Frederick County Stream Survey
2008-2011 Four-year Report

Prepared for

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1 INTRODUCTION

Freshwater streams are highly valued natural ecosystems that provide clean water and support fish and other aquatic life. Frederick County, Maryland, has initiated a stream monitoring and assessment program to collect information on the health of the County's streams. Findings will be used to help guide the County's watershed management programs to better protect and restore local waters.

The Frederick County Stream Survey (FCSS) is a program to assess the status of County streams in terms of water quality, biological condition, and habitat. The survey employs a statistical design, using a random sampling approach to draw inferences about stream condition in each of the County's 20 watersheds (Figure 1 and Table 1) and the entire County. The FCSS was designed to answer key questions about the condition of Frederick County's watersheds and streams and, in particular, the stressors affecting those streams. The site selection and stream sampling methods are based on Maryland Department of Natural Resources' Maryland Biological Stream Survey (MBSS), but the County is monitoring stream conditions at a smaller scale than the MBSS.

Table 1. List of abbreviations for Frederick County watersheds

Watershed Name	Abbreviation
Ballenger Creek	BALL
Bennett Creek	BENN
Lower Bush Creek	BUSL
Upper Bush Creek	BUSU
Carroll Creek	CARR
Catoctin Creek	CATO
Fishing Creek	FISH
Glade Creek	GLAD
Hunting Creek	HUNT
Israel Creek	ISRA
Lower Catoctin Creek South	LCCS
Lower Linganore Creek	LINL
Upper Linganore Creek	LINU
Little Pipe Creek	LIPI
Middle Creek	MIDD
Monocacy Direct Southwest	MODS
Owens Creek	OWEN
Potomac Direct	POTD
Toms Creek	TOMS
Tuscarora Creek	TUSC

In 2007, a Pilot Study was launched in the Bennett and Catoctin Creek watersheds to help develop, test, and refine the design and sampling protocols for the full FCSS (Versar Inc. 2009). The first round of the FCSS began in 2008 and continued through 2011. For each of the 2008-2011 sampling years, field crews contacted landowners and sampled 50 randomly selected sites stratified across the 20 watersheds in the County. Following methods detailed in the design report (Perot, et al. 2008), data were collected on water quality, physical habitat, and biological communities at each of the stream sites. This information was used to make an assessment of stream conditions Countywide. Because the sites were randomly selected, statistical estimates of the extent of streams (percentage of stream miles) in different condition classes for each assessment measure can be made. These results, including the raw data for each site sampled, can be found in the yearly FCSS reports (Versar, Inc. 2010a, Versar, Inc. 2010b, Versar, Inc. 2011, and Versar Inc. 2012 – available online at http://www.watershed-alliance.com /mcwa_pubs.html).

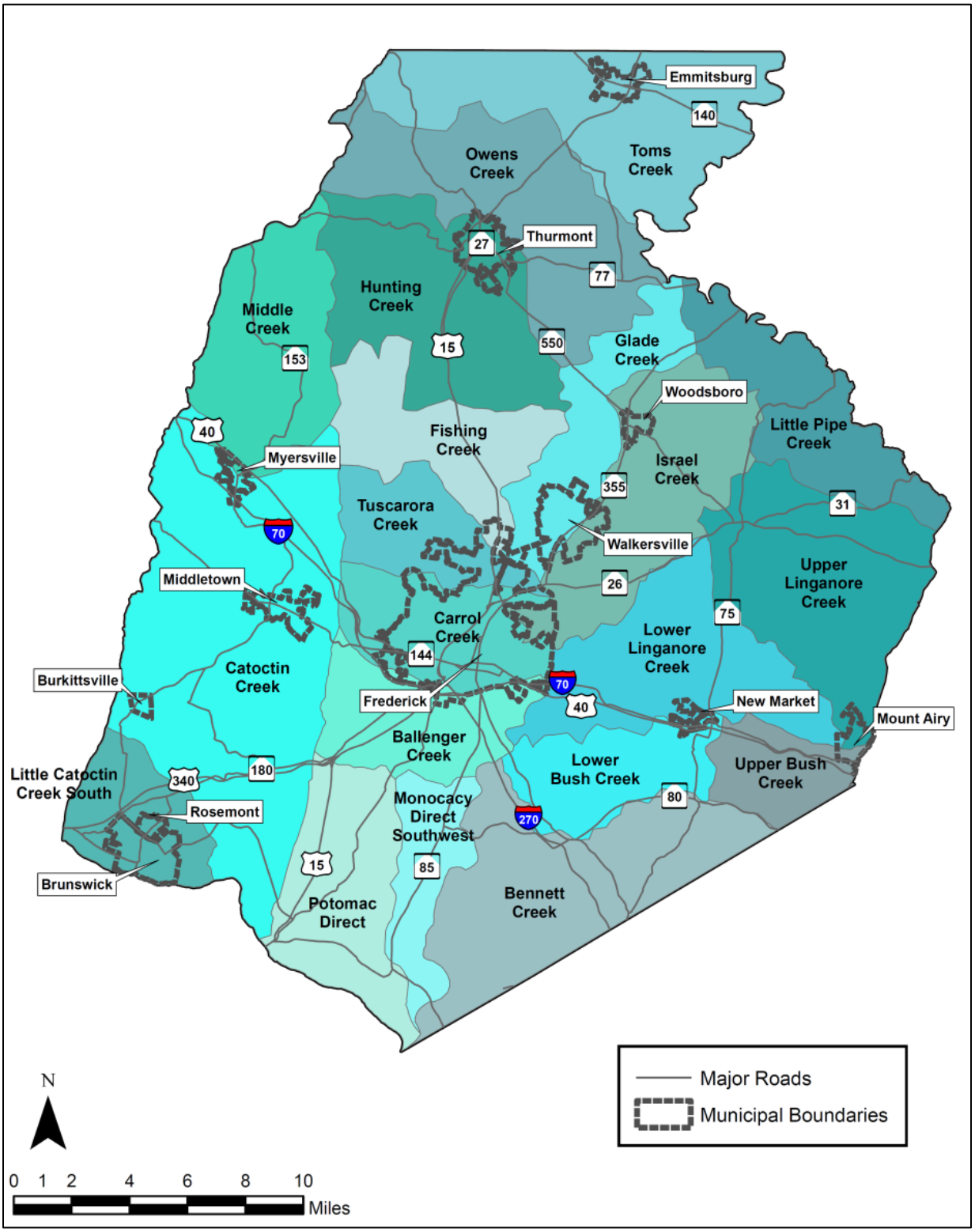


Figure 1. Frederick County watersheds

Once all 200 sites were sampled, there were a sufficient number of sites in each of the 20 watersheds to estimate condition at the watershed scale. This report presents the key findings at the countywide and watershed scale from the combined 2008-2011 sample years. An appendix provides estimates within the County's portion of the Maryland DNR 8-digit watersheds and their Total Maximum Daily Load (TMDL) areas.

2 LAND USE

Watershed land use is an indicator of how human activities and natural processes affect a stream. A watershed is an area of land that drains to a particular body of water. Watersheds form natural geographic units for assessing impacts on streams because land use within the watershed upstream of a specific stream site is representative of many of the human activities and natural processes affecting the stream at that point.

Conversion of naturally vegetated lands to urban and agricultural uses can result in serious impacts to streams and their aquatic inhabitants. In urban and suburban areas, impervious surfaces, such as roads, parking lots, sidewalks, and rooftops, cause a rapid increase in the rate that water is transported from the watershed to its stream channels. Effects include an increase in the variability of stream flows (more "flashy" flows), increased streambank erosion, habitat degradation caused by channel instability, increased pollutant runoff, elevated temperatures, and losses of biological diversity. Reviews of stream research in numerous watersheds indicate that impacts on stream quality are commonly noted at about 10% coverage by impervious surface (Schueler et al. 2009). Effects on sensitive species may occur at even lower levels (Roth et al. 1999). Agricultural impacts upon stream resources can include runoff of sediment, nutrients, and other pollutants, on top of natural sources from forests. Impacts from agriculture also include increased erosion leading to habitat and water quality degradation.

Frederick County has a diverse mix of land uses (Figure 2). Overall, 48% of the County is agriculture, 33% is forest, and 17% is urban/suburban (2% is "other," including wetlands/water and barren lands).

In the FCSS, land uses were characterized within the individual catchment areas upstream of sampled sites (Table 2). An estimated 52% of stream miles in the County had greater than 10% urban land use in their catchments. Additionally, 23% of stream miles had greater than 25% urban land use.

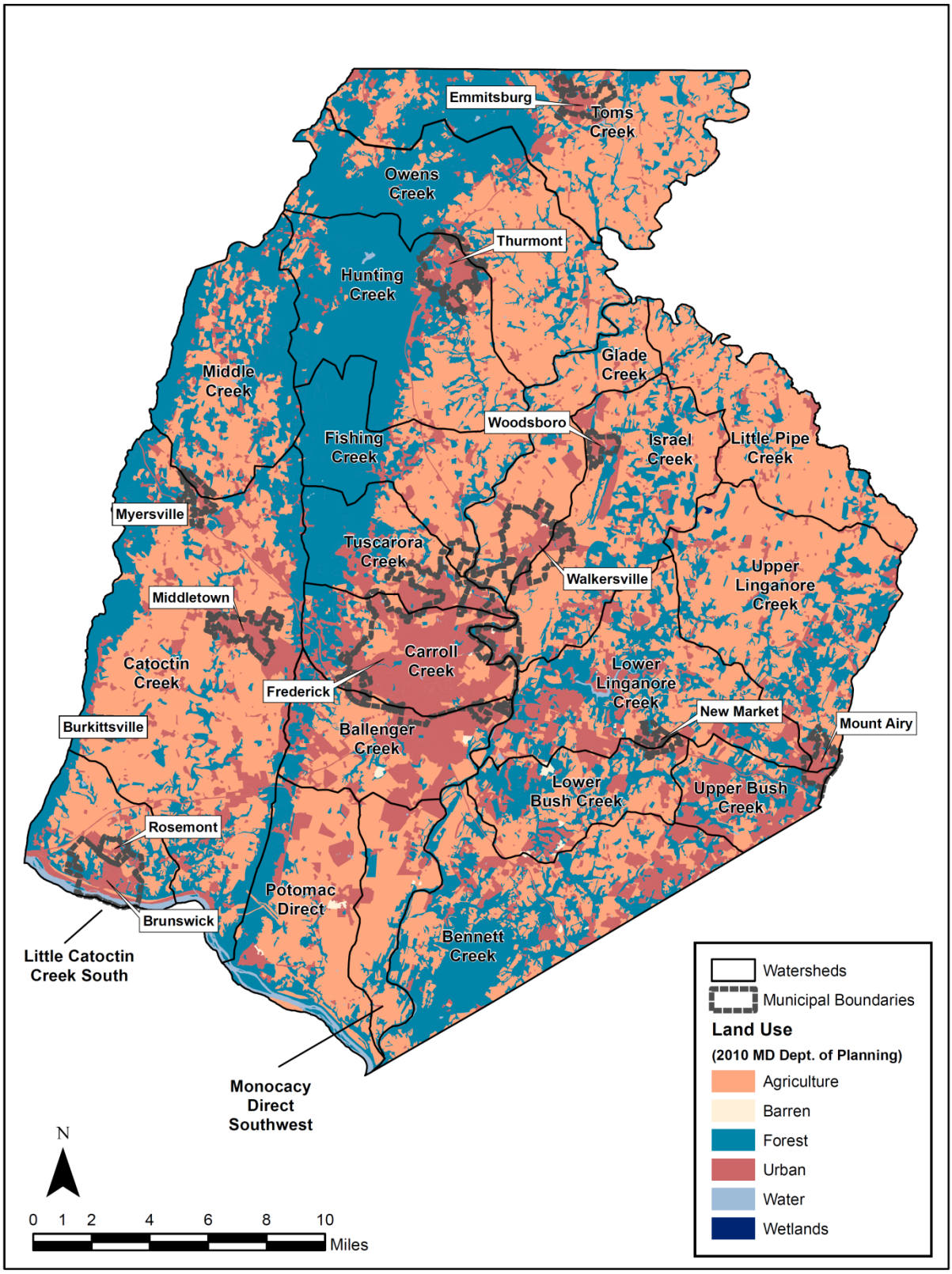


Figure 2. Land use in Frederick County (based on 2010 Maryland Department of Planning Land Use)

Two watersheds in the west-central portion of the County had the highest average forested land use in upstream catchments – Hunting Creek (84%) and Tuscarora Creek (80%). In contrast, Glade Creek and the Monocacy Direct Southwest watersheds had the least forested land use in upstream catchments (7% and 4%, respectively). These same two watersheds also had the highest percentage of agricultural land use in upstream land use (78% and 81%, respectively). Carroll Creek (9%), Hunting Creek (8%), and Tuscarora Creek (7%) had the lowest average percentage of agricultural land use in upstream catchments.

Upper Bush Creek and Ballenger Creek, both in the southern portion of the County, had the highest average urban land use in upstream catchments (59% and 41%, respectively). Hunting Creek (8%), Little Pipe Creek (7%), and Fishing Creek (5%) had the lowest average urban land use in upstream catchments.

Table 2. Average land use in upstream catchments for the FCSS 2008-2011 (percentage of catchment area)

Watershed	Agriculture	Forest	Urban
BALL	24.36	34.15	41.42
BENN	35.75	52.53	12.18
BUSL	50.64	22.13	26.78
BUSU	23.58	16.91	59.29
CARR	8.92	61.03	29.95
CATO	45.08	36.71	18.99
FISH	23.73	71.26	4.90
GLAD	78.09	7.08	14.84
HUNT	7.67	84.47	7.60
ISRA	63.33	19.31	17.33
LCCS	63.49	29.36	8.57
LINL	52.12	25.93	24.20
LINU	72.13	14.73	13.04
LIPI	80.70	12.31	6.99
MIDD	30.21	59.46	10.33
MODS	80.91	4.38	14.65
OWEN	31.94	60.62	7.36
POTD	43.25	40.44	18.00
TOMS	46.55	43.20	9.55
TUSC	6.61	80.02	13.01

Impervious Surface

Impervious surfaces are mainly constructed surfaces - rooftops, sidewalks, roads, and parking lots – covered by impenetrable materials such as asphalt, concrete, brick, and stone. These materials seal surfaces, repel water and prevent precipitation and meltwater from infiltrating soils. Soils compacted by urban development are also highly impervious. Impervious surfaces increase runoff, reduce evapotranspiration, have high thermal conductivities, and contribute to non-point source pollution problems. As a rule, water quality problems increase with increased impervious surface cover, leading to degraded stream conditions (http://chesapeake.towson.edu/landscape/impervious/what_imp2.asp). Schueler et al. (2009) define four categories of urban streams based on how much impervious surface exists in their upstream catchment:

- Sensitive – less than 10% impervious surface in the upstream catchment, are generally able to maintain their hydrologic function and support good to excellent aquatic diversity. In addition, Stranko et. al (2008), indicate that brook trout are almost never found in streams with upstream impervious cover greater than 4%.;
- Impacted – 10 to 25% impervious surface in the upstream catchment, show clear signs of declining stream health;

- Non-supporting – 25 to 60% impervious surface, no longer support their designated uses in terms of hydrology, channel stability, habitat, water quality, or biological diversity. They have become so degraded that it may be difficult to fully recover predevelopment stream function; and
- Urban drainage – greater than 60% impervious surface and basically just function as conduits for floodwater, they consistently have poor habitat and biodiversity scores.

In the 2008-2011 FCSS, the average percent imperviousness in catchments upstream of sample sites was 5.7%, well below the threshold for sensitive streams (Table 3) and similar to the mean for the whole County of 4.8% that is derived from the 2005 planimetrics. Impervious surface values ranged from 1.5% to 80%. Ninety-two percent of stream miles in the County fell into the "sensitive" streams category, while 5% of stream miles were "impacted." Two percent of stream miles were "non-supporting", while one percent of the stream miles (just two sites) fell into the urban drainage category.

Table 3. Percentage of stream miles in impervious land use categories and the watershed mean (based on catchments of the 200 FCSS sites) for the FCSS 2008-2011

Watershed	Sensitive	Impacted	Non-Supporting	Urban Drainage	Mean Percent Impervious in Site Catchment
Ballenger Creek	80	10	0	10	14.82
Bennett Creek	100	0	0	0	2.88
Lower Bush Creek	100	0	0	0	6.16
Upper Bush Creek	70	30	0	0	8.15
Carroll Creek	70	20	0	10	11.63
Catoctin Creek	90	0	10	0	6.74
Fishing Creek	100	0	0	0	2.78
Glade Creek	100	0	0	0	3.49
Hunting Creek	100	0	0	0	3.40
Israel Creek	80	10	10	0	9.08
Lower Catoctin Creek South	100	0	0	0	3.41
Lower Linganore Creek	90	10	0	0	4.87
Upper Linganore Creek	100	0	0	0	3.48
Little Pipe Creek	100	0	0	0	2.47
Middle Creek	100	0	0	0	2.52
Monocacy Direct Southwest	70	20	10	0	8.96
Owens Creek	100	0	0	0	2.99
Potomac Direct	80	20	0	0	7.13
Toms Creek	90	10	0	0	6.41
Tuscarora Creek	100	0	0	0	3.34

Based on the catchments upstream of the sample sites, all of the 20 watersheds in the County have the majority of their stream miles in the "Sensitive" category. In fact, estimates based on sample sites showed that 11 of the watersheds have 100% of stream miles in that

category. Only two watersheds, Ballenger Creek and Carroll Creek, have stream miles (10% each) in the "Urban Drainage" category in upstream catchments.

According to the Lower Monocacy Watershed Restoration Action Strategy (Hunicke and Moore, 2008) brook trout are found in streams in Middle Creek, Owens Creek, Hunting Creek, Fishing Creek, Tuscarora Creek, and in one stream in Bennett Creek watershed. According to the map of impervious surface by catchment within watersheds that is based on 2005 planimetric data (Figure 3), these six watersheds have a large amount of land with impervious surface below the brook trout threshold, but also have areas with impervious surface both in the "Sensitive" and "Impacted" categories. Owens Creek and Hunting Creek have higher impervious surfaces in the vicinity of Thurmont, while Tuscarora Creek is affected by the northwestern outskirts of the City of Frederick. Bennett Creek, which contains the southernmost brook trout stream in the Lower Monocacy watershed, also has higher levels of impervious surface in the eastern portion of the watershed.

3 HABITAT

Stream health, as determined by the condition of biological communities, is often directly correlated to the quality of physical habitat within a stream. Habitat loss and degradation have been identified as critical factors affecting biological diversity in streams worldwide. Habitat degradation can result from a variety of impacts occurring within the stream itself or in the surrounding watershed. Typical instream impacts include sedimentation, channelization, and bank erosion. Urban development, timber harvesting, agriculture, livestock grazing, and the draining or filling of wetlands are well-known examples of human activities affecting stream habitat at the watershed scale.

These activities may cause changes in vegetative cover, sediment loads, hydrology, and other factors influencing stream habitat quality. The amount of forest, meadow, and other vegetative cover in a watershed regulates the flow of water, nutrients, and sediments to adjacent streams. Riparian (streamside) forests can act as a filter, reducing the amounts of nutrients, sediments, and other pollutants reaching streams. They also provide local benefits of shade, leaf litter to feed the aquatic food web, and large woody debris, which in turn provides cover and forms pool and riffle microhabitats preferred by fish and other aquatic animals. The loss of watershed or riparian vegetation increases the potential for overland and channel erosion, often increasing the siltation of stream bottoms and obliterating the clean gravel surfaces used by many fish species as spawning habitat. Stream bottoms that become embedded with increased sediment offer poor habitat for many bottom-dwelling species. The impervious surfaces of

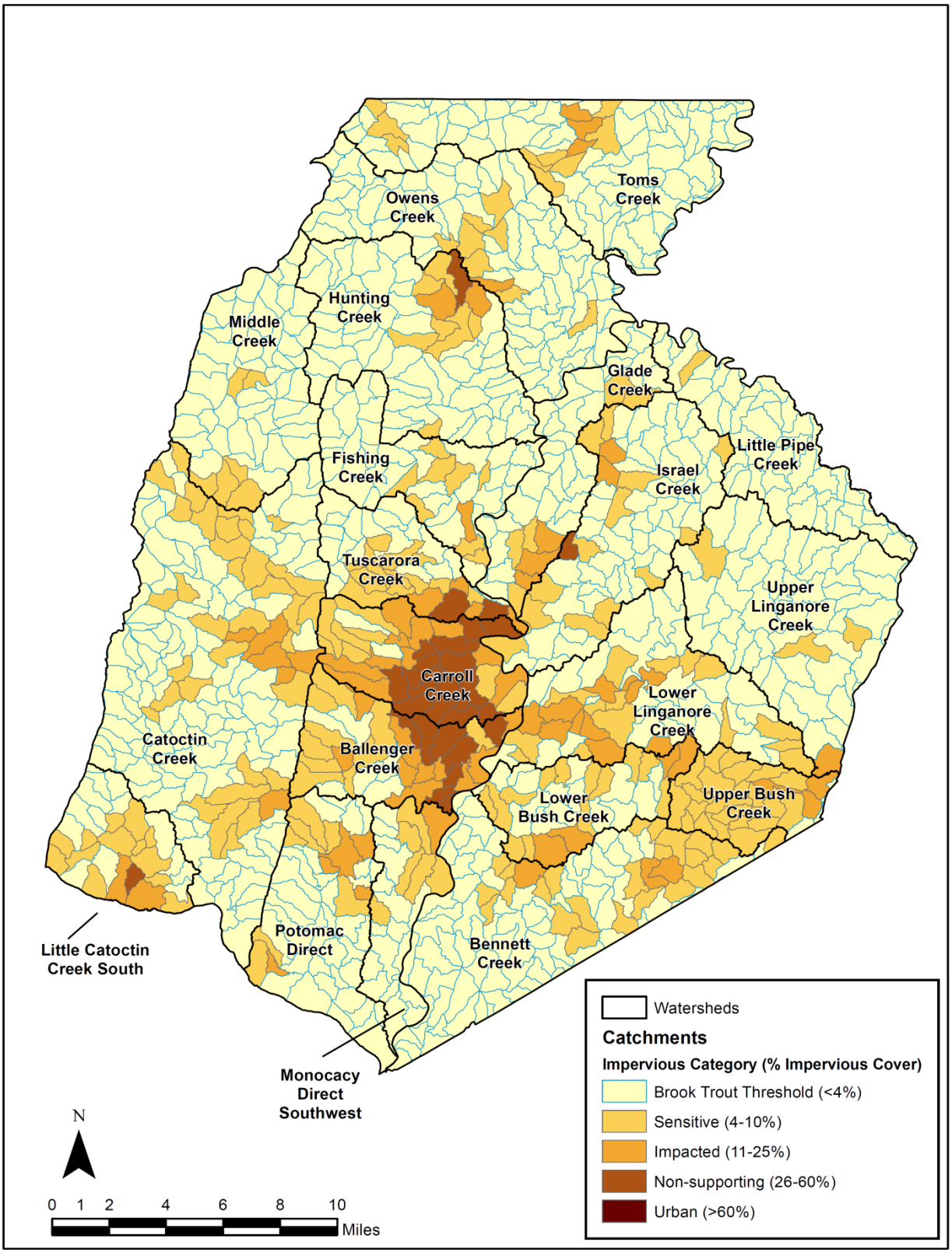


Figure 3. Impervious category for each catchment in Frederick County (based on 2005 planimetrics)

urban areas and the direct connection of runoff to stormwater pipes or channelized streams alter runoff patterns and creates "flashy" streams with more extreme high and low flows, increased scouring, and streambank erosion. These altered flows accelerate downcutting and widening of stream channels.

The FCSS collects data on many aspects of physical habitat, including the extent and type of vegetated riparian buffer, the severity of bank erosion observed, and an overall indicator of habitat quality. The Physical Habitat Index (PHI) for Maryland streams was developed using data from the Maryland Biological Stream Survey (Paul et al., 2002). This index combines several measures of physical habitat characteristics into one value that is then compared to minimally impacted ("reference") sites throughout the state.

Bank Erosion

Bank erosion observed in the County's streams ranged from none to severe (Table 4). Results varied by watershed (Figure 4, Table 5).

For the FCSS 2008-2011, 12% of stream miles in the County showed no indication of bank erosion, 33% showed evidence of mild erosion, 28% showed moderate erosion, and 28% showed severe bank erosion.

Table 4. Erosion severity classes

Erosion Severity Class	Score
None	0
Minimum	1
Moderate	2
Severe	3

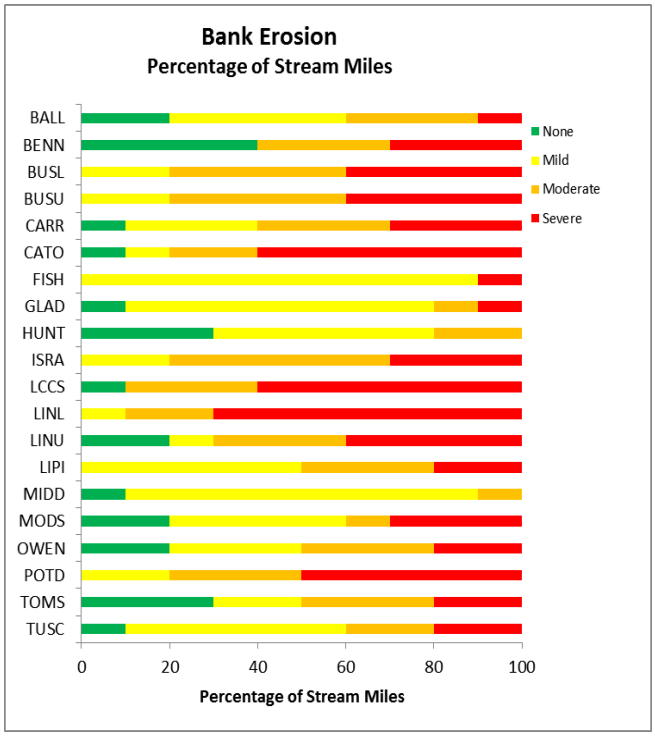


Figure 4. Percentage of stream miles in each bank erosion category for the 2008-2011 Frederick County Stream Survey

Bennett Creek (40%) and Toms Creek and Hunting Creek (30%) had the highest percentages of stream miles with no bank erosion. Four watersheds, all in the southern portion of the County, had 50% or greater stream miles with severe bank erosion: Lower Linganore Creek (70%), Little Catoctin Creek South (60%), Catoctin Creek (60%), and Potomac River Direct (50%). See Table 5 for results.

Table 5. Percentage of stream miles in bank erosion classes and the watershed mean for the FCSS 2008-2011

Watershed	None	Mild	Moderate	Severe	Mean Bank Erosion Score
Ballenger Creek	20	40	30	10	1.3
Bennett Creek	40	0	30	30	1.4
Lower Bush Creek	0	20	40	40	2.3
Upper Bush Creek	0	20	40	40	1.5
Carroll Creek	10	30	30	30	1.5
Catoctin Creek	10	10	20	60	1.0
Fishing Creek	0	90	0	10	1.7
Glade Creek	10	70	10	10	1.9
Hunting Creek	30	50	20	0	2.6
Israel Creek	0	20	50	30	2.4
Lower Catoctin Creek South	10	0	30	60	2.1
Lower Linganore Creek	0	10	20	70	0.9
Upper Linganore Creek	20	10	30	40	0.9
Little Pipe Creek	0	50	30	20	1.2
Middle Creek	10	80	10	0	2.3
Monocacy Direct Southwest	20	40	10	30	1.8
Owens Creek	20	30	30	20	2.2
Potomac Direct	0	20	30	50	2.2
Toms Creek	30	20	30	20	1.8
Tuscarora Creek	10	50	20	20	1.3

Riparian Buffer

For the purposes of this report, the riparian buffer width on both sides of the stream was summed together as a measure of riparian buffer integrity. According to a review of the literature (U.S. Army Corps of Engineers 1991, Wenger 1999, Fischer and Fischenich 2000, Broadmeadow and Nisbet 2004), different riparian buffer widths are adequate based on the necessary function of the buffer. For example:

- For erosion control, buffers should be between 30 and 98 feet (9-30 meters) on each side of the stream;
- For the removal of nitrogen and phosphorus, 16-164 feet (5-50 meters);

- For pesticide removal, 49-328 feet (15-100 meters);
- For the protection of aquatic wildlife, 33-164 feet (10-50 meters); and
- To provide adequate shading, 30-320 feet (9-98 meters).

Riparian buffer categories were assigned based on natural breaks in the data (Table 6). Fifteen percent of stream miles in the County had vegetated riparian buffer widths less than 15 meters, while 70% of stream miles in the County had vegetated riparian buffers of at least 60 meters.

Table 6. Riparian width sum classes

Category	Riparian Width Sum
1	≤ 15 m
2	15 m to ≤ 30 m
3	30 m to ≤ 60 m
4	> 60 m

With the exception of Little Pipe Creek and the Potomac River Direct watershed, all of the watersheds in Frederick County had greater than 60 meters of vegetated riparian buffer along the majority of their stream banks. These two watersheds also had the greatest percentage of stream miles with less than 15 meters of riparian buffer along their banks (Figure 5 and Table 7).

While no one watershed had an average riparian buffer value less than 30 meters, there were many sites scattered throughout the County that had no vegetated riparian buffer (Figure 6).

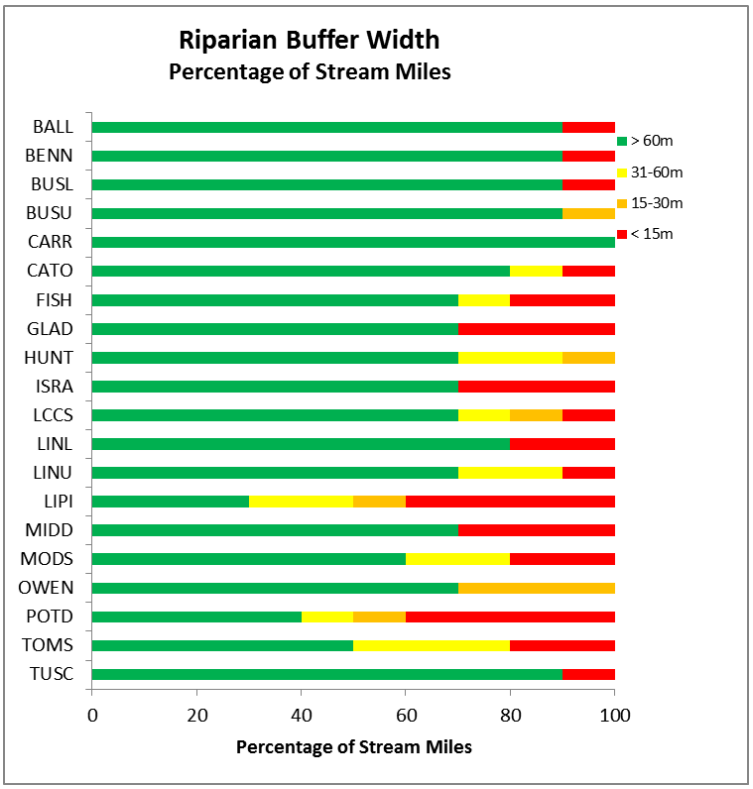


Figure 5. Percentage of stream miles in riparian buffer width categories for the 2008-2011 Frederick County Stream Survey

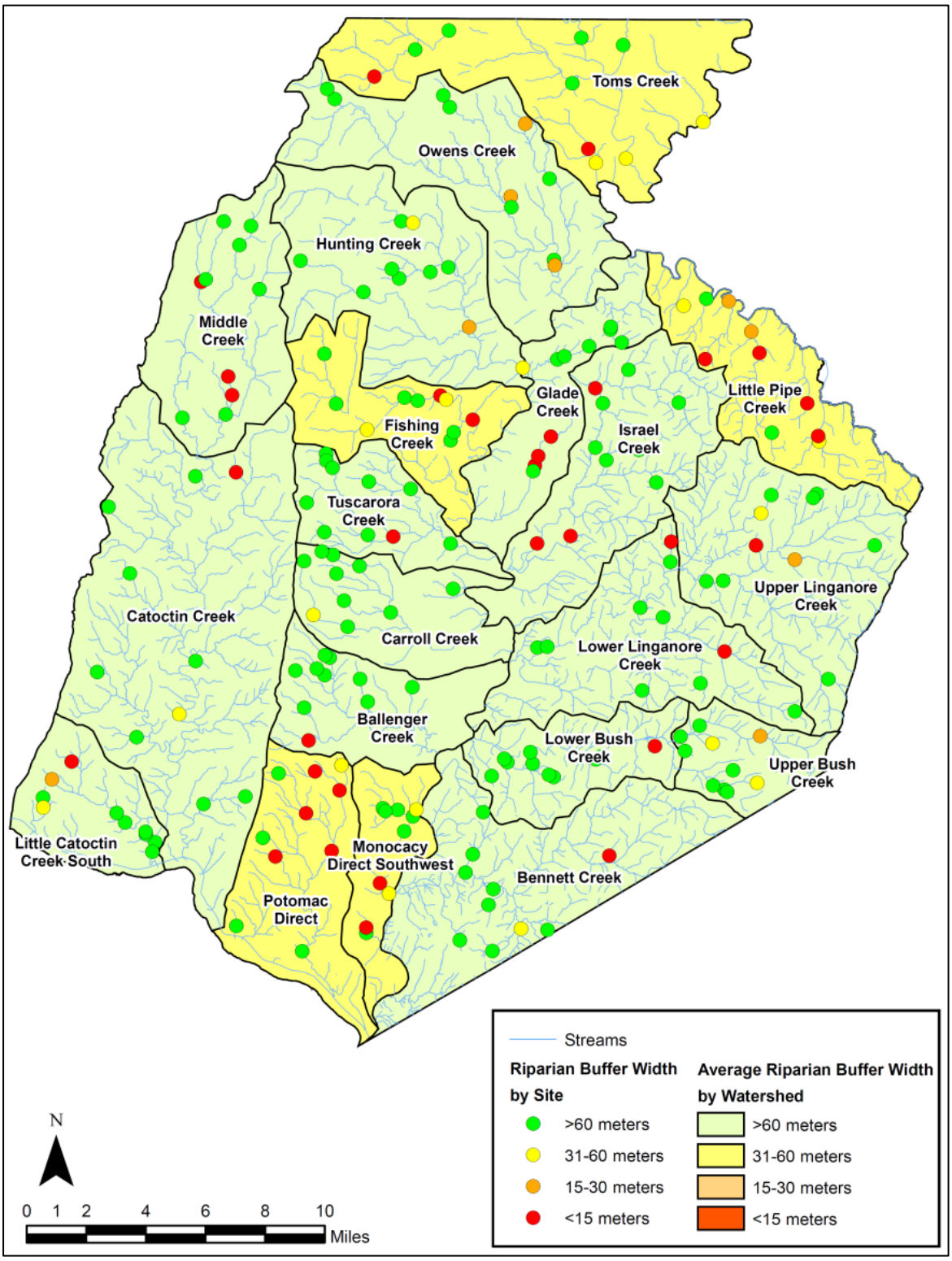


Figure 6. Map of Frederick County watersheds shaded according to average riparian buffer width, with riparian buffer width by site also shown, for the 2008-2011 Frederick County Stream Survey.

Table 7. Percentage of stream miles in riparian buffer classes and the watershed mean for the FCSS 2008-2011

Watershed	> 60 m	30-60m	15-30m	< 15 m	Mean Riparian Buffer Width (m)
Ballenger Creek	90	0	0	10	79
Bennett Creek	90	0	0	10	81
Lower Bush Creek	90	0	0	10	83
Upper Bush Creek	90	0	10	0	83
Carroll Creek	100	0	0	0	68
Catoctin Creek	80	10	0	10	83
Fishing Creek	70	10	0	20	58
Glade Creek	70	0	0	30	61
Hunting Creek	70	20	10	0	77
Israel Creek	70	0	0	30	65
Lower Catoctin Creek South	70	10	10	10	78
Lower Linganore Creek	80	0	0	20	73
Upper Linganore Creek	70	20	0	10	71
Little Pipe Creek	30	20	10	40	34
Middle Creek	70	0	0	30	63
Monocacy Direct Southwest	60	20	0	20	43
Owens Creek	70	0	30	0	72
Potomac Direct	40	10	10	40	46
Toms Creek	50	30	0	20	60
Tuscarora Creek	90	0	0	10	89

Physical Habitat Indicator

The Benthic Index of Biotic Integrity (see Section 5) and Physical Habitat Indicator categories used in this report can be found in Table 8.

Table 8. Thresholds for condition classes (Good, Fair, Poor, Very Poor) for BIBI and PHI scores in accordance with MBSS.

Condition Class	BIBI Range	PHI Range	Description (Roth et al. 1999)
Good/Marginally Degraded	4.00 – 5.00	81 – 100	Comparable to reference streams considered to be minimally impacted.
Fair/ Partially Degraded	3.00 – 3.99	66-80	Comparable to reference conditions, but some aspects of biological integrity may not resemble the qualities of minimally impacted streams.
Poor/ Degraded	2.00 – 2.99	51-65	Significant deviation from reference conditions, with many aspects of biological integrity not resembling the qualities of minimally impacted streams.
Very Poor/Severely Degraded	1.00 – 1.99	0-50	Strong deviation from reference conditions, with most aspects of biological integrity not resembling the qualities of minimally impacted streams.

In 2008-2011, 19% of stream miles in the County were rated as Severely Degraded and 21% were Minimally Degraded based on the Physical Habitat Indicator (PHI).

Catoctin Creek and Bennett Creek had the greatest percentage of stream miles with PHI scores in the top category, Marginally Degraded (60% and 50%, respectively). Little Pipe Creek (60%) and the Potomac River Direct Watershed (50%) had the highest percentages of stream miles in the Severely Degraded category. In fact, Little Pipe Creek, Glade Creek, and Lower Linganore Creek contained zero stream miles that were Marginally Degraded according to the PHI (Figure 7 and Table 9).

The average PHI score for watersheds in Frederick County (Figure 8) tended to be Partially Degraded in the western and southern portion of the county. Two exceptions are the Potomac Direct watershed and the Monocacy Direct Southwest watershed, which were Degraded on average, like most of the watersheds in the eastern portion of the County.

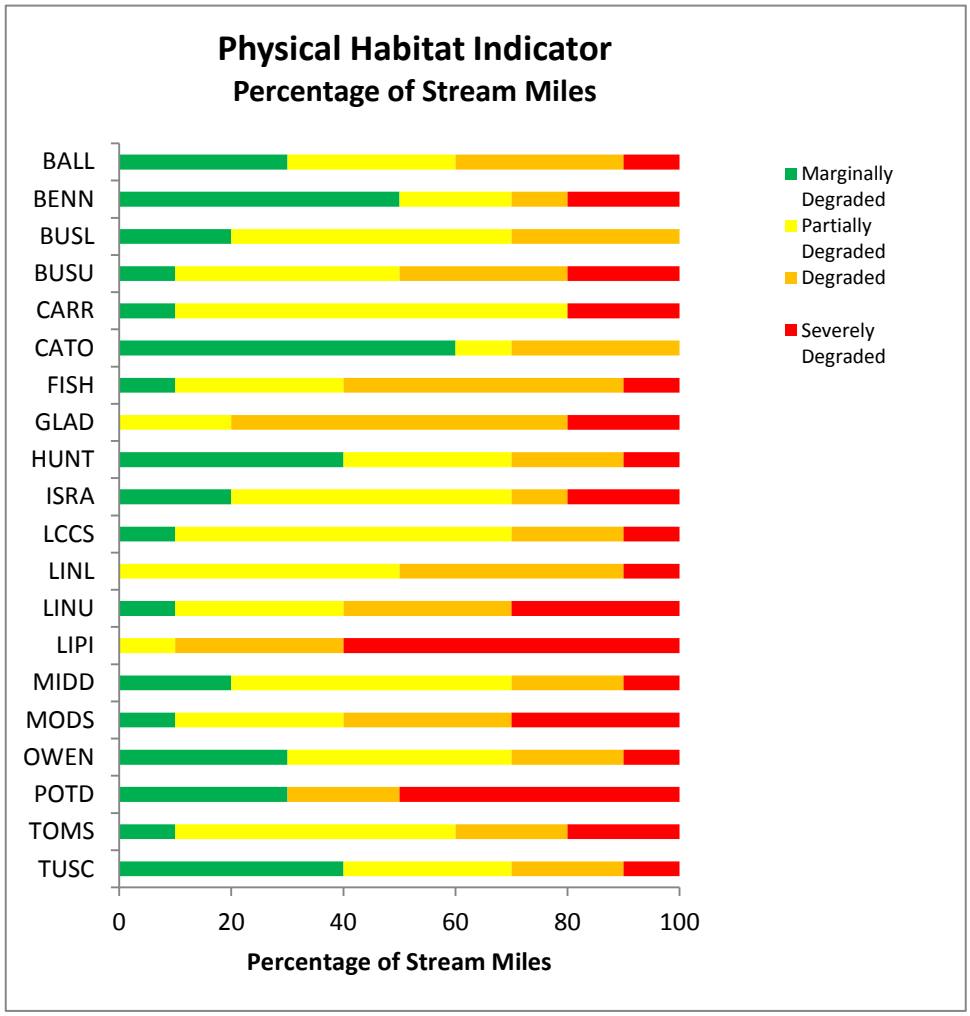


Figure 7. Percentage of stream miles in Physical Habitat Indicator (PHI) categories for the 2008-2011 Frederick County Stream Survey

Table 9. Percentage of stream miles in Physical Habitat Indicator (PHI) classes and watershed mean scores for FCSS 2008-2011

Watershed	Marginally Degraded	Partially Degraded	Degraded	Severely Degraded	Mean PHI Score
Ballenger Creek	30	30	30	10	66.9
Bennett Creek	50	20	10	20	72.3
Lower Bush Creek	20	50	30	0	72.9
Upper Bush Creek	10	40	30	20	63.9
Carroll Creek	10	70	0	20	66.9
Catoctin Creek	60	10	30	0	79.1
Fishing Creek	10	30	50	10	65.8
Glade Creek	0	20	60	20	55.7
Hunting Creek	40	30	20	10	73.9
Israel Creek	20	50	10	20	64.9
Lower Catoctin Creek South	10	60	20	10	68.7
Lower Linganore Creek	0	50	40	10	63.7
Upper Linganore Creek	10	30	30	30	57.6
Little Pipe Creek	0	10	30	60	50.3
Middle Creek	20	50	20	10	69.1
Monocacy Direct Southwest	10	30	30	30	59.3
Owens Creek	30	40	20	10	70.3
Potomac Direct	30	0	20	50	52.4
Toms Creek	10	50	20	20	64.3
Tuscarora Creek	40	30	20	10	71.9

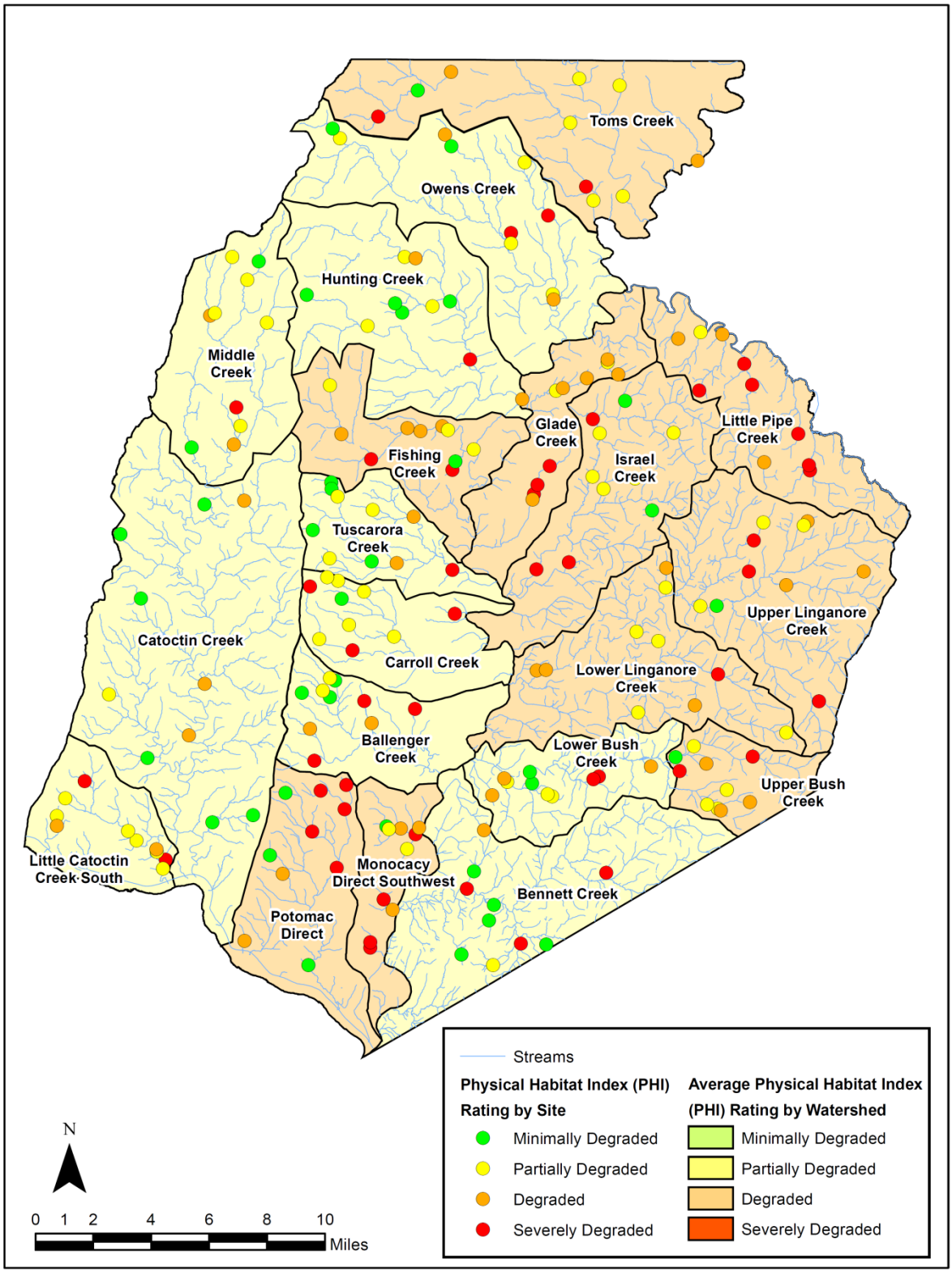


Figure 8. Map of Frederick County watersheds shaded according to average Physical Habitat Indicator (PHI), with PHI score by site also shown, for the 2008-2011 Frederick County Stream Survey.

4 WATER QUALITY

Nutrients such as nitrogen and phosphorus are important for life in all aquatic systems. In the absence of human influence, streams contain background levels of nutrients that are essential to the survival of the aquatic plants and animals. However, since the time of European settlement, the amount of nitrogen and phosphorus in many North American stream systems has increased, as a result of human influences such as agricultural runoff, wastewater discharge, and urban/suburban runoff.

Phosphorus (P) and nitrogen (N) are the primary nutrients that in excessive amounts pollute streams. Nitrogen enters the ecosystem in several chemical forms and also occurs in other dissolved or particulate forms. Phosphorus is a vital nutrient for converting sunlight into usable energy, and is essential to cellular growth and reproduction. Under natural conditions phosphorus is typically scarce in water. In the late 1960s scientists discovered phosphorus contributed by human activity to be a major cause of excessive algae growth and degraded water quality. Elevated nitrogen and phosphorus are major contributors to nutrient enrichment in Frederick County streams. Excessive nutrient loading (eutrophication) may lead to excessive plant growth in a water body, particularly in downstream estuaries like the Potomac River and Chesapeake Bay. Eutrophication can cause algal blooms, which can lead to decreased levels of dissolved oxygen in the water. Prolonged exposure to low dissolved oxygen conditions can asphyxiate fish, shellfish, and other animals.

Estimates of nitrogen sources in Maryland, as presented in the Chesapeake Bay TMDL (Chesapeake Bay Phase 5.2 Watershed model, 2008 Scenario), are that 36% is from agricultural sources, 29% from developed land, 10% from forest, and 25% from wastewater treatment plants.

Thresholds for categories for total nitrogen and total phosphorus can be found in Table 10. These thresholds are those used for the MBSS and derived from expert judgement (Ray Morgan, University of Maryland Frostburg, personal communication).

Table 10. Water quality thresholds (mg/l) for nutrients measured at sites sampled in the FCSS (Southerland et al. 2007)

Parameter	Low	Moderate	High
Total Nitrogen	< 1.5	1.5 – 7.0	> 7.0
Total Phosphorus	< 0.025	0.025 – 0.070	> 0.070

Nitrogen

Nitrogen levels within the watersheds in Frederick County varied geographically (Figures 9 and 10). In general, watersheds in the western portion of the County had lower total nitrogen levels than those in the eastern portion of the County. In fact, two watersheds in western Frederick County had 100% of stream miles in the "Low" category for total nitrogen – Hunting Creek and Fishing Creek.

Many watersheds had the majority of their stream miles in the "Moderate" category for total nitrogen, including Little Catoctin Creek South and Lower Bush Creek, which had 100% of stream miles in this category.

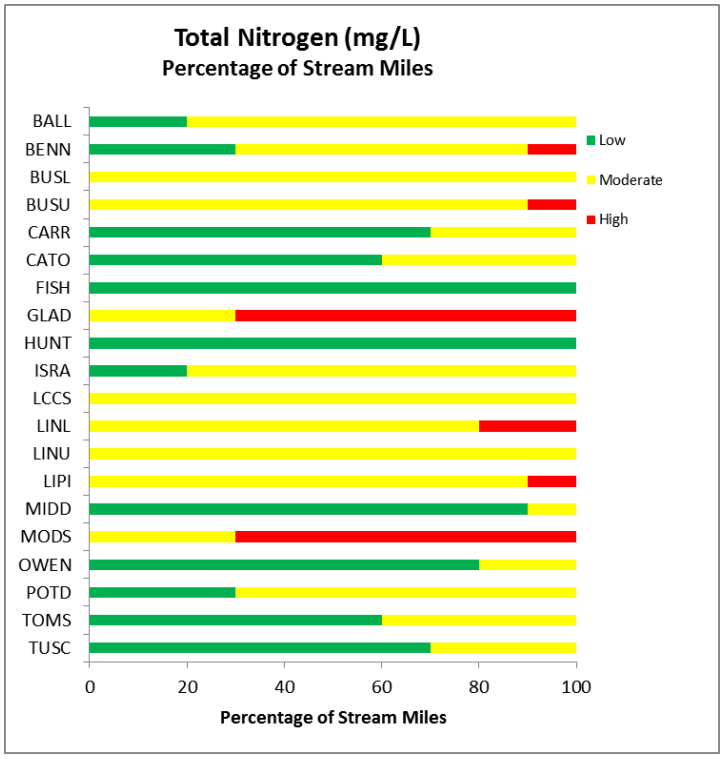


Figure 9. Percentage of stream miles in total nitrogen categories for the 2008-2011 Frederick County Stream Survey

Six watersheds in the central to eastern portion of the County had some stream miles in the "High" category for total nitrogen. Glade Creek and the Monocacy Direct watershed had 70% of stream miles in this category (Table 11).

The map of average total nitrogen by watershed mirrors the pattern shown in the percentage of stream miles. Watersheds in the northwestern portion of the County had average total nitrogen values in the "Low" category. With the exception of Glade Creek and the Monocacy Direct Southwest watershed (which had average total nitrogen values in the "High" category), the rest of the County had "Moderate" total nitrogen values on average.

Table 11. Percentage of stream miles in total nitrogen classes and watershed mean for FCSS 2008-2011

Watershed	Low	Moderate	High	Mean Total Nitrogen (mg/L)
Ballenger Creek	20	80	0	2.45
Bennett Creek	30	60	10	2.93
Lower Bush Creek	0	100	0	2.83
Upper Bush Creek	0	90	10	3.79
Carroll Creek	70	30	0	1.28
Catoctin Creek	60	40	0	2.36
Fishing Creek	100	0	0	0.43
Glade Creek	0	30	70	7.98
Hunting Creek	100	0	0	0.59
Israel Creek	20	80	0	2.69
Lower Catoctin Creek South	0	100	0	3.71
Lower Linganore Creek	0	80	20	4.56
Upper Linganore Creek	0	100	0	3.89
Little Pipe Creek	0	90	10	4.91
Middle Creek	90	10	0	0.93
Monocacy Direct Southwest	0	30	70	8.47
Owens Creek	80	20	0	0.99
Potomac Direct	30	70	0	2.96
Toms Creek	60	40	0	1.42
Tuscarora Creek	70	30	0	0.66

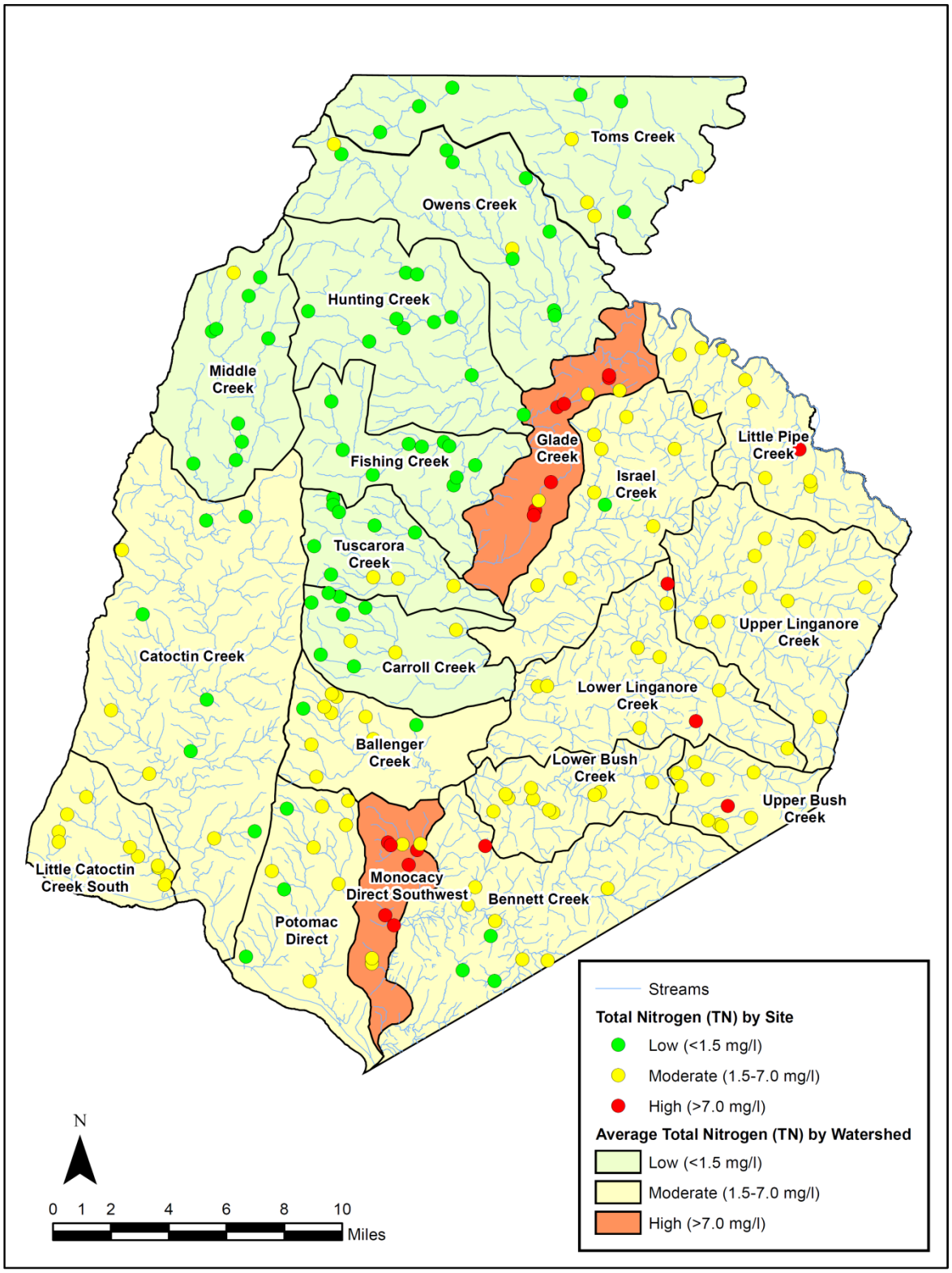


Figure 10. Map of Frederick County watersheds shaded according to average total nitrogen (mg/l), with total nitrogen by site also shown, for the 2008-2011 Frederick County Stream Survey.

Phosphorus

Phosphorus results by watershed are shown in Figures 11 and 12. The only watershed in Frederick County with no stream miles in the "Low" category for total phosphorus was Glade Creek. Bennett Creek and Owens Creek had the highest percentage of stream miles in the "Low" category (90%), followed closely by Carroll Creek, Middle Creek, and Tuscarora Creek (all at 80% of stream miles).

Glade Creek also had the highest percentage of stream miles in the "High" category (50%). Lower Linganore Creek and Little Pipe Creek each had 40% of stream miles in the "High" category (Table 12).

The pattern of average total phosphorus by watershed shown in the map (Figure 12) is similar to that of total nitrogen with "High" average values in Glade Creek and Monocacy Direct Southwest. Catoctin Creek and Upper Linganore Creek also had average total phosphorus in the "High" range.

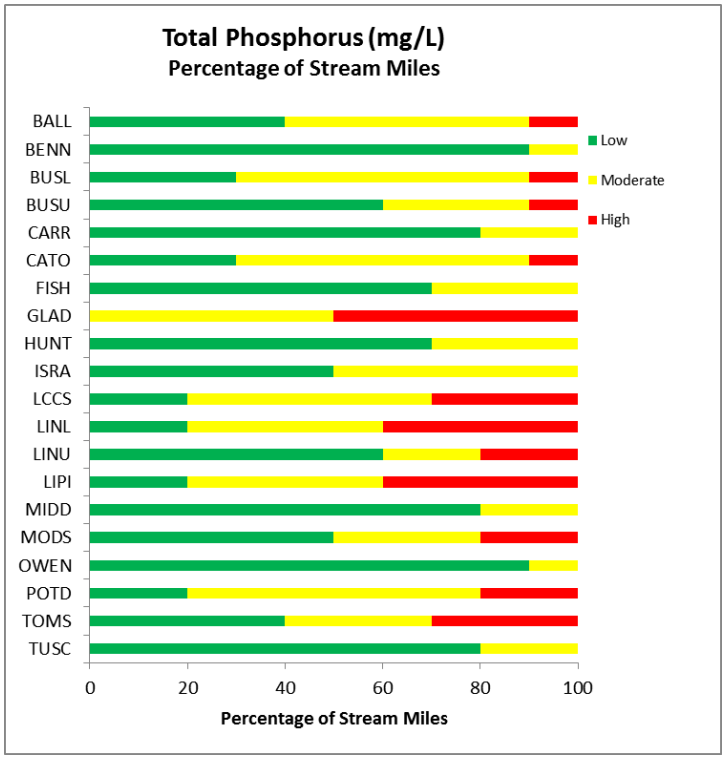


Figure 11. Percentage of stream miles in total phosphorus categories for the 2008-2011 Frederick County Stream Survey

Table 12. Percentage of stream miles in total phosphorus categories and watershed mean for FCSS 2008-2011

Watershed	Low	Moderate	High	Mean Total Phosphorus (mg/L)
Ballenger Creek	40	50	10	0.047
Bennett Creek	90	10	0	0.015
Lower Bush Creek	30	60	10	0.047
Upper Bush Creek	60	30	10	0.025
Carroll Creek	80	20	0	0.019
Catoctin Creek	30	60	10	0.136
Fishing Creek	70	30	0	0.024
Glade Creek	0	50	50	0.121
Hunting Creek	70	30	0	0.017
Israel Creek	50	50	0	0.027
Lower Catoctin Creek South	20	50	30	0.074
Lower Linganore Creek	20	40	40	0.069
Upper Linganore Creek	60	20	20	0.071
Little Pipe Creek	20	40	40	0.069
Middle Creek	80	20	0	0.014
Monocacy Direct Southwest	50	30	20	0.542
Owens Creek	90	10	0	0.015
Potomac Direct	20	60	20	0.045
Toms Creek	40	30	30	0.046
Tuscarora Creek	80	20	0	0.017

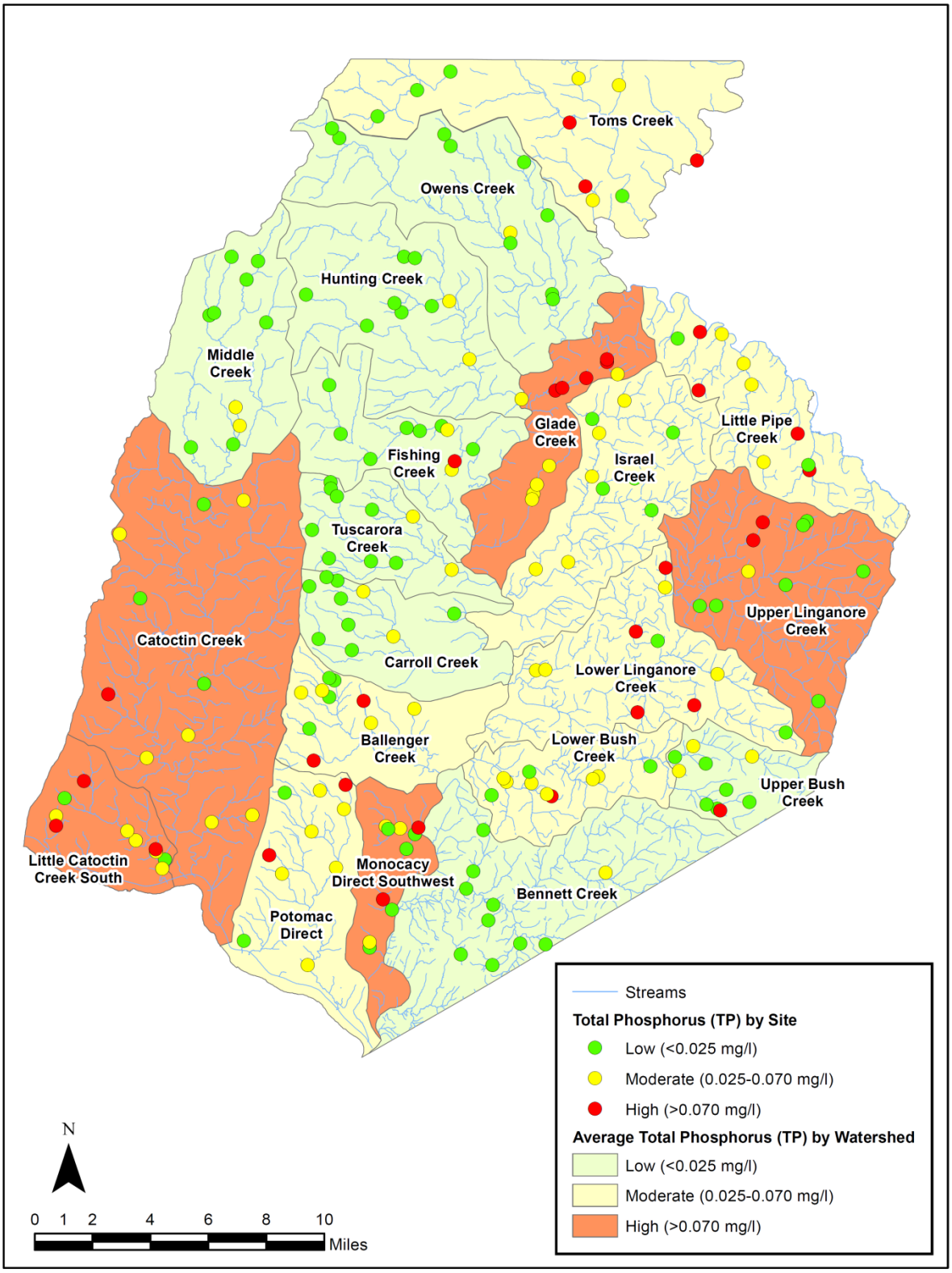


Figure 12. Map of Frederick County watersheds shaded according to average total phosphorus (mg/l), with total phosphorus by site also shown, for the 2008-2011 Frederick County Stream Survey.

5 BIOLOGICAL CONDITION

Freshwater benthic macroinvertebrates are bottom-dwelling aquatic animals without backbones that are larger than 0.5 millimeters long. These animals live in water on rocks, logs, sediment, debris and aquatic plants during some period in their life. Stream benthic macroinvertebrates include crustaceans such as crayfish, mollusks such as clams and snails, aquatic worms, and the immature forms of aquatic insects such as stonefly and mayfly nymphs.

Benthic macroinvertebrates are an important part of the food chain. Many invertebrates feed on algae and bacteria, which are on the lower end of the food chain. Some shred and eat leaves and other organic matter that enters the water. Because of their abundance and position as "middlemen" in the aquatic food chain, benthic macroinvertebrates play a critical role in the natural flow of energy and nutrients. As they die, they decay, leaving behind nutrients that are reused by aquatic plants and other animals in the food chain.

Unlike fish, benthic macroinvertebrates cannot move around much, so they are less able to escape the effects of sediment and other pollutants that diminish water quality and degrade habitat. Therefore, benthic macroinvertebrates can provide reliable information on stream degradation. Benthic macroinvertebrates represent an extremely diverse group of aquatic animals and a large number of species possess a wide range of responses to stressors such as organic pollutants, sediments, and toxic chemicals. They can serve as an early warning sign of declines in environmental quality.

The Benthic Index of Biotic Integrity (benthic IBI or BIBI) is a stream assessment tool that evaluates stream biological integrity based on characteristics of the various benthic organisms present at a site. Biological integrity is defined as the ability to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region (Karr and Dudley 1981).

Frederick County sites were evaluated using the benthic IBI developed for the Maryland Biological Stream Survey (for detailed methods, see Southerland, et al. 2007). IBI scores are determined by comparing the benthic assemblages at each site to those found at minimally impacted ("reference") sites within the same region. Site-specific IBI results were used to estimate the extent of streams within the study watersheds that were in good, fair, poor, and very poor condition with respect to the biotic integrity of the benthic community (see Table 8).

The benthic IBI average score for the County was 2.97 (Poor), with scores spread throughout the County. Seven percent of stream miles scored Very Poor, 41% scored Poor, 37% scored Fair, and only 15% of stream miles scored Good.

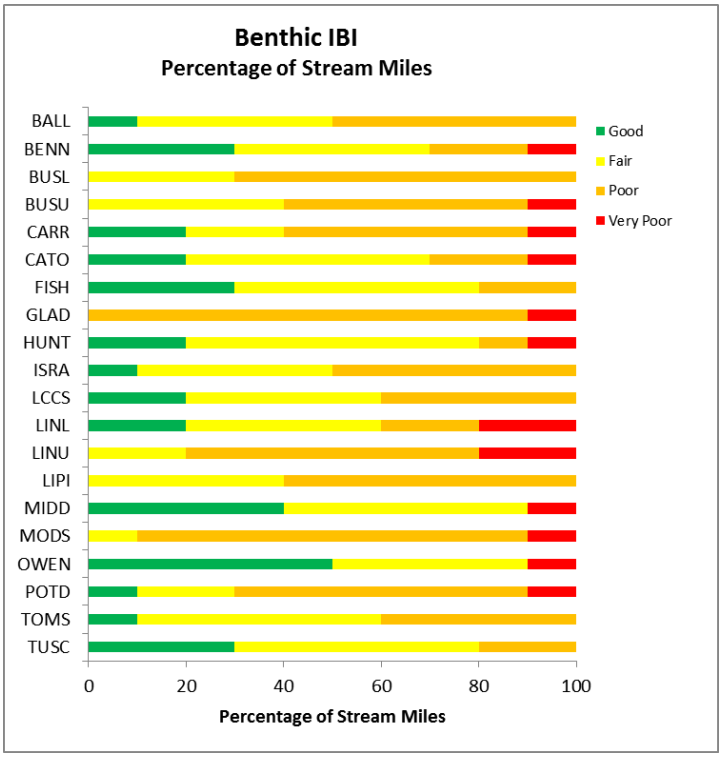


Figure 13. Percentage of stream miles in Benthic Index of Biotic Integrity (BIBI) categories for the 2008-2011 Frederick County Stream Survey

All 20 watersheds in Frederick County had the majority of their stream miles in the middle two scoring categories for benthic IBI (Fair and Poor; see Figure 13). In fact, six watersheds had no stream miles in Good condition. Owens Creek (50%) and Middle Creek (40%) had the highest percentage of stream miles in Good condition.

Eight watersheds had no stream miles in Very Poor condition. Two watersheds had the most stream miles in this category (20%): Upper Linganore Creek and Lower Linganore Creek (Table 13).

The BIBI map (Figure 14) shows that the average BIBI score for each watershed was either in the Fair or Poor category, with watersheds in the western portion of the County generally in better condition than those in the eastern portion.

Table 13. Percentage of stream miles in benthic IBI categories and watershed mean for FCSS 2008-2011

Watershed	Good	Fair	Poor	Very Poor	Mean BIBI Score
Ballenger Creek	10	40	50	0	2.95
Bennett Creek	30	40	20	10	3.30
Lower Bush Creek	0	30	70	0	2.78
Upper Bush Creek	0	40	50	10	2.68
Carroll Creek	20	20	50	10	2.95
Catoctin Creek	20	50	20	10	3.15
Fishing Creek	30	50	20	0	3.53
Glade Creek	0	0	90	10	2.25
Hunting Creek	20	60	10	10	3.38
Israel Creek	10	40	50	0	2.93
Lower Catoctin Creek South	20	40	40	0	3.10
Lower Linganore Creek	20	40	20	20	2.93
Upper Linganore Creek	0	20	60	20	2.28
Little Pipe Creek	0	40	60	0	2.60
Middle Creek	40	50	0	10	3.50
Monocacy Direct Southwest	0	10	80	10	2.43
Owens Creek	50	40	0	10	3.63
Potomac Direct	10	20	60	10	2.68
Toms Creek	10	50	40	0	3.10
Tuscarora Creek	30	50	20	0	3.35

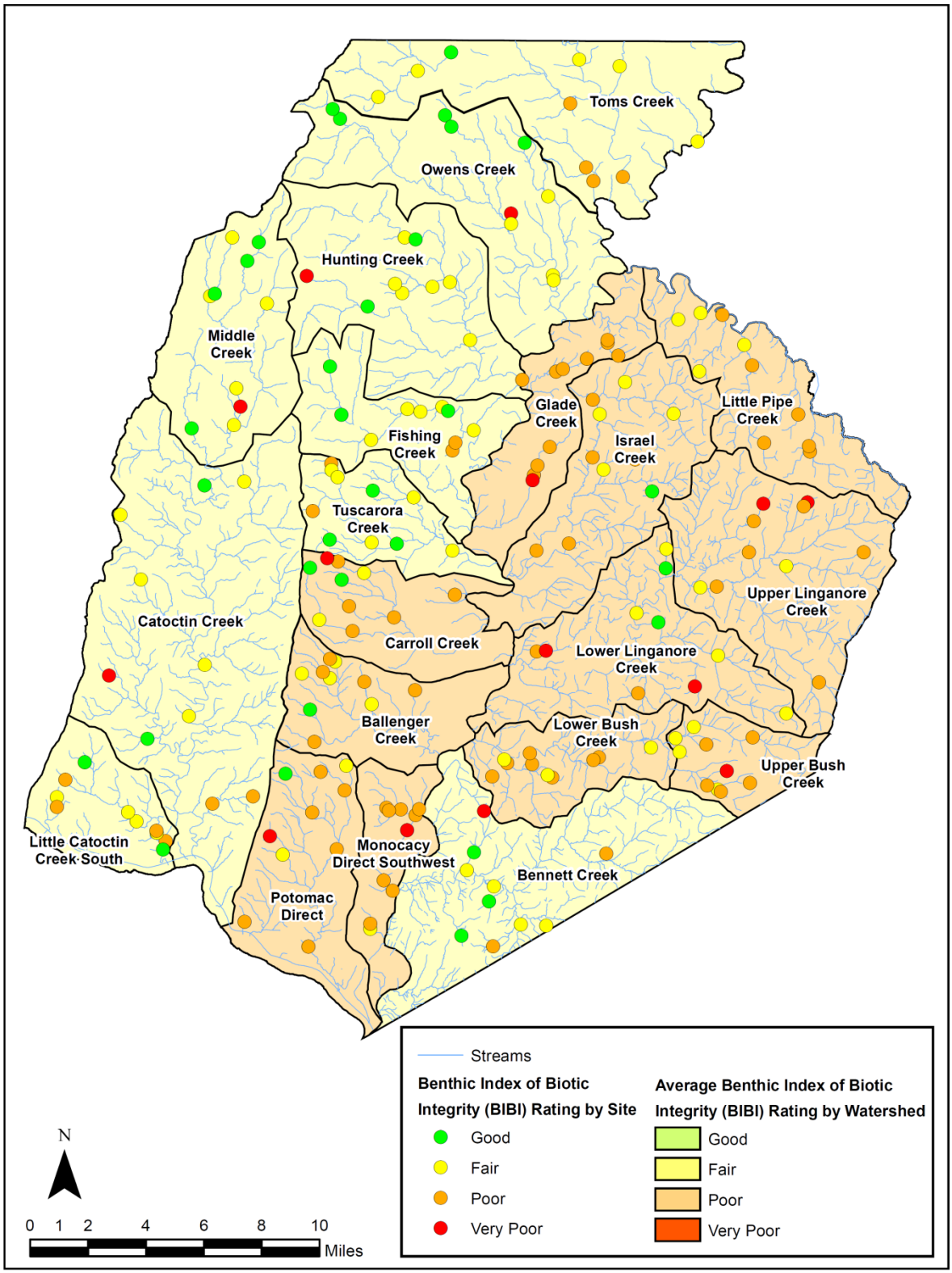


Figure 14. Map of Frederick County watersheds shaded according to average Benthic Index of Biotic Integrity (BIBI) with BIBI by site also shown, for the 2008-2011 Frederick County Stream Survey.

6 DISCUSSION

Relationships Among Biological, Physical, and Land Use Data

Regression analysis is a statistical technique for estimating the relationships among variables. It helps one to understand how the typical value of the one variable changes when another variable is varied. It allows a user to use measured data to predict future results. The result of a regression analysis is an R-squared value that ranges from 0 to 1.0. A higher number is indicative of a stronger relationship between the variables.

Land use, habitat, and water chemistry parameters were regressed against the benthic macroinvertebrate IBI scores for each site in order to examine the relationship of those parameters to the biological health of the stream.

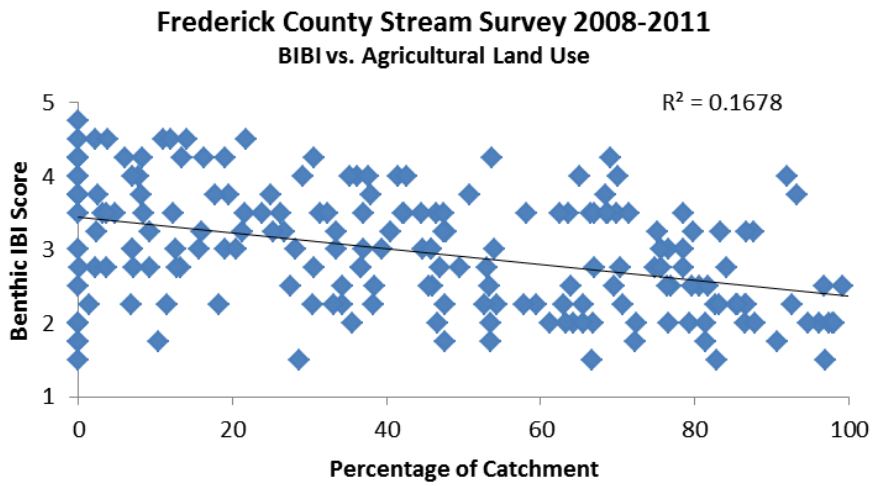
While the relationship of the BIBI to land use in the catchments upstream of the sample sites was not very strong, BIBI scores did decrease with increasing agricultural land use ($R^2 = 0.17$, $p < 0.001$) and increased with increasing forested land use ($R^2 = 0.25$, $p < 0.0001$). These results are consistent with the predictions that as forested land use increases, BIBI might increase and that as agricultural land use decreases, the BIBI might decrease. See Figure 15 for results.

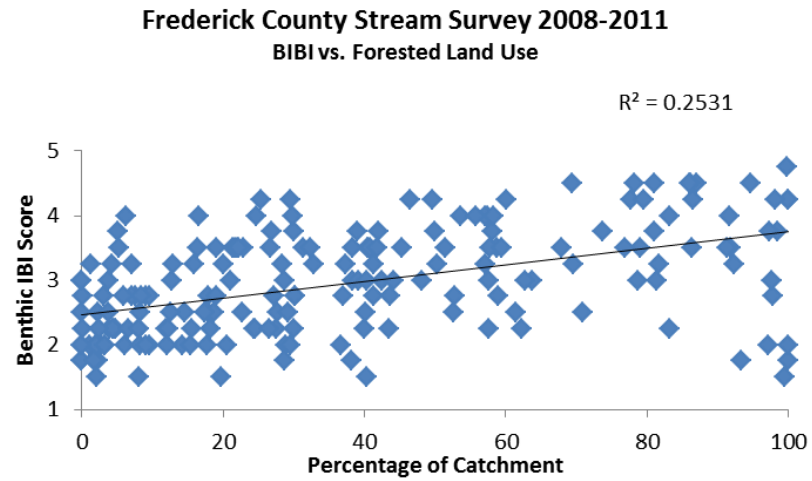
The relationship between the BIBI and urban land use ($R^2 = 0.02$, $p = 0.01$) was not very strong, probably because there were not many sites with high values of either percentage of urban land or impervious surface.

There was a positive relationship between the Physical Habitat Indicator and BIBI scores (Figure 16), although this was also not very strong ($R^2 = 0.10$, $p<0.0001$). The result is consistent with the prediction that as physical habitat quality increases, the quality of the benthic community also increases.

There was a negative relationship between BIBI scores and both total nitrogen and total phosphorus, although the relationship with nitrogen was stronger ($R^2 = 0.18$, $p<0.0001$ for nitrogen and $R^2 = 0.08$, $p<0.0001$ for phosphorus). These results are consistent with the prediction that as both total nitrogen and total phosphorus increase, the quality of the benthic community decreases.

One site in Catoctin Creek had a total phosphorus score much higher than the other scores in Frederick County. If that site is removed, the relationship of total phosphorus to the BIBI score is still negative, but is slightly stronger (with an $R^2= 0.11$)





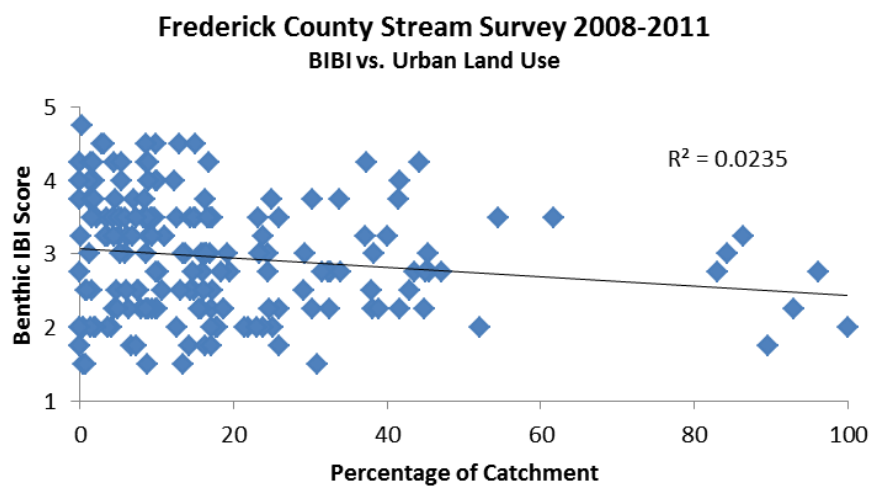


Figure 15. Regression relationships between the Benthic Index of Biotic Integrity (BIBI) and forested, urban, and agricultural land use in upstream catchments for the 2008-2011 Frederick County Stream Survey

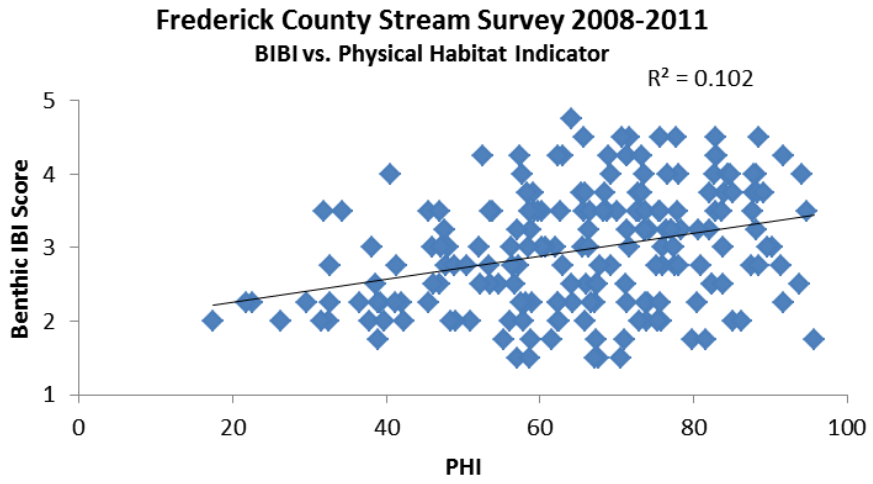
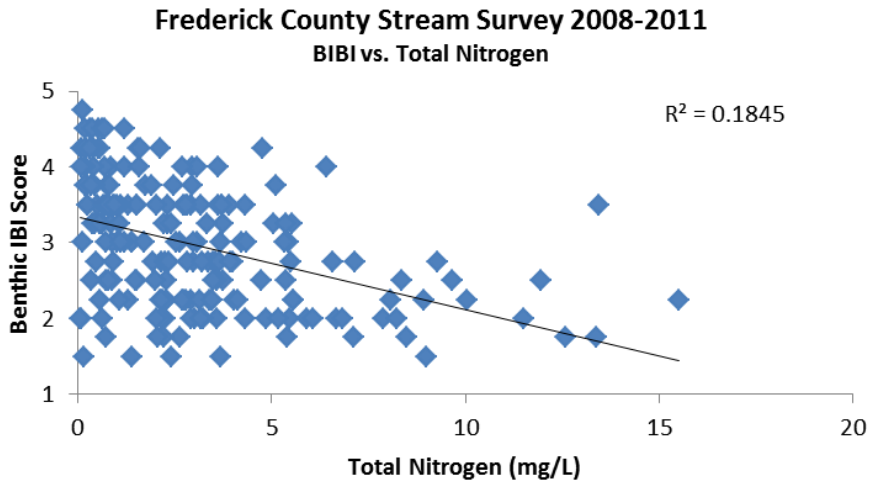


Figure 16. Regression relationship between the Benthic Index of Biotic Integrity (BIBI) and Physical Habitat Indicator (PHI) for the 2008-2011 Frederick County Stream Survey

Figure 18 shows the regression relationships between land use in the catchments upstream of the sample sites and total nitrogen. The relationship between agricultural land use and total nitrogen was significant and positive ($R^2 = 0.39$; $p < 0.0001$), supporting the prediction that increasing agricultural land use upstream of a sample site might increase the total nitrogen at that sample site. The relationship between forested land use and total nitrogen was significant and negative ($R^2 = 0.44$: $p < 0.0001$), supporting the prediction that increasing the forested land use upstream of a sample site might decrease the total nitrogen at that sample site. The relationship between urban land use upstream of the sample site and the total nitrogen at that site was not significant ($R^2 = 0.01$; $p = 0.06$).

The regression relationships between land use in the catchments upstream of the sample sites and total phosphorus were not as strong (Figure 19), but showed patterns similar to total nitrogen. There was a significant positive relationship between upstream agricultural land use and total phosphorus ($R^2 = 0.17$; $p<0.0001$), as well as a significant negative relationship with upstream forested land use and total phosphorus ($R^2 = 0.14$; $p<0.0001$). The relationship between urban land use upstream of the sample site and total phosphorus was not significant ($R^2 = 0.003$; $p=0.10$).



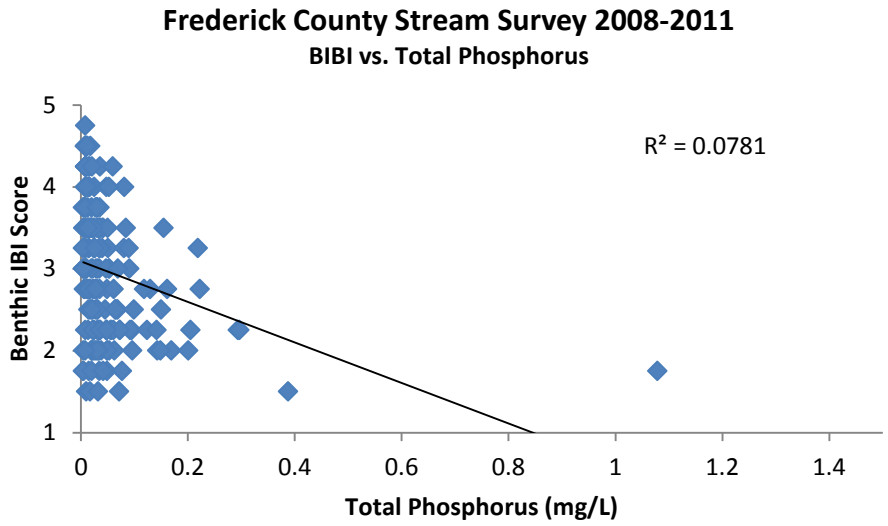
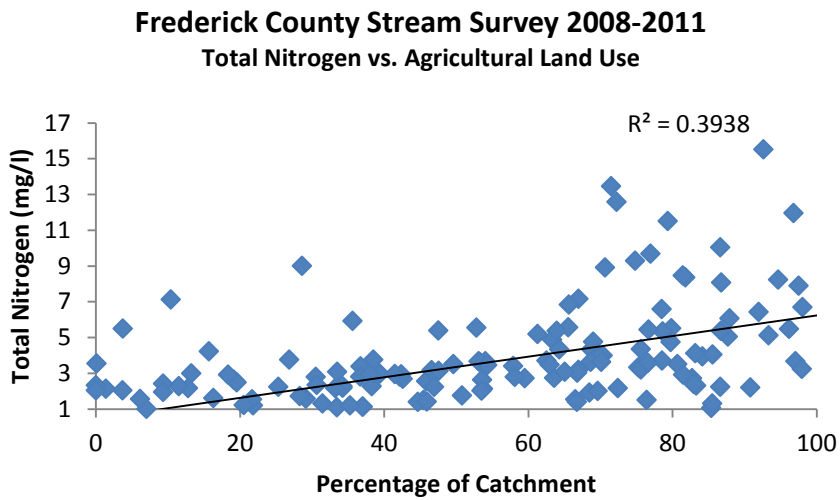
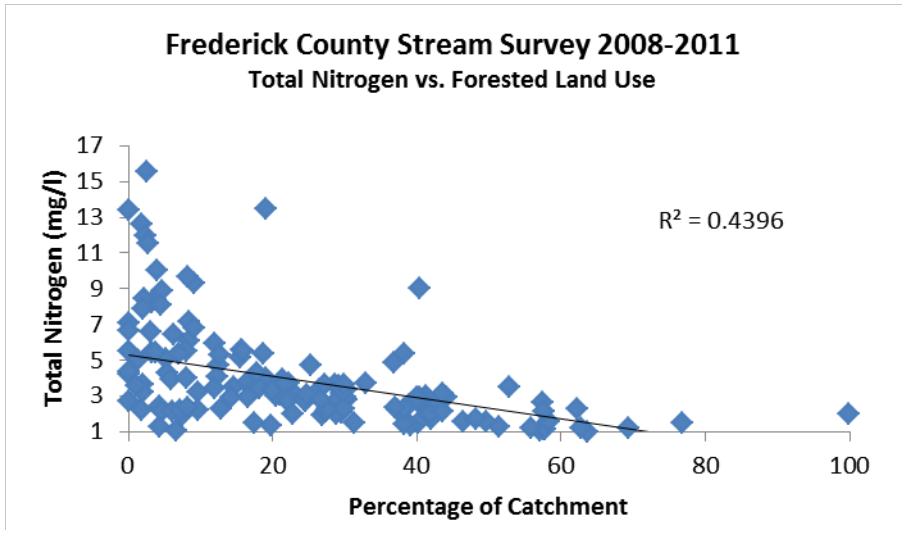


Figure 17. Regression relationships between the Benthic Index of Biotic Integrity and total nitrogen (mg/l) and total phosphorus (mg/l) for the 2008-2011 Frederick County Stream Survey





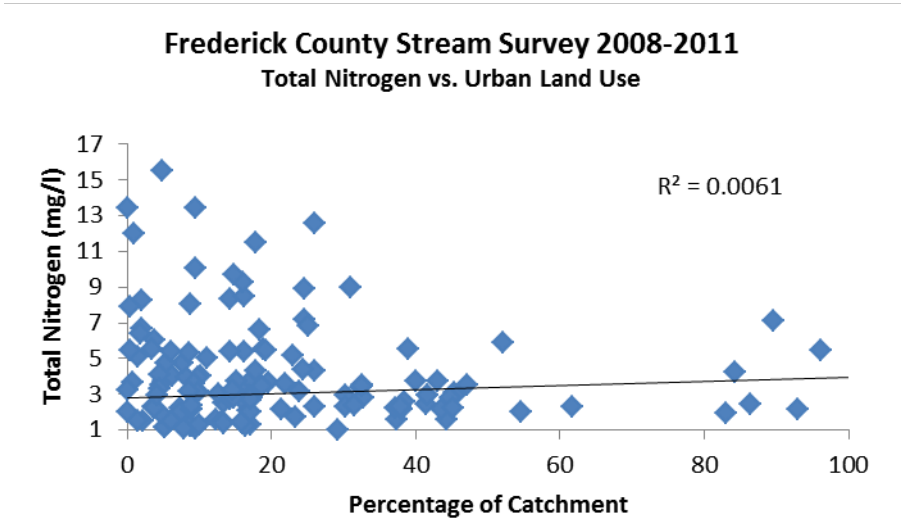


Figure 18. Regression relationships between total nitrogen (mg/l) and upstream land use for the 2008-2011 Frederick County Stream Survey

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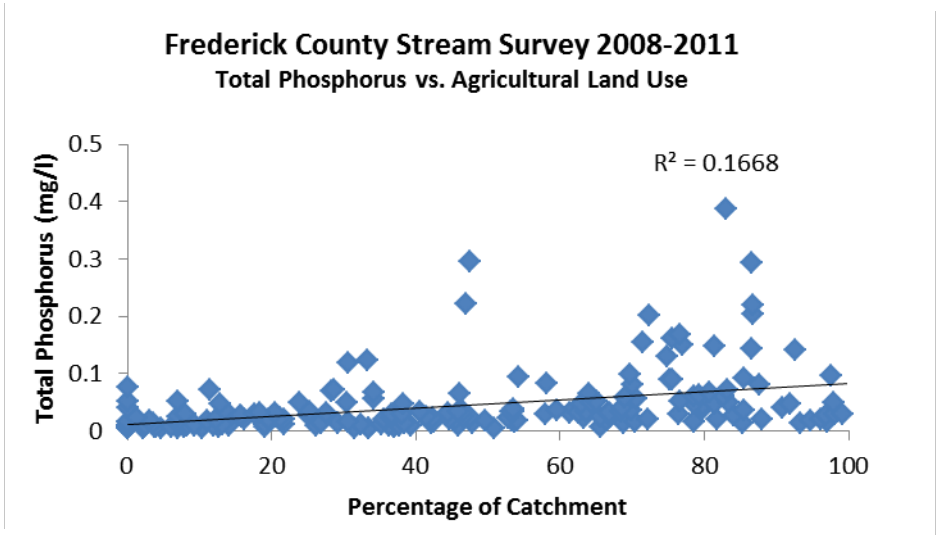

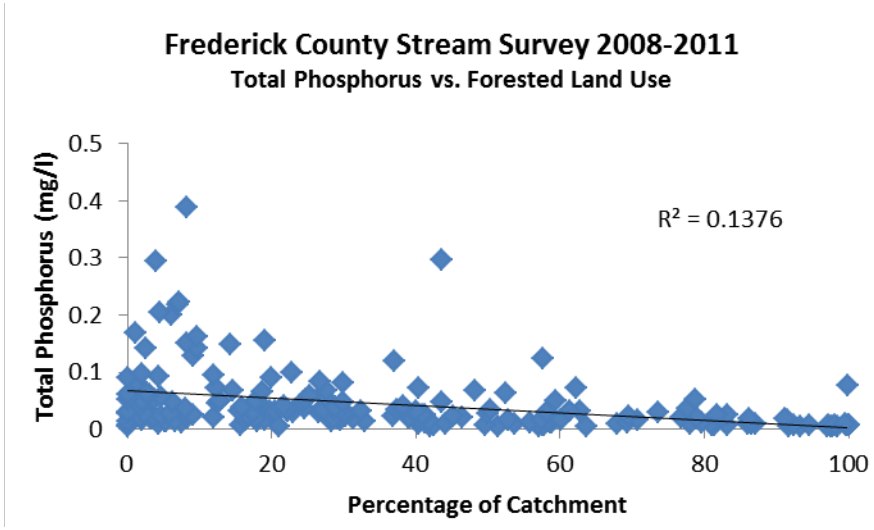

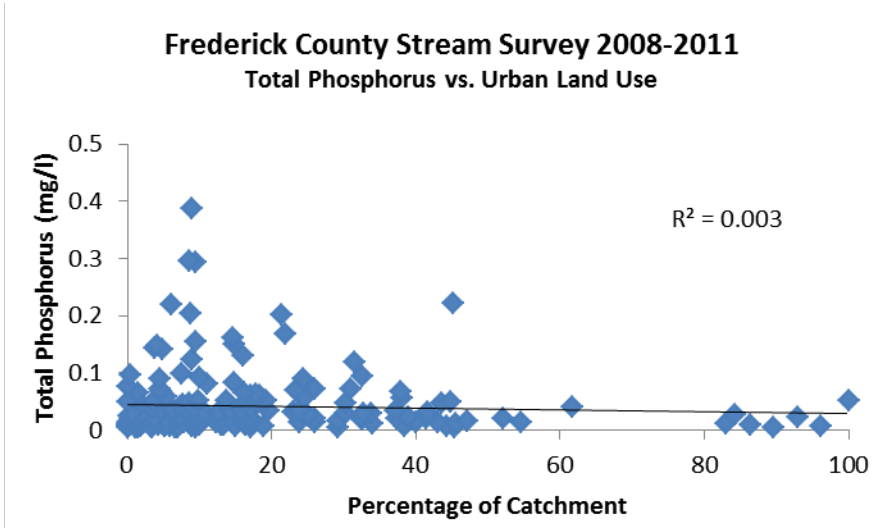

Figure 19. Regression relationships between total phosphorus (mg/l) and upstream land use for the 2008-2011 Frederick County Stream Survey

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FCSS Results Summarized for TMDL Watersheds

Within Frederick County, the Maryland Department of the Environment (MDE) has several established Total Maximum Daily Loads (TMDLs) which set limits for certain pollutants. The watersheds containing these TMDLs and their status as of 2012 are:

- Lower Monocacy – sediment and fecal coliform TMDLs are approved, nitrogen and phosphorus have been submitted;
- Upper Monocacy – sediment and fecal coliform TMDLs are approved, nitrogen and phosphorus have been submitted;
- Double Pipe Creek – sediment and fecal coliform TMDLs are approved, phosphorus has been submitted;
- Catoctin Creek – sediment TMDL has been approved, phosphorus has been submitted;
- Lake Linganore – sediment and phosphorus TMDLs have been approved.

The attached Appendix provides a summary table of the mean of the FCSS variables reported for each of the Frederick County portions of these watersheds.

7 CONCLUSIONS

While the average biological condition of streams in Frederick County in 2008-2011 was Poor (average BIBI score of 2.97), it is clear that condition varied greatly within and among the watersheds of the County. Biological condition is dependent on the location of the watershed within the County – watersheds in the northern and western portions of the County were generally in better condition than those in the southern and eastern portions of the County. Streams in forested areas tended to score higher than other streams.

There are a variety of factors affecting biological condition that make it difficult to identify any single major stressor to stream condition. In some areas, bank erosion maybe the predominant stressor, while in others the total inputs of nitrogen or phosphorus may have a stronger influence on biological condition. The FCSS provides data on a broad suite of land use, habitat, and water quality conditions that together affect Fredrick County's streams. After more data are collected in future sampling by the Survey, relationships between potential stressors and biological condition may become more readily apparent.

Round 2 of the FCSS began in the spring of 2013 and will continue through 2016. Once Round 2 is completed, comparisons can be made between the biological, physical, and chemical characteristics in each Round, allowing some conclusions to be drawn about the changes in condition in the County over time.

8 REFERENCES

Broadmeadow, S. and T.R. Nisbet. 2004. The effects of riparian forest management on the freshwater environment: a literature review of best management practice. Hydrology and Earth System Sciences, 8(3), 286-305.

Fischer, R.A. and J.C. Fischenich. 2000. Design recommendations for riparian corridors and vegetated buffer strips. U.S. Army Engineer Research and Development Center, Environmental Laboratory. Vicksburg, MS.

Hunicke, J. and S. Moore. 2008. Lower Monocacy River Watershed Restoration Action Strategy (WRAS) Supplement: EPA A-I Requirements. Prepared by the Frederick County Division of Public Works, Watershed Management Section for the Maryland Department of the Environment and the Environmental Protection Agency.

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

Perot, M., N. Roth, M. Southerland, J. Vølstad, B. Morgan and B. Franks. 2008. Draft. Design Report for the Frederick County Stream Survey. Prepared by Versar Inc., Columbia, MD for Frederick County Division of Public Works.

Paul, M.J., J.B. Stribling, R.J. Klauda, P.F. Kazyak, M.T. Southerland, and N.E. Roth. 2002. A Physical Habitat Index for Freshwater Wadeable Streams in Maryland. Prepared by Tetra Tech Inc., Owings Mills, MD; Versar Inc., Columbia, MD; and Maryland Department of Natural Resources, Monitoring and Non-Tidal Assessment Division.

Roth, N.E., M.T. Southerland, G. Mercurio, J.C. Chaillou, P.F. Kazyak, S.S. Stranko, A.T. Prochaska, D.G. Heimbuch, and J.C. Seibel. 1999. State of the Streams: 1995-1997 Maryland Biological Stream Survey Results. Prepared by Versar Inc., Columbia, MD and Post, Buckley, Schuh, and Jernigan, Inc., Bowie, MD for Maryland Department of Natural Resources, Monitoring and Non-Tidal Assessment Division.

Schueler, T., L. Fraley-McNeal, and K. Cappiella. 2009. Is Impervious Cover Still Important? A Review of Recent Research. *Journal of Hydrologic Engineering.* April, 2009.

Southerland, M.T., G.M. Rogers, M.J. Kline, R.P. Morgan, D.M. Boward, P.F. Kazyak, R.J. Klauda, and S.A. Stranko. 2007. Improving Biological Indicators to Better Assess the Condition of Streams. *Ecological Indicators* 7:751-767.

Stranko, S.A., R.H. Hilderbrand, R.P. Morgan, M.W. Staley, A.J. Becker, A. Roseberry-Lincoln, E.S. Perry, and P.T. Jacobson. 2008. Brook trout declines with land cover and temperature changes in Maryland. *North American Journal of Fisheries Management* 28:1223-1232.

U.S. Army Corps of Engineers. 1991. Buffer strips for riparian zone management. Waltham, MA.

Versar Inc. 2012. Frederick County Stream Survey, 2008-2011 Countywide Results. Prepared by Versar Inc., Columbia MD for Frederick County Community Development Division of Public Works

Versar Inc. 2011. Frederick County Stream Survey, 2008-2010 Countywide Results. Prepared by Versar Inc., Columbia MD for Frederick County Community Development Division of Public Works

Versar Inc. 2010a. Frederick County Stream Survey, 2008 Countywide Results. Prepared by Versar Inc., Columbia MD for Frederick County Division of Public Works

Versar Inc. 2010b. Frederick County Stream Survey, 2008-2009 Countywide Results. Prepared by Versar Inc., Columbia MD for Frederick County Division of Public Works

Versar, Inc. 2009. Frederick County Stream Survey 2007 Pilot Study Results: Bennett and Catoctin Creek Watersheds. Prepared by Versar, Inc., Columbia, MD for Frederick County Division of Public Works, Frederick, MD. January.

Wenger, S. 1999. A review of the scientific literature of riparian buffer width, extent and vegetation. Institute of Ecology, University of Georgia. Athens, GA

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APPENDIX

Appendix Table 1. Summary table of the mean of the FCSS variables reported for each of the Frederick County portions of the Maryland DNR 8-digit watersheds (as well as the sites draining to Lake Linganore).

Watershed	Percent Agricultural Land Use	Percent Forested Land Use	Percent Urban Land Use	Percent Catchment Impervious Surface	Bank Erosion	Riparian Buffer Width (m)	PHI Score	Total Nitrogen (mg/l)	Total Phosphorus (mg/l)	BIBI Score
Catoctin Creek	35.94	51.05	13.02	4.63	1.65	74.10	74.08	1.64	0.08	3.33
Double Pipe Creek	80.70	12.31	6.99	2.47	1.70	34.00	50.25	4.91	0.07	2.60
Lower Monocacy River	46.36	27.50	26.30	7.78	1.91	77.07	65.38	3.65	0.04	2.80
Potomac River Frederick County	53.37	34.90	13.56	5.27	2.35	61.65	60.54	3.33	0.06	2.89
Upper Monocacy River	32.43	57.78	9.54	3.73	1.23	70.52	66.94	2.01	0.04	3.20
Lake Linganore Watershed	53.30	24.16	25.30	4.75	2.44	72.78	63.87	5.17	0.07	3.08