-0.47 0.0551	0.09 0.7254	0.09 0.7292
Turbidity (TURB)	-0.17 0.5164	0 0.9851	0.12 0.639	-0.09 0.7434	0.02 0.9515	-0.04 0.8886
Water Temperature (WATEMP)	0 0.9851	0.06 0.833	-0.22 0.3916	0.27 0.2999	0.23 0.3809	-0.25 0.3381

Benthic Index Trend	-0.13 0.6326	0.15 0.5592	-0.07 0.7825	0 0	-0.1 0.6938	1 _

Station MON0155

Station MON0155 is on the Monocacy River. Monthly samples are taken from the boat ramp at Pine Cliffs Park on the left bank upstream of the bridge on Reels Mill Road. USGS gauge #1643000 is located on the right bank 500 ft downstream from US 70 highway bridge 0.5 miles above Pine Cliffs Park. The area of the watershed above the gauge is 817 mi2. The distribution of land cover within the watershed is agricultural (57%), forest (36%) and urban (6%). The benthos are sampled annually by Surber sampler.

Total nitrogen and total phosphorus were high. Total nitrogen has decreased since 1986 and there has been no change in TP. Median TOC is high indicating organic enrichment at MON0155. Total alkalinity and pH are high most likely as a result of limestone substrate in the upper Monocacy. Photosynthetic activity can elevate pH as well but CHLA is low at this station and not likely to contribute to elevated pH. TALK and COND are correlated ($PCC=0.83$, $p<0.001$). Both increased since 1986. For a complete examination of the Water Quality Parameters concentrations and trends see Map #27, below.

The Diversity index significantly increased. The index was correlated with pH ($p<0.05$). A graph of the number of taxa observed each year and a summary table of the Spearman Rank Coefficients and p-values for each benthic and water quality parameter measured is presented here: (Table 27, below)

Map 27 MON 0155 Monocacy - Frederick County

Water Quality Parameter	Median Concentration 2002-2004	Linear Trend 1986-2004	% Change	Significant Quadratic Term
Chlorophyll a CHLA	2.09 µg/L (Lower)	NS	-22.9	NS
Conductivity COND	266 µmhos/cm (Middle)	Increasing	18.7	NS
Dissolved Oxygen DO	9.0 mg/L (Lower)	Decreasing	-10.2	NS
Ammonium NH4	0.044 mg/L (Middle)	Decreasing	-22.5	Concave Up
Nitrate NO3	2.17 mg/L (Upper)	NS	-20.4	Concave Down

Nitrite NO2	0.018 mg/L (Middle)	Decreasing	-34.6	Concave Up
Nitrate + Nitrite NO23	2.19 mg/L (Upper)	Decreasing	-20.3	Concave Down
Total Kjeldahl Nitrogen TKN	0.682 mg/L (Upper)	Decreasing	-20.6	Concave Up
pH	7.6 (Middle)	NS	0	Concave Down
Orthophosphate PO4	0.077 mg/L (Upper)	NS	6.8	NS
Sulfate SO4	NA	NA	NA	NA
Total Alkalinity TALK	69 mg/L (Upper)	Increasing	13.5	NS
Total organic carbon TOC	4.22 mg/L (Upper)	NS	-2.8	NS
Total nitrogen TN	3.03 mg/L (Upper)	Decreasing	-17.7	Concave Down
Total phosphorus TP	0.125 mg/L (Upper)	NS	0	NS
Total suspended solids TSS	9 mg/L (Upper)	NS	0	NS
Turbidity TURB	9 NTU (Middle)	NS	-27.8	NS
Water temperature WATEMP	13.9° C (Upper)	NS	-5.8	NS

NA = not available
NS = not significant
( ) = indicates station median concentration fall within benchmark data set concentration tercile

Table 27 MON 0155 Monocacy - Frederick County

Correlations of Benthic Metrics with Water Quality variables for station MON 0155 through 2004. The upper number is the Spearman Rank Correlation coefficient, the lower number is the p-value.

Water Quality Variable	Tatal Abundance	Tatal Taxa	Biotic Index	Diversity	Percent EPT	WQ parameter Trend
Chorophyll a (CHLA)	0.38 0.1325	-0.1 0.7147	0.38 0.131	-0.37 0.1434	-0.07 0.7897	-0.33 0.1981
Conductivity (COND)	0.04 0.8738	0.55 0.0236	-0.02 0.9328	0.38 0.1336	0.2 0.4387	0.3 0.2356
Dissolved Oxygen (DO)	-0.48 0.0496	-0.15 0.5661	0.05 0.8366	-0.1 0.715	-0.08 0.7717	-0.25 0.3283
Ammonium (NH4)	0.26 0.3187	-0.19 0.4703	0.09 0.7283	-0.23 0.3812	-0.62 0.0077	-0.46 0.0611
Nitrate (N03)	-0.11 0.6873	0.31 0.2192	-0.25 0.324	0.22 0.3866	0.62 0.0078	-0.06 0.8226
Nitrite (NO2)	0.3 0.2477	-0.26 0.3106	0.24 0.3615	-0.38 0.1364	-0.41 0.099	-0.74 0.0008
Nitrite + Nitrate (NO23)	-0.12 0.6529	0.28 0.2787	-0.23 0.3745	0.19 0.4533	0.6 0.0105	-0.09 0.7363
Total Kjeldahl Nitrogen (TKN)	0.38 0.1325	0.16 0.5375	0.45 0.0724	-0.41 0.0981	-0.17 0.519	-0.5 0.041
Acidity (pH)	-0.68 0.0029	0 0.9851	-0.33 0.2017	0.52 0.0329	0.26 0.3063	0.14 0.5798
Orthophosphate (PO4)	0.05 0.8372	0.44 0.0784	-0.24 0.3437	0.27 0.295	-0.02 0.9292	0 0.9851
Sulfate (SO4)	. .	. .	. .	. .	. .	. .
Total Alkalinity (TALK)	0.29 0.2644	0.62 0.0078	0.29 0.2605	0.24 0.3579	0.19 0.4588	0.21 0.4167

Total Organic Carbon (TOC)	0.09 0.7222	-0.01 0.9702	0.02 0.9514	0.16 0.5506	-0.29 0.2512	-0.21 0.4279
Total Nitrogen (TN)	0.1 0.6942	0.22 0.3967	0.02 0.9477	-0.09 0.7361	0.41 0.0979	-0.42 0.094
Total Phosphorus (TP)	0.19 0.4682	0.47 0.059	-0.09 0.7318	0.24 0.3452	0.13 0.6122	-0.08 0.7648
Total Suspended Solids (TSS)	-0.03 0.896	-0.28 0.2678	0.05 0.8623	-0.08 0.7575	-0.06 0.8296	-0.2 0.4392
Turbidity (TURB)	0 0	-0.19 0.4733	0.05 0.8439	-0.26 0.3136	-0.28 0.2812	-0.42 0.0919
Water Temperature (WATEMP)	-0.07 0.8008	-0.06 0.8077	-0.1 0.7036	0.16 0.5474	-0.03 0.9218	-0.42 0.094
Benthic Index Trend	-0.23 0.3685	0.32 0.2117	-0.39 0.1244	0.7 0.0018	0.36 0.1549	1 _