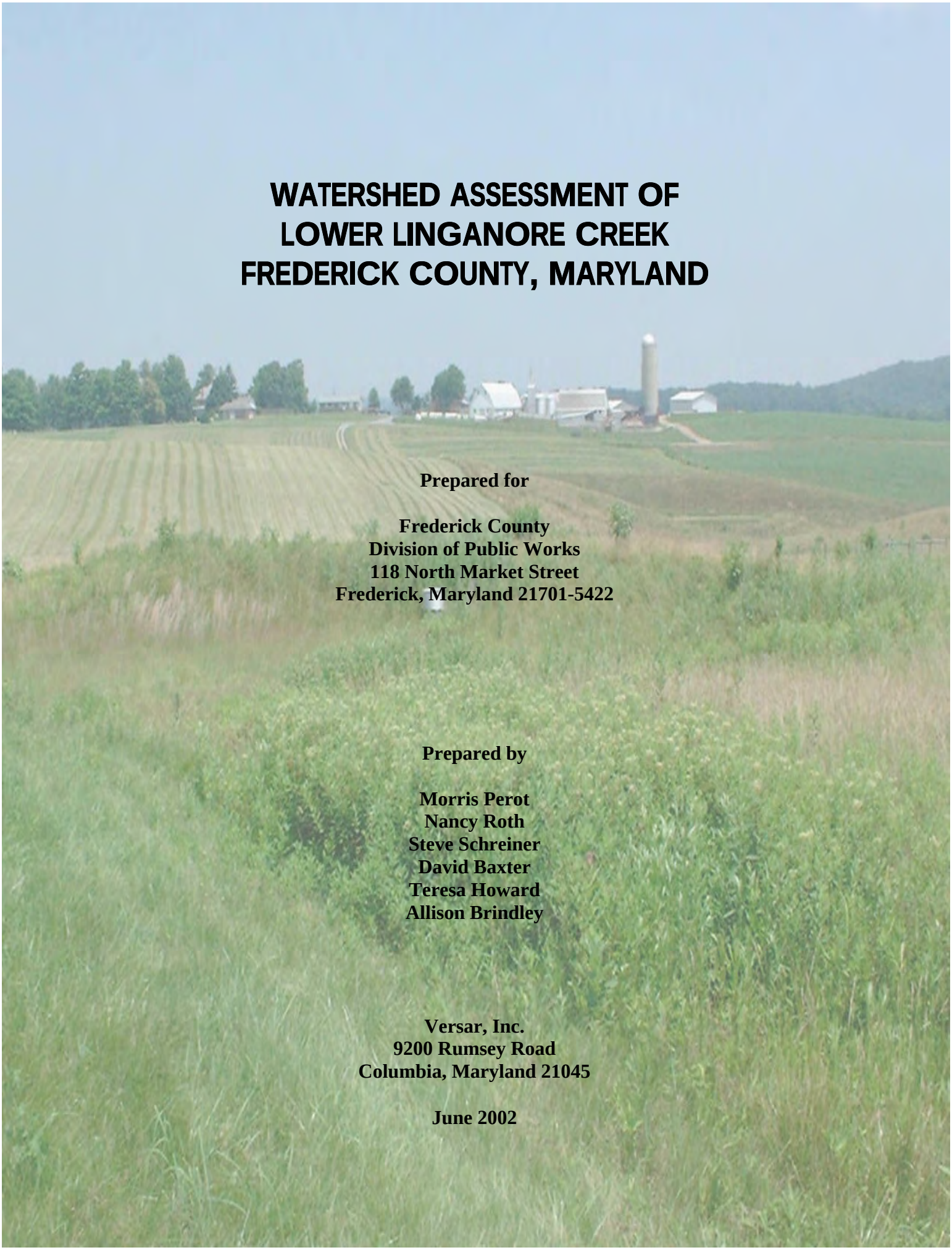

WATERSHED ASSESSMENT OF LOWER LINGANORE CREEK FREDERICK COUNTY, MARYLAND

Prepared for

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EXECUTIVE SUMMARY

Lower Linganore Creek was selected as the third watershed to be assessed under Frederick County's National Pollution Discharge Elimination System (NPDES) municipal stormwater permit (Permit Number MD0068357) because of extensive development around Lake Linganore and the presence of surface water intakes for water supplies serving the County, the City of Frederick, and a country club. The focus of this watershed assessment was to assess conditions in the watershed, identify water quality problems, describe opportunities to improve water quality, and develop a water quality plan. Methods utilized in the County's previous two watershed assessments were employed in this study, with some minor modifications to the stream survey to improve consistency and compatibility with other county and state monitoring programs. In addition, the scope of this study was expanded to include computer modeling to assess watershed and subwatershed runoff and pollutant loading characteristics.

Watershed Characteristics

Linganore Creek, classified as Class IV Recreational Trout Waters, drains approximately 88 square miles of agricultural, forested, and residential land located east-northeast of the City of Frederick. This study focused upon the lower half of the watershed, designated as Frederick County Watershed M-5.4, which is approximately 24,350 acres (38 square miles) in size. To facilitate analysis, Lower Linganore Creek watershed was divided into 10 subwatersheds of approximately equal size.

The watershed is located almost entirely within the Piedmont Upland portion of the Division, which is characterized by heavily rolling upland with numerous low knobs and ridges and shallow, narrow streambeds. Field observations indicate that land cover, wetlands, and wildlife conditions within the watershed are similar to those found elsewhere in the County.

Ten stream monitoring stations were established on the mainstem and tributaries of Lower Linganore Creek. Field activities involved testing water quality, quantifying physical conditions through geomorphic surveys, completing qualitative habitat assessments, sampling benthic macroinvertebrates, and conducting electrofishing surveys. Spring, summer, and fall 2001 surveys indicated that the stream supports a variety of fish and macroinvertebrate biota, including several sportfish species. Analysis of habitat condition, benthic Index of Biotic Integrity (IBI), and fish IBI scores showed that most ratings fell within the second highest category (i.e., fair). Half of the stations received fish IBI scores of poor and very poor, which is indicative of high numbers of tolerant fish species. To some degree, these conditions are typical for streams in this region, and reflect the area's long agricultural history as well as more recent urban development.

Statewide land use data from 1997 indicate that the watershed is dominated by agriculture (51%) and forest (29%), predominantly in the northern and western portions of the study area. Low-density residential (11%) and medium density residential (5%) are the next most prevalent uses, and are concentrated around Lake Linganore. Future projections of land use, based on a complete buildout scenario under current zoning plans and assuming no down-zoning, predict that low-density residential will increase to 17% and medium-density residential will increase to 18%.

Current and future population statistics indicate that an estimated 16,050 people resided in the watershed in 2000, up 25 percent from 1995. Population is expected to steadily increase over the next 20 years, reaching 26,222 in 2020, more than double the 1995 level. In 1995, there were 4,841 households in Lower Linganore Creek watershed. By 2020, the projected number of households is 9,922, again more than doubling the 1995 value.

Analysis of existing infrastructure shows that the Spring Ridge and Lake Linganore communities in the central portion of the watershed are currently served by public water and sewer, and that in the near future, service will be extended into the south-central portions of the watershed. Approximately two-thirds of the watershed is currently served by residential wells and septic systems.

An inventory of potential pollution sources revealed that 33 stormwater management facilities are located within the watershed. A review of MDE and USEPA databases indicate no significant threats from known discharges to water, hazardous waste sites, or releases likely to adversely affect watershed conditions. A large portion of the development in the Lake Linganore area lacks modern stormwater management controls. Narrow riparian buffers around the lakes and along the streams were a widespread problem, as were livestock impacts to streams in rural areas. The amount of impervious surface area within Lower Linganore Creek watershed, estimated at 7 percent, is less than the 10 percent imperviousness threshold at which adverse effects are often reported.

SWMM Modeling

The Stormwater Management Model (SWMM) was used to assess runoff and pollutant loading characteristics of the watershed and its 10 subwatersheds. Results for the current scenario indicated that the highest urban pollutant loadings are in the Mainstem Linganore Creek and Long Branch subwatersheds, while Chestnut Grove and Detrick subwatersheds had the highest agricultural loadings. The future scenario predicted that the Mainstem Linganore Creek, Long Branch, and Hazelnut Run subwatersheds would have the highest urban pollutant loadings, while Chestnut Grove and New London subwatersheds would have the highest agricultural pollutant loadings.

Assessment and Ranking of Water Quality Problems

Problems affecting water quality in Lower Linganore Creek and its tributaries are predominantly those arising from both urban and agricultural nonpoint sources. General problems evident in the watershed include alteration of natural flow regimes (i.e., rapid conveyance of stormwater into stream channels), sediment deposition, and physical habitat degradation. In many cases, problems have resulted in minor or moderate impacts, particularly where vegetated or forested buffer or existing stormwater management facilities have provided some protection from the impacts of nearby land uses. Taken individually, many of the activities in the watershed likely have little detrimental effect; however, the cumulative effect of these activities throughout the watershed can be of greater concern.

Water quality impacts within Lower Linganore Creek loosely fall into ten groups centered around the following issues: cumulative impacts, hydrologic modification, livestock access to stream, cropland runoff, failing septic systems, new construction, future development, industrial/commercial development, existing structures, and inadequate SWM controls. Site-specific and/or general programmatic opportunities were identified for each problem that would help improve water quality within the watershed. Sites were sorted by overall rating for the entire watershed, and by subwatershed, to help prioritize problems and focus future improvement efforts.

Watershed Water Quality Plan

The most promising opportunities to address water quality problems in the Lower Linganore Creek watershed were selected as components of a watershed water quality plan. Further implementation will depend upon cost, available funding, feasibility, and the likelihood of success in improving or sustaining stream habitat and water quality. Recommendations include general programmatic approaches that can be expected to provide benefit to large areas or even County-wide, as well as more site-specific opportunities to implement best management practices (BMPs) at particular locations. Additional recommendations include stream corridor restoration at two locations along Bens Branch, and the further investigation of an automotive scrapyard, which may release contaminants to soil, groundwater, or surface water resources. Actions will address the primary threats to water quality, including stormwater runoff from existing development, livestock access to streams, agricultural runoff, and future construction and development.

Table ES-1 summarizes actions recommended in the watershed water quality plan and presents the proposed implementation schedule. A preliminary cost estimate was also developed for each recommendation.

The final part of the water quality plan includes periodically monitoring conditions within the watershed to evaluate the effectiveness of water quality improvements as a result of project

implementation. It is recommended that conditions at the ten Lower Linganore Creek watershed monitoring stations be reevaluated approximately every three years using the biological and physical assessment methods described in Section 2.3.1. In addition to stream monitoring data, it is recommended that supplemental visual inspections and photographic documentation of specific site locations be conducted periodically to monitor effectiveness of management actions. Because natural variability may make it difficult to detect trends in stream monitoring data until a long-term data set is amassed, visual inspection results will help demonstrate whether management actions are beginning to achieve the desired benefit, or whether additional corrective measures are needed.

Table ES-1. Timetable for the recomm[illegible] improve water quality in the Lower Linganore Creek Watershed, starting after plan approval

Event	Plan Approval	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6	
		1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half
rammatic Opportunities													
ource water protection plan for Linganore Creek		on-going											
ontinued Interagency Coordination		on-going											
Ionitor Agricultural Preservation Districts													
asement and site maintenance agreements													
etrofit and restoration feasibility analysis													
Select watersheds and subwatersheds													
Conduct feasibility analysis in first subwatershed													
Management Practices													
acilitate local SWM control efforts in older developments near lake			on-going										
educe livestock access to streams		on-going											
Iaintenance issues													
pportunities to improve water quality on County-owned properties													
Inquiries to ES3 (Linganore High School)													
Retrofit to ES3 (Linganore High School)													
ES2 (County public safety training facility) project		on-going											
npaved construction roads		on-going											
m Corridor Restoration													
ens Branch across from Millime Court													
Feasibility evaluation													
Design								†					
Construction										‡			
ens Branch at Gas House Pike													
Feasibility evaluation													
Design								†					
Construction										‡			
her Investigations at Specific Sites													
CD1) Countryside Auto Parts													

s:
:hedule begins with approval of feasibility evaluation
:hedule begins with approval of designs

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1.0 INTRODUCTION

This report documents a Watershed Assessment and Watershed Water Quality Plan for Lower Linganore Creek watershed that was prepared for the Frederick County Division of Public Works (DPW). The report summarizes the work performed, findings, and recommendations for watershed protection measures in the Lower Linganore Creek watershed. Lower Linganore Creek is located in eastern Frederick County and consists primarily of agricultural and suburban areas; however, a quarter of the watershed remains forested.

The focus of this study was to assess current conditions in the Lower Linganore Creek watershed, and then use this information to identify opportunities to improve water quality. Because geology, vegetation, and land use all influence watershed hydrology, water quality, and aquatic habitat, the watershed assessment was tailored to gather data on the watershed=s natural resources and then to consider rural and urban stormwater impacts. Information on present and future stormwater impacts was then used to develop recommendations that will help Frederick County implement long-term strategies for stormwater management (SWM).

The Watershed Water Quality Plan focuses primarily on stormwater runoff because runoff from excess precipitation falling on rural, suburban, and urban areas carries many pollutants, including nutrients, oil and grease, heavy metals, and organic pollutants such as residues from pesticides. Because pollutants carried by stormwater runoff typically enter surface water bodies from diffuse locations at intermittent times during and after rainfall, it is usually referred to as "nonpoint source pollution" or "nonpoint pollution." Runoff volume and quantities and types of nonpoint pollution are commonly related directly to the amount of imperviousness associated with each land use category within the drainage area. For example, compacted soils, roads, rooftops, parking lots, driveways, and other impervious surfaces are major sources of nonpoint pollution. This nonpoint pollution contributes to water quality degradation and loss of aquatic habitat and is the major threat to water quality in the Lower Linganore Creek watershed.

Data gathered in this assessment will also serve as a baseline against which the efficacy of future best management practices (BMPs) to control nonpoint source pollution can be measured. As BMPs are implemented, continued monitoring will provide data that can be compared to this baseline and other historical information. Reductions in pollutants (i.e., improved water quality) provided by the new BMPs should be evident in the monitoring data. A process of adaptive management (based on the long-term monitoring), maintenance of existing BMPs, and the introduction of additional BMPs and source controls should effectively reduce nonpoint source pollution within the study area.

1.1 DESCRIPTION OF THE STUDY AREA

Lower Linganore Creek was selected as the third watershed to be assessed under Frederick County=s National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer Systems Discharge Permit, Permit Number MD0068357. This watershed was considered a high priority for assessment because its close proximity to the rapidly growing

City of Frederick has caused the watershed to experience significant residential development in the Lake Linganore area. In 1968, construction of Lake Linganore and an eventual 8,900-units around the lake was approved (FCDPZ 1993). Current zoning maps indicate that a large majority of the remaining agricultural and forested land around Lake Linganore has been zoned for Planned Unit Development (PUD), indicating that the intensity of land use will continue to increase in this area. Adding to the mix of older and newer development, future development threatens to adversely affect stream and water quality by increasing the cumulative impacts to the watershed. Without appropriate attention to stormwater management and other BMPs, continuing urbanization of the watershed could lead to degradation of existing conditions.

Agriculture has played an important role in this region and a large majority of the watershed is classified as farmland of statewide importance. However, agricultural practices can play a significant role in influencing watershed water quality. As noted by the Frederick County Department of Planning and Zoning (1995), ALinganore Creek has been a priority watershed for the State because of its agricultural land use and its erodible soil. Research and extension programs have focused on voluntary use of best management practices to reduce sediment - a major pollutant of the Monocacy River. Lake Linganore itself acts as a sediment trap and thereby loses potential water storage...@

Linganore Creek also plays a critical role in providing drinking water to citizens living in the Frederick region. The City of Frederick operates a water treatment facility that withdraws water from the Creek just downstream from Lake Linganore. The County operates a facility with an intake 1,200 feet upstream from the Lake Linganore dam. A third drinking water intake is located immediately upstream of Lake Linganore and is operated by the Westwinds Country Club (FCDPZ 1993; 1995). As such, stormwater pollution entering Linganore Creek can adversely affect this source of drinking water and raise human health concerns (MDE 2002).

Recreation within the watershed may also be somewhat affected by the alteration of watershed hydrology and water quality brought about by agricultural uses and increasing development. Linganore Creek has been classified by the State as Class IV, Recreational Trout Waters, and typical stormwater impacts such as increased turbidity and sediment load often cause decreases in trout populations. The role of Lake Linganore as a regional recreational attraction for boaters, swimmers, and anglers also raises health concerns as people ingest fish from or come into direct contact with water potentially containing elevated levels of stormwater pollutants.

1.2 STUDY ELEMENTS

Major elements of this study included the following:

- Characterizing existing conditions within the Lower Linganore Creek watershed
- Monitoring biological and physical habitat conditions at ten representative stream segments across the watershed and assessing ecological condition using existing Piedmont reference stream conditions

- Screening land use and other available data to identify and inventory potential pollutant sources and problem areas in the watershed

- Site visits for visual inspection of potential stressors of stream quality, outfall screening for water quality problems, and source identification

- Analysis of land use patterns, infrastructure, and population trends

- Hydrological and water quality modeling analysis using a modified version of the United States Environmental Protection Agency=s (USEPA=s) Stormwater Management Model (SWMM) to assess watershed and subwatershed runoff and loading characteristics

- Development of prioritized management measures for the reduction of nonpoint source pollution and other watershed problems

1.3 SCOPE OF REPORT

This report integrates existing and new data and presents recommendations for the protection of water quality in the Lower Linganore Creek watershed. Existing data were drawn from multiple sources. Frederick County DPW supplied data for geographic information systems (GIS) analysis, including information on the watershed boundary, land use, roads, stream network, and stormwater management facilities. Zoning, soils, wetlands, and other information utilized in this assessment was obtained from other County, State, and Federal Agencies, as described below. New information was collected in focused field surveys of physical and biological conditions, and did not include the collection and analysis of stormwater chemical monitoring data. However, existing data were sufficient to support the water quality model used in this investigation.

In this report, Section 2 describes existing physical and biological characteristics of the watershed, including information on land use, population, infrastructure, impervious surfaces, stormwater management and point source outfalls. Section 3 summarizes stormwater modeling in the watershed. Section 4 prioritizes opportunities to improve water quality in the watershed. Section 5 contains recommendations and an implementation schedule to improve water quality, and references may be found in Section 6.

2.0 WATERSHED CHARACTERISTICS

Linganore Creek is a large stream located east-northeast of the City of Frederick, Maryland, that drains approximately 88 square miles of agricultural, forested, and residential land (FCDPZ 1993, 1995). The Creek has been classified by Maryland Department of the Environment (MDE) as Class IV, Recreational Trout Waters (FCDPZ 1998). The watershed has been divided into upper and lower sections by the County and the latter section is the focus of this watershed assessment report. Designated as Frederick County Watershed M-5.4, Lower Linganore Creek watershed (including lakes) is approximately 24,350 acres (38 square miles) in size (Figure 2-1). Land area within the watershed is approximately 24,100 acres.

This section provides an overview of the physical, biological, and land use characteristics found within Lower Linganore Creek watershed. These conditions, which include surface hydrology, geologic setting, ecological resources, land use, population, infrastructure, and an inventory of pollution sources and watershed stressors, are important because they strongly influence the quantity and quality of water within the stream system. This inventory of watershed land surface features was used to evaluate nonpoint pollution impacts and develop water quality management recommendations for the Lower Linganore Creek watershed.

Information was obtained via field sampling and visual surveys, telephone contacts, and reviews of existing databases, reports, geographic information system (GIS) data, and paper maps. Methods employed in this watershed assessment followed those outlined in the Long-Term Monitoring Plan for the Peter Pan Watershed (Southerland et al. 1999) and the Watershed Assessment of Lower Bush Creek, Frederick County, MD (Roth et al. 2001b). Alternative procedures, if applicable, have been described in the following sections.

2.1 SURFACE HYDROLOGY AND SUBWATERSHEDS

Linganore Creek drains westward from just inside the western edge of Carroll County, and the creek and its tributaries pass through several earth dams (e.g., at Lake Linganore, Lake Merle, Lake Anita Louise, Lake Marion) in the central portion of the lower watershed. Lake Linganore is the largest non-mainstem impoundment in the Monocacy River basin, and stores 883.2 million gallons of water captured from its 82.3 square mile catchment for recreational use and water supply (FCDPZ 1998). The Creek is also one of the largest tributaries to the Monocacy River, a National Scenic River placed on MDE=s 303(d) list of waters impaired by nonpoint source pollution (FCDPZ 1995).

To facilitate analysis, the Lower Linganore Creek watershed was divided into 10 subwatersheds of approximately equal size and stream order as shown in Figure 2-2. Subwatersheds and their relative sizes are listed in Table 2-1. Subwatersheds were delineated on 1:24,000 topographic maps (USGS 1993a-d) and then digitized into a GIS. The boundary of Lake Linganore was also delineated as part of the subwatershed boundaries. Once digitized, the subwatershed boundaries were adjusted to match the outer watershed boundary provided by the

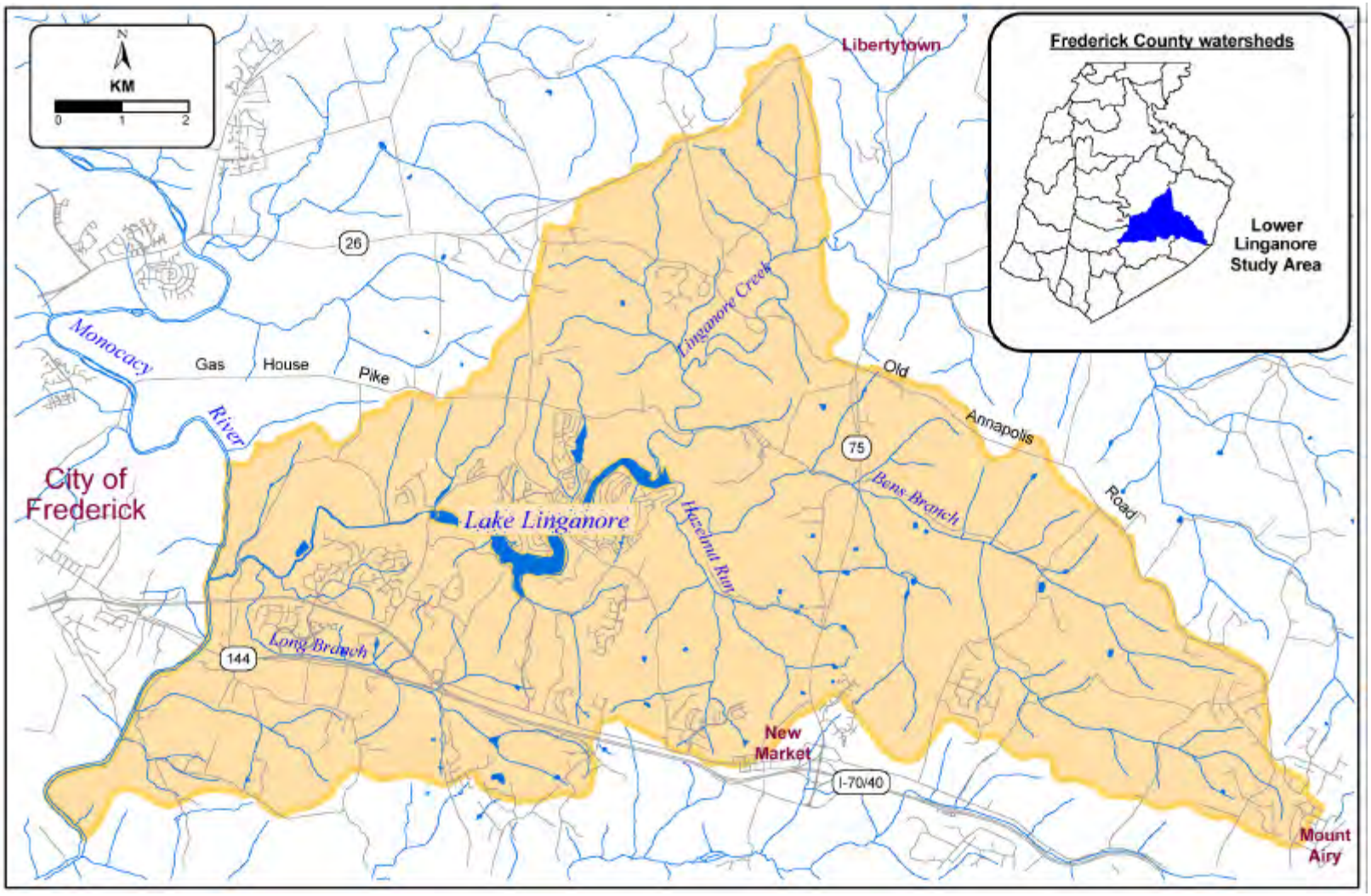

Figure 2-1. Lower Linganore Creek watershed, Frederick County, Maryland

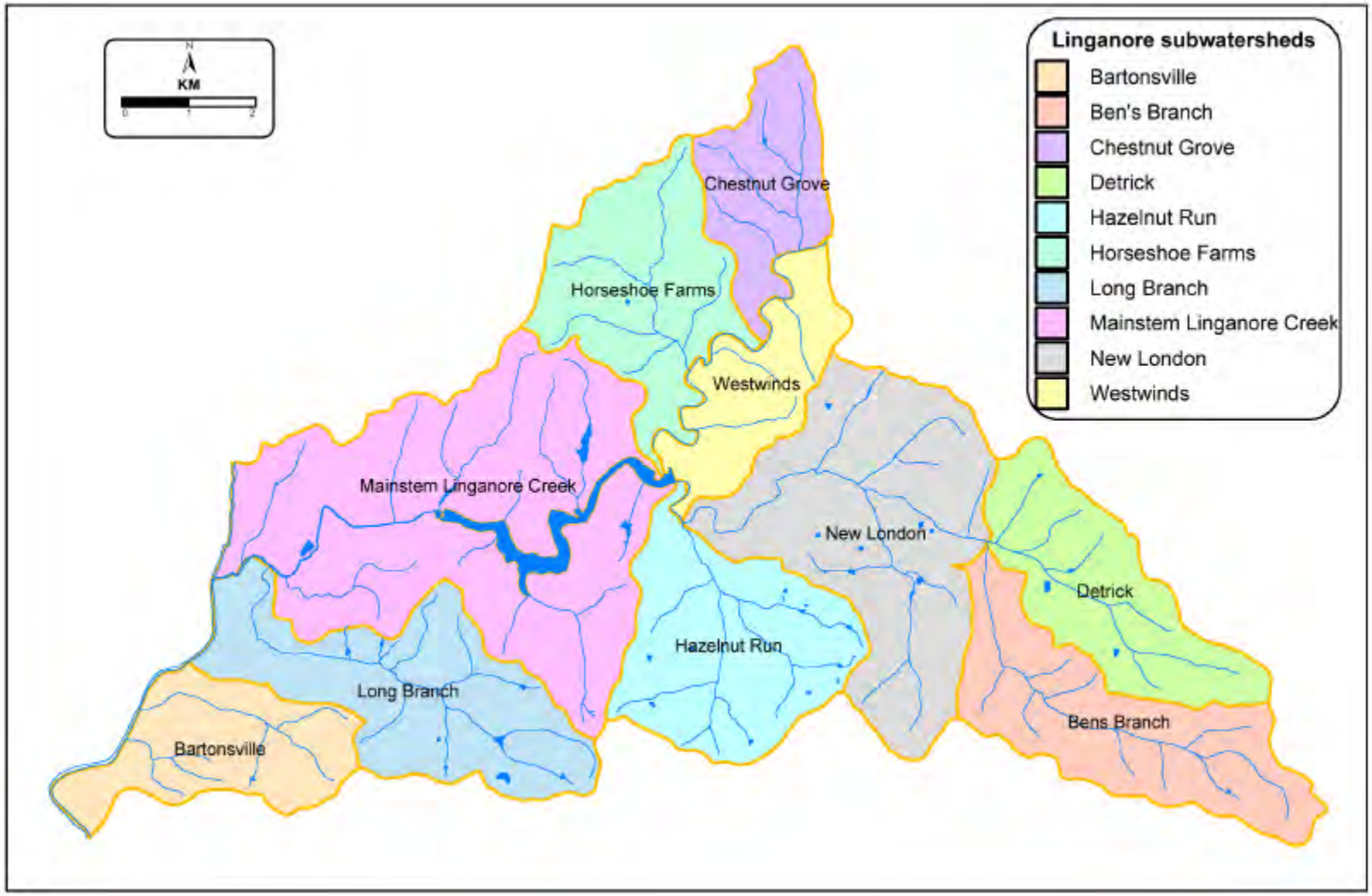

Figure 2-2. Subwatersheds within Lower Linganore Creek watershed

County. These subwatersheds, which were named according to prominent features identified within each area in the Frederick County Street Map Book (ADC 2000), have been utilized throughout this report. It should be noted that the boundary for Lake Linganore digitized from the topographic maps differs slightly from other GIS data proved by the County, a situation that is quite common when utilizing GIS data from different sources and produced at different scales.

Table 2-1. Subwatersheds within Lower Linganore Creek

Subwatershed	Acres	Percent of Watershed
Bartonsville	1,545	6%
Bens Branch	2,286	10%
Chestnut Grove	1,253	5%
Detrick	1,841	8%
Hazelnut Run	2,297	10%
Horseshoe Farms	2,023	8%
Mainstem Linganore Creek	5,379	22%
Long Branch	2,532	11%
New London	3,504	15%
Westwinds	1,250	5%
Lake	192	1%
Total	24,102	100%

2.2 GEOLOGIC SETTING

The geologic setting for the Lower Linganore Creek watershed was characterized using recent topographic and geological maps, background information compiled by the County Department of Planning and Zoning, and soils maps prepared by the Natural Resource Conservation Service (NRCS).

2.2.1 Surficial Geology

Frederick County lies within two of the five geologic provinces found in Maryland, the Piedmont Plateau Province and the Blue Ridge Province (FCDPZ 1998). Lower Linganore Creek watershed lies entirely within the Piedmont Plateau Province, which extends westward from Washington D.C. and Baltimore to Catoctin Mountain. The watershed is located almost entirely within the Piedmont Uplands portion of the Province, with a very small portion adjacent to the Monocacy River located in the Frederick Valley (Figure 2-3).

The Piedmont Upland was formed on bedrock composed of slightly metamorphosed slate, phyllite, and metabasalt that are Late Pre-Cambrian in age (Figure 2-4). The area is characterized by heavily rolling uplands with numerous low knobs and ridges. Stream beds are typically shallow and narrow in this portion of the Province. Before metamorphism, this rock

consisted of volcanic ash and basaltic lava flows that erupted in the Late Pre-Cambrian time from a volcanic center lying to the east. Areas of limestone, now formed into marble, occur as lenses within the meta-volcanic rock. Other phyllites and quartzites, originally marine shales and limestones, occur in the Piedmont Upland with the meta-volcanic rocks. The quartzites form the characteristic low knobs and ridges that rise above the surrounding land surfaces (FCDPZ 1998).

The Frederick Valley is a large area of limestone bedrock, the Frederick Limestone formation, which ranges in age from Middle Cambrian to Early Ordovian. Most of the bedrock consists of thin-bedded, dark bluish gray limestone with thin, shaley partings. Some thick-bedded, light gray, high calcium limestone, massive dolomite, and quartzite limestone also occur in a strip along the center of the valley. Because the limestone is easily eroded and dissolved in the humid climate of eastern North America, the bedrock of the Frederick Valley has formed a low-lying, level terrain. Cavernous zones and solution channels that permit underground drainage are common in the limestone bedrock of the Frederick Valley. Soils are irregular in depth but generally thick. Knobs or pinnacles of the more resistant bedrock layers protrude from beneath the soil cover in many places.

Streams in the Piedmont Plateau Province generally flow within valleys that have cut into the landscape through many years of erosion. These streams often have moderate slopes that are controlled by bedrock outcrops at the surface. Over time, the landscape increasingly becomes dissected via vertical and lateral stream erosion processes and may be mostly hills and slopes. Drainage networks are typically dendritic, branching systems. In the western portions of the Province, stream beds are mostly composed of a mix of gravel and sand, with flat stones predominant in areas of metamorphosed schist rocks (Smith et al. 2000).

2.2.2 Topography

Topography within the Piedmont Upland generally slopes from east to west and slopes between 3 to 15 percent. In many instances, the stream valleys (including mainstem Linganore Creek) have steeper slopes (FCDPZ 1993). Topographic maps show that the watershed generally slopes westward, though topography and slope vary among individual drainages within the watershed (USGS 1993a-d). The highest point in the Lower Linganore watershed is in the headwaters of Bens Branch near Mount Airy, where elevations reach 793 feet above sea level. The mouth of Linganore Creek at its confluence with the Monocacy River is the lowest point in the watershed, with an elevation slightly less than 240 feet. Average elevation within the watershed is approximately 500 feet.

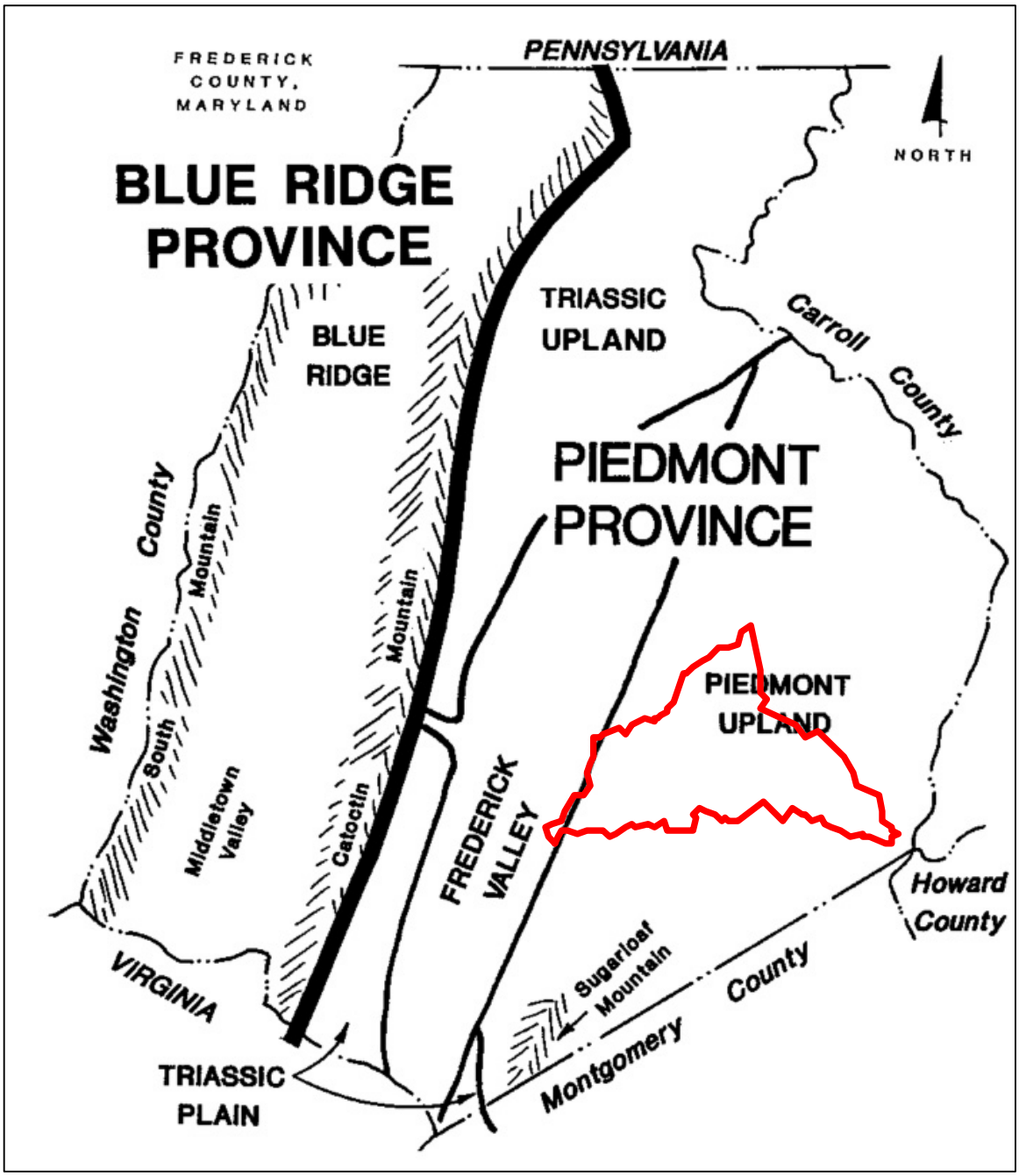

Figure 2-3. Physiographic provinces within Frederick County (FCDPZ 1998), with Lower Linganore Creek watershed outlined in red

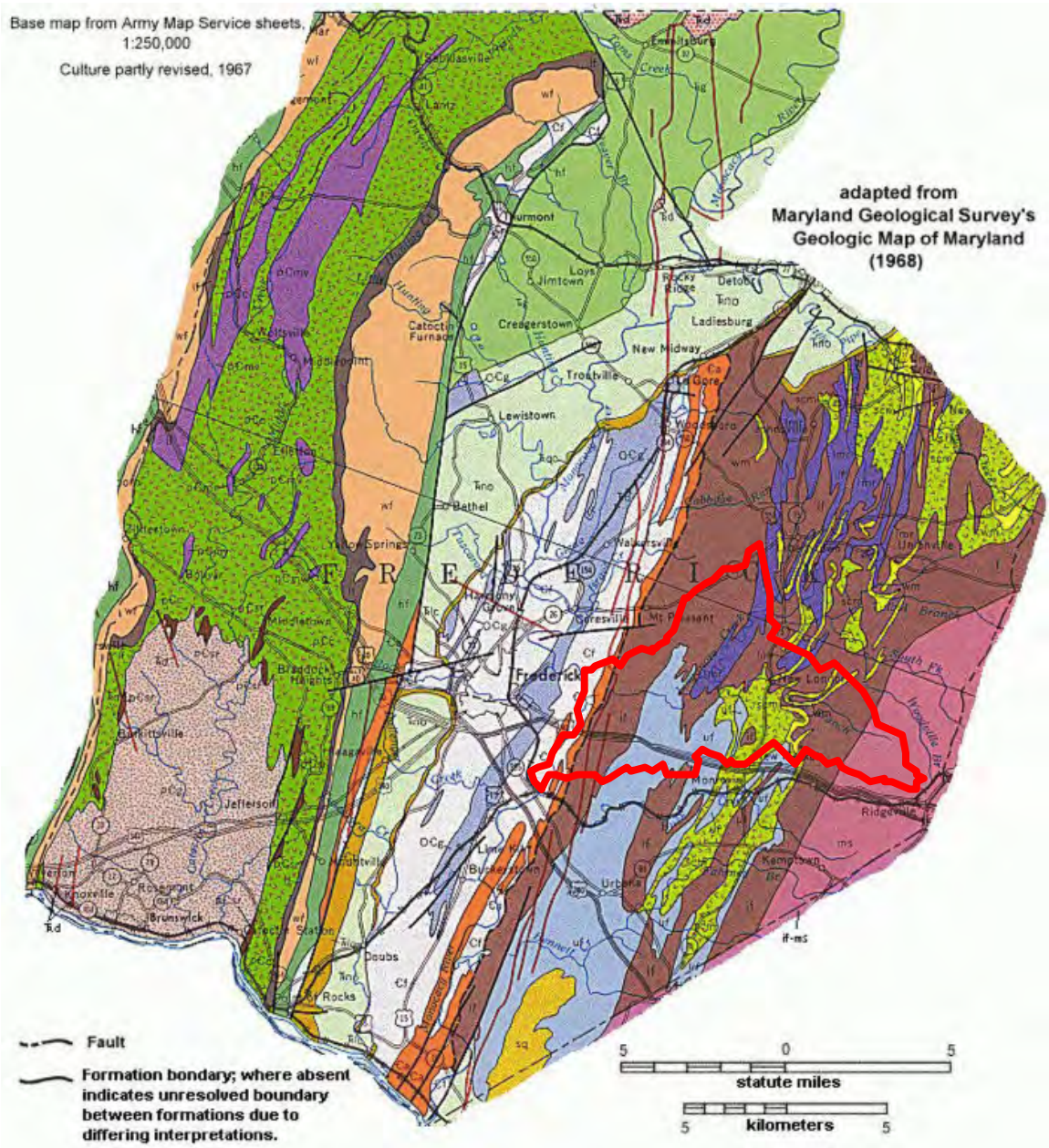

Figure 2-4. Geologic map of Frederick County (Maryland Geologic Survey 1968), with Lower Linganore Creek watershed outlined in red

TRIASSIC

Diabase Sills and Dikes
Sills: greenish-gray to black, medium-grained;
dikes: greenish-gray to black, medium- to fine-grained; local contact metamorphic aureoles.

Newark Group

Gettysburg Shale
Red shale and soft red sandstone, siltstone; estimated thickness less than 5,000 feet.

New Oxford Formation
Red, maroon, and gray sandstone, silts tone and shale; basal conglomerate member: From vicinity of Maryland Rte. 73 and southward, limestone conglomerate with red and gray calcareous matrix, northward, quartz conglomerate with red sandy matrix, estimated total thickness 4,500 feet.

ORDOVICIAN

Grove Limestone
Dark gray to light dove, thick-bedded limestone; dolomite beds in lower part; highly quartzose limestone at base; Upper Cambrian to Lower Ordovician in age; thickness approximately 590 feet.

CAMBRIAN

Frederick Limestone
Blue, slabby, thin-bedded limestone and minor shale; contains Upper Cambrian (Trempealeauian) fuamule; thickness approximately 480 feet.

Tomstown Dolomite
Interbedded light gray to yellowish-gray, thin- to thick-bedded dolomite and limestone; some shale layers; gradational contact with Antietam; thickness 200 to 1,000 feet.

Chilhowee Group

Antietam Formation
White to dark gray and brown, thick-bedded, fine- to coarse-grained quartzite with thin argillaceous partings; first occurrence of Lower Cambrian fossils; cleavage generally obscures bedding; increasingly metamorphosed and phyllitic toward east; estimated thickness 300 to 800 ft.

Harpers Formation
Brown to dark bluish-gray banded shale, light bluish-gray, finely laminated phyllite, distinctively pale purple in basal part; bedding obscured by cleavage; increasingly metamorphosed toward east from shale to slate and phyllite; estimated thickness 2,000 feet.

Weverton Formation
Interbedded white to dark gray, thin-bedded micaceous, ferruginous, and sericitic quartzites, phyllites, and white, thick-bedded, ledge-making quartzites; some gray to brown ferruginous quartz conglomerate and purple-banded phyllite; thickness approximately 100 feet in south, increases to 425 feet in north.

Loudoun Formation
Upper conglomerate member: Quartz and granitic pebbles in pale purple phyllitic matrix; basal phyllite member: Pale purple, discontinuous, lenticular; members are in gradational contact; total thickness 0 to 200 feet.

LATE PRECAMBRIAN (?)

Metarhyolite and Associated Pyroclastic Sediments
Metarhyolite: Dense, blue, cryptocrystalline, with white feldspar phenocrysts and glassy quartz; red porphyritic metarhyolite at contact with Catoctin Metabasalt; Pyroclastic sediments: Tuff breccia, blue slaty tuff, white tuffaceous sericitic schist, and banded green slate.

Catoctin Metabasalt
Thick-bedded metabasalt with amygdaloidal layers and secondary veins of quartz, calcite, and epidote; interbedded green tuffaceous phyllite and blue amygdaloidal metaandesite.

Swift Run Formation
Sericitic quartzite and phyllite; blue and green tuffaceous slate with sericitic blebs; some white marble with interbedded phyllite.

LATE PRECAMBRIAN (?)

Urbana Formation
Dark gray to green sericite-chlorite phyllite, metasiltstone, and quartzite; thin lenses of impure marble and calcareous phyllite occur locally.

Sugarloaf Mountain Quartzite
Massive white quartzite interbedded with softer sericitic quartzite, slate, and phyllite.

Libertytown Metarhyolite
Purple, bluish-black and red, dense, fine-grained metarhyolite with feldspar phenochrysts; interbedded with blue and purple amygdaloidal metaandesite; both rhyolite and andesite interbedded with blue, purple, and green phyllitic slates.

Sams Creek Metabasalt
Grayish-green, massive to schistose, amygdaloidal metabasalt.

Wakefield Marble
White, fine-grained marble; subordinate white, green, and pink variegated marble; and blue marble.

Silver Run Limestone
Blue, thin-bedded, finely crystalline schistose limestone and calcareous slate.

Ijamville Formation
Blue, green, or purple phyllite and phyllitic slate, with interbedded metasiltstone and metagraywacke; flattened pumiceous blebs occur locally.

Marburg Schist
Bluish-gray to silvery-green, fine-grained, muscovite-chlorite-albite-quartz schist; intensely cleaved and closely folded; contains interbedded quartzites.

Wissahickon Formation
Muscovite-chlorite schist, chloritoid schist, and quartzite; intensely folded and cleaved.

PRECAMBRIAN

Granodiorite and Biotite Granite Gneiss
Light gray to pale green, fine-grained, granodiorite gneiss, and dark gray biotite granite gneiss with some augen gneiss; in places a sheared muscovite-biotite gneiss; local biotite schist bands; intruded by metadiabase feeder dikes of Catoctin Metabasalt.

Figure 2-4. (Continued)

2.2.3 Soils Characteristics

The NRCS classifies soils into four hydrologic soil groups based on their infiltration characteristics, permeability, slope, and erosion potential as these characteristics directly affect water quality and runoff volume. The four soil groups are defined as follows (CDM 1997):

Group A - Soils with high infiltration rates that are typically deep, well drained to excessively drained sands or gravel;

Group B - Soils with moderate infiltration rates that are generally moderately deep to deep, moderately well to well-drained soils with moderately fine to moderately coarse textures;

Group C - Soils with slow infiltration rates which are mainly soils with a layer that impedes downward water movement or soils with moderately fine to fine texture; and,

Group D - Soils with very slow infiltration rates which are mainly clay soils, soils with a permanently high water table, and shallow soils over nearly impervious material.

The NRCS is currently updating the Frederick County soil survey and producing an electronic version for GIS. The Maryland office of the NRCS provided draft GIS data for hydrologic soil groups for use in this report (James Brown, NRCS State Soil Scientist, personal communication, June 8, 2001). Figure 2-5 shows the distribution of these hydrologic soil groups within the Lower Linganore Creek watershed. As indicated in Table 2-2, almost 41 percent of the watershed=s soils fall within groups C and D and have low to very low infiltration rates and are expected to contribute significantly to surface runoff. Hydrologic soil group data were not available for those areas covered by lakes (234 acres), about 1 percent of the watershed.

Table 2-2. Hydrologic Soil Group distribution in Lower Linganore Creek

Hydrologic Soil Group	Acres	Percent
A	3,690	15%
B	10,400	43%
C	4,542	19%
D	2,059	9%
C/D	3,176	13%
No data	234	1%

The 1960 Frederick County Soil Survey (Matthews 1960; Soil Survey Division, NRCS 2001) was also reviewed to identify the predominant soils in the watershed. Predominant soils include the Manor, Glenelg, Linganore and Brandywine series. Other soils series are present

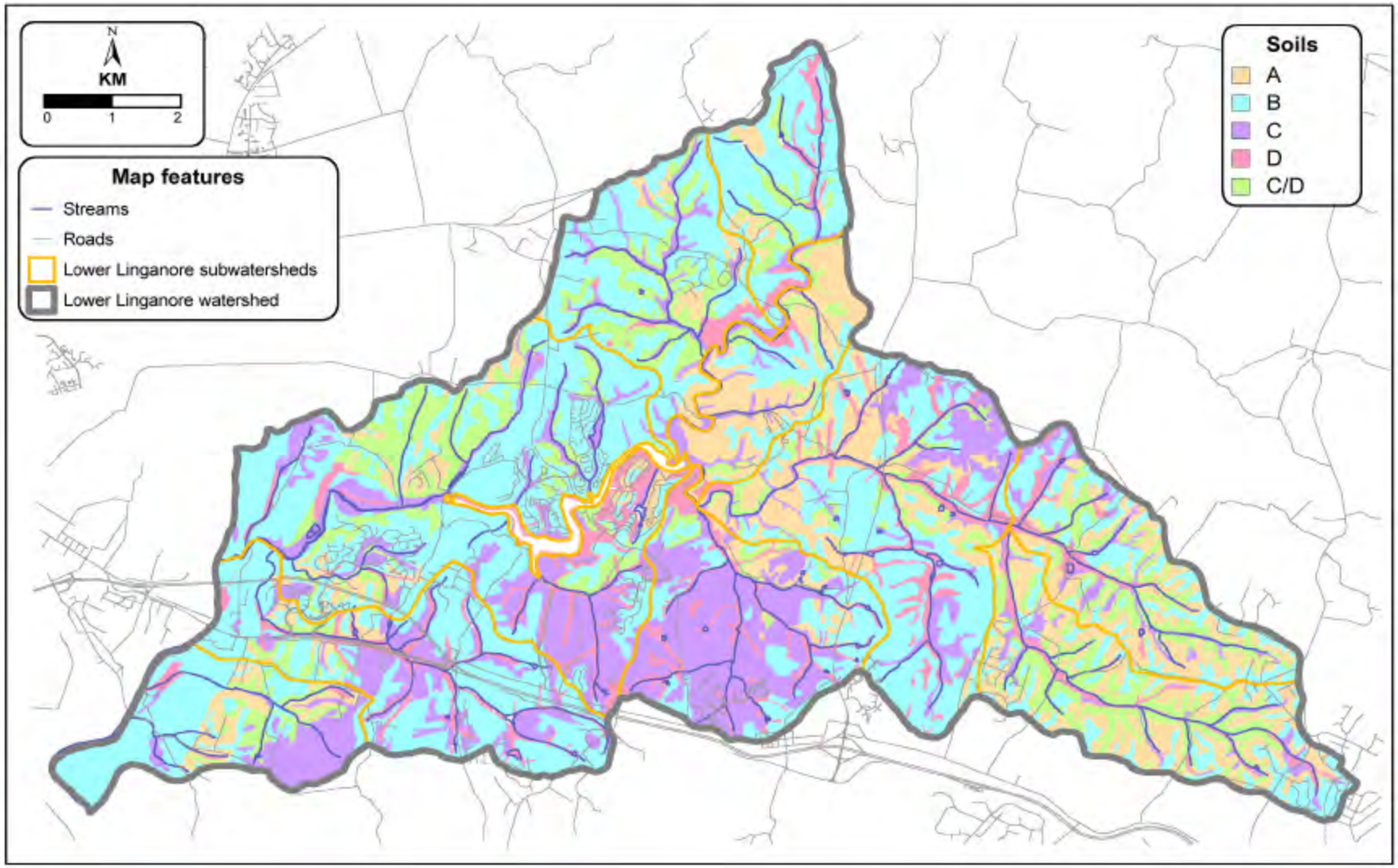

Figure 2-5. Hydrologic Soil Group distribution in Lower Linganore Creek watershed

within the watershed, but are found in small, scattered locations. The predominant soils are described below.

The 1960 Frederick County Soil Survey (Matthews 1960; Soil Survey Division, NRCS 2001) was also reviewed to identify the predominant soils in the watershed. Predominant soils include the Manor, Glenelg, Linganore and Brandywine series. Other soils series are present within the watershed, but are found in small, scattered locations. The predominant soils are described below.

Manor Series. The Manor Series is distributed throughout the watershed area and is also the most extensive soil series in Frederick County. The soils in this series are very deep, and well drained to somewhat excessively drained. They formed in materials weathered from thin, platy schistose rocks that in most places contain a large amount of mica. The soils are not highly fertile or productive and erode very easily if not properly maintained. Permeability is moderate or moderately rapid. Manor soils have slopes ranging from 0 to 65 percent. None of the soils within the Manor series have been classified as prime farmland soils by the Natural Resources Conservation Service, however, they are classified as farmland of statewide importance.

Glenelg Series. Glenelg soils are very deep and well drained. They are formed in materials weathered from micaceous schists, most of which contain considerable quartzite. The Glenelg soils are more strongly weathered than the Manor soils, but the parent materials are the same or very similar. This series also occurs throughout most of the watershed, except for the area east of Detrick Road. Permeability is moderate and slope ranges from 0 to 55 percent. Four of the Glenelg soils are considered prime farmland.

Linganore Series. The Linganore soils are moderately deep and are well drained on uplands. They formed in materials weathered from dark-colored hard, slaty schist or phyllite. Permeability is moderate to moderately rapid. In general, these soils are found extensively throughout the watershed. Small to fairly large areas are widely scattered on slaty ridges throughout the Piedmont areas. Slopes range from 0 to 55 percent but generally are between 3 and 25 percent. In some places hard bedrock is only a few inches below the surface. In many eroded areas the surface soil is a mass of slate chips with little fine soil material. None of the Linganore soils are classified as prime farmland.

Brandywine Series. The Brandywine soils are very deep and somewhat excessively drained. They formed in material weathered from gneiss. Permeability is moderately rapid on the uplands. These soils are mostly found north and south of the western end of Lake Linganore. The soil is strongly acidic to extremely acidic, unless limed. Slopes range from 0 to 65 percent and are generally more than 15 percent.

2.3 ECOLOGICAL RESOURCES

The environmental assessment of Lower Linganore Creek watershed involved the collection of field and ancillary data on a wide range of ecological components to characterize current conditions. Field surveys were used to collect information on streams, vegetation,

wetlands, and wildlife within the watershed, while ancillary data sources were used to supplement data collected in the field.

2.3.1 Aquatic Resources

As part of this assessment, ten long-term stream monitoring stations were established to characterize aquatic resources within Lower Linganore Creek and its tributaries. Stream data were also extracted from statewide databases developed by the Maryland Biological Stream Survey (MBSS), a program of the Maryland Department of Natural Resources (MDNR), and examined to supplement the County's data collection efforts. In addition, water quality data from the City of Frederick's and the County's surface water intakes were also examined.

The biological and physical monitoring elements of Frederick County's stream assessment plan are based on standard field and laboratory methods as established by EPA's Rapid Bioassessment Protocols (RBP, Plafkin et al. 1989, Barbour et al. 1999). In 2001, with the approval of Maryland Department of the Environment (MDE), the County began its use of MBSS sampling methods for biological and physical habitat assessment. MBSS methods (Kazyak 2001) are a regional application of EPA's RBP. In past years, Frederick County had used other, similar monitoring methods developed by neighboring Montgomery County Department of Environmental Protection (DEP, Van Ness et al. 1997). Use of the MBSS methods and analytical tools (e.g., the MBSS fish and benthic indices of biotic integrity) will facilitate better integration of Frederick County's monitoring efforts with MBSS and other state and county programs. In fact, recognizing these benefits, Montgomery County DEP itself switched to MBSS sampling protocols during 2001.

Biological monitoring of Lower Linganore Creek involved collecting data on both the stream's fish community and the benthic macroinvertebrates inhabiting the stream bed. MBSS fish sampling methods employed at each site involve double-pass electrofishing of a 75-m stream segment. MBSS benthic sampling uses a D-net to collect macroinvertebrates at 20 locations within the 75-m sample segment. Assessment guidelines and standard sampling protocols described in the MBSS Sampling Manual (Kazyak 2001), fish Index of Biotic Integrity (IBI) report (Roth et al. 2000), and benthic IBI documentation (Stribling et al. 1998) were used to collect and interpret the biological monitoring data.

In addition to use of the MBSS physical habitat monitoring protocols (Kazyak 2001), the more detailed geomorphic habitat assessment methods employed in previous watershed assessments in the County since 1999 (and as utilized by Montgomery County) were retained to monitor stream channel integrity at established cross-sections. The physical assessment of Lower Linganore Creek employed both quantitative geomorphologic techniques and qualitative evaluation of physical habitat characteristics described by Barbour et al. (1999), Van Ness et al. (1997), and Rosgen (1996). Using the techniques specified above to characterize the stream channel at each station, field crews estimated the embeddedness of the channel substrate, conducted a Wolman pebble count, and surveyed both the cross-sectional profile of the transect's mid-point and the longitudinal slope of the water's surface. Physical habitat data were collected along a 75-m segment as well as at three cross-sections (i.e., the two end-points and mid-point)

to develop the longitudinal and cross-sectional habitat profiles. Stream velocities were measured so that discharge could be calculated. Bank erosion rates were monitored through the placement of a bank pin at the mid-point cross-section. Riparian buffer widths and their land use were assessed along both sides of the stream channel. Photographs of the site were taken to record the condition of each watershed monitoring station. The MBSS habitat assessment protocols (Kazyak 2001) provided additional assessments of stream characteristics such as bank stability, bank vegetation cover, riffle quality, habitat suitability for fish and macroinvertebrates, and embeddedness.

Long term monitoring stations in the watershed were established at three mainstem locations, six tributaries to Lower Linganore Creek, and one tributary to the Monocacy River (Figure 2-6). Photographs of these locations have been included as a photographic log in Appendix A. Spring field activities were conducted on April 24-30, 2001, and involved testing water quality parameters, quantifying physical habitat, conducting qualitative habitat assessments, and sampling benthic macroinvertebrates. Summer activities were conducted on July 10-August 7, 2001, and included testing water quality parameters, quantifying physical habitat, and sampling for fish species and abundances. Fall field activities, conducted on September 24-26, 2001, included qualitative habitat assessments and sampling for benthic macroinvertebrates.

2.3.1.1 Water Quality

Water quality results from April and July/August 2001 were generally indicative of healthy stream conditions (Table 2-3). Water temperatures were within a normal range for cool water streams, and temperatures varied only a few degrees throughout the whole watershed. Dissolved oxygen (DO) concentrations were in a range considered healthy for aquatic biota. As expected in typical Maryland Piedmont streams, pH values indicated that the streams are well buffered from acid deposition. Conductivity measurements were generally within a normal range for Linganore Creek, however LING-06 and LING-09 tended to have slightly higher measurements than the rest of the sites. This higher conductivity may be attributable to the close proximity of each of these sites to a major road (Rt. 75 and Rt. 144 respectively), and its traffic volume and surface runoff. Turbidity readings in April were generally normal; however, summer readings were somewhat elevated. Spring and summer turbidity readings at the three mainstem sites (LING 01- LING-03) indicate that water below the dam is less turbid than above.

Additional water quality data collected from Linganore Creek were also reviewed. MDE is currently preparing a Source Water Assessments report (MDE 2002) for the City of Frederick, which cites extensive croplands, pasturelands, and increasing residential development in the Linganore Creek watershed as major water quality concerns because they serve as potential nonpoint sources of nutrients (from fertilizer), synthetic organic compounds (from herbicides), sediment, metals (runoff from impervious surfaces), and pathogens (from animal wastes). MDE cites high turbidity levels from “severe” sediment loads in the creek, stemming from both residential development and agricultural sources. In this drinking water study, very low concentrations of inorganic chemicals were reported; however, nitrogen was somewhat elevated in samples collected between 1993 and 2000, ranging from approximately 1.1 milligrams per liter (mg/l) to 5.5 mg/l. While not necessarily excessive for drinking water purposes, these

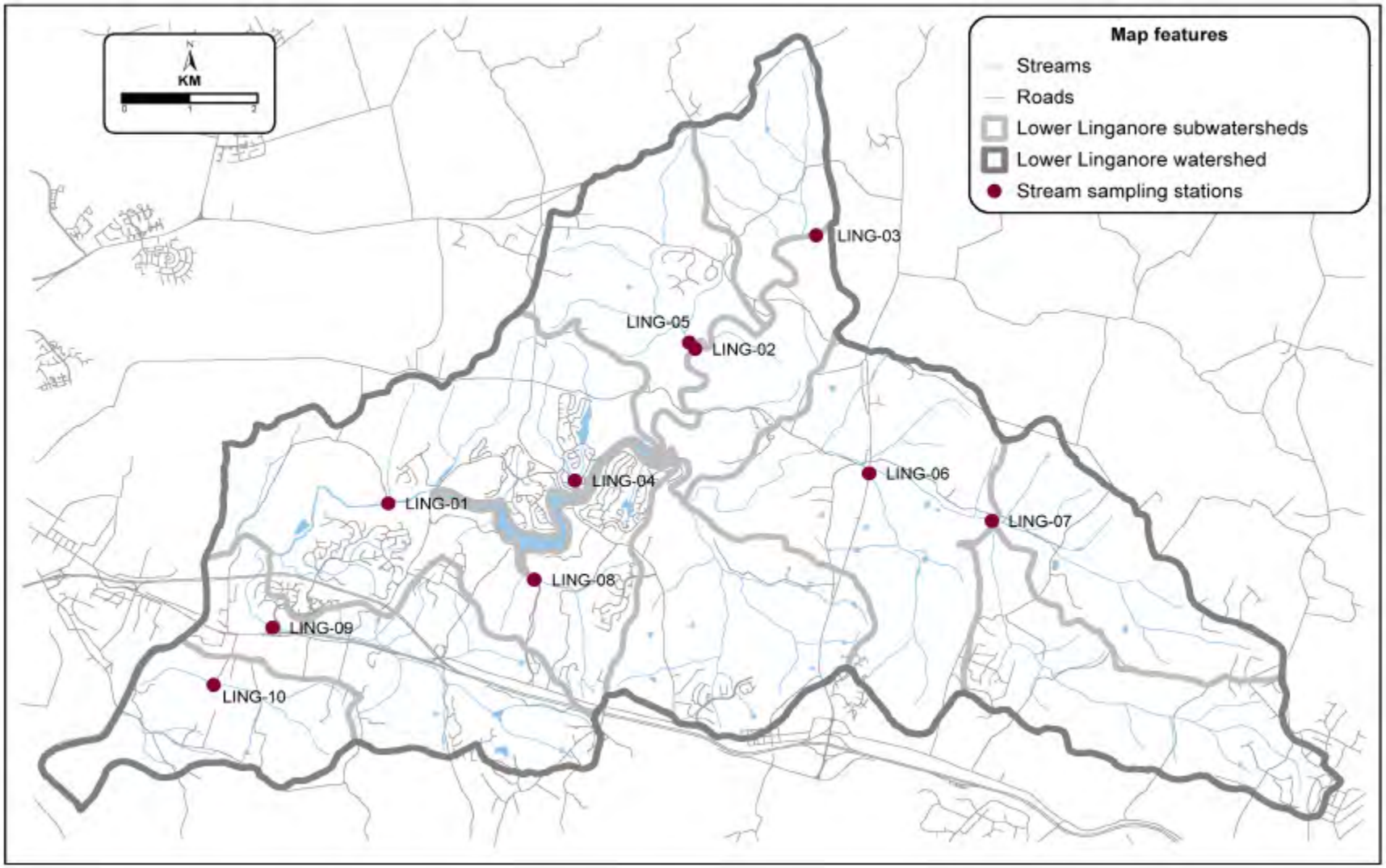

Figure 2-6. Stream sampling stations (2001) in Lower Linganore Creek watershed

concentrations of nitrogen can stimulate algal blooms and lead to eutrophication. Atrazine, a commonly used agricultural herbicide, was detected in ten samples collected between 1996 to 2000, at concentrations from 0.1 micrograms per liter (µg/l) to 0.5 µg/l. The atrazine detections were well below the 3 µg/l USEPA drinking water standard and are not considered to be a major concern by MDE. MDE and the County have also collected samples for fecal coliform, an indicator of sewage or agricultural contamination, and MDE reports that counts have periodically exceeded State water quality standards, resulting in several bathing beach closings in Lake Linganore by the County Health Department.

Table 2-3. Water quality results from Lower Linganore Creek

Station ID	Date Sampled	Water Temperature (^oC)	Dissolved Oxygen (mg/l)	pH	Specific Conductivity (mS/cm)	Turbidity (NTU)
LING-01	4/25/01	13.46	10.44	7.91	0.226	6.9
	7/24/01	23.50	6.72	7.53	0.259	12.9
LING-02	4/25/01	12.84	11.35	7.86	0.239	26.8
	7/27/01	21.00	7.57	7.50	0.243	19.6
LING-03	4/25/01	12.87	12.22	8.27	0.240	22.9
	8/7/01	25.10	10.30	7.37	0.246	49.2
LING-04	4/25/01	12.33	10.47	7.47	0.218	5.4
	7/24/01	19.60	8.20	7.61	0.213	11.6
LING-05	4/25/01	11.16	12.13	7.80	0.116	0
	7/27/01	21.30	8.80	7.48	0.145	3.9
LING-06	4/24/01	18.93	9.13	8.11	0.324	6.8
	7/12/01	20.10	10.50	8.02	0.421	24.4
LING-07	4/25/01	14.40	12.49	8.48	0.170	7.3
	7/13/01	21.60	*	7.83	0.250	10.4
LING-08	4/24/01	17.59	9.90	7.94	0.302	0.7
	7/12/01	19.20	10.80	7.88	0.361	2.9
LING-09	4/24/01	19.10	10.46	8.10	0.361	0.5
	7/23/01	19.10	9.10	7.54	0.753	20.9
LING-10	4/24/01	18.62	9.72	7.53	0.158	2.1
	7/23/01	21.40	9.60	7.67	0.475	27.0

* Equipment malfunction

2.3.1.2 Physical Habitat

Physical conditions at the ten stations within the Lower Linganore Creek watershed were generally similar and within a normal range in April and July/August 2001 (Table 2-4). For instance, each station generally had wide and shallow stream beds, sand and gravel substrate, moderately sloping banks, and moderate overhead cover. Linganore Creek's tributaries have gradual slopes that meander their way through rolling hills and pastures, leveling out just before entering the mainstem on Lake Linganore. Median particle diameters (D50) at each station were

generally between fine sand and coarse gravel, with substrate at most stations in the fine gravel range.

Table 2-4. Summary of physical data from Lower Linganore Creek

Station ID	Date Sampled	Avg. Thalweg Depth	Slope	Discharge (cfs)	Discharge (cms)	D50 (mm)	Average Canopy Cover	Buffer Width Left Bank (m)	Buffer Width Right Bank (m)
LING-01	4/25/01	0.61	0.0002	51.65	1.463	6.3	50%	12	50
	7/24/01	0.5	ns	19.81	0.561	ns	65%	ns	ns
LING-02	4/25/01	0.75	0.0009	51.77	1.466	0.2	27%	50	50
	7/27/01	0.5	ns	15.39	0.436	ns	90%	ns	ns
LING-03	4/25/01	0.42	0.0025	37.3	1.056	0	37%	4	50
	8/7/01	0.34	ns	*	*	ns	30%	ns	ns
LING-04	4/25/01	0.1	0.0215	0.59	0.017	19.3	67%	2	50
	7/24/01	0.09	ns	0.144	0.003	ns	90%	ns	ns
LING-05	4/25/01	0.19	0.0149	7.14	0.202	9.3	77%	50	50
	7/27/01	0.1	ns	0.334	0.009	ns	95%	ns	ns
LING-06	4/24/01	0.16	0.0107	1.11	0.031	16	80%	50	8
	7/12/01	0.14	ns	0.664	0.018	ns	90%	ns	ns
LING-07	4/25/01	0.2	0.0014	5.42	0.154	2	0%	0	0
	7/13/01	0.2	ns	2.64	0.075	ns	0%	ns	ns
LING-08	4/24/01	0.12	0.0116	0.37	0.011	15.9	70%	50	10
	7/12/01	0.08	ns	0.253	0.007	ns	95%	ns	ns
LING-09	4/24/01	0.23	0.0086	1.94	0.055	13.6	50%	35	25
	7/23/01	0.2	ns	0.331	0.009	ns	80%	ns	ns
LING-10	4/24/01	0.18	0.0157	0.74	0.021	16.1	87%	50	50
	7/23/01	0.1	ns	0.038	0.001	ns	85%	ns	ns

ns = Not sampled
* = Equipment malfunction

Nearly every station showed signs of stream instability, such as sedimentation and bank erosion. As observed in the field, four of the ten stations (LING-03, LING-06, LING-07, LING-09) had moderate to severe bank erosion, suggesting high sediment loads. Embeddedness scores were good at six of the ten stations, however embeddedness scores of 40 percent and above were recorded at four stations (LING-01, LING-02, LING-03, and LING-05), also suggesting high sediment loads in some parts of the watershed. Fall embeddedness scores were similar. Bank pins remained unchanged between April and September with the exception of LING-06, which lost one centimeter of its bank in that time frame.

Stream discharge in Linganore Creek reflected regional patterns influenced by normal precipitation. Each station showed July flows considerably lower than those in April (Table 2-4). The smaller tributaries monitored had very little water in July (e.g., 0.038 cfs at LING-10) and September showing as much as a 20-fold reduction in discharge than in the spring.

The qualitative habitat assessment scored each habitat parameter individually to show specific differences between streams, with each parameter assigned to a category (Table 2-5).

Table 2-5. Scoring classes for qualitative habitat assessments	
Category	**Scores for Individual Habitat Parameters**
Optimal	16-20
Sub-Optimal	11-15
Marginal	6-10
Poor	0-5

Habitat scores in the Lower Linganore Creek watershed generally ranged from marginal to optimal in June and September, 2001 (Table 2-6) and are typical of similar streams in the region. Lower scoring stations generally had higher embeddedness, which can fill in pools and cover rocks, both excellent forms of habitat for fish and the macroinvertebrates they feed on. A general lack of habitat such as instream rootwads and woody debris, large cobble and boulders, and undercut banks also lowers habitat scores. In June and September, station LING-01 received a score of zero for riffle-run quality because it is a wide and flat section of the mainstem below Lake Linganore, and is dominated by pool and glide habitat. LING-05 received the highest overall scores in June, highlighted by a 16 for habitat, and a 17 for epifaunal substrate. Although LING-05 had a somewhat elevated embeddedness score (40 percent), it was offset by the segment's plunge-pools, large cobble, and woody debris. LING-05 also received high scores in the fall. Trash ratings were good for most of the stations, indicating minimal dumping and littering. The trash rating for LING-10 is the only exception, as several large pieces of trash had been dumped next to the stream.

Table 2-6. Qualitative habitat scores for Lower Linganore Creek

Site	Date Sampled	Instream Habitat (0-20)	Epifuanal Substrate (0-20)	Velocity-depth Diversity (0-20)	Pool-Glide Quality (0-20)	Riffle-Run Quality (0-20)	Embed-dedness	Shading	Trash Index (0-20)
LING-01	7/24/01	10	8	6	10	0	40%	65%	17
	9/24/01	11	9	3	13	0	45%	40%	17
LING-02	7/27/01	8	5	16	11	13	60%	90%	17
	9/26/01	13	12	15	13	10	35%	60%	17
LING-03	8/7/01	13	16	10	10	16	40%	30%	17
	9/26/01	15	12	14	15	11	40%	60%	17
LING-04	7/24/01	11	14	7	6	13	15%	90%	15
	9/24/01	8	14	8	6	9	40%	85%	15
LING-05	7/27/01	16	17	12	10	13	40%	95%	18
	9/26/01	13	15	10	7	13	45%	95%	18
LING-06	7/12/01	14	16	16	13	13	25%	90%	14
	9/26/01	11	14	11	11	14	20%	85%	14
LING-07	7/13/01	12	11	7	6	14	15%	0%	19
	9/26/01	12	15	9	9	15	30%	0%	19
LING-08	7/12/01	15	13	10	8	14	30%	95%	19
	9/24/01	10	16	7	8	10	25%	95%	19
LING-09	7/23/01	15	12	14	15	15	25%	80%	16
	9/24/01	15	13	10	15	10	35%	60%	16
LING-10	7/23/01	15	13	7	6	10	30%	85%	12
	9/24/01	13	17	5	6	6	25%	90%	12

Habitat scores for each of the stations did not change much between June and September; however, a few differences were noted. Seven of the ten stations received lower scores in velocity-depth diversity, which could be due to decreased flow in the fall eliminating some types of stream habitat (i.e. fast-moving, shallow water). This is also displayed in the riffle-run quality category, in which six stations received lower scores than in the summer. Half of the stations received lower instream habitat scores, which could also be attributed to lower flows. Epifaunal substrate seemed to be enhanced in the fall, as six of the ten stations received higher scores than in the summer. This could be due to more woody debris in the stream channel, as well as more vegetation overhanging the banks.

2.3.1.3 Biological Assessment

Fish and benthic macroinvertebrate populations at each station were evaluated using Indices of Biotic Integrity (IBI; Karr et al. 1986). The IBI is a widely accepted multi-metric indicator used for biological assessment; it is recommended in USEPA's RBPs (Barbour et al. 1999) and employed by many state and local water quality programs nationwide. The IBI compares the condition of biological assemblages to that of a least-disturbed reference condition. Individual metrics quantitatively describe attributes of the biological community; a series of these metrics are scored and combined into a single index (Table 2-7). Originally developed for midwestern fish communities (Karr et al. 1986), the IBI approach has been adapted for a variety of regions (Simon and Lyons 1995) and taxonomic groups, including freshwater macroinvertebrates (e.g., Fore et al. 1996, Barbour et al. 1996). For this assessment, fish and macroinvertebrate IBIs were calculated using protocols developed for use in the Maryland Biological Stream Survey (MBSS) (Roth et al. 2000; Stribling et al. 1998).

The benthic macroinvertebrate IBI was originally developed by MBSS using nine metrics particular to non-coastal plain streams, based on data taken from minimally impacted streams between 1994 and 1997. Total number of taxa, number of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa, number of Ephemeroptera taxa, number of Diptera taxa, percent Ephemeroptera, percent Tanytarsini, number of intolerant taxa, percent tolerant individuals, and percent collectors are the metrics used for the IBI (Stribling et al. 1998).

Benthic organisms were identified from sub-samples taken at the ten Lower Linganore Creek stations in April and September 2001. IBI scores from April and September showed normal stream conditions and ranged from poor to good (Table 2-8). Spring benthic IBI scores are also shown in Figure 2-7. Biological diversity at each of the ten stations during both sampling seasons as measured by numbers of benthic taxa found was good. However, the number of intolerant taxa at most of the stations was somewhat low. Intolerant taxa are indicators of good water quality, and while several stations had higher numbers of taxa in the spring, few retained similar levels of intolerant taxa in the fall. Eight of the stations had lower numbers of intolerant taxa in the fall than in the spring, and although the percentage of tolerant individuals was reduced at five stations, five had a higher percentage. As a result, six of the ten stations received lower IBI scores in the fall than in the spring. Note that the benthic IBI was originally developed for spring data, so comparisons with fall sampling results should be made with caution, because some differences may be due to natural seasonality variability.

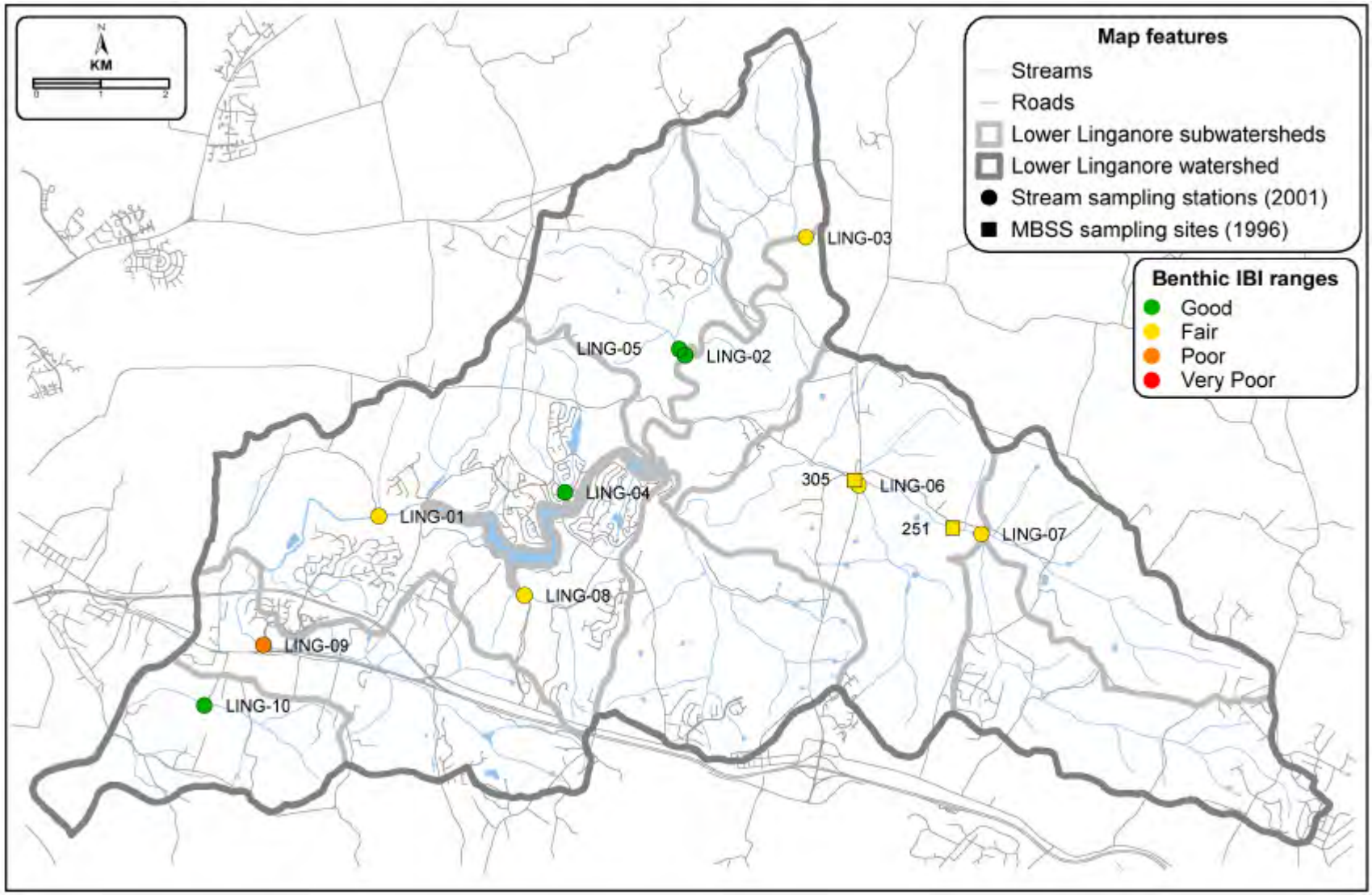

Figure 2-7. Benthic IBI scores from Lower Linganore Creek watershed (Frederick County spring 2001 and MBSS spring 1996 sampling)

Table 2-7. Narrative descriptions of stream biological integrity associated with each of the MBSS IBI categories (Roth et al. 2000)		
Good	IBI score 4.0 - 5.0	Comparable to reference streams considered to be minimally impacted. On average, biological metrics fall within the upper 50% of reference site conditions.
Fair	IBI score 3.0 - 3.9	Comparable to reference conditions, but some aspects of biological integrity may not resemble the qualities of these minimally impacted streams. On average, biological metrics fall within the lower portion of the range of reference sites (10th to 50th percentile).
Poor	IBI score 2.0 - 2.9	Significant deviation from reference conditions, with many aspects of biological integrity not resembling the qualities of these minimally impacted streams, indicating degradation. On average, biological metrics fall below the 10th percentile of reference site values.
Very Poor	IBI score 1.0 - 1.9	Strong deviation from reference conditions, with most aspects of biological integrity not resembling the qualities of these minimally impacted streams, indicating severe degradation. On average, biological metrics fall below the 10th percentile of reference site values; most or all metrics are below this level.

Table 2-8. Summary of benthic macroinvertebrate results from Lower Linganore Creek

Station ID	Date Sampled	Number of Taxa	Number of Intolerant Taxa	Percent Tolerant Individuals	Benthic IBI Score	Benthic IBI Rating
LING-01	4/25/01	23	4	24%	3.22	Fair
	9/24/01	20	0	83%	2.56	Poor
LING-02	4/25/01	28	3	35%	4.11	Good
	9/26/01	29	1	19%	2.78	Poor
LING-03	4/25/01	30	4	37%	3.67	Fair
	9/26/01	34	4	22%	3.67	Fair
LING-04	4/25/01	29	3	24%	4.11	Good
	9/24/01	33	1	19%	4.11	Good
LING-05	4/25/01	31	6	9%	4.33	Good
	9/26/01	38	5	26%	3.67	Fair
LING-06	4/24/01	28	0	20%	3.67	Fair
	9/26/01	34	1	26%	3.44	Fair
LING-07	4/25/01	37	0	27%	3.00	Fair
	9/26/01	34	3	35%	3.67	Fair
LING-08	4/24/01	28	6	2%	3.67	Fair
	9/24/01	27	0	48%	3.22	Fair
LING-09	4/24/01	28	1	62%	2.78	Poor
	9/24/01	36	0	34%	3.44	Fair
LING-10	4/24/01	33	7	4%	4.56	Good
	9/24/01	26	1	2%	3.67	Fair

The fish IBI was developed by MBSS using 1994 to 1997 data taken from minimally impacted streams. In the highlands region of Maryland, seven metrics are used representing various measures of species richness and composition, indicator species, trophic function, fish abundance and condition, and reproductive function (Roth et al. 2000). For purposes of the fish IBI, Linganore Creek falls within the highlands geographic region of the state.

Fish IBI scores for Linganore Creek ranged from fair to very poor at the ten stations in July 2001, with most of the stations receiving a score of fair (Table 2-9, Figure 2-8). Although none of the stations were in the good category, fish populations were rated fair at half of the stations. The number of species per station varied from five to twenty-four (LING-04 and LING-10, and LING-02 respectively), indicating a relatively diverse assemblage of fish species. Tolerance refers to a species' known ability to tolerate a variety of types of environmental degradation such as siltation, lowered flows, low dissolved oxygen, and contaminants. Results from the electrofishing survey revealed that with the exception of two sites (LING-09 and LING-06), the percent of the species observed at each site tolerant to degradational stresses ranged from 38 percent (LING-09) to 98 percent (LING-10). The prevalence of tolerant species indicates that degradational stresses are widespread. Species intolerant of degradational stress were observed at the three mainstem stations and at LING-09. In spite of the Recreational Trout Waters classification, no trout were observed in habitat likely to support them during field sampling activities at the ten monitoring stations. In addition, drought-induced low stream flows during the summer months of 2001 may have resulted in somewhat lower than anticipated fish IBI ratings in Lower Linganore Creek.

Table 2-9. Summary of fish results from Lower Linganore Creek

Station ID	Date Sampled	Number of Taxa	Number of Intolerant Taxa	Percent of Tolerant Individuals	Fish IBI Score	Fish IBI Rating
LING-01	7/24/01	15	2	68%	2.71	Poor
LING-02	7/27/01	24	5	69%	3.00	Fair
LING-03	8/7/01	20	5	52%	3.57	Fair
LING-04	7/24/01	5	0	81%	2.43	Poor
LING-05	7/27/01	7	0	48%	2.71	Poor
LING-06	7/12/01	11	0	39%	3.00	Fair
LING-07	7/13/01	15	0	50%	3.00	Fair
LING-08	7/12/01	6	0	87%	2.14	Poor
LING-09	7/23/01	10	1	38%	3.57	Fair
LING-10	7/23/01	5	0	98%	1.57	Very Poor

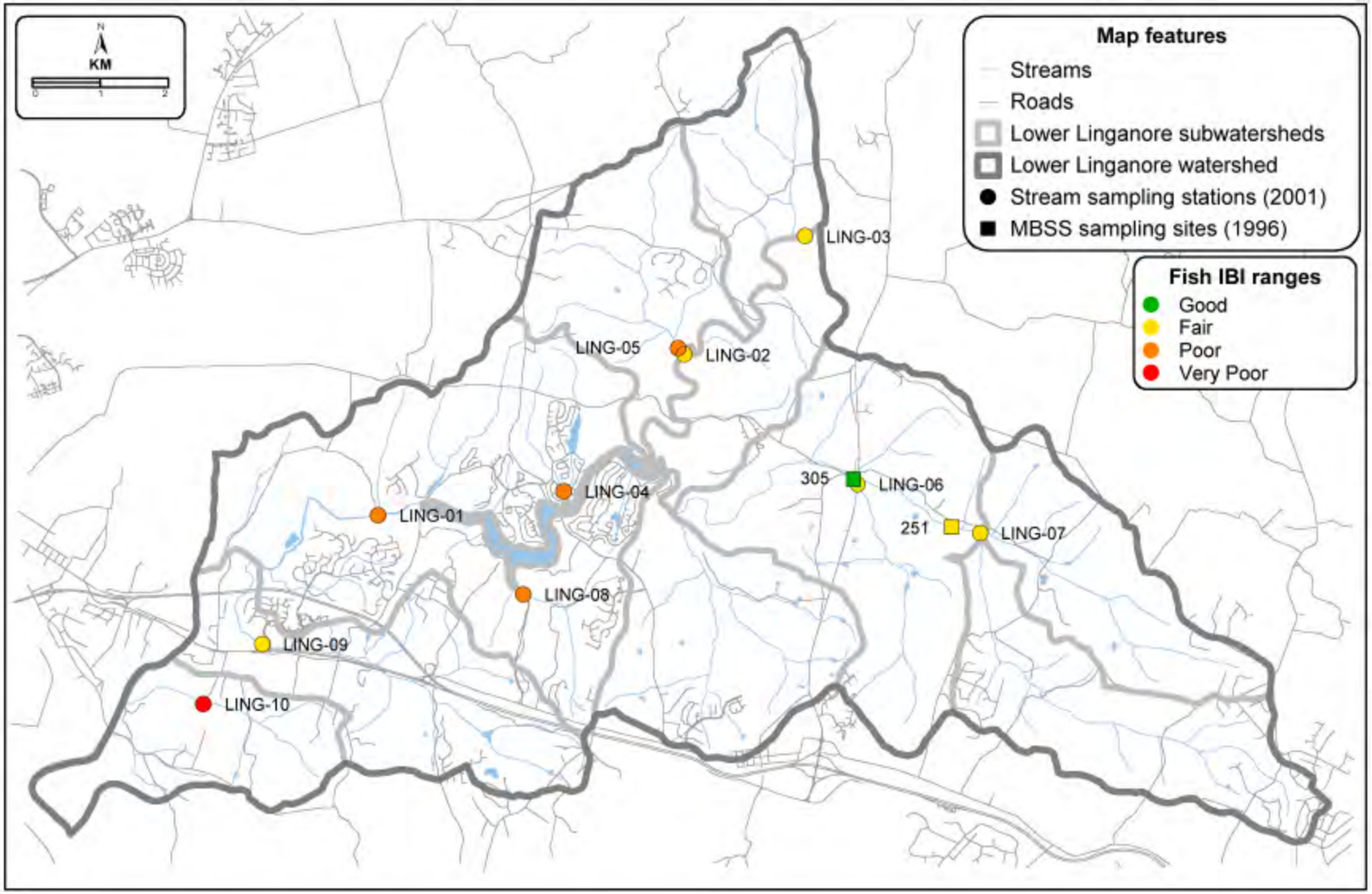

Figure 2-8. Fish IBI scores from Lower Linganore Creek watershed (Frederick County summer 2001 and MBSS Summer 1996 sampling)

2.3.1.4 MBSS Sites

A review of MBSS records indicates that to date, two randomly selected sampling locations have been monitored within the Lower Linganore Creek watershed. The sites were monitored in 1996 and are located on Ben's Branch near Lake Linganore (Figure 2-9). Data from these sites have been used to supplement the County's field collection efforts. These data indicate that conditions in Lower Linganore Creek watershed were generally fair (Table 2-10). Key results are listed below:

Water Chemistry. Instream nitrate-nitrogen concentrations were somewhat elevated at both of the MBSS sites; one site was 2.49 mg/l, and the other was 3.68 mg/l. Values greater than 1 mg/l generally indicate anthropogenic contributions of nitrogen. These sites are located near pastures and roads, which are often sources for nitrogen.

Physical Habitat. Habitat scores for the two stations were relatively good, with most parameters in the optimal and sub-optimal categories. Both stations had good pool and riffle areas, and good channel diversity, allowing for better fish diversity. Embeddedness and bank stability were normal at one station, but somewhat degraded at the other, which may have been affected by the adjacent cow pasture.

Table 2-10. MBSS sites in Lower Linganore Creek Watershed, Frederick County, MD

Site ID	Riparian Buffer Width (m)	Catchment Area (acres)	Benthic IBI Score	Benthic IBI Rating	Fish IBI Score	Fish IBI Rating	Nitrate Nitrogen (mg/l)
FR-P-411-305-96	0	6391	3.67	Fair	4.14	Good	3.68
FR-P-461-251-96	0	4225	3.22	Fair	3.86	Fair	2.49

Site ID	Instream Habitat (0-20)	Epifaunal Substrate (0-20)	Velocity/ Depth Diversity (0-20)	Pool/Glide/ Eddy Quality (0-20)	Riffle/Run Quality (0-20)	Bank Stability (0-20)	Embed-dedness (percent)
FR-P-411-305-96	16	16	16	15	17	15	15%
FR-P-461-251-96	9	10	14	17	11	6	35%

Biological Assessment. Both fish and benthic IBI scores for each station were in the fair to good categories (3.86 and 3.22 respectively for Site 251, the upstream station, and 4.14 and 3.67 for Site 305, the downstream station) (Figures 2-7 and 2-8). There were 18 species of fish found at the upstream station, while the downstream station had 14 species. The upstream station was next to a cow pasture, and nutrient rich streams of this nature tend to support more species of minnows than stations fully forested.

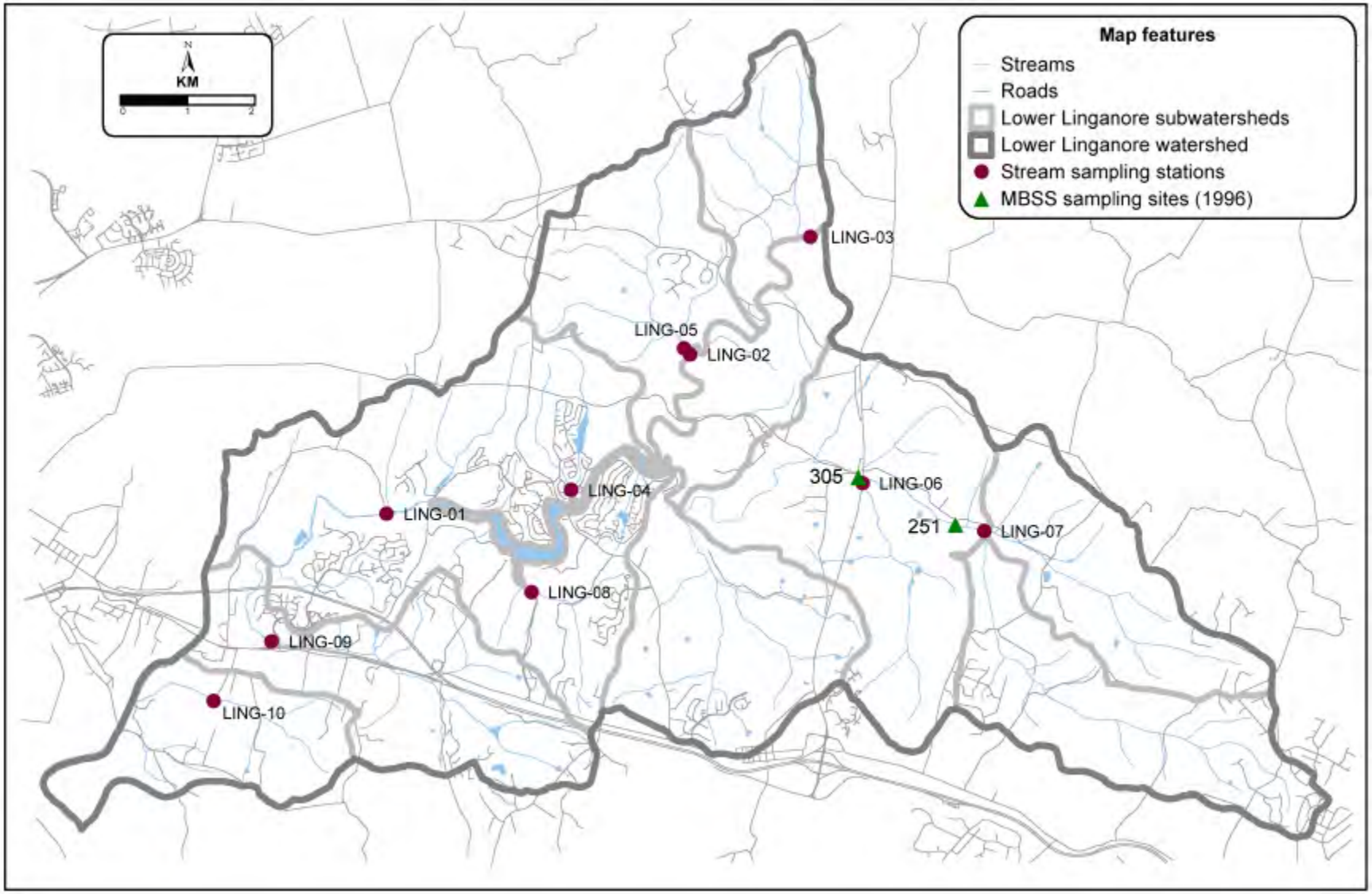

Figure 2-9. Frederick County stream sampling stations (2001) and Maryland Biological Stream Survey sites (1996) in Lower Linganore Creek watershed

Land Use. Agriculture is the dominant land use upstream of these sites, with a few housing and community developments far upstream. The fish and benthic IBI scored well. However, the benthic scores, which are slightly lower than the fish scores, are more sensitive to the impacts of agriculture on stream quality.

2.3.1.5 Integrated Analysis

An integrated analysis of the chemical, physical, and biological data for Linganore Creek indicate that conditions within the stream have been somewhat impacted by historical and recent land use activities within the catchment. Stream conditions, as shown by the biological indicator data summarized in Table 2-11 and Figure 2-10, are predominantly fair, with an equal number of good and poor ratings. Water quality data also show somewhat elevated levels of nonpoint pollutants. To some degree, these conditions are typical for streams in this region, and reflect the area's history of both agricultural activities and more recent urban development. However, Linganore Creek is not severely degraded at present and care should be taken to prevent further degradation of this valued natural resource.

Table 2-11. Summary of biological assessment results from Linganore Creek using MBSS protocols.

Station ID	Year Sampled	Spring Benthic IBI Rating	Fish IBI Rating
LING-01	2001	Fair	Poor
LING-02	2001	Good	Fair
LING-03	2001	Fair	Fair
LING-04	2001	Good	Poor
LING-05	2001	Good	Poor
LING-06	2001	Fair	Fair
LING-07	2001	Fair	Fair
LING-08	2001	Fair	Poor
LING-09	2001	Poor	Fair
LING-10	2001	Good	Very Poor

Statistical analysis was not performed on these data as the small sample size, namely a maximum of two data points for each station, would not produce statistically meaningful results. Additional data collected during future years would expand the data set greatly and would support a more descriptive and analytical review.

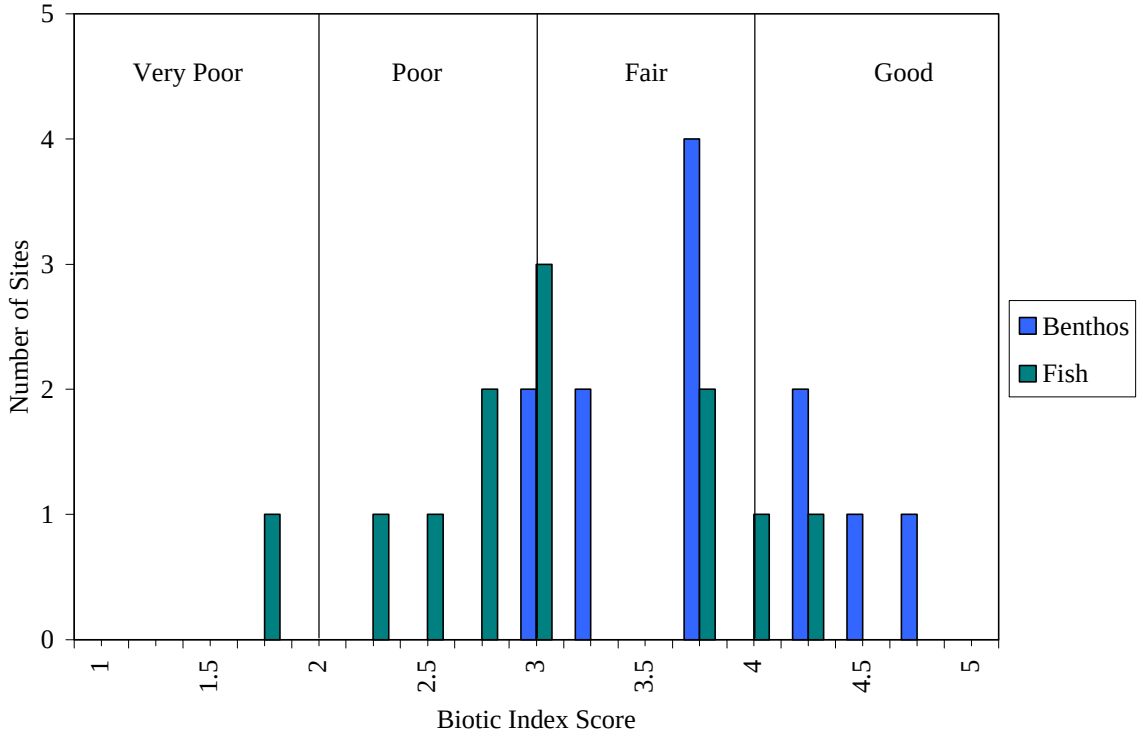

Figure 2-10. Most benthic and fish IBI scores from Lower Linganore Creek fall within the fair range

2.3.2 Upland Vegetation and Land Cover

Vegetation and land cover were assessed and characterized throughout the Lower Linganore watershed as part of this study. Several sources of data were used to initiate the assessment, including the 1997 land use and land cover data, part of the state wide data set prepared by the Maryland Office of Planning (MOP). In addition, electronic copies of color, low-altitude vertical aerial photographs from March 31, 2000 (provided by Frederick County DPW) were overlain with the Maryland Department of Natural Resources (MDNR) Technology Toolbox (v5.3) Wetlands map layer covering the study area. The boundary of the Linganore watershed was then transposed onto the aerial photographs. The resulting multilayered photo-map of the watershed was used to prioritize specific areas for observation during the subsequent field visit by Versar ecologists on August 20, 2001. Many of the plant species observed during this survey, as well as those reported for this area in a 1996 survey, are presented in Appendix B, Table B-1.

Upland vegetation and land cover in the Linganore watershed consists of agricultural land, forest (deciduous and mixed deciduous), oldfield (transitional vegetation), and developed areas (residential, commercial, and industrial). These land cover types are described below (note that wetlands are discussed in a separate section). The estimated aerial extent of each as a percentage of the overall Linganore watershed study area is also presented.

Agricultural land covers slightly more than 50 percent of the Linganore watershed, and includes row crops, hay crops, tree farms, and pasture. The principal row crops planted at the time of the August 2001 field visit were corn, barley, and wheat; alfalfa and clover were the most common hay crops observed. Pastures in the watershed are typically planted in grasses palatable to livestock, such as fescues, orchard grass, and bluegrasses. In addition, a few sizeable Christmas tree farms were observed in the southeastern part of the watershed. Several varieties of soybeans are planted in this area, including full season and partial season types. The partial season varieties are typically planted in late March or early April in the area, after an early season crop such as winter wheat is harvested. Dairy farms in the area typically plant hay, legumes, and corn fodder crops.

Of all the Maryland counties, Frederick County possesses one of the smallest percentages of forest cover. Much of what was formerly dense hardwood forest has been converted to farmland, residential, or industrial areas. Together, forested areas cover approximately 28 percent of the Linganore watershed (this includes MOP map units for deciduous, evergreen, and mixed deciduous forests). Because of the generally human-influenced nature of the area, upland forest is usually located within areas having topographic constraints for farming or development, such as steep slopes and ridges and stream corridors. It is in these areas where the largest contiguous forested parcels are located. Forested parcels of significant size occur on upland ridges and/or riverine areas along Linganore Creek and the Monocacy River in the study area. Smaller parcels and forested lots are scattered throughout the watershed.

Several upland forest types occur in the Linganore watershed. Along many of the stream corridors are riparian forests characterized by stands of relatively mature trees with sparse shrub layers and dense herbaceous layers. The trees in these riparian stands generally possess average diameters of 16 to 30 inches diameter at breast height (dbh) and canopy heights on the order of about 60 to 100 feet. Some larger individual trees exist, but these are scattered throughout in general, the riparian forests do not appear as extensively cut-over as some of the ridge forests. Principal trees in the riparian forests are silver maple, red maple, boxelder, sycamore, musclewood, and tulip poplar. In most areas of the riparian forest the shrub layer is dominated by spicebush and poison ivy; multiflora rose is also locally co-dominant. Predominant herbaceous species in the floodplain forests include false nettle, clearweed, wingstem, jewelweed, jumpseed, wicker microstegium, and in wetter areas, lizard=s tail and various unidentified grasses and sedges.

Many areas of upland ridge forests are also present within the watershed along the sides and tops of the rocky ridges in this Piedmont setting. The trees in these ridge stands generally possess average diameters of 20 to 28 inches dbh and canopy heights on the order of about 40 to 80 feet. Predominant species in the upland ridge forests vary, depending on the position of the slope. On the sides of the ridges, American beech, slippery elm, tulip poplar, and red maple are the predominant trees. On the ridge tops, chestnut oak, black oak, northern red oak, pignut hickory, and shagbark hickory are the predominant trees. Also occasionally present on the ridge tops were pitch pine trees as scattered individuals and in small stands. The shrub layer in most areas of the ridge forests is generally sparse to moderately dense; principal species typically include spicebush, black huckleberry, poison ivy, witch hazel, pawpaw, and saplings of the

dominant tree species. Because of the dense canopy from the dominant tree canopy, the herbaceous layer is generally sparse throughout the ridge forests. The principal species include mayapple, white avens, jumpseed, and clearweed.

Several oldfield areas within the Linganore watershed were observed along the edges of cultivated fields and abandoned lots. The oldfield observed in the study area was primarily herbaceous with few scrubby trees and shrubs, and was dominated by broomsedge, yarrow, late flowering boneset, white snakeroot, and butter-and-eggs. The small trees that are scattered within the areas of oldfield or occur around the periphery (generally at the outer edge of cultivated fields and upland deciduous forest) included tree of heaven, black locust, black cherry, and sassafras.

Developed areas within the Linganore watershed consist of single and multiple unit residential dwellings, industrial complexes, roads, parking lots, and other human-influenced facilities. Many of these yards, neighborhoods, and facilities possess areas of mowed lawns with landscaped areas planted in non-native and native cultivar trees and shrubs. The lawn areas consist of typical mixtures of planted native and non-native grasses and volunteer weeds. Typical lawn species include Kentucky bluegrasses, Bermuda grass, Poa grasses; typical weeds include English plantain, dandelion, mouse-eared chickweed, Canada thistle, and others.

2.3.3 Wetlands

Approximately 7,325 acres of Frederick County (approximately 1.7 percent of the county) were mapped as wetlands by the National Wetlands Inventory during the late 1970s. About 6,355 acres (87 percent) of these wetlands were vegetated; the remaining 970 acres were unvegetated wetlands (primarily open waters of ponds and lakes). The most abundant vegetated wetland types in Frederick County were non-tidal deciduous forested (3,775 acres) and non-tidal emergent (1,789 acres).

MDNR=s Wetlands Features Inventory was reviewed to identify wetlands within the study area. This inventory is based on photo interpretation of high altitude, color aerial photography of the study area from April 8, 1993 using the Cowardin et al. (1979) classification system. Wetlands within the Linganore watershed are closely associated with Linganore Creek and the Monocacy River, and their tributaries, and are generally linear, as shown in Figure 2-11. Isolated wetlands (i.e., not directly associated with any of the streams or tributaries in the watershed) are generally herbaceous and are very small (2 acres or less); most of these are associated with farm ponds in agricultural areas. The largest mapped area of wetlands comprises Lake Linganore and its impounded, deepwater habitats. Wetland types shown in Figure 2-11 are defined in Table 2-12.

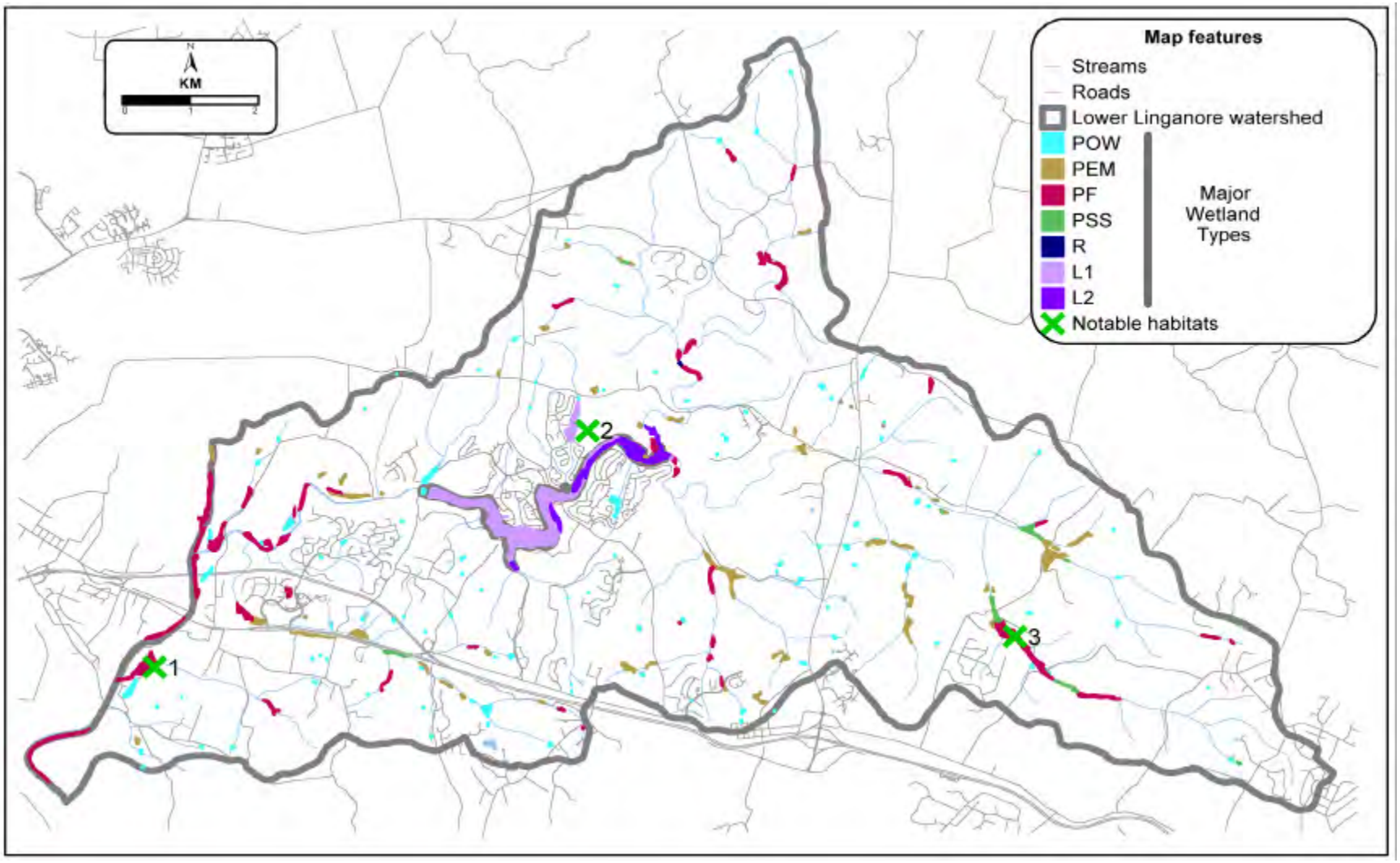

Figure 2-11. Wetlands and three notable habitat areas within Lower Linganore Creek watershed

Table 2-12. Major wetland types reported in Lower Linganore Creek watershed	
Code	**Definition**
POW	Palustrine Open Water
PEM	Palustrine Emergent
PF	Palustrine Forested
PSS	Palustrine Scrub/Shrub
R	Riverine
L1	Lacustrine Limnetic
L2	Lacustrine Littoral

Representative examples from each of the mapped general wetlands types within the Linganore watershed were briefly investigated during the field visit on August 20, 2001. Principal vegetation was noted during the field visit by spot-checking the three major types of wetlands (forested, herbaceous, and lacustrine), as described below.

Forested wetlands were noted throughout the watershed, but the largest parcels occur along Linganore Creek and the southeastern part of Bens Branch. Typical species found in the tree layer of the forested wetlands surveyed were red maple, silver maple, green ash, box elder, sycamore, eastern cottonwood, and black willow. These wetlands differ somewhat from the upland riparian wetlands in that they possess a permanently saturated substrate and they are clearly dominated by red and silver maples. The predominant shrubs in the shrub layers in the wetland forests are spicebush, southern arrowwood, multiflora rose (found in dry to wet places), speckled alder (in wettest places), as well as small saplings of the predominant tree species. The herbaceous layer in the forested wetlands is moderately dense to sparse, depending on the density of the tree and shrub canopies. Jewelweed, dotted smartweed, lady's thumb, clearweed, false nettle, jack-in-the-pulpit, cinnamon fern, and lizard's tail are the most abundant herbaceous species throughout the forested wetlands.

Herbaceous wetlands were also noted throughout the watershed, primarily in small parcels that were associated with Linganore Creek and its tributaries. The herbaceous wetlands appeared to be diverse in the total number of species present. Predominant species in the herbaceous wetlands generally include jewelweed, common rush, reed canary grass, cattail, barnyard grass, rice cut grass, dotted smartweed, red-rooted cypress, arrow leaved tearthumb, sensitive fern, sallow sedge, and hollow joe pye weed. Depending on wetness, the degree of human disturbance, and other factors (such as cattle grazing), the shrub layer was moderately dense to nonexistent in some wetlands; principal shrub and woody vine species include spicebush, red osier dogwood, poison ivy, multiflora rose, speckled alder, and southern arrowwood. Scattered small trees, including black willow, green ash, red maple, and silver maple were present in some of the herbaceous wetlands.

Lacustrine (i.e., lake) habitats exist in the Linganore watershed, as within Lake Linganore and Lake Merle. Both of these lake systems consist primarily of unvegetated, open water

habitats, but they also contain small areas of emergent herbaceous wetlands and forested wetlands that possess the same principal species as those previously described.

2.3.4 Wildlife

This assessment did not attempt to quantify wildlife directly; animals, however, were recorded from observations made in the watershed during a reconnaissance survey on August 20, 2001, and during numerous trips to the area for previous studies conducted during the springs and summers of 1996, 1999, and 2000.

Observations on wildlife were made on August 20, 2001; results indicate that wildlife species within the Linganore watershed are similar to those found elsewhere in the County. Approximately forty-seven species of mammals are likely to occur in the Linganore watershed; five of these were documented during the field survey, including white-tailed deer, raccoon, Virginia opossum, eastern cottontail, gray squirrel, and woodchuck (Appendix B, Table B-2). Signs of white-tailed deer, including tracks and scats, were common throughout all habitats; the species was directly observed in the upland ridge forests adjacent to Linganore Creek and its tributaries in the southwestern part of the watershed. Woodchucks were infrequently observed, but evidence of their common occurrence was noted by the numerous burrows found along the edges of woodlands and adjacent to croplands. Gray squirrels were observed in upland ridge forests where oaks, hickories, and beech were the dominant trees. Raccoons were not directly observed; tracks and scats, however, were observed in many places around the study area, particularly along streams or wetland habitats. Sightings of coyotes have been reported within several areas of the County (Glenn Therres, MDNR, personal communication, 2001). According to the MDNR, black bears are occasionally observed in the vicinity of the Catoctin Ridge to the immediate west of the Linganore watershed (Glenn Therres, MDNR, personal communication, 1999).

Seventy-four species of birds have been documented in the vicinity of the watershed in prior surveys since 1996; a total of 46 species were documented during the August 20, 2001 survey (Appendix B, Table B-3). Common resident birds identified throughout the watershed included American crow, blue jay, northern cardinal, American goldfinch, song sparrow, European starling, and mourning dove. Birds most common to grassland, cropland, and shrub-edge habitats included song sparrow and American robin and common grackle. Forested areas mostly along stream corridors were host to a number of common birds including red-bellied and downy woodpeckers, common flicker, Carolina chickadee, rufous-sided towhee, and gray cat-bird. Although many transients or fall migrants were absent from the list, including many warbler species, they may be present within the study area during other times of the year. Raptors identified within the study area included red-shouldered hawk, red-tailed hawk, black vulture, and turkey vulture.

Herpetofauna of the Linganore watershed were represented in the August 20, 2001 survey and during stream monitoring events by several species, including northern two-lined salamander, dusky salamander, longtail salamander, bullfrog, green frog, pickerel frog, southern leopard frog, Fowlers toad, northern water snake, black rat snake, and eastern box turtle. Most

of these species were observed at several locations in the Linganore watershed, particularly within Linganore Creek and its tributaries. The two-lined salamanders were observed in their larval state. None of the species observed were particularly abundant within any parts of the Linganore watershed.

A number of readily identifiable invertebrates were also noted from the survey. Butterflies included tiger swallowtail, black swallowtail, monarch, and cabbage butterfly. Dragonfly species observed included green darner, common whitetail, and eastern amberwing.

Aquatic organisms observed within Lower Linganore Creek and its tributaries during the course of this study were numerous. Many types of benthic macroinvertebrates were collected from the ten stations spread throughout the watershed. These invertebrates include stoneflies, mayflies, caddisflies, dragonflies, damselflies, water beetles, water bugs, midges, horse and deer flies, crane flies, and many others. Fish from seven taxonomic families (freshwater eels, suckers, minnows, sculpins, sunfish, bullhead catfish, and perches) were collected from Linganore Creek (Appendix B, Table B-4). Several species collected from larger portions of Linganore Creek are considered sport fish, including rock bass, smallmouth bass, and largemouth bass.

2.3.5 Threatened and Endangered Species

To augment field observations discussed above, written inquiries were made to the U.S. Fish and Wildlife Service (USFWS), Chesapeake Bay Field Office and the MDNR, Wildlife and Heritage Division (MDNR Heritage Program) regarding the presence of species of concern within the watershed boundaries.

A July 24, 2001 response from the USFWS states that, AExcept for occasional transient individuals, no federally proposed or listed endangered or threatened species are known to exist within the project impact area.@ In addition, the USFWS stated that since Federal and state partners of the Chesapeake Bay Program have adopted an interim goal of no overall net loss of the Basin=s remaining wetlands, and the long term goal of increasing the quality and quantity of the Basin=s wetland resource base, the USFWS recommends avoiding wetland impacts.

In an August 3, 2001 letter, the MDNR Heritage Program stated that their Environmental Review of the study area revealed several records of Maryland-listed species of special concern within or adjacent to the study area (Table 2-13). The correspondence from the MDNR Heritage Program indicates records for three listed species within the watershed, including brook floater (*Alasmidonta varicosa*) and green floater (*Lasmigona subviridis*), both freshwater mussels, and one plant called bashful bulrush (*Scirpus verecundus*). The MDNR Heritage Program indicates that records for brook floater are from a pre-1960 collection from Linganore Creek; the most recent records for green floater are from 1984, from the Monocacy River at or near the mouth of Linganore Creek. According to the MDNR Heritage Program, an historical record from 1881 placed bashful bulrush in the vicinity of Mt. Airy. Because none of these three species have apparently been observed for many years (120 years in the case of the bashful bulrush) it is unlikely these species still occur in the locations indicated by MDNR Heritage Program within the Linganore watershed.

Table 2-13. Threatened and endangered plants and animals cited by the Maryland Department of Natural Resources Forest, Wildlife and Heritage Service as potentially existing within appropriate habitats in the Lower Linganore watershed.

Scientific Name	Common Name	State Status/Rank*
PLANTS		
Scirpus verecundus	Bashful bulrush	Rare
ANIMALS		
Alismidonta varicosa	Brook floater	Endangered
Lasmigona subviridis	Green floater	Endangered

***Explanation of State Status and Rank Categories** (as defined by the Maryland Department of Natural Resources)

Endangered - a species whose continued existence as a viable component of the State's flora or fauna is determined to be in jeopardy.

In Need of Conservation - an animal species whose population is limited or declining in the State such that it may become threatened in the foreseeable future if current trends or conditions persist.

Threatened - a species of flora or fauna which appears likely, within the foreseeable future, to become endangered in the State.

Endangered Extirpated - a species that was once a viable component of the flora or fauna of the State, but for which no naturally occurring populations are known to exist in the State.

State Rare - imperiled in Maryland because of rarity (typically 6 to 20 estimated occurrences or few remaining individuals or acres in the state) or because of some factor(s) making it vulnerable to becoming extirpated. Species with this rank are actively tracked by the Natural Heritage Program.

Neither these three state-listed species or any other state or federal listed species or other species known to be of special management concern were observed during the August 20, 2001 field visit to the watershed.

2.3.6 Notable Habitats

Of those portions of the Linganore watershed observed during the August 20, 2001 field visit, three general areas of habitat stood out in terms of their apparent ecological value; these areas are denoted on Figure 2-11. This analysis is not intended to provide an overall ranking of habitats within the watershed; it provides additional information on habitats of note. The following are brief descriptions of each of these notable areas.

Area 1 is to the immediate southeast of Pinecliff Park (adjacent to the Monocacy River), and consists of a mixture of upland ridge forest, upland riparian forest, and wetland deciduous forest. The upland ridge forests in this area are relatively mature and exhibit oak, hickory and beech trees that average about 24 inches to 28 inches dbh, with individual trees to 40 inches dbh. This forest likely provides a significant hard mast crop, and appears to support a variety of wildlife. A large group of white-tailed deer were observed bedding down in this forest, and a variety of native forest-dwelling birds and several eastern box turtles were also observed in this area. The wetland forest along the unnamed tributary to the Monocacy River also possesses

large individual trees with a dense herbaceous understory that likely provides at least moderate quality habitat for wildlife.

Area 2 is to the north of the upper part of Lake Linganore and east of Lake Merle. It consists of upland deciduous and mixed deciduous forest along the moderately steep ridges adjacent to both lakes. The forest in this location is relatively mature, although parts of it have been selectively logged. The average diameter of trees is about 20 inches dbh, with individual trees to about 30 inches dbh. As in Area 1, Area 2 possesses a variety of oak, hickory, and beech trees, and likely provides a significant hard mast crop valuable to wildlife. Some large pitch pine trees are also present. Several long, ridge-top trails allow for scenic walks through the forest and give hikers an aesthetically-pleasing experience of "remoteness." Some of the ridge forest adjacent to the lakes possess particularly good aesthetic values, and are also likely valuable to wildlife.

Area 3 is adjacent to Bens Branch, south of Knoll Road, in the southeastern part of the Linganore watershed. It is part of the largest mapped area of forested wetlands in the watershed. The wetland forest occurs in a long, narrow corridor that undoubtedly provides a travel corridor for wildlife that is essentially uninterrupted for several miles. This factor may be particularly important in light of the fact that this area is bounded by the Catoctin View and Sherwood Forest developments to the southwest and by the Hawthorne Acres development to the southeast, where little natural wildlife habitat remains.

2.4 WATERSHED LAND USE

Existing and future land use information provided by the County and other local municipalities was examined to characterize land use within the watershed and identify potential threats to water quality in Linganore Creek. Information on existing land use (1997) was prepared by MOP and provided by Frederick County. Estimates of future land use are based upon zoning information for the watershed on the assumption that development patterns for the area would match zoning distributions in the future.

2.4.1 Existing Land Use

Statewide land use data from 1997 indicates that the watershed is dominated by agriculture (about 51 percent of watershed area) and forested or brush vegetation areas, with smaller amounts of residential and commercial/industrial/institutional (Figure 2-12). Low-density residential development is fairly scattered around the outer margins of the watershed in older rural developments, while medium- and high-density residential areas are located in the central portion of the watershed. The Lake Linganore PUD was started in 1968, and since then, several other PUDs have been initiated in the central portion of the watershed, including the communities of Spring Ridge, Bartonsville, and Holly Hills (FCDPZ 1993).

Table 2-14 contains a detailed summary of the current land use data for the Lower Linganore Creek watershed. Development within the watershed consists of residential, commercial, industrial, and institutional land uses and involves 17 percent of the land area. Most of this

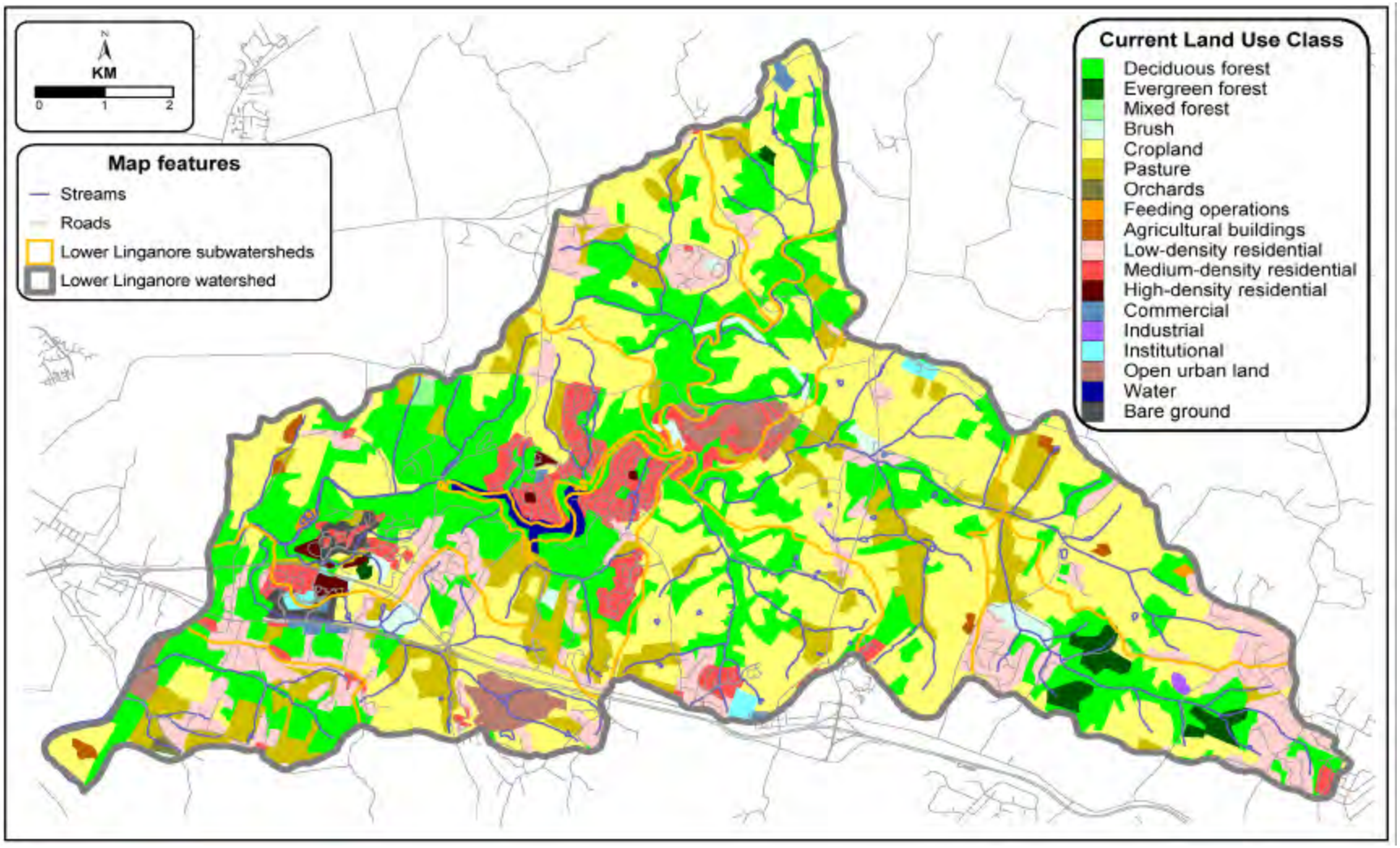

Figure 2-12. Current (1997) land use within Lower Linganore Creek watershed

development is residential; collectively low-, medium- and high-density residential development covers about 16 percent of the watershed land area. Deciduous forests, located mainly in the north central portion of the watershed along Linganore Creek and to a lesser extent, in the stream valley of Hazelnut Run and headwaters of Bens Branch, cover more than a quarter (27 percent) of the watershed=s land area. Fifty-one percent of the watershed is utilized for agriculture, with almost 10,000 acres dedicated to cropland. Most of the agricultural lands within the watershed have been designated as being of statewide importance (FCDPZ 1993, 1995).

Table 2-14. Existing (1997) land use in Lower Linganore Creek

Land use	**Acres**	**Percent**
Agricultural	12,225	50.7%
Cropland	*9,697*	*40.2%*
Pasture	*2,402*	*10.0%*
Orchards/Vineyards/Horticulture	*20*	*0.1%*
Feeding Operations	*28*	*0.1%*
Agricultural Facilities	*78*	*0.3%*
Residential	3,902	16.2%
Low-Density Residential	*2,636*	*10.9%*
Medium-Density Residential	*1,175*	*4.9%*
High-Density Residential	*91*	*0.4%*
Commercial	83	0.3%
Industrial	5	0.1%
Institutional	96	0.4%
Open Urban Land	468	1.9%
Forested	7,044	29.2%
Deciduous Forest	*6,459*	*26.8%*
Evergreen Forest	*253*	*1.1%*
Mixed Forest	*32*	*0.1%*
Brush	*299*	*1.2%*
Water	124	0.5%
Bare Ground	146	0.6%

As foreseen in Regional Plans, much of the planned or proposed new development in the watershed will occur within the PUDs located in the central portion of the watershed (FCDPZ 1993, 1995). The County=s Adequate Public Facilities Ordinance (APFO) states that preliminary plan or site plan approval for new development is contingent upon evidence that adequate schools, roadway facilities, and water and sewer facilities exist or will be provided by the County or the developer. Adequate water and sewer capabilities must be available before development can be approved. As described in Section 2.6.1, these designated PUD areas are all located within 20-year planned water and sewer service areas.

2.4.2 Future Land Use

Future land use projections were made for Lower Linganore Creek watershed to characterize and predict future environmental conditions, particularly in relation to water quality and stormwater management. Zoning information for the watershed was digitized from the New Market and Walkersville Region Plans (FCDPZ 1993, 1995), a current zoning map provided by the Town of New Market, and a 1996 zoning map for the Town of Mount Airy (Figure 2-13; Table 2-15). Projections were based upon the most recent zoning maps available and represent an ultimate future "build out" condition in the watershed in which each area was assumed to be completely developed according to its zoned use. In addition, it was also assumed that existing pockets of higher intensity land use in lower zoned areas would remain at their current level of use and not be down-zoned. These projections are conservative in that all parcels are assumed to be developed to their highest potential use allowable under current zoning regulations, regardless of ownership or current regulations limiting the intensity or extent of development on a given parcel.

Table 2-15. Frederick County, New Market, and Mt. Airy Zoning Classes for Lower Linganore Creek

Code	Zoning Class	Acres	Percent
A	Agriculture	14,989	62.2%
GC	General Commercial	72	0.3%
HD/RA	Historic District/Residential Antique	11	0.04%
MM	Mineral Mining	49	0.2%
OS	Open Space	119	0.5%
PUD	Planned Unit Development	4,662	19.3%
R1	Residential (R1)	3,050	12.7%
R2	Residential (R2)	78	0.3%
R3	Residential (R3)	541	2.2%
R5	Residential (R5)	13	0.1%
RC	Resource Conservation	519	2.2%
RS	Residential Service	0.2	0.001%

Twelve zoning classes are represented in the Lower Linganore Creek watershed (Figure 2-13). To facilitate comparison of projected future land use data to the existing land use information, each zoning class was assigned to one of the MOP land use classifications as shown in Table 2-16. Based upon this conversion, and the assumption that current uses would not be down-zoned to less intensive uses, projected future land use in the watershed is shown in Figure 2-14. Table 2-17 summarizes both current and future land uses within Lower Linganore Creek watershed.

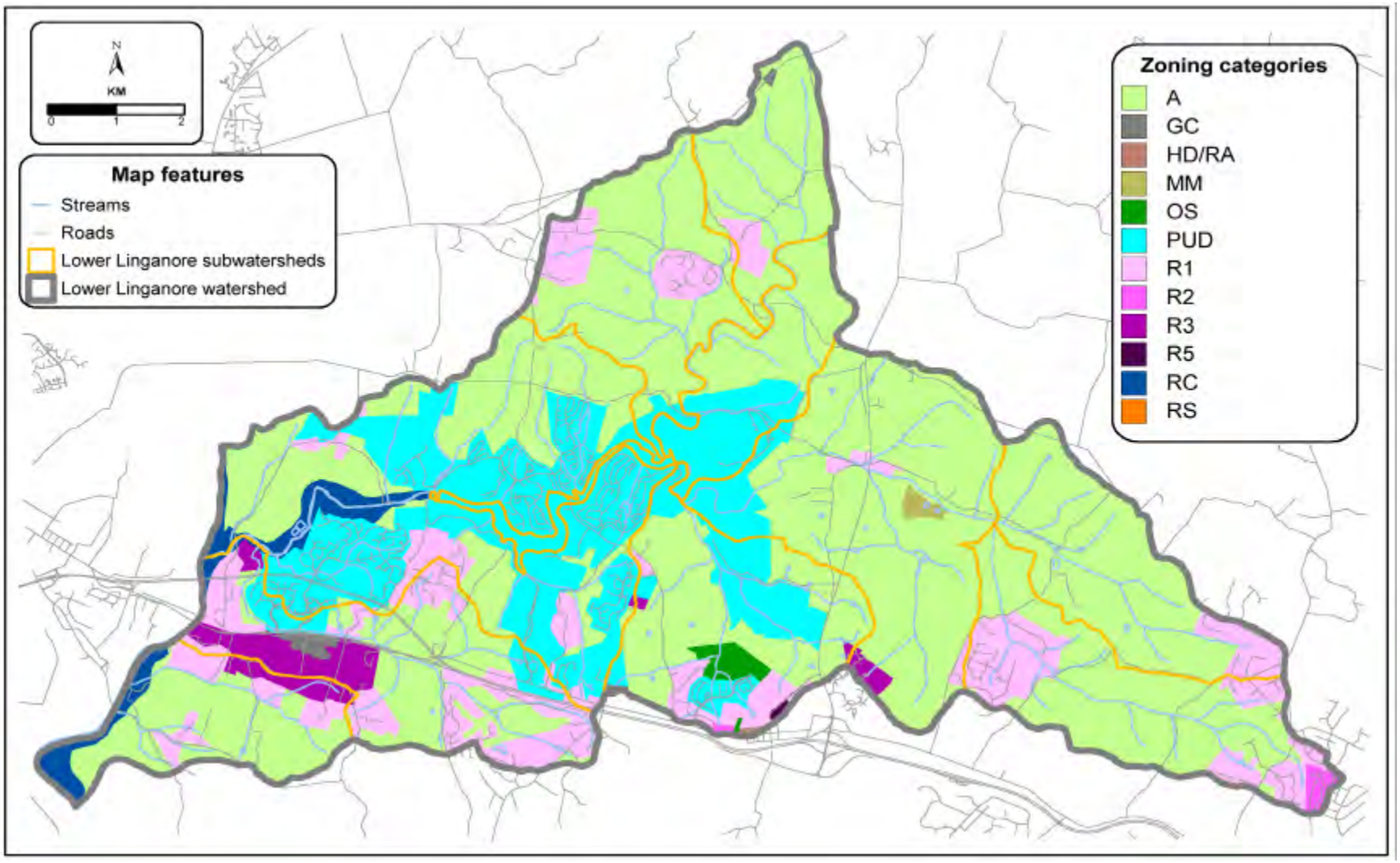

Figure 2-13. Current zoning within Lower Linganore Creek watershed

Table 2-16. Frederick County, New Market, and Mt. Airy Zoning Classes for Lower Linganore Creek and their assigned land use class	
Zoning Class	**Future Land Use Class**
Resource conservation	Forest
Agriculture	Agriculture
Mineral mining	Extractive
Residential (R1)	Low-density residential
Residential (R3)	Low-density residential
Residential (R5)	Medium-density residential
Residential (R8)	Medium-density residential
Planned Unit Development	Medium-density residential
Residential service	Medium-density residential
Historic district/Residential antique	Medium-density residential
General commercial	Commercial
Open space	Open urban land

Table 2-17. Existing (1997) and projected future land use in Lower Linganore Creek				
	Present		**Future**	
Land use	**Acres**	**Percent**	**Acres**	**Percent**
Agricultural	12,225	50.7%	14,270	59.2%
Low-Density Residential	2,636	10.9%	4,150	17.2%
Medium-Density Residential	1,175	4.9%	4,374	18.1%
High-Density Residential	91	0.4%	91	0.4%
Commercial	83	0.3%	120	0.5%
Industrial	15	0.1%	15	0.1%
Institutional	96	0.4%	92	0.4%
Open Urban Land	468	1.9%	586	2.4%
Forested	7,044	29.2%	231	1.0%
Water	124	0.5%	124	0.5%
Bare Ground	146	0.6%	-	-
Extractive	-	-	49	0.2%

Land use projections indicate a substantial increase in human activities within the watershed. If the watershed is "built out" according to the zoned categories, residential use is projected to reach about 36 percent, more than doubling the current area. Medium-density

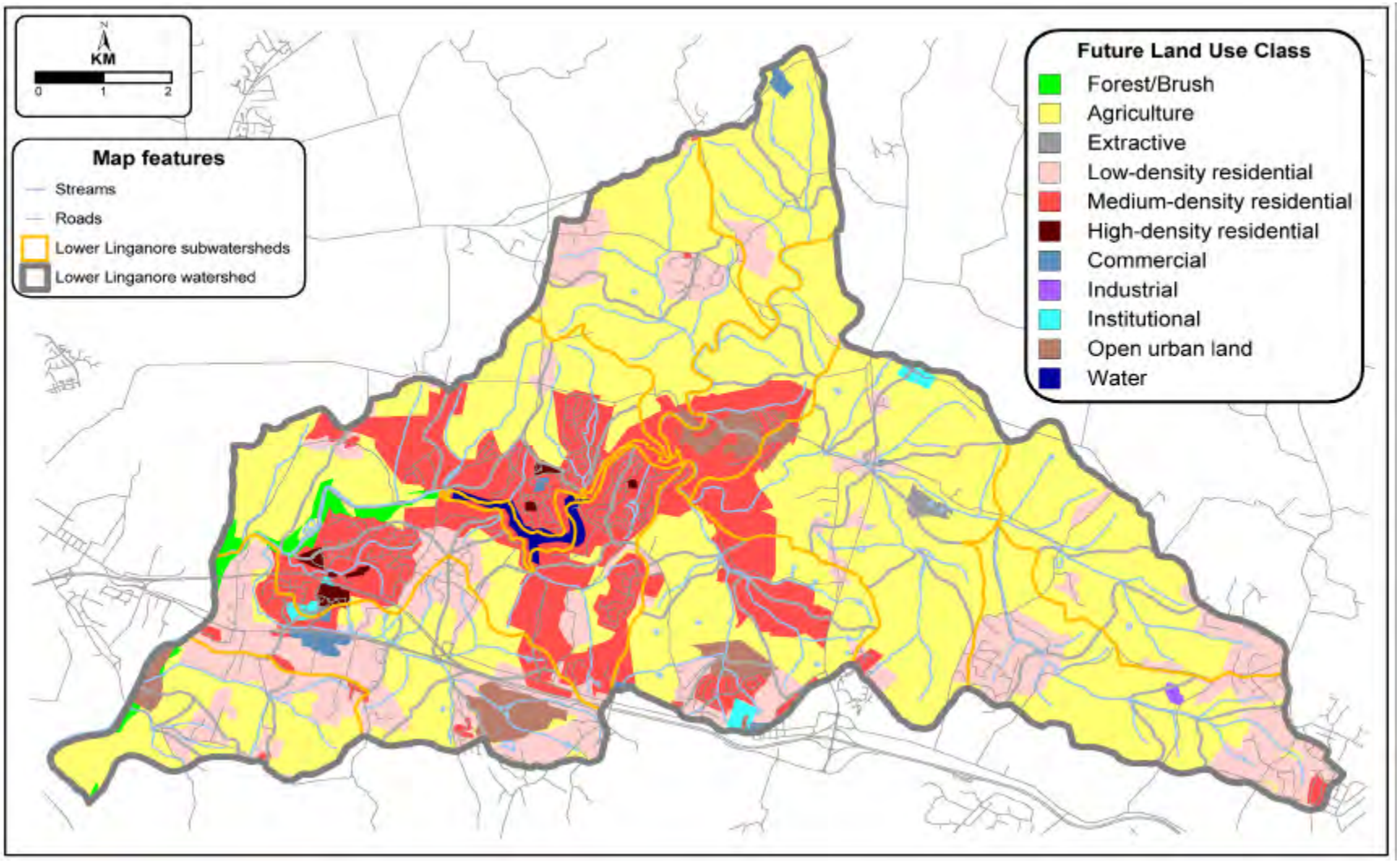

Figure 2-14. Projected future land use within Lower Linganore Creek watershed

residential will expand more than three-fold to 18 percent and low-density residential will increase to 17 percent of the watershed area. As planned, most new residential development will occur in the central portion of the watershed, primarily in the Mainstem Linganore Creek subwatershed, and to a lesser extent, the Hazelnut Run and New London subwatersheds. Commercial, industrial, institutional, and open urban land are anticipated to remain relatively unchanged. Agriculture is expected to increase from 51 percent to 59 percent. Forest was projected to drop from 29 percent to 1 percent; however, this may overestimate forest loss. Since zoning does not contain a forest class, existing forest areas were reclassified according to their zoned use. Such a dramatic loss of forested areas is somewhat unlikely given building constraints such as steep slopes and the protection offered by the County's Forest Resource Ordinance.

2.5 POPULATION

Current and future populations within the Lower Linganore Creek watershed were derived from data provided by Frederick County Department of Planning and Zoning (Dudley 2000). The County supplied population, housing, and employment projections through the year 2020 for a set of 22 traffic analysis zones (TAZs) covering the area of the watershed. Because some TAZs extended outside the watershed boundary, TAZ boundaries were digitized from a map provided by the County, and GIS was used to calculate the proportion of area of each TAZ falling within the watershed. Proportions were then multiplied by the County's TAZ demographic statistics, and values then summed to estimate the watershed's current and future population, number of households, and employment.

2.5.1 Existing Population

As of January 2000, Frederick County had a population of 199,369 representing an increase of 49,161 individuals (33 percent) since the 1990 census. By the year 2020, the County's population is projected to reach 281,710, an increase of 82,341 (41 percent) above its current level (all figures from FCDPZ 2000). Accompanying this growing population is a substantial increase in new housing and commercial/industrial construction. Countywide statistics estimate a total cost of new construction for 1999 of $437 million, a 13 percent increase over the previous year. More than 17,300 additional housing units in 79 major residential projects are in the County's development project pipeline (FCDPZ 2000), while commercial and industrial development also continues apace.

Current estimates of population for the Lower Linganore Creek watershed indicate that 16,050 people resided in the watershed in 2000. As shown in Table 2-18, this estimate of current population is up 25 percent from 1995.

Table 2-18. Projected population, number of households, and employment in Linganore Creek watershed, 1995-2020							
	1995	**2000**	**2005**	**2010**	**2015**	**2020**	**Increase 1995-2020**
Population	12,869	16,050	18,673	21,368	23,939	26,222	104%
Number of Households	4,841	5,811	6,846	7,912	8,937	9,922	105%
Population Density (people/sq. mile)	550	686	798	913	1,023	1,121	104%
Employment	1,288	1,975	2,218	2,377	2,729	3,172	146%

2.5.2 Future Population

Projected population trends within Linganore Creek watershed indicate that population will steadily increase over the next 20 years (Figure 2-15). By 2020, the watershed's population is expected to reach 26,222, more than double the 1995 level. In 1995, there were 4,841 households in Linganore Creek watershed. By 2020, the projected number of households is 9,922, again more than doubling the 1995 value. Population density (number of people per square mile) is expected to increase from 550 in 1995 to 1,121 in 2020.

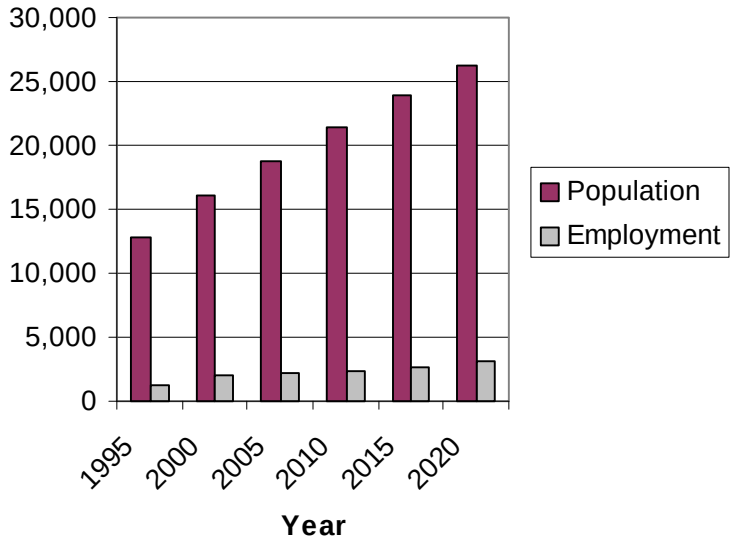

Figure 2-15. Current and projected population and employment within Lower Linganore Creek watershed, 1995-2020

Employment in the watershed is projected to continue to increase (Figure 2-15), reaching more than 3,000 in 2020, far less than the projected population number for that year. Note that projecting population and employment at this localized level is inherently an uncertain exercise.

Future growth in areas like Linganore Creek that face strong development pressure is a function of land use policies, land prices, and individual landowner actions. The decision by a single landowner to sell his property, and the subsequent approval of a new, large residential subdivision, could suddenly and significantly increase the population of Linganore Creek watershed. Similarly, development of remaining lands zoned for office/research and commercial uses is expected to increase employment; however, space allocated for employment within the watershed is extremely limited and the precise timing of such buildout is unknown.

2.6 INFRASTRUCTURE ANALYSIS

Staffs at the Frederick County Planning and Zoning Department, Division of Public Works, and Division of Utilities and Solid Waste Management were contacted regarding relevant information on water, sewer, and transportation infrastructure. Information sources included County and Regional Plans and digital maps.

2.6.1 Water and Sewer Service

Electronic CADD (computer aided drafting and design) maps of the current and planned water and sewer service areas were provided by the Division of Public Works. Analysis of existing infrastructure shows that the Spring Ridge and Lake Linganore communities in the central portion of the watershed are currently served by public water and sewer (Figure 2-16). Figure 2-16 also indicates that in the near future, service will be extended into the south-central portions of the watershed.

Within the Lower Linganore Creek watershed, as in all rapidly developing areas of the County, adequate water and sewage capacity will be needed to accommodate the expected growth in the area=s residential and commercial development. Approximately half of the watershed falls within the County=s 20-year planned water and sewer service areas (Figure 2-17). Note that the actual timing of extensions of the current water and sewer lines within this planned area will to a large extent depend upon economic conditions and patterns of land development, because extensions are often funded by individual developers.

2.6.2 Transportation

Regional plans for New Market and Walkersville include consideration of major roadways to handle the expected increase in traffic volume as more areas of the region are developed. Planned road designations and improvement projects within the watershed, according to the Regional plans, are as follows (FCDPZ 1993; FCDPZ 1995):

1) Freeway: I-70, MD 40
2) Interchanges: I-70/Rt. 75, I-70/Rt.144
3) Major arterial roads: Old National Pike (MD 144) and Liberty Road (MD 26)

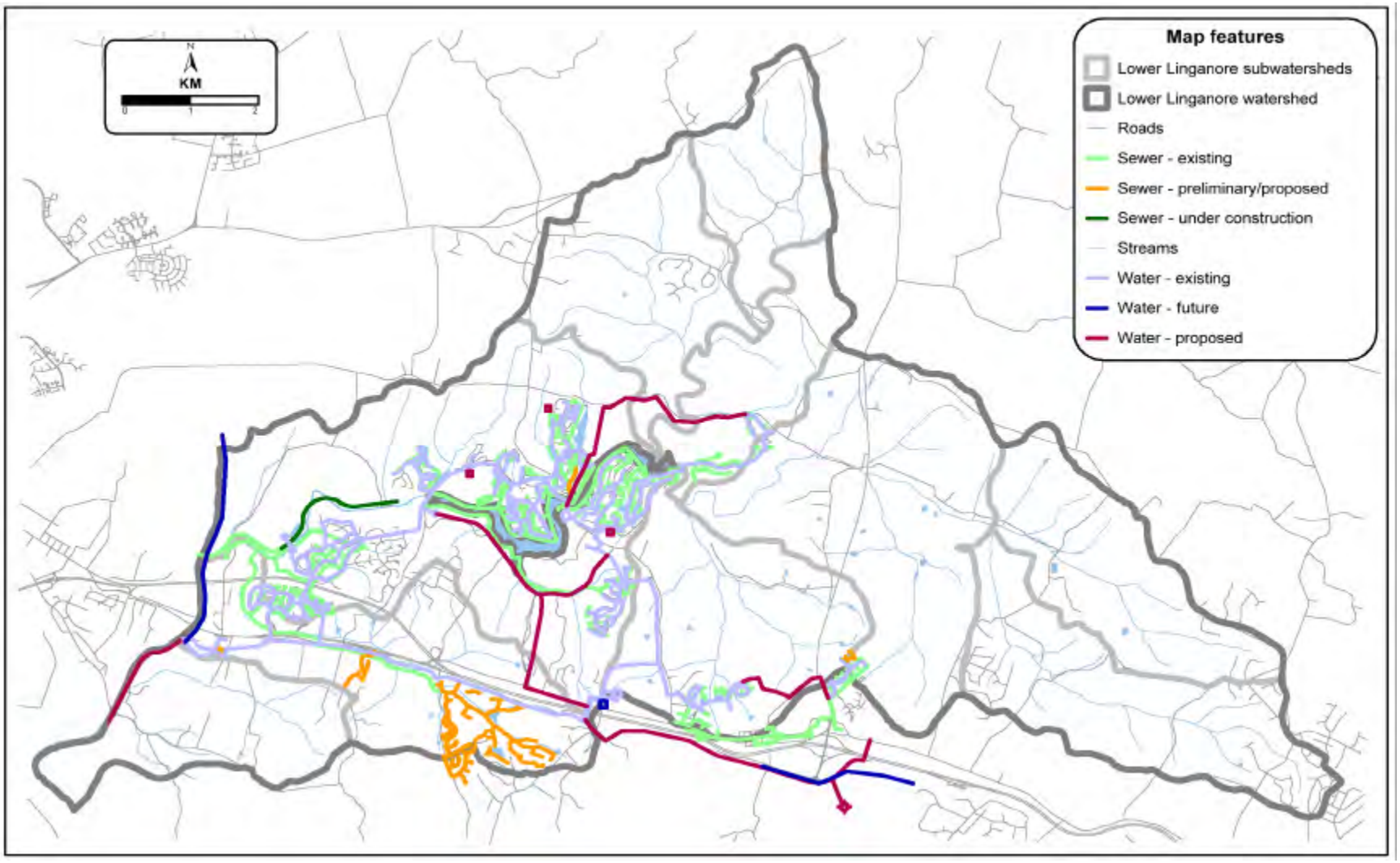

Figure 2-16. Major water and sewer infrastructure (existing and planned) within Lower Linganore Creek watershed

Figure 2-17. Twenty-year planned water and sewer service areas within Lower Linganore Creek watershed

4) Minor arterial roads: Gas House Pike, Boyers Mill Road, Linganore Road, MD 75 (north of I-70), Old Annapolis Road, Ijamsville Road, and Meadow Road

5) Collectors: Reich's Ford Road, Detrick Road, Woodville Road, Old Annapolis Road, and Sydney Road

A freight rail line runs from Carroll County to Woodsboro and Walkersville, however the tracks are damaged at the Monocacy River crossing and have not been repaired since 1972. Plans have been proposed to repair the tracks for freight and commuter service to the City of Frederick, but an additional crossing at MD 26 would have to be constructed.

Plans have been made to allow access to Meadow Road from westbound I-70. Currently it is only accessible from the eastbound direction. Park and Ride facilities are also being considered.

Where major highways and other roadways pass through the Lower Linganore Creek watershed, there is potential for detrimental effects to water quality. Cars, trucks, and trains can leave behind residues of oil and grease, as well as metals from tire wear, and exhaust emissions. Through rainfall and runoff, this build up of pollutants and road salts can, over time, pose a threat to nearby streams. There is also some risk of small leaks or catastrophic spills from truck and railroad transport of bulk or hazardous materials.

2.7 INVENTORY OF POLLUTION SOURCES

Typically, watersheds contain a wide range of potential pollution sources that are likely to affect water quality and physical habitat. Given the size of the Lower Linganore Creek watershed and the amount of development contained within, it was impractical to conduct an exhaustive inventory of pollution sources. Therefore, this inventory of possible pollution sources was compiled using ancillary data and limited field investigation to serve as an example of the types of pollution likely to be found within the Lower Linganore Creek watershed. The purpose of this inventory is to aid in characterizing stormwater impacts and other contributors to water quality degradation. Both point and nonpoint sources were identified in this assessment, including stormwater management facilities, permitted discharges, nonpoint source pollution from development and agriculture, and other potential sources of contaminants.

2.7.1 Nonpoint Pollution from Agriculture

As previously mentioned, a large portion of the eastern watershed is used for agricultural purposes. This type of land use creates specific stresses on a watershed. Unrestricted livestock access to the stream and narrow riparian buffers were both observed along Lower Linganore Creek and its tributaries. The exclusion of livestock from the stream can allow riparian vegetation to recover and, combined with efforts to increase the number and width of riparian buffers, can help protect streams in rural areas from sediment, nutrient, and erosion problems.

Agricultural problems within the Linganore Creek watershed have been the focus of several recent studies (USDA 1989, Simonson 1999). Nearly all of the farms in Linganore Creek are located within 1,000 feet of a stream or river. In 1989, there were 80 livestock farms in Linganore Creek watershed, of which only 30 had adequate waste management systems in place. The remaining 50 farms allowed wastes to be washed into nearby streams (USDA 1989). NRCS has focused recent efforts on providing cost-share assistance and working with a number of local farmers to improve management practices and reduce pollutant runoff. To help identify problem areas such as these in Linganore Creek, the Lake Linganore Ecology Committee (LLEC) was developed in conjunction with the Frederick County Soil Conservation District. They found that high siltation rates due to land development and agricultural activities, as well as manure and fertilizer runoff from pasture and crop applications were both major sources of nonpoint pollution (Simonson 1999).

Additionally, ongoing efforts are underway to develop a Source Water Protection plan for Linganore Creek. This effort, funded by a USEPA grant, is being headed by Dan Nees of the Environmental Finance Center, University of Maryland, College Park. The goal of the project is to develop and implement a resource-based source water protection plan, that is, one that involves strategies like riparian buffer restoration, land set-asides, and other ecologically-based ways to protect drinking water sources. The implementation is to be coordinated by a local Task Force, which includes representatives from Frederick County, MDE, NRCS, the City of Frederick, and local citizens groups (i.e., Lake Linganore Association and Lake Linganore Conservation Society).

2.7.2 Nonpoint Pollution from Development

New development in the Lower Linganore Creek watershed is ongoing and stormwater management facilities designed to address nonpoint pollution have been integrated into these areas. However, for these stormwater management facilities to remain effective, they must continue to be actively monitored and maintained. As new technologies and strategies for addressing stormwater issues are constantly emerging, opportunities to upgrade existing facilities should be aggressively pursued to increase their effectiveness and protect ground and surface water resources.

Older developments typically predate modern stormwater management regulations and were often built without adequate stormwater management controls. A number of older residential developments, such as the rural subdivisions in the eastern watershed and much of the Lake Linganore community were observed with non-existent or inadequate stormwater management controls. The LLEC described urban runoff of litter and domestic pet excrement, and potential sewer leaks from underground pipes as nonpoint sources of fecal coliform and nutrient loading (Simonson 1999).

Local efforts are underway in the Lake Linganore community to address stormwater management issues. The Lake Linganore Conservation Society (LLCS), a non-profit group started by the Lake Linganore Association was established to serve as the primary contact for the Linganore Community Development Authority (CDA). A primary goal of LLCS's mission is to

protect the community's streams and lake by applying environmentally conscious road designs, building SWM systems, and increasing public awareness and appreciation through watershed education efforts (LLCS 2001). To this end, LLCS initiated a road and stormwater management design study for the Linganore CDA that is currently in progress. LLCS is also coordinating study efforts and implementation plans with the Lake Linganore Association and the County.

2.7.3 Impervious Surfaces

The amount of impervious surfaces found within a watershed (e.g., rooftops, pavement, sidewalk, etc.) has been linked to a wide range of detrimental impacts to stream hydrology, stream morphology, biological habitat, and water quality. Research has shown that sensitive stream elements are lost when impervious cover exceeds about 10 percent, and at 25 to 30 percent imperviousness, studies show that most indicators of stream quality shift to a poor condition as a result of severe impacts from erosion, channel instability, severe habitat degradation, and decreasing biological integrity (Center for Watershed Protection [CWP] 1998). In addition, MBSS data from nearly 1,000 streams in Maryland indicate that when watershed imperviousness exceeded 15 percent, stream quality was never rated good (Boward et al. 1999).

Percent imperviousness was calculated within the Lower Linganore Creek watershed using 1997 MOP land use data and percent impervious values listed in Table 2-19. The percent impervious values were assigned to each land use class. Impervious values were then multiplied by the area of their respective land uses, followed by summing the products. The total was then divided by the total area to produce a percent impervious value for each subwatershed and for the entire Lower Linganore Creek watershed.

Table 2-19. Percent impervious values assigned to land uses in Lower Linganore Creek (after Camp, Dresser, and McKee 1997; CWP 1998)

Land Use	**Percent Impervious**
Agriculture (cropland, pasture, orchards/vineyards/horticulture*)	3
Feeding Operations/Agricultural Facilities	3
Low Density Residential	15
Medium Density Residential/Institutional	35
High Density Residential	60
Commercial	90
Industrial	80
Extractive*	80
Open Urban Land	5
Forest (deciduous, evergreen, mixed, brush)	1
Water	100
Bare Ground*	80
* Estimated values	

Currently, the amount of impervious surfaces within the Lower Linganore Creek watershed is good, with the estimated 7 percent imperviousness falling below the 10 percent

threshold value mentioned above (Table 2-20; Figure 2-18). The percent of impervious land cover was lowest in the New London subwatershed (3.8 percent) and highest in the Mainstem Linganore Creek subwatershed (10.9 percent). Therefore, while impervious values within the watershed are generally good at present, Long Branch and Mainstem Linganore Creek subwatersheds are approaching the threshold at which sensitive elements are likely to be lost.

Table 2-20. Estimates of impervious land cover in Lower Linganore Creek

Subwatershed	**Current**	**Future**
Bartonsville	5.5%	7.1%
Bens Branch	6.4%	8.6%
Chestnut Grove	4.2%	5.4%
Detrick	4.5%	4.8%
Hazelnut Run	5.8%	14.8%
Horseshoe Farms	4.3%	6.2%
Mainstem Linganore Creek	10.9%	21.6%
Long Branch	9.4%	14.1%
New London	3.8%	7.5%
Westwinds	5.1%	12.5%
Watershed Total	7.0%	12.4%

Future estimates of imperviousness, based on our projections of future land use, indicate that imperviousness within the watershed will reach 12.4 percent under the current maximum build-out scenario (Table 2-20). While this level of imperviousness is relatively low compared to many urbanized areas in Maryland, considerable increases in subwatershed imperviousness are predicted for Hazelnut Run, Mainstem Linganore Creek, Long Branch, and Westwinds. These areas are likely to incur greater stream and water quality impacts as more intensive development is targeted to these areas. Clearly, wise application of stormwater management measures will be needed throughout the watershed to prevent stream degradation in light of the expected increases in impervious surface.

2.7.4 Stormwater Management Facilities

To identify and describe the existing stormwater management facilities within the Lower Linganore Creek watershed, a GIS was used to plot site locations from Frederick County's SWM facility database (Figure 2-19). A review of the database identified 33 stormwater management facilities in Lower Linganore Creek watershed (Table 2-21; Figure 2-19).

Of the SWM facilities within the database, the most commonly found practices are extended dry detention (18 facilities) and extended wet detention (four facilities). There are two infiltration trenches, three dry ponds, two shallow marshes, and one oil and grit separator. Three of the facilities did not have a type listed in the database. One facility is reported to use a combination of extended dry detention and vegetation for stormwater management purposes. Two of these facilities, located at the Public Safety Training Facility and the Deer Crossing Elementary School, are County-owned and maintained.

Figure 2-18. Generalized view of current impervious surface coverage within Lower Linganore Creek watershed

Figure 2-19. Stormwater management facilities within Lower Linganore Creek watershed

Table 2-21. Stormwater management facilities in Lower Linganore Creek watershed

Subwatershed	Structure Number	Structure Name	Total Drainage Area (acres)	Storage Area (ac ft)	Practice Type
Bartonsville	123	Public Safety Training Facility	230	20	EDSW
Bens Branch	51	Jacobs Run	0.62	0.01	OGS
Bens Branch	484	White Oaks, Section 1 - ED Pond	28.4	1.05	EDSD
Bens Branch	485	White Oaks, Section 2, SWM Basin I	3.62	0.34	EDSD
Bens Branch	486	White Oaks, Section 2 - SWM Basin II	16	1.4	EDSD
Bens Branch	604	Hope Valley Golf Course, Basin #1	34.1	1.03	SM
Bens Branch	605	Hope Valley Golf Course, Basin #2	20.46	1	SM
Chestnut Grove	85	Libertytown Plaza, ED Basin	5.21	0.42	DP
Hazelnut Run	42	New Market West, SWM Pond No. 2	148.9	8.31	EDSD
Hazelnut Run	591	New Market West, SWM Pond #1	86	6.19	EDSD
Hazelnut Run	600	Deer Crossing Elementary School E.D. Pond	14.7	3.4	-
Long Branch	40	The Greens - Retention Pond	-	-	-
Long Branch	41	Spring Ridge - SWM Pond #8	71.7	10.2	EDSD
Long Branch	334	Turf Care Center at Holly Hills, WQ Facility	0.5	0.08	EDSD
Long Branch	346	Holly Hills, SWM Pond No. 2	36	2.47	EDSD & VEG
Long Branch	464	Spring Ridge - SWM Pond #9	25.2	6.3	EDSD
Long Branch	557	Preston - SWM Pond #1	12.1	1.58	EDSD
Long Branch	615	Fairwinds, Section 2	41.47	3.33	EDSD
Mainstem Linganore Creek	35	Aububon Terrace South	0	0	-
Mainstem Linganore Creek	302	Summerfield Pond No. 2	31.5	3.29	EDSD
Mainstem Linganore Creek	309	Summerfield Pond No. 1	44.9	3.77	EDSD
Mainstem Linganore Creek	324	Summerfield Pond No. 3	16	1.14	EDSD
Mainstem Linganore Creek	458	Spring Ridge, Quality Pond #4A	49	6.2	EDSD
Mainstem Linganore Creek	459	Spring Ridge, SWM Pond #4	439.4	19.5	DP
Mainstem Linganore Creek	460	Spring Ridge - SWM Pond #6	9.5	1.83	EDSD
Mainstem Linganore Creek	461	Spring Ridge - SWM Pond #7 (Retention Pond)	47.4	6	EDSW
Mainstem Linganore Creek	462	Spring Ridge - SWM Pond #7 (SHA Dry Pond)	34	2.86	DP
Mainstem Linganore Creek	463	Spring Ridge - SWM Pond #10	43.9	5	EDSD
Mainstem Linganore Creek	35A	Audubon, Sect. 4, SWM Pond	46	2.1	EDSD
New London	126	E.B. Machine Shop - Infiltration Trench	1.2	0.06	IT
New London	129	BFI, Inc. (was Eastern Waste Management)	4.18	0.08	IT
New London	468	Westwinds Tennis Pavilion - Phase B	23.7	2.94	EDSW
Westwinds	467	Westwinds, Phase 1A - Retention Pond	31	2	EDSW

Practice Types
EDSW – Extended Wet Detention EDSD – Extended Dry Detention DP – Dry Pond IT– Infiltration Trench
OGS – Oil & Grit Separator SM – Shallow Marsh VEG – Vegetation

2.7.5 NPDES-permitted Discharges

A review of the USEPA's Permit Compliance System (PCS) on-line database of NPDES permits, as well as the Permit Tracking System (PERTS) database that covers major permits issued by the MDE, identified no facilities with discharges to water in the Lower Linganore Creek watershed (USEPA 2001; Robert Daniel, MDE, personal communication, June 28, 2001).

2.7.6 Potential Sources of Contaminants

The USEPA maintains several databases accessible via the Internet that contain information on facilities that have been impacted by the improper use, storage, and/or disposal of hazardous and toxic materials. An on-line review of the USEPA's Toxic Releases Inventory (TRI) and the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) databases revealed that no facilities in Lower Linganore Creek watershed have been listed.

In rural areas such as the eastern portion of Lower Linganore Creek watershed, sewage from individual residential properties is frequently handled through the use of on-site septic tanks and leach fields. As these systems get older, they sometimes fail for a number of reasons, including a lack of proper maintenance. Their failure can lead to the introduction of insufficiently treated sewage into nearby surface and sub-surface waters. However, no obvious signs of these problems were noted in the watershed.

2.8 VISUAL INSPECTION FOR WATERSHED STRESSORS

A visual inspection of Lower Linganore Creek was conducted on June 26 and 27, 2001 to identify the types and locations of potential watershed stressors likely to impact water quality. Although it was impractical to visually inspect the entire watershed, inspection efforts were targeted to characterize potential impacts from each land use type. Prior to the visual survey, the County's SWM facility database, MDE's PERTS database, and the USEPA's PCS, CERCLIS, and TRI databases, as described in previous sections, were reviewed to identify the location of facilities that may involve the release of pollutants to surface water. During the visual inspection, personnel drove through the watershed and observed conditions at most of the stream and road crossings, as well as a large number of stormwater management facilities. Notes and photographs were taken at many of these locations to document stream and watershed conditions. To assess conditions at locations without road access, topographic maps and aerial photographs from March 2000 were also examined.

This survey revealed that while agriculture is clearly the dominant watershed land use, residential development has expanded steadily since about 1970. In the northern part of the study area, several older rural subdivisions, approximately 20-30 years old, were observed west of MD 75 and south of MD 26 amidst the area's agricultural and forested lands. The eastern part of the watershed is dominated by agriculture, particularly the New London, Bens Branch, and Detrick subwatersheds; however low-density residential development associated with Mount Airy and New Market is encroaching into the latter two subwatersheds. In the central and western portions of the watershed, residential development has largely been focused in several PUDs located around Lake Linganore. Sections of the Lake Linganore PUD, started in 1968, are still being constructed, including the Woodridge area north of the Lake Linganore dam. Although growth associated with the City of Frederick is expanding eastward into the watershed along the Interstate 70/MD 144 corridor into the Spring Ridge PUD, large tracts of the southwestern portion of the watershed remain under forest or agricultural use.

Hydrologic modifications, likely stemming from the area=s long agricultural history and development predating current stormwater management regulations, were the most apparent past and potential stressor to Lower Linganore Creek watershed. Agricultural practices, especially historical ones, such as clearing forests and riparian vegetation, draining wetlands, channelizing streams, plowing perpendicular to slopes, and situating pastures next to streams, have increased sedimentation, nutrient loads, and water transport in streams across the country (Smith et al. 2000). Historical development practices without stormwater management controls also increase sedimentation and rapidly convey water to natural drainage systems. Impacts can also occur even with modern stormwater management controls in place because they can effectively shorten the recurrence interval between channel forming flows. These modifications (and events) often upset the dynamic equilibrium between velocity, flow resistance, stream discharge, sediment size, and sediment load that influences channel morphology (i.e., channel width, depth, and slope) in natural stream channels (Nunnally 1978; Rosgen 1993). Once the equilibrium has been upset, it can often take several decades to reestablish a balance B one that could be very different than previously exhibited by the stream. It also may not be possible for a morphologically stable channel to develop, even after a considerable time (Keller 1975, 1978).

A number of locations along Lower Linganore Creek were observed to be severely incised and have destabilized banks due to changes in the stream=s dynamic equilibrium. The loss of equilibrium is likely brought about by an increase in impervious surfaces in the watershed and the increased flashiness that results from this change. The increased flashiness exacerbates flood pulses within the stream channel, and helps create more frequent channel forming flows. Additional sediment from upstream instabilities (e.g., farm field runoff, erosion from denuded construction sites, and trampled stream banks in livestock pastures) can also lead to downstream changes in channel morphology.

Specific findings of the visual assessment, including both good examples of stormwater management and several problem areas, are summarized below. For each site of interest, the current conditions and if applicable, associated stressors are described. Site numbers correspond with locations identified in Figure 2-20 and are listed from west to east. Structure ID numbers refer to the SWM structures listed in Table 2-21.

Site ID: 1
Description: Herbicide use at the Public Safety Training Facility (Structure ID 123)
Subwatershed: Bartonsville
Stream affected: Unnamed tributary to Monocacy River

Firefighter training activities are conducted at the County Public Training Facility. Water is withdrawn from the on-site, extended wet detention pond during training events. Much of the training facility is paved and most of the water used during training exercises drains back into the pond. As discussed with firefighting staff at the facility, to protect the pond's water quality, no hydrocarbons are used to fuel training fires. Inspection of the pond revealed that herbicides had apparently been used to control vegetation around the perimeter of the pond and around the water collection structures (Figure 2-21). Because certain herbicides are quite harmful to humans, fish and other aquatic organisms, herbicide applicators should ensure that only USEPA

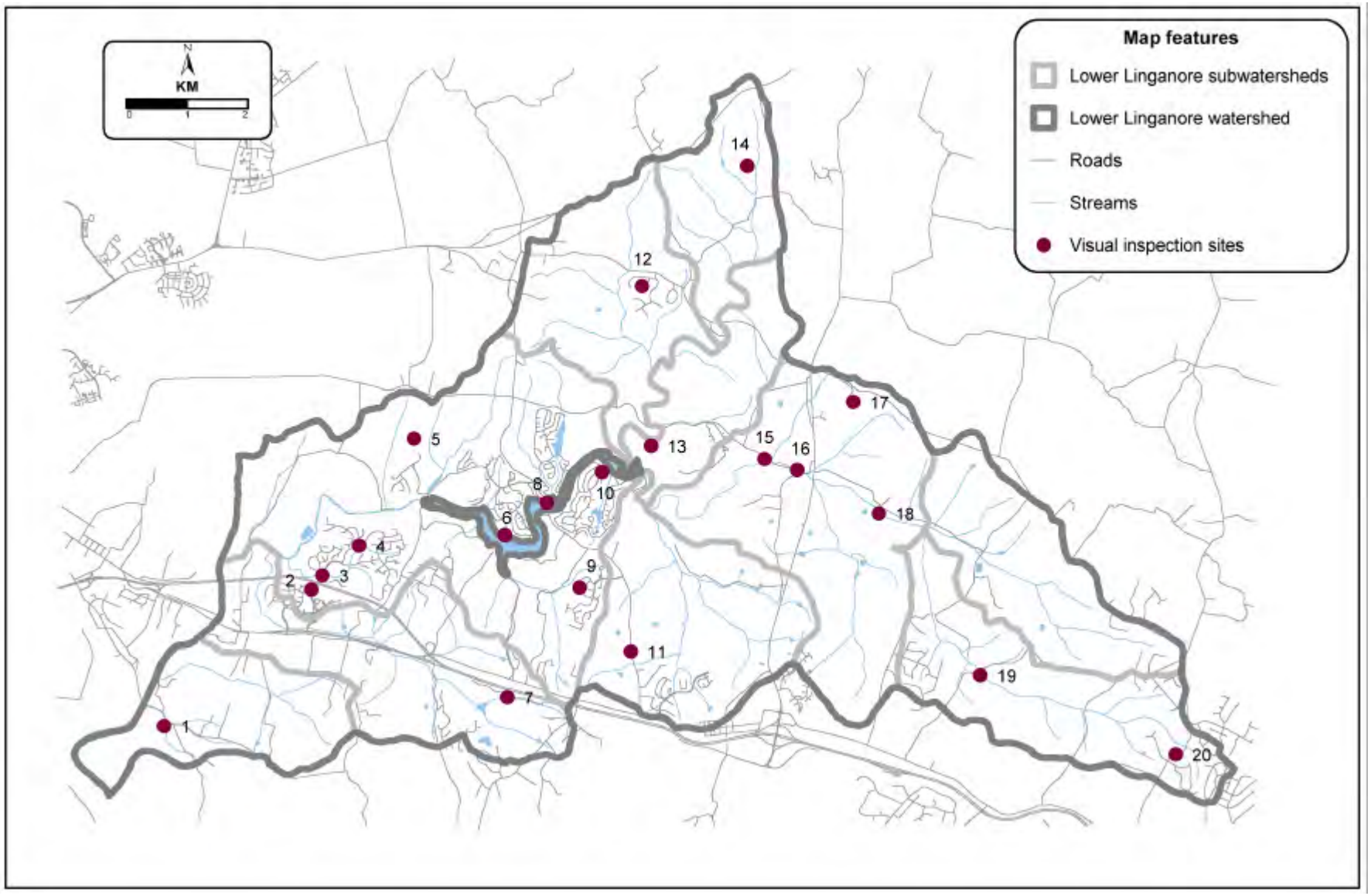

Figure 2-20. Visual inspection for watershed stressors within Lower Linganore Creek, Summer 2001

approved herbicides are used and that application conforms to the directions on the product labels. This recommendations is offered as general guidance only; the specific types of pesticides currently used at this site were not evaluated in this watershed assessment.

Figure 2-21. Only herbicides approved by the USEPA for use near water should be used to control vegetation around SWM facilities such as this one at the County's Public Safety Training Facility.

Site ID:	2
Description:	Extended dry detention facility (Structure ID 463) with trees growing in berm and around outlet
Subwatershed:	Mainstem Linganore Creek
Stream affected:	Unnamed tributary to Linganore Creek

Although the SWM facility appeared to be in good shape, trees and other woody vegetation were observed growing in the berm and around the outlet structure. Roots can penetrate the inner impervious clay barrier of the structure, loosen the seal around the outlet piping, and otherwise weaken the integrity of the structure, potentially leading to catastrophic failure.

Site ID: 3

Description: Wetland filtering flow into dry pond (Structure ID 459)

Subwatershed: Mainstem Linganore Creek

Stream affected: Unnamed tributary to Linganore Creek

An example of more recent SWM techniques evident in the Spring Ridge PUD, this wetland acting as a biofilter appeared to be well maintained and functioning properly (Figure 2-22).

Figure 2-22. Wetland vegetation used to slow stormwater runoff, trap sediment, and uptake nutrients in the Spring Ridge development.

Site ID: 4

Description: Stormwater impacts to drainage swale at Spring Forest Road and Barrington Drive

Subwatershed: Mainstem Linganore Creek

Stream affected: Unnamed tributary to Linganore Creek

The County notes that the developer of the Spring Ridge Community performed a TR-20 analysis at 0.5 acre resolution to support the use of stromdrain structures that back up to detain stormwater flow. However, an ephemeral channel draining the northern portion of the community shows signs of stormwater impacts. A fitness trail parallels the upper reaches of this swale and signs of erosion, including copious amounts of loose gravel located in the bottom of the channel, were evident in places (Figure 2-23). Farther down the hill, near Spring Forest Road and Barrington Drive, the swale passes through a culvert beneath the paved footpath. A blockage of the culvert had recently been cleared and signs indicated that the path had been overtopped and flows diverted into a stream in the adjacent woods. Large deposits of gravel had been deposited in the section of swale impounded by the blocked culvert. The culvert opening has also caused additional erosion of the swale as it flows into a vegetated swale (Figure 2-24). Concentrated flows appear to pass all the way through the swale, indicating that this facility is not working properly. Stormdrains from Spring Forest Road outlet into the swale below the vegetated section, which then flows into the top of a SWM pond by the park on Spring Forest Road. Major headcutting was evident at the upper end of this SWM pond, with flows cutting down 6-8 feet through a fractured and highly weathered schist outcrop (Figure 2-25).

Figure 2-23. Gravel deposits in a drainage swale along a footpath near Spring Forest Road.

Figure 2-24. Erosion of a drainage swale as it passes beneath a footpath and into a vegetated swale near Spring Forest Road and Barrington Drive.

Figure 2-25. Headcutting through weathered bedrock at the upper end of a SWM pond near Spring Forest Road and Barrington Drive. Note that the vertical drop is about 7 feet.

Site ID: 5
Description: Woodridge area of Lake Linganore
Subwatershed: Mainstem Linganore Creek
Stream affected: Unnamed tributaries to Linganore Creek

Unpaved roads, like those in the Woodridge area currently being developed, can undergo significant wind and water erosion and be a major source of sediment to nearby streams (Figure 2-26). This sediment can disrupt the dynamic equilibrium of stream channels, fill in the habitat used by fish and aquatic insects, and reduce the health, and reproductive and feeding success of living organisms. Stormdrains and curbs had been installed along portions of Woodland Road at the time of the site visit; however, the drains appeared to discharge a short distance into the steep, wooded slopes adjacent to the road. Flow controls were not apparent for these stormdrains. Several houses were also observed in the initial stages of construction; erosion controls and flow control structures were not readily apparent at that time.

Figure 2-26. Erosion of the road surface and adjacent ditches, as shown along this road in the Woodridge area, can be a major source of sediment to nearby streams and cause numerous physical and biological impacts.

Site ID: 6

Description: Direct drainage to Lake Linganore at North Shore Way

Subwatershed: Mainstem Linganore Creek

Stream affected: Lake Linganore

In many areas around Lake Linganore, including this area at the northwestern end of the lake, residential development is directly adjacent to the water. Curb breaks were observed on North Shore Way that drain stormwater from the road surface into grassy swales that connect directly to Lake Linganore (Figure 2-27). Although curb breaks and grassy swales are an important tool being used in Low Impact Development (LID) designs, their use here may be inappropriate given that riparian buffers in this area were almost non-existent, with steep roads and sloping lawns leading down to the waterline in many areas. As such, nonpoint pollution from roadways and lawns is probably washed directly into the water with little to no filtration or trapping of suspended sediments. It should be noted that the County does not have easements at this location.

Figure 2-27. Curb breaks and lawns allow road surface runoff to drain directly into Lake Linganore.

Site ID: 7
Description: Holly Hills Golf Course
Subwatershed: Long Branch
Stream affected: Long Branch

Several issues were noted at the Holly Hills Golf Course located in the southwestern portion of the watershed. Turf management at golf courses is an intensive activity and frequently large quantities of fertilizers, pesticides, and herbicide are used to provide lush, healthy greens. A cursory inspection of Holly Hills indicates that many of the greens extend down to the edges of streams and other waterbodies throughout the course. Because riparian buffers can typically minimize or mitigate nonpoint pollutant loads, the lack of buffer at the course indicates that loadings may be elevated. As also observed from Holly Hills Drive, silt fencing and soil from the construction of a golf cart path was collapsing into a stream (Figure 2-28).

Figure 2-28. Collapsed silt fencing and a lack of riparian buffers along streams were observed at the Holly Hills Golf Course.

Site ID: 8
Description: Waterfront properties at Boyers Mill Road
Subwatershed: Mainstem Linganore Creek
Stream affected: Lake Linganore

Residential properties along Boyers Mill Road were also observed to have little to no riparian buffer to protect the lake from lawn chemicals, road runoff, or other nonpoint pollution sources. An elevated sewer aqueduct running along the north side of the lake was also observed from this location (Figure 2-29).

Figure 2-29. Waterfront properties near Boyers Mill Road also have little to no riparian buffers to protect water quality. An elevated sewer aqueduct along the north side of the lake appears in the back of this photograph.

Site ID: 9

Description: Extended dry detention pond (Structure ID 302) at Huckleberry Way

Subwatershed: Mainstem Linganore Creek

Stream affected: Unnamed tributary to Lake Linganore

In the Summerfield development, most road drainage was directed into well-vegetated, grassy swales capable of slowing runoff velocities and trapping sediments. The swales were protected in places with riprap. Curbs and drains were present in the cul-de-sacs. Swales and drains fed into SWM facilities like the one shown in Figure 2-30.

Figure 2-30. Extended dry detention pond (Structure ID 302) at Huckleberry Way

Site ID: 10
Description: Inadequate SWM controls in Pinehurst area
Subwatershed: Mainstem Linganore Creek
Stream affected: Lake Anita Louise and unnamed tributary to Lake Linganore

The Pinehurst area was constructed in the 1970s and as with many developments constructed at this time, few SWM controls were incorporated into the design. The slopes leading down to Lake Anita Louise and unnamed tributary are relatively steep and impervious surfaces are moderately extensive. Flow control structures were not evident in this area. In general, road drainage is diverted into grassy swales that parallel the roads, offering minor protection as swales tend to slow runoff velocities somewhat and trap sediment. This area is currently being studied as part of LLCS's efforts to to identify potential SWM and road improvements.

Site ID: 11
Description: Livestock in the stream at Boyers Mill Road
Subwatershed: Hazelnut Run
Stream affected: Unnamed tributary to Hazelnut Run

Livestock were observed to have unrestricted access to the stream channel in this tributary to Hazelnut Run. Streambanks had been trampled and excessive algal growth was observed (Figure 2-31). Fecal matter deposited directly into the water is another likely impact to this stream that feeds into Lake Linganore, a major source of drinking water for the City of Frederick and surrounding areas.

Figure 2-31. Unrestricted livestock access to streams, such as this location on Boyers Mill Road, can not only cause excessive sedimentation, but can also threaten downstream drinking water sources like Lake Linganore.

Site ID: 12

Description: Older development at Horseshoe Farms Estates

Subwatershed: Horseshoe Farms

Stream affected: Unnamed tributary to Linganore Creek

Horseshoe Farms Estates is a rural subdivision built approximately in the 1970s. In this area, grass swales direct water to stormdrains that exit into the adjacent woods. The stormdrains were in disrepair, but appeared to be functional (Figure 2-32). Curbs are not present along the roads and structural flow controls were not apparent. Some sediment deposition and minor erosion was observed in the woods below one of the stormdrain outfalls (Figure 2-33). Although the slope was relatively steep in this area, conditions appeared to be somewhat stable.

Figure 2-32. Horseshoe Farms Estates is drained by grassy swales that drain to stormdrains in need of minor repairs.

Figure 2-33. Stormwater collected from Horseshoe Farms Estates is discharged into the adjacent woods, where minor erosion was observed.

Site ID: 13
Description: Road construction in the Westwinds development
Subwatershed: Westwinds
Stream affected: Lake Linganore

Sediment runoff from a road construction project through the Westwinds golf course was designed to flow into an on-site sediment basin; however, ruts and site grading prevented much of the runoff from flowing into the basin (Figures 2-34 and 2-35). In addition, the road continued downhill past the basin for approximately a half-mile, where it ended at the bottom of the steep slope approximately 30 feet from the wooded edge of Lake Linganore (Figure 2-36). Construction of the road beyond the sediment basin left berms on both sides that effectively funneled concentrated flows of water down the road, where super silt fence (chain link fence with fabric) was the only control at the bottom. County staff indicate that inappropriate erosion and sediment controls were implemented at this site; inadequate maintenance was also a problem, but has been addressed.

Figure 2-34. Road construction through the Westwinds golf course.

Figure 2-35. Sediment basin at the Westwinds road construction project. Water was prevented from entering the sediment basin by wheel ruts and improper grading. These maintenance issues have since been addressed.

Figure 2-36. Berms along both sides of the road prevent water from exiting the roadway, causing erosion and rutting down the half-mile long hill. Erosion and sediment controls may have been inadequately designed to protect Lake Linganore at the bottom of the hill.

Site ID: 13
Description: Sewer pipeline bisects floodplain forest
Subwatershed: Westwinds
Stream affected: Lake Linganore

A sewer pipeline was recently constructed on private property along the shore of Lake Linganore. The pipeline runs through a floodplain forest, approximately halfway between the edge of the water and the toe of the adjacent slope. MDE has determined that this forest is not a jurisdictional wetland. As shown in Figure 2-37, the pipeline has been elevated above the level of the floodplain to maintain grade and serve as a road, effectively creating a levee along this side of the Lake. Although this project has received a Waterway Construction Permit from MDE, the placement of the pipeline and supporting berm has effectively disconnected a large portion of the floodplain in this area, which can reduce natural flood storage area, alter the hydrology and forest composition behind the berm, and potentially exacerbate flooding elsewhere.

Figure 2-37. Sewer line and road bed construction along Lake Linganore has created a levee-like structure that is likely to reduce flood storage, impact forested wetlands, and potentially exacerbate flooding elsewhere.

Site ID: 14
Description: Exposed soil on hilltop west of Artie Kemp Road
Subwatershed: Chestnut Grove
Stream affected: Unnamed tributary to Linganore Creek

A large expanse of bare soil was observed about a half mile west of Artie Kemp Road behind the farm at 3601 Artie Kemp Road (Figure 2-38). Uncontrolled soil erosion may be problematic at this location. In addition, metal and other objects, visible from the road, may have been improperly disposed of at this location.

Figure 2-38. Area of exposed soil visible from northbound Artie Kemp Road.

Site ID: 15
Description: Livestock in the stream at Gas House Pike
Subwatershed: New London
Stream affected: Bens Branch

Livestock were observed to have unrestricted access to the stream channel all along this section of Bens Branch. Trampled streambanks have introduced large quantities of sediment to the stream at this location, resulting in channel adjustments that have lead to a wide channel incised into the landscape that has shallow water depths. Fecal matter deposited at this location may also threaten downstream drinking water quality.

Site ID: 16
Description: Incised stream reach at Gas House Pike
Subwatershed: New London
Stream affected: Bens Branch

Channel instabilities (e.g., downcutting, bank slumping, excess sediment load) and a severe lack of riparian vegetation were evident along a section of Bens Branch that extends from approximately Old Lime Plant Road downstream to the bridge at Gas House Pike. Eroding banks and other channel adjustments introduce excessive sediment load that increases downstream turbidity, reduces water quality and impairs physical habitat.

Site ID: 17
Description: Linganore High School
Subwatershed: New London
Stream affected: Unnamed tributary to Bens Branch

Trash and fine sediments from the parking lots had been washed into the stormdrains and deposited in the riprap aprons and grassy swales below the stormdrain outlets. Although no SWM facility was present at this location, it presents a potential retrofit and educational opportunity. In addition, herbicides had apparently been used around stormwater pathways at this County operated facility (Figure 2-39). As a general recommendation, herbicide applicators should ensure that only USEPA approved herbicides are used and that application conforms to the directions on the product labels.

Figure 2-39. Herbicides used around surface water pathways should be approved by USEPA for use near water.

Site ID: 18
Description: Braided stream channel across from Millime Court
Subwatershed: New London
Stream affected: Bens Branch

Bens Branch flows through a low gradient valley at this location and historical disturbances have likely caused the stream to become braided and potentially unstable in this approximately half-mile reach. The main channel branches out, and the two or more channels meander tortuously along the valley, just north of the old limestone quarry.

Site ID: 19
Description: Road debris washed into Bens Branch at Jessie Smith Road
Subwatershed: Bens Branch
Stream affected: Bens Branch

A widespread problem in many jurisdictions, gravel and trash is frequently washed from roadside ditches directly into streams as in this example at Bens Branch at Jessie Smith Road (Figure 2-40).

Figure 2-40. Roadside ditches typically discharge gravel, trash, and other road debris directly into many streams, as seen at Bens Branch at Jessie Smith Road.

Site ID: 20

Description: Countryside Auto Parts

Subwatershed: Bens Branch

Stream affected: Bens Branch

Countryside Auto Parts is a large scrapyard for cars and trucks located at 5242 Sydney Road near Mount Airy (Figure 2-41). The facility is located in the headwaters of Bens Branch. Slopes in this area are relatively steep and the facility did not appear to have adequate stormwater controls to prevent materials (e.g., fuel, oil and grease, metals) from washing into the receiving waters, although a detailed inspection was not done for this assessment. The County reports that illicit connection complaints have been received about this scrapyard site; however, the site is grandfathered for zoning and stormwater management ordinances. The County performed water quality tests for standard stormwater pollutants in January 2002 and observed that tested parameters (pH, phenol, chlorine, detergent, and copper) were slightly lower downstream of the scrapyard than above it.

Figure 2-41. Countryside Auto Parts is a scrapyard located in the headwaters of Bens Branch. If not properly controlled, runoff could wash contaminants into the receiving waters

3.0 SWMM MODELING

Present and future pollutant loadings from the Lower Linganore Creek watershed were modeled to provide information on the types and quantities of pollutants likely to threaten water quality. This information will enable Frederick County officials to make better decisions about where to focus their efforts and resources to protect existing and future water quality. In this section, we document details of the modeling method, input data, and assumptions, along with results for Lower Linganore Creek watershed.

For this simulation, a modified version of USEPA's Stormwater Management Model (SWMM) was chosen. This model incorporates hydrological, topographical, and land use data from the watershed, and uses this information to calculate pollutant loads. Total pollutant loads over several representative years were simulated in order to give a more accurate picture of the watershed.

SWMM is made up of many different modules, or "blocks". For the Lower 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 can simulate up to ten different pollutants at one time. The ten pollutants that were modeled were total nitrogen (TN), total phosphorus (TP), ortho phosphorus (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, 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 water quality of the simulation.

3.1 HYDROLOGICAL DATA

Historical rain information from BWI Airport for the period from 1980 to 1992 was examined. Simulations were run for three years, 1989, 1991, and 1992, respectively representing the wet, dry and average years, during that period. Monthly rainfall totals used in the simulations are summarized in Table 3-1. Rainfall data from BWI were used because it was the closest rain gauge to the study area that contained hourly rainfall data for the simulation period.

Monthly evaporation rates (Table 3-2) 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).

Table 3-1. Summary of monthly rainfall totals (inches) from BWI airport used for the Lower Linganore Creek SWMM simulation period. Simulations were run for wet (1989), dry (1991), and average (1992) years.

	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 3-2. 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

3.2 TOPOGRAPHICAL DATA

There are approximately 24,100 acres in the Lower Linganore Creek watershed. To improve the resolution of the model, the 10 subwatersheds shown in Figure 2-2 were subdivided into 52 catchments following methods outlined in Section 2.1.

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 established following the appropriate contours of the map. Once the flow length was determined, the width and slope of each catchment were calculated. Table 3-3 shows the width, area, and slope of each of the 52 catchments.

Table 3-3. Topographical data for each catchment in Lower Linganore Creek watershed			
Catchment	**Width (feet)**	**Area (acres)**	**Slope (ft/ft)**
Bartonsville – A	3811	419	0.0334
Bartonsville – B	1306	135	0.0401
Bartonsville – C	2189	541	0.0223
Bartonsville – D	3831	449	0.0470
Bens Branch – A	3558	307	0.0160
Bens Branch – B	4679	341	0.0063
Bens Branch – C	5601	690	0.0149
Bens Branch – D	2259	263	0.0355
Bens Branch – E	2136	159	0.0432
Bens Branch - F	2651	527	0.0231
Chestnut Grove - A	3863	750	0.0284
Chestnut Grove - B	2553	504	0.0279
Detrick – A	4152	758	0.0176
Detrick - B	2553	476	0.0148
Detrick - C	2700	607	0.0245
Hazelnut Run - A	3603	273	0.0061
Hazelnut Run - B	1424	154	0.0404
Hazelnut Run - C	2963	679	0.0160
Hazelnut Run - D	2397	442	0.0249

Table 3-3. (Continued)			
	Width (feet)	**Area (acres)**	**Slope (ft/ft)**
Hazelnut Run - E	2209	417	0.0243
Hazelnut Run - F	3056	333	0.0295
Horseshoe Farms - A	4466	986	0.0125
Horseshoe Farms - B	4201	1037	0.0260
Linganore Creek - A	3079	565	0.0175
Linganore Creek - B	4535	691	0.0301
Linganore Creek - C	2825	665	0.0273
Linganore Creek - D	2975	629	0.0282
Linganore Creek - E	3117	110	0.1297
Linganore Creek - F	4318	298	0.0533
Linganore Creek - G	1991	207	0.0309
Linganore Creek - H	3674	216	0.0861
Linganore Creek - I	4532	892	0.0268
Linganore Creek - J	1869	131	0.0589
Linganore Creek - K	927	58	0.0444
Linganore Creek - L	6851	349	0.0992
Linganore Creek - M	3224	568	0.0130
Long Branch - A	3442	450	0.0141
Long Branch - B	3638	432	0.0039
Long Branch - C	5025	454	0.0102
Long Branch - D	2763	373	0.0221
Long Branch - E	3153	593	0.0195
Long Branch - F	2648	231	0.0264
New London - A	2861	804	0.0041
New London - B	2231	318	0.0258
New London - C	2589	506	0.0223
New London - D	3047	494	0.0071
New London - E	2568	593	0.0119
New London - F	3497	789	0.0142
Westwinds - A	3039	256	0.0491
Westwinds - B	2192	308	0.0424
Westwinds - C	2688	287	0.0517
Westwinds - D	3740	399	0.0430

3.3 LAND USE

Because land use is a major driving force in pollutant loadings, three scenarios were simulated for each year: pre-development, existing, and future land use. The pre-development scenario assumed the area was completely forested. Existing land use was determined using 1997 MOP land use. Future land use was based on zoning maps and projected build-out conditions, as described in Section 2.4.2. Current land uses represent a mixture of residential, agriculture, and forest types, varying by subwatershed (Table 3-4). Because of uncertainties in

preojecting specific land uses, some categories were grouped in the future scenario (e.g., cropland and pasture were grouped together as agriculture). Future land uses by subwatershed are shown in Table 3-5.

SWMM used land use percentages directly to calculate how much pollutant buildup there will be in a catchment. Land use percentages by catchment were also used to determine percentage of impervious areas and Manning roughness coefficients, 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 3-6. The estimated percent DCIA and pervious and impervious Manning coefficients in each Lower Linganore catchment are listed in Table 3-7.

Depression storage represents 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.

3.4 SOILS

Hydrologic soil group data, as described in Section 2.2.3 and shown in Figure 2-5, were also used in 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 3-8. The maximum and minimum infiltration rates calculated for each Lower Linganore catchment are listed in Table 3-9.

Table 3-4. Percentages of land use by subwatershed under current conditions

Subwatershed	Low-density Residential	Medium-density Residential	High-density Residential	Commercial	Open Urban Land	Cropland	Pasture	Forested	Bare Ground	Water
Bartonsville	23%	1%	0%	0%	4%	15%	24%	33%	0%	0%
Bens Branch	27%	1%	0%	1%	0%	24%	6%	40%	0%	0%
Chesnut Grove	3%	0%	0%	2%	0%	64%	4%	27%	0%	0%
Detrick	14%	0%	0%	0%	0%	67%	8%	11%	0%	0%
Hazelnut Run	6%	7%	0%	0%	0%	55%	10%	22%	0%	0%
Horseshoe Farms	14%	1%	0%	0%	1%	43%	8%	34%	0%	0%
Linganore Creek	6%	15%	2%	0%	0%	26%	11%	38%	1%	1%
Long Branch	20%	3%	0%	1%	8%	35%	11%	20%	3%	0%
New London	4%	2%	0%	0%	1%	60%	13%	20%	0%	0%
Westwinds	0%	8%	0%	0%	12%	30%	5%	45%	0%	0%

Table 3-5. Percentages of land use by subwatershed under future conditions

Subwatershed	Low-density Residential	Medium-density Residential	High-density Residential	Commercial	Open Urban Land	Agriculture	Forested	Water
Bartonsville	31%	1%	0%	0%	4%	61%	2%	0%
Bens Branch	39%	1%	0%	1%	0%	59%	0%	0%
Chesnut Grove	7%	0%	0%	2%	0%	91%	0%	0%
Detrick	15%	0%	0%	0%	0%	85%	0%	0%
Hazelnut Run	11%	30%	0%	1%	5%	53%	0%	0%
Horseshoe Farms	18%	3%	0%	0%	1%	78%	0%	0%
Linganore Creek	7%	49%	2%	0%	0%	38%	3%	1%
Long Branch	47%	10%	0%	2%	8%	31%	1%	0%
New London	6%	8%	0%	2%	1%	83%	0%	0%
Westwinds	0%	29%	0%	0%	12%	59%	0%	0%

Table 3-6. 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 3-7. DCIA percentages and Manning Coefficients in each catchment for current and future conditions

Catchment	Current			Future		
	DCIA	Impervious Manning Coefficients	Pervious Manning Coefficients	DCIA	Impervious Manning Coefficients	Pervious Manning Coefficients
Bartonsville - A	4%	0.0150	0.3603	5%	0.0150	0.3801
Bartonsville - B	10%	0.0150	0.3244	10%	0.0150	0.3218
Bartonsville - C	6%	0.0150	0.3060	9%	0.0150	0.3278
Bartonsville - D	6%	0.0150	0.3222	9%	0.0150	0.3413
Bens Branch - A	10%	0.0150	0.2991	12%	0.0150	0.2933
Bens Branch - B	3%	0.0150	0.3594	7%	0.0150	0.3618
Bens Branch - C	3%	0.0150	0.3311	6%	0.0150	0.3814
Bens Branch - D	12%	0.0150	0.2972	13%	0.0150	0.3259
Bens Branch - E	2%	0.0150	0.3415	4%	0.0150	0.3986
Bens Branch - F	10%	0.0150	0.2782	13%	0.0150	0.2808
Chestnut Grove - A	3%	0.0150	0.3637	5%	0.0150	0.3816
Chestnut Grove - B	6%	0.0150	0.3709	8%	0.0150	0.3936
Detrick - A	4%	0.0150	0.3849	4%	0.0150	0.3941
Detrick - B	4%	0.0150	0.3747	5%	0.0150	0.3884
Detrick - C	7%	0.0150	0.3411	8%	0.0150	0.3478
Hazelnut Run - A	4%	0.0150	0.3503	12%	0.0150	0.3398
Hazelnut Run - B	3%	0.0150	0.3899	8%	0.0150	0.3643
Hazelnut Run - C	4%	0.0150	0.3637	8%	0.0150	0.3621
Hazelnut Run - D	3%	0.0150	0.3696	13%	0.0150	0.3314

Table 3-7. (Continued)

Catchment	Current			Future		
	DCIA	Impervious Manning Coefficients	Pervious Manning Coefficients	DCIA	Impervious Manning Coefficients	Pervious Manning Coefficients
Hazelnut Run - E	3%	0.0150	0.3767	14%	0.0150	0.3253
Hazelnut Run - F	16%	0.0150	0.3022	20%	0.0150	0.2581
Horseshoe Farms - A	4%	0.0150	0.3354	6%	0.0150	0.3744
Horseshoe Farms - B	5%	0.0150	0.3516	7%	0.0150	0.3608
Linganore Creek - A	3%	0.0150	0.3677	6%	0.0150	0.3777
Linganore Creek - B	3%	0.0150	0.3313	12%	0.0150	0.3284
Linganore Creek - C	3%	0.0150	0.3401	10%	0.0150	0.3529
Linganore Creek - D	8%	0.0150	0.3551	12%	0.0150	0.3415
Linganore Creek - E	6%	0.0150	0.2996	17%	0.0150	0.3075
Linganore Creek - F	28%	0.0217	0.2803	35%	0.0217	0.2619
Linganore Creek - G	20%	0.0150	0.2674	25%	0.0150	0.2536
Linganore Creek - H	24%	0.0268	0.2972	34%	0.0268	0.2823
Linganore Creek - I	7%	0.0150	0.3413	19%	0.0150	0.2829
Linganore Creek - J	7%	0.0150	0.2993	12%	0.0150	0.3194
Linganore Creek - K	4%	0.0150	0.2918	18%	0.0150	0.2842
Linganore Creek - L	4%	0.0150	0.2998	18%	0.0150	0.2734
Linganore Creek - M	15%	0.0150	0.3023	27%	0.0150	0.2536
Long Branch - A	7%	0.0150	0.2948	15%	0.0150	0.2697
Long Branch - B	15%	0.0150	0.2986	26%	0.0150	0.2740
Long Branch - C	6%	0.0150	0.3501	8%	0.0150	0.3402
Long Branch - D	6%	0.0150	0.3535	10%	0.0150	0.3353
Long Branch - E	5%	0.0150	0.3453	11%	0.0150	0.2748
Long Branch - F	6%	0.0150	0.3774	8%	0.0150	0.3535
New London - A	4%	0.0150	0.3578	11%	0.0150	0.3421
New London - B	4%	0.0150	0.3836	5%	0.0150	0.3905
New London - C	5%	0.0150	0.3743	6%	0.0150	0.3860
New London - D	3%	0.0150	0.3695	13%	0.0150	0.3801
New London - E	4%	0.0150	0.3678	5%	0.0150	0.3888
New London - F	4%	0.0150	0.3774	6%	0.0150	0.3835
Westwinds - A	10%	0.0150	0.2932	18%	0.0150	0.2675
Westwinds - B	4%	0.0150	0.3180	17%	0.0150	0.2872
Westwinds - C	2%	0.0150	0.3469	4%	0.0150	0.4000
Westwinds - D	3%	0.0150	0.3519	4%	0.0150	0.3984

Table 3-8. 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 3-9. Maximum and minimum infiltration rates per catchment.					
Catchment	**Maximum infiltration (in/hr)**	**Minimum infiltration (in/hr)**	**Catchment**	**Maximum infiltration (in/hr)**	**Minimum infiltration (in/hr)**
Bartonsville – A	0.74	0.02	Linganore Creek - D	0.66	0.02
Bartonsville – B	0.80	0.03	Linganore Creek - E	0.68	0.02
Bartonsville – C	0.68	0.02	Linganore Creek - F	0.67	0.02
Bartonsville – D	0.56	0.02	Linganore Creek - G	0.63	0.02
Bens Branch – A	0.66	0.02	Linganore Creek - H	0.43	0.02
Bens Branch – B	0.70	0.02	Linganore Creek - I	0.51	0.02
Bens Branch – C	0.68	0.02	Linganore Creek - J	0.68	0.02
Bens Branch – D	0.71	0.02	Linganore Creek - K	0.74	0.02
Bens Branch – E	0.71	0.02	Linganore Creek - L	0.63	0.02
Bens Branch – F	0.73	0.02	Linganore Creek - M	0.68	0.02
Chestnut Grove - A	0.67	0.02	Long Branch – A	0.69	0.02
Chestnut Grove - B	0.63	0.02	Long Branch – B	0.60	0.02
Detrick – A	0.64	0.02	Long Branch – C	0.59	0.02
Detrick – B	0.66	0.02	Long Branch – D	0.66	0.02
Detrick – C	0.75	0.02	Long Branch – E	0.64	0.02
Hazelnut Run - A	0.52	0.02	Long Branch – F	0.64	0.02
Hazelnut Run - B	0.55	0.02	New London – A	0.75	0.02
Hazelnut Run - C	0.49	0.02	New London – B	0.75	0.03
Hazelnut Run - D	0.67	0.02	New London – C	0.58	0.02
Hazelnut Run - E	0.57	0.02	New London – D	0.61	0.02
Hazelnut Run - F	0.53	0.02	New London – E	0.68	0.02
Horseshoe Farms - A	0.61	0.02	New London – F	0.65	0.02
Horseshoe Farms - B	0.65	0.02	Westwinds – A	0.76	0.03
Linganore Creek - A	0.68	0.02	Westwinds – B	0.84	0.03
Linganore Creek - B	0.55	0.02	Westwinds – C	0.69	0.02
Linganore Creek - C	0.63	0.02	Westwinds - D	0.83	0.03

3.5 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 availabe 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 availabe for washoff, lbs/ac
r	=	runoff rate during time interval, in/hr
t	=	time interval, hr

Calibrated QFACT(1) values are shown in Table 3-10.

3.6 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 3-11) were taken from the Patapsco study and adjusted according to Winer (2000).

3.7 CALIBRATION

Rainfall data from 1980 to 1986 was used in the calibration of the Lower Linganore Creek model. 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

Table 3-10. 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 3-11. 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

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 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%. The calibrated QFACT(1) values were then used for the simulations for the Lower Linganore Creek watershed.

3.8 MODELED POLLUTANT LOADS

Once all the simulations were run, the total yearly pollutant loads were analyzed and mapped for the wet year. Results for wet year conditions are presented here because they have the highest loadings and represent a worst-case scenario. To facilitate overall comparison of the subwatersheds, the pollutant loads per acre were calculated. The ten subwatersheds were ranked by wet-year pollutant loadings, with larger loadings receiving a higher rank. For example, an area with the highest loadings would be ranked 10 and an area with the lowest loadings would be ranked 1. Rankings for both current and future scenarios, are shown in Tables 3-12 and 3-13. Those pollutants with the highest rankings have the highest pollutant loads per acre, and vice versa. 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 most heavily impacted by pollutants. Pollutant removals provided by existing SWM facilities have been factored into the following scenarios.

3.8.1 Current Scenario

For the current scenario, pollutant loadings for total nitrogen, total phosphorus, BOD, TSS, copper and zinc, are shown in Figures 3-1 through 3-6. Since Total and ortho phosphorus have similar results, as do BOD and COD, only figures for TP and BOD were included. Copper is shown because it is an agricultural pollutant, while zinc is used to illustrate the impact urban pollutant metals may have on the watershed.

The three subwatersheds that contain the highest agricultural pollutant loadings are Chestnut Grove, Detrick and Hazelnut Run. As shown in the land use map (Figure 2-9), these subwatersheds have the highest amounts of agricultural lands. Forested areas produce relatively

Table 3-12. Lower Linganore Creek subwatershed rankings by pollutant loadings for a current wet year scenario

	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	1	1	1	3	1	1.4	1	2	4	6	6	7	5.0	6
Bens Branch	3	3	3	1	2	2.4	3	5	7	8	8	8	7.2	7
Chestnut Grove	9	9	9	9	10	9.2	9	7	5	5	4	3	4.8	5
Detrick	10	10	10	10	9	9.8	10	6	6	4	3	4	4.6	4
Hazelnut Run	8	8	8	8	8	8.0	8	9	8	7	7	6	7.4	8
Horseshoe Farms	5	4	4	5	5	4.6	5	1	2	2	2	2	1.8	2
Linganore Creek	4	5	5	4	4	4.4	4	10	10	10	10	10	10.0	10
Long Branch	6	6	6	6	6	6.0	6	8	9	9	9	9	8.8	9
New London	7	7	7	7	7	7.0	7	3	1	1	1	1	1.4	1
Westwinds	2	2	2	2	3	2.2	2	4	3	3	5	5	4.0	3

Table 3-13. Lower Linganore Creek subwatershed rankings by pollutant loadings for a future wet year scenario

	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	5	2	2	4	6	3.8	4	3	5	5	4	5	4.4	4
Bens Branch	4	3	3	3	5	3.6	3	5	6	6	6	6	5.8	6
Chestnut Grove	10	10	10	10	10	10.0	10	4	3	2	3	2	2.8	3
Detrick	8	7	7	8	8	7.6	8	1	1	1	1	1	1.0	1
Hazelnut Run	6	8	8	6	4	6.4	6	9	9	8	8	8	8.4	8
Horseshoe Farms	7	6	6	7	7	6.6	7	2	2	3	2	3	2.4	2
Linganore Creek	2	5	5	2	1	3.0	2	10	10	10	10	10	10.0	10
Long Branch	1	1	1	1	2	1.2	1	7	8	9	9	9	8.4	9
New London	9	9	9	9	9	9.0	9	6	4	4	5	4	4.6	5
Westwinds	3	4	4	5	3	3.8	5	8	7	7	7	7	7.2	7

Figure 3-1. Pollutant loadings (lb/ac) for TN in the Lower Linganore Creek watershed, for the current scenario

Figure 3-2. Pollutant loadings (lb/ac) for TP in the Lower Linganore Creek watershed, for the current scenario

Figure 3-3. Pollutant loadings (lb/ac) for BOD in the Lower Linganore Creek watershed, for the current scenario

Figure 3-4. Pollutant loadings (lb/ac) for TSS in the Lower Linganore Creek watershed, for the current scenario

Figure 3-5. Pollutant loadings (lb/ac) for copper in the Lower Linganore Creek watershed, for the current scenario

Figure 3-6. Pollutant loadings (lb/ac) for zinc in the Lower Linganore Creek watershed, for the current scenario

smaller agricultural pollutant loads, and as such, subwaterhed with larger proportions of forest were ranked lower. The three subwatersheds with the least agricultural pollutant loadings are Bartonsville, Bens Branch, and Westwinds. All of these have more forested than agricultural land, so the low rankings were expected.

Urban pollutant rankings were highest for the Mainstem Linganore Creek and Long Branch subwatersheds. Both contain a high percentage of medium-density and high-density residential land, as well as some commercial lands. The next highest ranked subwatersheds for urban pollutants are Hazelnut Run and Bens Branch. Hazelnut Run contains a large amount of medium-density residential and commercial land, while Bens Branch contains more low-density residential along with some medium-density residential lands. Horseshoe Farms and New London subwatersheds have the least amount of urban pollutants, because both have very little residential land, and no commercial land.

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, Mainstem Linganore Creek may have the highest urban loadings, but has less than average agricultural loadings. However, Long Branch and Hazelnut Run subwatersheds both have high agricultural and urban rankings because they have large amounts of residential and commercial lands, as well as a high percentage of agricultural lands.

3.8.2 Future Scenario

Pollutant loadings for the future scenario are shown in Figures 3-7 through 3-12. As outlined for the current scenario, maps include total nitrogen, total phosphorus, BOD, TSS, copper and zinc.

In the future scenario, the Chestnut Grove and New London subwatersheds have the highest concentration of agricultural pollutants. Future land use projections indicate that in both of these subwatersheds, along with several others, considerable amounts of forested land will be converted to agricultural land uses. Chestnut Grove and New London subwatersheds also had high agricultural pollutant rankings in the current scenario. The two other subwatersheds that had high agricultural rankings in the current scenario, Detrick, and Hazelnut Run, had very little new agricultural land in the future, and therefore are ranked lower than Chestnut Grove and New London. They continue to have higher agricultural pollutant rankings than the other six subwatersheds.

Figure 3-7. Pollutant loadings (lb/ac) for TN in the Lower Linganore Creek watershed, for the future scenario

Figure 3-8. Pollutant loadings (lb/ac) for TP in the Lower Linganore Creek watershed, for the future scenario

Figure 3-9. Pollutant loadings (lb/ac) for BOD in the Lower Linganore Creek watershed, for the future scenario

Figure 3-10. Pollutant loadings (lb/ac) for TSS in the Lower Linganore Creek watershed, for the future scenario

Figure 3-11. Pollutant loadings (lb/ac) for copper in the Lower Linganore Creek watershed, for the future scenario

Figure 3-12. Pollutant loadings (lb/ac) for zinc in the Lower Linganore Creek watershed, for the future scenario

The Long Branch subwatershed has the lowest agricultural pollutant loadings in the future scenario. In the current scenario, it had a higher than average rank. The Bartonsville, Westwinds and Bens Branch subwatersheds had the least agricultural pollutants in the current scenario, and were still ranked very low in the future scenario. The Long Branch subwatershed lost forested and agricultural lands to low-density residential development in the future scenario, and therefore has less agricultural pollutants.

Urban pollutant loadings in the future scenario were highest for the mainstem Linganore Creek and Long Branch subwatersheds. The Hazelnut Run subwatershed is also ranked highly. In all three subwatersheds, agricultural lands had been converted into medium density residential lands, which increased urban pollutant loadings.

The three subwatersheds in the future scenario that have the least urban pollutant loadings are Chestnut Grove, Detrick, and Horseshoe Farms subwatersheds. Although urban pollutant loadings increased for all subwatersheds, these three subwatersheds had the smallest increase because most of the other subwatersheds had much more development.

In general, pollutant loadings increased for most subwatersheds in the future scenario (Figures 3-7 to 3-12). Only the pollutants dependent on agricultural and forested land uses decreased as those land uses were converted to residential uses. This trend occurred with copper, total and ortho phosphorus, total nitrogen, and total suspended solids. Copper loadings decreased in most subwatersheds, including Long Branch, Hazelnut Run, and Linganore Creek subwatersheds, which are projected to lose much forested area to residential development. The four remaining pollutants (TP, OP, TN, and TSS) decreased in Long Branch E, Hazelnut Run F and Linganore Creek M catchments, due to conversions of current agricultural land to future residential lands.

3.9 POLLUTANT REMOVAL BY STORMWATER FACILITIES

Currently, there are 33 stormwater facilities in the Lower Linganore Creek watershed. Several of these have very small drainage areas (i.e., less than nine acres), and therefore, would have little impact on the pollutant loadings within the watershed as a whole. From the remaining stormwater facilities, with a drainage area of more than nine acres, 25 were chosen for more in-depth analysis. The 25 facilities are located within seven subwatersheds.

Each SWM pond was analyzed separately in SWMM to determine the impact it had on its subwatershed. First, the drainage area of each facility was delineated on a topographic map so that the shape of the drainage area could be determined. These shapes were then digitized into a GIS and overlaid onto land use maps to find the type and amount of land draining into each pond. Slopes for each drainage area 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.

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).

The largest pond in the watershed (Structure ID 459 in the Mainstem Linganore Creek subwatershed) was much larger than all the other facilities, and several smaller ponds, and their drainage areas, were located entirely within its drainage area. To properly analyze this pond, only the area that was not covered by the other ponds was used to find the pollutant loadings. To find the total pollutant loadings entering the largest pond, the loadings from SWMM were combined with the loadings coming out of the ponds inside of the drainage area of the large pond after they had removed a percentage of the pollutants. The total pollutants were then multiplied by the removal efficiency for that pond.

Once the pollutant removals were calculated for each of the 25 ponds, they were compared to the pollutant loadings for each subwatershed. The percent of pollutants removed from each associated catchment and subwatershed were calculated, and are presented in Tables 3-14 and 3-15 for the current scenario, and in Tables 3-16 and 3-17 for the future scenario. Over 50 percent of some pollutants were removed from the Linganore Creek M catchment for the current scenario. Linganore Creek M and Hazelnut Run F catchments both exhibited greatly reduced loadings due to existing SWM ponds. Long Branch A and F, and Westwinds B catchments also had large removals. Once the catchments were aggregated at the subwatershed level (Table 3-14), the impacts of the stormwater facilities were not as dramatic. Nevertheless, individual subwatersheds had up to thirteen percent of pollutants removed by the SWM facilities.

Hazelnut Run and Long Branch subwatersheds, as shown in Table 3-12, had high rankings for both agricultural and urban pollutant loadings. Tables 3-14 through 3-17 demonstrate that both of these subwatersheds also had some of the highest pollutant removals by SWM facilities.

In the future scenario (Table 3-16), pollutant removals by catchment followed a similar pattern to the current scenario. However, a maximum of 40 percent of some pollutants were removed. When catchment removals were aggregated by subwatershed (Table 3-17), SWM facilities removed up to nine percent of pollutants.

3.10 CONCLUSION

SWMM modelling provided useful results for comparing nonpoint pollutant loadings originating from various areas within Lower Linganore watershed. In the current scenario, subwatersheds with the highest urban pollutant loadings were Mainstem Linganore Creek and Long Branch (Table 3-12). Those subwatersheds with the least urban pollutants are New London and Horseshoe Farms. The subwatersheds with the highest agricultural pollutant loadings are Chestnut Grove and Detrick, while the lowest agricultural loadings are Bartonsville,

Table 3-14. Percentage of removals by stormwater facilities in each catchment for the wet year, current scenario. Area (acres) indicates the total surface treated by SWM facilities.

	Catchment Area (ac)	TN	TP	OP	BOD	COD	TSS	PB	CU	ZN	CD
Bartonsville - A	419	2%	3%	4%	2%	2%	6%	6%	2%	5%	2%
Bens Branch - C	690	1%	1%	1%	1%	1%	2%	2%	2%	2%	3%
Bens Branch - F	527	3%	2%	-1%	3%	3%	5%	5%	2%	3%	6%
Hazelnut Run - B	154	4%	2%	-1%	3%	3%	7%	5%	3%	3%	6%
Hazelnut Run - F	333	25%	15%	-8%	15%	16%	48%	25%	24%	17%	34%
Linganore Creek - F	298	4%	3%	-1%	3%	3%	8%	4%	4%	3%	7%
Linganore Creek - I	892	3%	3%	-2%	7%	6%	5%	17%	1%	10%	12%
Linganore Creek - L	349	1%	1%	-1%	2%	2%	2%	7%	1%	3%	4%
Linganore Creek - M	568	14%	27%	6%	10%	9%	25%	56%	17%	24%	58%
Long Branch - A	450	8%	6%	-3%	8%	7%	23%	20%	8%	13%	18%
Long Branch - B	432	4%	2%	-1%	4%	3%	7%	8%	3%	5%	6%
Long Branch - E	593	3%	2%	-1%	2%	2%	6%	3%	3%	2%	4%
Long Branch - F	231	15%	8%	4%	16%	16%	15%	23%	12%	20%	18%
New London - A	804	1%	2%	3%	1%	1%	3%	3%	1%	4%	1%
Westwinds - B	308	6%	10%	12%	5%	5%	14%	19%	5%	16%	5%

Table 3-15. Percentages of removals by stormwater facilities in each subwatershed for the wet year, current scenario

	Subwatershed Area (ac)	TN	TP	OP	BOD	COD	TSS	PB	CU	ZN	CD
Bartonsville	1545	0.6%	1.0%	1.2%	0.4%	0.4%	2.0%	1.0%	0.8%	1.0%	0.5%
Bens Branch	2286	0.8%	0.8%	0.0%	0.9%	1.0%	1.6%	2.2%	0.9%	1.4%	2.4%
Hazelnut Run	2297	4.2%	2.9%	-1.6%	4.3%	4.3%	7.7%	11.6%	3.1%	6.6%	9.4%
Linganore Creek	5379	2.4%	4.1%	0.4%	2.8%	2.5%	4.4%	13.5%	2.1%	6.0%	11.3%
Long Branch	2532	4.0%	2.5%	-0.4%	4.1%	3.7%	7.1%	8.4%	3.7%	5.8%	6.9%
New London	3504	0.2%	0.4%	0.5%	0.2%	0.3%	0.6%	0.5%	0.3%	0.7%	0.3%
Westwinds	1250	1.2%	2.1%	2.6%	1.2%	1.2%	2.9%	4.2%	1.1%	3.6%	1.1%

Table 3-16. Percentage of removals by stormwater facilities in each catchment for the wet year, future scenario

	Catchment Area (ac)	TN	TP	OP	BOD	COD	TSS	PB	CU	ZN	CD
Bartonsville - A	419	2%	3%	4%	2%	2%	5%	8%	3%	6%	2%
Bens Branch - C	690	1%	2%	2%	1%	1%	5%	2%	2%	2%	3%
Bens Branch - F	527	2%	2%	-1%	2%	2%	4%	5%	2%	3%	6%
Hazelnut Run - B	154	2%	2%	-1%	5%	4%	4%	14%	1%	8%	10%
Hazelnut Run - F	333	22%	14%	-7%	17%	17%	38%	32%	21%	20%	37%
Linganore Creek - F	298	4%	3%	-2%	4%	4%	9%	5%	3%	4%	8%
Linganore Creek - I	892	3%	2%	-1%	4%	3%	6%	7%	1%	4%	8%
Linganore Creek - L	349	1%	1%	0%	1%	1%	2%	3%	1%	2%	2%
Linganore Creek - M	568	13%	22%	5%	7%	7%	22%	41%	16%	18%	39%
Long Branch - A	450	8%	5%	-3%	10%	8%	15%	22%	6%	15%	17%
Long Branch - B	432	2%	1%	-1%	3%	2%	4%	6%	3%	4%	5%
Long Branch - E	593	3%	2%	-1%	2%	2%	6%	3%	3%	2%	4%
Long Branch - F	231	13%	8%	4%	21%	20%	13%	33%	9%	29%	22%
New London - A	804	1%	1%	1%	0%	1%	2%	1%	1%	2%	1%
Westwinds - B	308	3%	5%	6%	3%	3%	7%	7%	4%	7%	3%

Table 3-17. Percentage of composited removals by stormwater facilities in each subwatershed for the wet year, future scenario

	Subwatershed Area (ac)	TN	TP	OP	BOD	COD	TSS	PB	CU	ZN	CD
Bartonsville	1545	0.6%	1.0%	1.2%	0.5%	0.5%	1.5%	1.2%	0.8%	1.1%	0.4%
Bens Branch	2286	0.9%	1.1%	0.4%	0.8%	0.9%	2.3%	2.0%	0.9%	1.3%	2.4%
Hazelnut Run	2297	2.1%	1.7%	-0.9%	3.3%	3.4%	3.7%	8.9%	1.5%	5.2%	8.2%
Linganore Creek	5379	1.6%	2.6%	0.2%	2.1%	1.9%	3.0%	9.0%	0.9%	4.3%	7.8%
Long Branch	2532	3.6%	2.3%	-0.3%	4.7%	3.9%	5.3%	8.6%	2.8%	6.2%	6.9%
New London	3504	0.1%	0.2%	0.3%	0.1%	0.2%	0.4%	0.3%	0.2%	0.5%	0.2%
Westwinds	1250	0.6%	1.2%	1.4%	0.9%	0.9%	1.5%	3.2%	0.6%	2.9%	0.9%

Westwinds and Bens Branch. In general, stormwater facilities are already located in subwatersheds that have higher pollutant loadings. However, the existing facilities may not be sufficient for each subwatershed because their removals do not considerably lower the pollutant loadings within subwatersheds. Only when the subwatersheds are broken down into smaller areas, and analyzed at a localized level do the benefits of the existing stormwater facilities become apparent.

As expected, future loadings of many pollutants were predicted to increase as a result of land use changes (Figures 3-1 to 3-12). In the future scenario, the Mainstem Linganore Creek, Long Branch and Hazelnut Run subwatersheds are projected to have the highest urban pollutant loadings (Table 3-13). This was due to an increase in the percentage of residential lands in each subwatershed. In contrast, the Chestnut Grove, Detrick, and Horseshoe Farms subwatersheds contained the lowest urban pollutant loads, as they are expected to have less residential or commercial land. Chestnut Grove and New London subwatersheds are projected to have the highest agricultural pollutant loads, assuming much existing forested land will be used for agriculture in the future. Long Branch subwatershed will lose both forested and agricultural lands to future residential development, and therefore is expected to have the lowest agricultural pollutant loadings.

These SWMM results, when integrated with other watershed assessment findings, provide valuable information for targeting general areas (subwatersheds) where water quality improvement opportunities would be most effective. This will assist the County in identifying potential areas for implementing new structural BMPs, retrofits to existing structures, stream restoration projects, or other site-specific improvements. Further application of the SWMM model would involve modeling to help select specific locations and types of structural BMPs for implementation. In this extended application, the baseline model presented here (which estimates current and future pollutant loads) would be augmented with simulations of pollutant loading reductions from potential BMPs in new locations or from retrofitting existing structures. Running various "what-if" scenarios would help identify specific locations for the most cost-effective BMPs that would result in the greatest improvement in water quality in watershed streams and lakes. This extended application would refine the SWMM model output and support more detailed recommendations and cost estimates for watershed planning.

4.0 ASSESSMENT OF WATER QUALITY PROBLEMS

The focus of this watershed assessment is to assess existing conditions in the Lower Linganore Creek watershed, identify water quality problems, and describe opportunities to improve water quality and stream habitat. The assessment of current conditions presented in Section 2 indicates a wide range of potential stressors, including both urban and agricultural land use activities. In addition, projections of future development, estimates of future impervious surface, and SWMM modeling scenarios highlight the need to consider potential future impacts.

Within the last 20-30 years, and more rapidly within the last 10 years, development around the City of Frederick has expanded eastward, replacing rural, agricultural, and undeveloped lands in the south-central and western portions of Lower Linganore Creek watershed. Projections of future development predict that medium- and high-density residential land use, currently at approximately 5 percent, will expand substantially, to about 18.5 percent. Impervious surface in the watershed is currently approaching a level where stream impacts are typically observed, and an increase brought about by additional development is likely to place additional stress on Lower Linganore Creek's water quality, biological integrity, and physical habitat. SWMM modeling also predicts considerable increases in future pollutant loadings.

Common stresses associated with urbanization include the loss of natural vegetation throughout the watershed and particularly the loss of riparian vegetation, which supports many important stream processes. Riparian vegetation stabilizes both streambanks and lake shorelines, and reduces the inputs of nutrients, sediment, and other pollutants. Riparian vegetation also provides shade and contributes to shoreline and stream habitat quality by supplying rootwads and other woody debris that serve as cover for amphibians, reptiles, mammals, fish, and invertebrates. Other effects of urbanization can include more variable stream flows, increased erosion and sedimentation, habitat degradation caused by channel instability, increased nonpoint source pollutant loading, elevated air and water temperatures, and losses of biological diversity.

A list of water quality problems, including some non-urban problems, in Lower Linganore Creek watershed was developed by integrating information gleaned from the environmental assessment, visual inspection for potential watershed stressors, and other analyses compiled for this report. These problems may have a low benefit/cost ratio or occur on private lands that may not be feasible for the County to address. The objective was to identify a range of problems and their likely causes as a basis for identifying opportunities to improve water quality. As discussed in the next section, problems were ranked based on extent, severity, and potential for environmental restoration benefit to prioritize those observations and eliminate those that are not feasible because of land ownership or little opportunity for restoration.

Problems affecting water quality in Lower Linganore Creek and its tributaries are predominantly those arising from both urban and agricultural nonpoint sources. General problem types evident in the watershed include alterations of natural flow regimes (i.e., rapid conveyance of stormwater into stream channels), sediment deposition, and physical habitat degradation. In many cases, problems are minor, particularly where the presence of extensive

forest buffer or existing stormwater management facilities provides some protection from the impacts of nearby land uses. Taken individually, many of the activities in the watershed likely have little detrimental effect; however, the cumulative effect of these activities throughout the watershed can be of greater concern.

Water quality problems within Lower Linganore Creek loosely fall into ten general groups centered around the following issues: cumulative impacts, hydrologic modification, livestock access to stream, cropland runoff, failing septic systems, new construction, future development, industrial/ commercial development, existing structures, and inadequate SWM controls.

4.1 RANKING OF WATER QUALITY PROBLEMS

In order to prioritize the water quality problems, specific criteria were developed to assess and rank problems identified. For each problem, scores of 1 to 5 were assigned for the following factors:

- Extent: the spatial extent of the problem, ranging from local (1) to widespread (5)
- Severity: the degree to which the problem is a detriment to stream quality, ranging from mild (1) to most severe (5)
- Potential for environmental restoration benefit: this factor answers the questions "Would action likely bring about improvement in the condition of the environmental resource?" and "Overall, would restoration action likely be successful and cost-effective at this site?" Answers were scaled from little potential restoration benefit (1) to great potential benefit (5).

An average of the extent, severity, and restoration potential scores was then calculated to produce an overall water quality problem rating (1-5). Problems with an overall rating score of 3.0 or higher were then selected as priority issues because they present the greatest opportunities for improving water quality.

A summary of specific problems under each of the ten general groups, along with rankings, is given in Table 4-1.

4.1.1 Watershed Perspective

A prioritized list of water quality problems for the entire Lower Linganore Creek watershed is listed in Table 4-2. This prioritized list of problems was developed by sorting the water quality problems identified in Table 4-1 by their respective Overall Rating scores.

Table 4-1. Assessment of water quality problems in Lower Linganore Creek watershed. Shading indicates problems with the greatest opportunity for improving water quality

Problem ID	Location	Description of Problem	Stream Affected	Subwatershed(s) Affected	Extent of Problem	Severity of Problem	Potential for Environmental Restoration Benefit	Overall Rating	Opportunities to Improve Stream Water Quality
Cumulative impacts									
CI1	Lake Linganore	Cumulative effects of upstream impacts have degraded lake water quality and caused significant sedimentation	Linganore Creek and tributaries	Chestnut Grove, Horseshoe Farms, Westwinds, New London, Detrick, Bens Branch, and Hazelnut Run	5	5	5	5.0	See HM1, MH2, HM3, LA1, LA2, CR1, FSS1, NC1, NC2, FD1, ES1, ES3
Hydrologic modifications									
HM1	Watershed-wide (e.g., Bens Branch at Jessie Smith Road)	Sediment, trash, and other materials from road surface discharged directly into stream channel at road crossings	Entire watershed	Entire watershed	5	4	3	4.0	Continue coordination with Highway Dept. to implement recommendations from the recent Road Maintenance Assessment report
HM2	Bens Branch across from Millime Court	Braided stream channel likely caused by historical disturbances	Bens Branch	New London	3	5	4	4.0	Monitor stream conditions to determine if channel has reached equilibrium at this location
HM3	Bens Branch at Gas House Pike	Channel instabilities caused by historical disturbances	Bens Branch	New London	3	5	4	4.0	Monitor stream conditions to determine if channel has reached equilibrium at this location

Table 4-1. (Continued)

Problem ID	Location	Description of Problem	Stream Affected	Subwatershed(s) Affected	Extent of Problem	Severity of Problem	Potential for Environmental Restoration Benefit	Overall Rating	Opportunities to Improve Stream Water Quality
Livestock access to stream									
LA1	Gas House Pike	Unrestricted livestock access to stream	Bens Branch	New London	3	4	5	4.0	Implement previously established coordination procedures with NRCS or SCD conservation specialists about problem area so that they can try to help farmers limit livestock access to streams with streambank fencing, and develop alternate watering and stream crossing facilities. Planning and Zoning may also be able to contribute staff time and knowledge to help obtain funding and encourage landowner participation. Follow up to confirm how problems have been addressed
LA2	Boyers Mill Road	Unrestricted livestock access to stream	Unnamed tributary to Hazelnut Run	Hazelnut Run	2	4	5	3.7	Implement previously established coordination procedures with NRCS or SCD conservation specialists to report problem area so that they can try to help farmers limit livestock access to streams with streambank fencing, and develop alternate watering and stream crossing facilities. Planning and Zoning may also be able to contribute staff time and knowledge to help obtain funding and encourage landowner participation. Follow up to confirm how problems have been addressed

Table 4-1. (Continued)

Problem ID	Location	Description of Problem	Stream Affected	Subwatershed(s) Affected	Extent of Problem	Severity of Problem	Potential for Environmental Restoration Benefit	Overall Rating	Opportunities to Improve Stream Water Quality
Cropland runoff									
CR1	Watershed-wide	General agricultural impacts arising from agriculture - sediment, excess fertilizers, narrow/absent riparian buffers	Entire watershed	Entire watershed	3	3	4	3.3	NRCS or SCD conservation specialists can help farmers implement current agricultural BMPs to manage nutrients, prevent soil erosion, trap sediment, and plant riparian buffers. Implement previously established coordination procedures with NRCS or SCD staffs to report specific problems (see LA1 above)
Failing septic systems									
FSS1	Watershed-wide	Older houses may have failing septic systems that could affect water quality	Entire watershed	Entire watershed	2	2	1	1.7	Coordinate with Health Department and Division of Solid Waste to develop educational materials for residential property owners, provide technical assistance for upgrades and maintenance and investigate grants, loans, or other funding for septic improvements. Additional efforts could include monitoring for fecal coliform, conducting dye studies of suspect systems, and connection to nearby public sewers.
New construction									
NC1	Woodridge area of Lake Linganore	Sediment and dust eroded from unpaved construction roads can impair adjacent streams	Unnamed tributary to Linganore Creek	Mainstem Linganore Creek	4	3	4	3.7	Inspect site and work with construction manager to improve site conditions and maintenance efforts. Require developers to implement BMPs for unpaved roads such as those discussed in the County's Road Maintenance Assessment report. Take opportunity to educate manager about the need and importance of these BMPs and their continued upkeep.

Table 4-1. (Continued)

Problem ID	Location	Description of Problem	Stream Affected	Subwatershed(s) Affected	Extent of Problem	Severity of Problem	Potential for Environmental Restoration Benefit	Overall Rating	Opportunities to Improve Stream Water Quality
NC2	Westwinds area of Lake Linganore	Unpaved road under construction channels runoff away from sediment basin and directly down long hill towards wooded edge of Lake Linganore; inadequate design and maintenance of erosion and sediment controls	Lake Linganore	Westwinds	2	4	5	3.7	Require developers to implement BMPs for unpaved roads such as those discussed in the County's Road Maintenance Assessment report. Take opportunity to educate manager about the need and importance of these BMPs and their continued upkeep. Identify ways to better educate designers and reviewers of E&S plans.
NC3	Hilltop west of Artie Kemp Road	Large expanse of bare soil may have uncontrolled erosion problems. Metal and other items may also have been improperly disposed of at this location	Unnamed tributary to Linganore Creek	Chestnut Grove	1	2	5	2.7	Request NRCS to inspect farm and address issues as needed.
Future development									
FD1	Watershed-wide	Regional growth associated with City of Frederick will increase population and development within the watershed	Entire watershed	Entire watershed	5	4	3	4.0	Continue to enforce planning and construction requirements for SWM controls, with the goal of not altering flows or pollutant loads from predevelopment conditions. Minimize short-term construction impacts. Identify locations for new structural BMPs in the watershed as new developments are proposed
Industrial/Commercial development									
ICD1	Countryside Auto Parts	Automobile scrapyard in headwaters of Bens Branch appeared to have inadequate stormwater controls. Soil contamination issues may also be likely	Bens Branch	Bens Branch	2	3	4	3.0	Contact MDE to determine jurisdiction and appropriate course of investigative action.

Table 4-1. (Continued)

Problem ID	Location	Description of Problem	Stream Affected	Subwatershed(s) Affected	Extent of Problem	Severity of Problem	Potential for Environmental Restoration Benefit	Overall Rating	Opportunities to Improve Stream Water Quality
Existing structures									
ES1	Drainage swale along Spring Forest Road, Spring Ridge PUD	Stormwater flows are eroding the drainage pathway, depositing gravel in the channel, and blocking a culvert. Concentrated flows are passing through a swale, and headcutting upon entry into a SWM pond	Unnamed tributary to Linganore Creek	Mainstem Linganore Creek	3	5	4	4.0	Inspect drainage network and structure and work with facility manager to improve self-inspection and maintenance efforts. Take opportunity to educate facility manager about the need and importance of these BMPs and their continued upkeep
ES2	Public Training Safety Facility	Herbicide used around SWM facilities may not be appropriate for use near surface water, potentially killing fish and contaminating water and sediments	Unnamed tributary to Monocacy River	Bartonsville	1	3	5	3.0	Check with facility maintenance staff to ensure that only USEPA approved herbicides are used and that application conforms to label directions
ES3	Linganore High School	Apparent herbicide use around drainage pathways (see ES1); trash and fines from parking lots washed through stormdrains into grassy swales below outlet structures	Unnamed tributary to Bens Branch	New London	1	3	5	3.0	Check with facility maintenance staff to ensure that only USEPA approved herbicides are used and that application conforms to label directions. Potential retrofit opportunity to improve water quality and quantity. Also educational opportunity with students and community.
ES4	Spring Ridge - SWM Pond #10 (Structure ID 463)	Trees are growing on the berm and around the outlet structure in this EDD facility	Unnamed tributary to Linganore Creek	Mainstem Linganore Creek	1	1	3	1.7	Inspect structure and work with facility manager to improve self-inspection and maintenance efforts. Take opportunity to educate facility manager about the need and importance of the BMP and its continued upkeep

Table 4-1. (Continued)

Problem ID	Location	Description of Problem	Stream Affected	Subwatershed(s) Affected	Extent of Problem	Severity of Problem	Potential for Environmental Restoration Benefit	Overall Rating	Opportunities to Improve Stream Water Quality
Inadequate controls									
IC1	North Shore Way	Roadway and lawns drain directly to Lake Linganore without passing through vegetated riparian buffers	Lake Linganore	Mainstem Linganore Creek	4	5	4	4.3	Contact citizen stakeholder groups (e.g., LLCS, Friends of the Lake) to develop ways in which the County can assist their efforts to improve riparian buffers on private property around the lake, perhaps through grant or incentive partnerships. In addition, the County may be able to provide input for LLCS's stormwater and road design study currently underway that would improve road runoff conditions
IC2	Boyers Mill Road	Residential areas have narrow or absent riparian buffer to protect Lake Linganore from fertilizers, herbicides, pet wastes, and other NPS pollutants	Lake Linganore	Mainstem Linganore Creek	4	5	4	4.3	See IC1 above
IC3	Pinehurst area of Lake Linganore	Area of older development with few controls to reduce stormwater flow volumes, velocities, and pollutants	Lake Anita Louise and unnamed tributary to Lake Linganore	Mainstem Linganore Creek	4	4	4	4.0	See IC1 above
IC4	Holly Hills Golf Course	Greens extend down to edge of streams, with little to no riparian buffers to filter nutrient runoff. In addition, silt fencing for construction of a golf cart path was collapsing into the stream	Long Branch	Long Branch	2	3	3	2.7	Take opportunity to educate facility manager about the need and importance of these BMPs, self-inspections, and their continued upkeep. In addition, contact citizen stakeholder groups (e.g., LLCS, Friends of the Lake, club members) to see if they could provide support of riparian buffer initiatives at the golf course
IC5	Horseshoe Farms Estates	Area of older development with few controls to reduce stormwater flow volumes, velocities, and pollutants	Unnamed tributary to Linganore Creek	Horseshoe Farms	2	2	4	2.7	Inspect existing swale and drain structures and work with facility manager to improve self-inspection and maintenance efforts. Take opportunity to educate facility manager about the need and importance of these BMPs and their continued upkeep. In addition, see IC1 above.

Table 4-2. Summary of water quality problems for the Lower Linganore Creek Watershed, sorted by Overall Rating. Shading indicates problems with the greatest opportunity for improving water quality

Problem ID	Location	Overall Rating
CI1	Lake Linganore	5.0
IC1	North Shore Way	4.3
IC2	Boyers Mill Road	4.3
ES1	Drainage swale along Spring Forest Road, Spring Ridge PUD	4.0
FD1	Watershed-wide	4.0
HM1	Watershed-wide; Bens Branch at Jessie Smith Road	4.0
HM2	Bens Branch across from Millime Court	4.0
HM3	Bens Branch at Gas House Pike	4.0
IC3	Pinehurst area of Lake Linganore	4.0
LA1	Gas House Pike	4.0
LA2	Boyers Mill Road	3.7
NC1	Woodridge area of Lake Linganore	3.7
NC2	Westwinds area of Lake Linganore	3.7
CR1	Watershed-wide	3.3
ES2	Public Training Safety Facility	3.0
ES3	Linganore High School	3.0
ICD1	Countryside Auto Parts	3.0
IC4	Holly Hills Golf Course	2.7
IC5	Horseshoe Farms Estates	2.7
NC3	Hilltop west of Artie Kemp Road	2.7
ES4	Spring Ridge - SWM Pond #10 (Structure ID 463)	1.7
FSS1	Watershed-wide	1.7

4.1.2 Subwatershed Perspective

A prioritized list of water quality problems for Lower Linganore Creek's subwatersheds is listed in Table 4-3. This prioritized list of problems was developed by sorting the water quality problems identified in Table 4-1 by their respective subwatersheds, and then again by their Overall Rating scores.

The water quality problems identified in this assessment stem from a wide range of interconnected stressors that often cannot be separated into individual stressors. However, the SWMM modeling can help focus future efforts to address these and yet to be discovered water quality problems by identifying locations and types of problems that are likely to need attention. For example, Table 3-13 indicates that pollutant loadings from urbanization are, and will continue to be, the greatest impact within the Mainstem Linganore Creek subwatershed. Chestnut Grove and Long Branch subwatersheds are also likely to be impacted to a similar degree by agricultural an urban nonpoint pollutants, respectively.

Table 4-3. Summary of water quality problems for subwatersheds of Lower Linganore Creek, sorted by Overall Rating. Shading indicates problems with the greatest opportunity for improving water quality

Problem ID	Location	Overall Rating
Bartonsville		
ES2	Public Training Safety Facility	3.0
Bens Branch		
ICD1	Countryside Auto Parts	3.0
Chestnut Grove		
NC3	Hilltop west of Artie Kemp Road	2.7
Hazelnut Run		
LA2	Boyers Mill Road	3.7
Horseshoe Farms		
IC5	Horseshoe Farms Estates	2.7
Long Branch		
IC4	Holly Hills Golf Course	2.7
Mainstem Linganore Creek		
IC1	North Shore Way	4.3
IC2	Boyers Mill Road	4.3
ES1	Drainage swale along Spring Forest Road, Spring Ridge PUD	4.0
IC3	Pinehurst area of Lake Linganore	4.0
NC1	Woodridge area of Lake Linganore	3.7
ES4	Spring Ridge - SWM Pond #10 (Structure ID 463)	1.7
New London		
HM2	Bens Branch across from Millime Court	4.0
HM3	Bens Branch at Gas House Pike	4.0
LA1	Gas House Pike	4.0
ES3	Linganore High School	3.0
Westwinds		
NC2	Westwinds area of Lake Linganore	3.7
Entire watershed		
CI1	Lake Linganore	5.0
FD1	Watershed-wide	4.0
HM1	Watershed-wide; Bens Branch at Jessie Smith Road	4.0
CR1	Watershed-wide	3.3
FSS1	Watershed-wide	1.7

4.2 OPPORTUNITIES TO IMPROVE WATER QUALITY

In the last several years, Frederick County has expended considerable resources and effort to expand its NPDES stormwater management programs. These efforts have resulted in

strong facility inspection, GIS and database management, permit review, stormwater sampling, and watershed assessment components. The County's recent efforts to update its stormwater management ordinance to reflect recent changes in State requirements represents a significant step in improving stormwater management.

In order to increase the effectiveness of the County's SWM management programs, an adaptive management process is being followed, with refinements continuously considered and implemented. As such, a number of recommended opportunities that would enable the County to better address SWM issues and improve water quality in Lower Linganore Creek watershed have been included with the problem identification and rankings table (Table 4-1). These opportunities include site-specific activities as well as general programmatic refinements that could apply to many areas and thus address cumulative effects throughout the Lower Linganore Creek watershed.

Many of the programmatic approaches recommended in the County's two previous watershed assessments (Roth et al. 2001a, 2001b) are applicable to the problems noted here and opportunities recommended in this report build upon or take advantage of the earlier recommendations. As funding and staff resources allow, implementation of these approaches, especially those pertaining to education/outreach and agricultural issues, will bring about Countywide improvements and therefore help conditions in Lower Linganore Creek.

Several of the recommendations presented in this report involve issues within the Lake Linganore community. The entire community is represented by a homeowners association, Lake Linganore Association; each village around the lake is also represented by individual homeowners associations. Also, the Linganore CDA is an additional authority within the area. Implementation of any recommendations in this area is likely to be a complex task requiring close coordination and approval of each of these entities. It is therefore important for the County to establish a working relationship with these groups as well as the citizen stakeholder groups, which may prove to be a valuable advocate for stormwater management improvements.

Even with strict adherence to the practices specified the recently adopted 2000 Maryland Stormwater Design Manual, and implementation of BMPs for erosion and sediment control, it will be difficult to prevent any diminishment of the current level of stream water quality and habitat integrity in the watershed, especially given the projected level of development within the watershed. For example, most construction sites within Frederick County meet current erosion and sediment control requirements; however, not all sediment is contained given the limits of existing technology. Therefore, the County may want to find ways to improve the efficiency of site controls in order to better retain topsoil and protect water resources. Given that no SWM practices are 100 percent effective in reducing runoff, sediment, and erosion, some degree of stream degradation is also likely to occur, as indicated by the expected increase in the amount of impervious surface within the watershed. However, without such stormwater control measures, far greater degradation would likely result. In addition, promotion of low impact development techniques can reduce stormwater runoff volumes and velocities, and nonpoint pollution at its source, thereby reducing stresses to water quality and stream habitat within the watershed.

5.0 WATERSHED WATER QUALITY PLAN

The focus of the County's previous watershed assessments (i.e., Lower Bush and Ballenger Creeks) was largely upon programmatic recommendations to help refine the County's SWM program activities so that they could be used to address water quality impacts across the County and not just within a specific watershed. As these programmatic refinements take place, the focus of subsequent watershed assessments will be directed increasingly towards site-specific problems.

This plan for Lower Linganore Creek contains both programmatic and site-specific recommendations to address the watershed's top priority water quality problems, as identified in the previous section. In particular, improving SWM practices within the areas of older development around Lake Linganore presents specific challenges due to the myriad of stakeholders, each with differing levels of authority and responsibility.

5.1 INTEGRATION OF WATERSHED ASSESSMENT RESULTS

The water quality problems in Lower Linganore Creek watershed are the result of cumulative effects of both agricultural and urban development. SWMM results (Section 3) indicate that a substantial amount of TSS, nutrients, and other pollutants originate from agricultural areas. However, model results also demonstrate that current and future urban development contributes or will contribute a significant portion of the pollutant load. Therefore, any effective strategy for improving water quality in Linganore Creek (and Lake Linganore) must control both agricultural and urban nonpoint sources.

The Lower Linganore Creek watershed is characterized by the heavily rolling topography of the Piedmont Uplands. Agriculture is the dominant land use within the watershed; however, the south-central and western part of the watershed is heavily developed with residential subdivisions and PUDs. Given the long history of human habitation and agricultural land use in the region, streams are far from pristine; however, much of Lower Linganore Creek and its tributaries appear to be in moderately good condition at present. The creek supports a variety of fish and invertebrate biota, including several sportfish species. Remaining forest and wetland areas support good biological diversity. As no individual industrial or municipal dischargers were identified in the watershed, pollutants stem almost entirely from nonpoint sources.

Development pressures are strong in Frederick County, and in order to protect natural resources, growth has been targeted to selected areas of the County in an effort to minimize overall environmental impacts. The Lake Linganore and Spring Ridge PUDs are developing quickly, and projections indicate that medium density residential land uses in Lower Linganore Creek watershed will increase more than three-fold from current levels of about 5 percent. A major challenge in managing the Lower Linganore Creek watershed is to minimize environmental impacts within the rapidly growing areas, while also preserving the natural character of other sensitive resource areas.

An assessment and ranking of water quality problems (Section 4) confirms that reducing impacts of current and future development, as well as those from agriculture, are key issues within the watershed. The identification of these issues provides an opportunity to develop measures to improve existing water quality in Lower Linganore Creek, as well as pro-actively address future issues.

5.2 RECOMMENDED ACTIONS TO IMPROVE WATER QUALITY

From a list of water quality problems and potential opportunities to improve water quality in Lower Linganore Creek, the most promising opportunities (shaded problems in Tables 4-1 through 4-3) were selected as part of this watershed plan. Implementation of these opportunities depends upon cost, available funding, jurisdiction, feasibility, and the likelihood of success in improving or sustaining stream habitat and water quality. Recommended actions (including both programmatic and site-specific opportunities) are presented below. These recommended actions have been developed to address the primary threats to water quality, as identified in the watershed assessment, and include fixing inadequate SWM controls, improving maintenance of existing structures, avoiding and minimizing hydrologic modifications, limiting livestock access to streams, reducing agricultural runoff, and minimizing impacts from new construction and development. Table 5-1 outlines a suggested implementation schedule for these recommendations.

5.2.1 Programmatic Opportunities

Programmatic refinements to Frederick County=s stormwater management activities are expected to be important because their potential benefits extend beyond the watershed under study to encompass the entire County. The Countywide focus of these approaches is also likely to build public and institutional support for stormwater management programs.

For example, the County's adoption of the 2000 Maryland Stormwater Design Manual as its new standard for developing on-site stormwater pollution controls is a major programmatic step towards improved stormwater management. The County's Sediment and Erosion Control conference planned for Fall 2002 is another example of efforts to work with the local development and construction community. Frederick County will continue to work with the development community so that incentives for Innovative Site Planning approaches to reduce the need for structural BMPs may be used. County staff will continue to meet with the development community every other month to discuss issues and new policies. In addition, staff members will continue to encourage developers to attend pre-submittal meetings in which stormwater management options and approaches are discussed prior to the design phase.

Table 5-1. Timetable for the recommended actions to improve water quality in the Lower Linganore Creek Watershed, starting after plan approval

Event	Plan Approval	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6	
		1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half
Programmatic Opportunities													
- Source water protection plan for Linganore Creek		on-going											
- Continued Interagency Coordination		on-going											
- Monitor Agricultural Preservation Districts													
- Easement and site maintenance agreements													
- Retrofit and restoration feasibility analysis													
Select watersheds and subwatersheds													
Conduct feasibility analysis in first subwatershed													
Best Management Practices													
- Facilitate local SWM control efforts in older developments near lake			on-going										
- Reduce livestock access to streams		on-going											
- Maintenance issues													
- Opportunities to improve water quality on County-owned properties													
Inquiries to ES3 (Linganore High School)													
Retrofit to ES3 (Linganore High School)													
ES2 (County public safety training facility) project		on-going											
- Unpaved construction roads		on-going											
Stream Corridor Restoration													
- Bens Branch across from Millime Court													
Feasibility evaluation													
Design								†					
Construction										‡			
- Bens Branch at Gas House Pike													
Feasibility evaluation													
Design								†					
Construction										‡			
Further Investigations at Specific Sites													
- (ICD1) Countryside Auto Parts													

Notes:
† - schedule begins with approval of feasibility evaluation
‡ - schedule begins with approval of designs

In addition to the continued support and implementation of programmatic recommendations presented in the County's previous two watershed assessments, the following measures are recommended:

Source Water Protection Plan For Linganore Creek: DPW is strongly recommended to continue its participation with the development of this plan. The Task Force formulating the plan is currently discussing development, stormwater management, drinking water, land use planning, riparian buffer, and other issues that directly affect the County. Participation in this Task Force and its working committees will help ensure that DPW's interests and concerns are adequately addressed before the plan is implemented. Plan development potentially offers other resources that could be capitalized upon to facilitate existing DPW efforts in the watershed and elsewhere in the County. Active participation would likely involve regular attendance at meetings, participation in developing plan components, and support during plan implementation and possible downstream impacts.

SCHEDULE: On-going
ESTIMATED COST: Nominal

Continued Interagency Coordination: A number of local agencies have programs in place to address issues that either directly or indirectly affect nonpoint pollution and stormwater management (e.g., the review and approval of Erosion and Sediment Control Plans (E&S Plans) by SCD and Planning and Zoning's riparian restoration projects). As the County's lead agency for the NPDES Municipal Stormwater Permit, DPW can play a critical role in coordinating these individual efforts into a comprehensive management program, as well as serve as the County's experts in stormwater management. To this end, DPW should increase coordination with other agencies participating in relevant programs. The recent appointment of a Planning and Zoning liaison and his attendance at regular DPW NPDES meetings brings critical knowledge and other resources to the County's stormwater and watershed management efforts. Coordination will facilitate the development of specific strategies with the NRCS and SCD to address issues such as cropland runoff (i.e., CR1, Tables 4-1 through 4-3) and riparian buffer restoration (e.g., along Bens Branch). Because active construction sites can be large sources of nonpoint pollution, DPW is strongly encouraged to establish regular dialog and meetings with SCD staff who review and approve E&S Plans. Additional strategies should be established with the Department of Highways and Transportation to continue to address issues such as nonpoint pollution from roads (i.e., HM1), and the Division of Utilities and Solid Waste to use the review process for siting future sewer and water lines to avoid or minimize repeated stream crossings and floodplain disconnection, as well as develop strategies to minimize nonpoint pollution generated during sewer and water line installation and maintenance activities.

SCHEDULE: On-going
ESTIMATED COST: Nominal

Monitor Agricultural Preservation Districts: Agricultural landowners who have volunteered to designate their prime farmlands as Agricultural Preservation Districts under the Maryland Agricultural Land Preservation Foundation (MALPF) Program are required, under the terms of their contract with the state, to implement soil and water conservation plans. Visits to several District farms by County Planning and Zoning staff revealed that a number of farms have not kept up with the BMPs specified in their conservation plans. As such, efforts to monitor these farms to ensure that they comply with the terms of their contracts may be inadequate. Frederick County should bring this issue to the attention of the MALPF program staff, determine what measures may be taken, and identify personnel, and a schedule, to carry out these measures. Frederick County should also contact the local NRCS staff and request that they target additional outreach and other conservation efforts to the Agricultural Preservation Districts, especially those farms known to be out of compliance with their conservation plans.

SCHEDULE: Complete within 6 months of plan approval
ESTIMATED COST: Nominal

Easement and Site Maintenance Agreements: Complete a County-wide review of SWM facilities to identify facilities that 1) are not covered by Easement and Site Maintenance Agreements, 2) do not need agreements, 3) are covered by outdated agreements that do not meet current needs, or 4) are covered by adequate agreements. Meet with County legal staff to determine what can be done to establish Easement and Site Maintenance Agreements with SWM facilities that are not covered by agreements, and ways to upgrade outdated agreements that might not meet current needs. Develop an approach and schedule to upgrade or establish agreements with property and SWM facility managers.

SCHEDULE: Complete within 1 year of plan approval
ESTIMATED COST: Nominal

Retrofit and Restoration Feasibility Analysis: Identify and prioritize structural BMPs to better manage urban stormwater through implementation of a Retrofit and Restoration Feasibility Analysis. Opportunities may include retrofits of existing SWM facilities, establishing new County-owned or private facilities in uncontrolled areas, and engaging in watershed restoration projects. Efforts should be targeted to selected watersheds (and subwatersheds), based on their need for water quality improvements, potential opportunities, current and future growth patterns, and other factors. For each selected study area, the analysis would involve an evaluation of current SWM facilities and their sufficiency for controlling water quantities and qualities (specific to pollutants of interest). The analysis would also investigate opportunities for new structures in areas where stormwater is not currently controlled. The objective of the analysis would be to identify specific structures or locations where improvements could be implemented. Efforts within the Lower Linganore Creek watershed should be coordinated with those in other County watersheds, depending on priorities.

SCHEDULE:	Within 2 years of plan approval – select watersheds or subwatersheds Within 1 year of watershed selections – conduct Feasibility analysis in first (pilot) subwatershed (other watersheds may follow according to a yet to be determined schedule)
ESTIMATED COST:	Nominal – select pilot study area $30,000 – feasibility analysis of pilot subwatershed with analysis of approximately 10 BMPs

5.2.2 Site-Specific Opportunities

A number of opportunities to improve water quality were identified at various locations in the watershed and site-specific approaches were developed to address these issues. These opportunities have been grouped into two categories; BMPs and stream corridor restoration. A third category contains recommendations for further study, where insufficient information was available to fully assess impacts or develop recommendations. As discussed in Section 3, results from the SWMM modeling were used to prioritize subwatersheds and this prioritization should be used as a guide when implementing the following recommendations. Further application of the SWMM model to evaluate the effectiveness of potential new or retrofit BMPs can provide more detailed recommendations.

5.2.2.1 Best Management Practices

The cumulative impact of individual stressors to Lake Linganore (CI1) was given the highest priority in the ranking of water quality problems. Many of the individual stressors contributing to the problems identified in the Lake are addressed by the following BMPs recommended in the Lower Linganore Creek watershed:

Facilitate local SWM control efforts in older developments near Lake Linganore: To address inadequate SWM controls at IC1, IC2, and IC3, as well as other opportunities that may be identified, contact local citizens groups in the Lake Linganore Community to explore opportunities for collaboration on common goals, such as improvements of riparian buffers around the lake, reduction of sediment inputs into the lake, and coordinated stormwater education efforts which may also have site-specific benefits. Options include County support for these community activities by offering grant, matching grant, in-kind service, or other incentive-based programs. In addition, continue to collaborate with LLCS on their on-going road and SWM design study for the Lake Linganore CDA and other community efforts (e.g., leading community partnerships on grant applications and other activities).

SCHEDULE:	Initiate within 6 months of plan approval
ESTIMATED COST:	$5,000 – educational outreach $5,000 – trees/shrubs for volunteer planting

Limit livestock access to streams: To address stream destabilization and water quality issues associated with unrestricted livestock access to streams at LA1 and LA2, implement coordination procedures (see Ballenger Creek Watershed Water Quality Plan; Roth et al. 2001a) by notifying NRCS and SCD staff of problems at these locations.

SCHEDULE: On-going
ESTIMATED COST: Nominal

Maintenance issues: At ES1, a vegetated swale and SWM facility were observed to have erosion and headcutting issues. DPW should check to see if there is an easement and maintenance agreement for this facility; if an agreement is in place, appropriate action should be taken to remedy these issues. If an agreement does not exist, DPW should encourage the developer to reestablish vegetation along the swale and make improvements to the intake structure that would prevent additional headcutting and possible downstream impacts.

SCHEDULE: Address issue within 2 years of plan approval
ESTIMATED COST: Nominal

Opportunities to improve water quality management on County-owned properties: DPW should work with maintenance staff at Linganore High School (ES3) to retrofit existing stormdrains with appropriate BMPs to capture gravel, trash, and other materials washed from the parking lots. Structural BMPs that offer water quality treatment, such as SWM wetlands, should be considered because they also present valuable outdoor education and teaching opportunities. Because schools are community focal points, participation of the High School's Principal in retrofit planning discussions would help to maximize educational and outreach opportunities for students, teachers, and the community. In addition, a maintenance schedule that includes periodic cleanouts should be established for any retrofits implemented at ES3.

New development, currently under consideration, at the County Public Safety Training Facility (ES2) will be subject to the Maryland 2000 design criteria. As such, the County is encouraged to incorporate innovative site design approaches at this location that could be used as a local demonstration project to help the County and local development community gain hands-on experience with their design, construction, and maintenance.

SCHEDULE:	(ES3)	Inquiries within 6 months of plan approval
		Retrofits within 6-8 years of plan approval
	(ES2)	On-going
ESTIMATED COST:	(Both)	To be determined

Unpaved construction roads: Considerable threats to water quality were noted from two unpaved construction roads associated with development in the Woodridge (i.e., NC1) and Westwinds (i.e., NC2) sections of Lake Linganore. Because these locations comply with erosion and sediment control restrictions, and they are private roads, DPW

opportunities are limited. DPW staff should continue to inspect these types of sites and encourage construction managers to reduce sediment and dust impacts from these roads while they are unpaved. Approaches laid out in the County's Road Maintenance Assessment Report (Versar 2002), in addition to unpaved road programs run by Pennsylvania and South Dakota (Penn State University 2002; Skorseth and Selim 2000), could provide site managers with low-cost construction and maintenance techniques to reduce nonpoint impacts from these roads.

SCHEDULE: On-going
ESTIMATED COST: Nominal

5.2.2.2 Stream Corridor Restoration

Flooding, excessive erosion and deposition, and poor physical habitat are common problems associated with destabilized stream channels. Stream corridor restoration is a valuable tool that can help return these streams to a more natural condition, and thereby prevent additional degradation of water quality, habitat, and biological resources. However, a number of major considerations must be addressed in order to achieve success, as discussed below.

Unmodified stream channels are the product of a dynamic equilibrium between erosional and depositional processes. This equilibrium fluctuates over time and, typically, stream channels are able to recover after disturbance events such as flood pulses or temporary influxes of excess sediment. However, changes in the underlying variables can force the equilibrium to re-establish itself (and the stream) differently. For example, development within a watershed typically results in a flashier streamflow regime as increased imperviousness causes stormwater to be conveyed more rapidly to stream channels. The channel may respond to flashier flows with geomorphic changes, evident in destabilized banks and altered channel structure. The new flow regime can be incorporated into stable restoration designs, recognizing that the resulting stream system may be quite different from that which existed prior to major disturbances.

New methods for rehabilitation of channelized rivers have emerged over the last few decades. These successful methods are based on emulating the natural form and processes that take place in an undisturbed, meandering channel (Brookes 1985, 1987; Newbury and Gaboury 1993). Advantages of rehabilitating stream systems via this approach include: increasing channel stability, because pools and riffles help dissipate energy; reducing disturbance to biotic systems through the maintenance of habitat diversity; and the improvement of many intangible benefits which arise from greater visual, aesthetic, and recreational potential (Brookes 1987; Keller 1975).

Rehabilitation projects attempt to re-create selected processes that shape natural systems, although often the results of these projects only approximate natural systems (NRC 1992). Fluvial ecosystems are very complex, and their reconstruction is often based on considerations of stream hydraulics. This approach is centered on the observation that organisms live where there is suitable habitat, and suitable habitat is formed by diversity in the stream's hydraulic conditions (Petts 1995). Under this approach, developing variability in hydraulic conditions will lead to increased morphological (habitat) diversity, and ultimately, to increased biotic diversity. The

variable nature of fluvial systems also necessitates that channel improvement plans be tailored to a particular site (Brookes 1985).

The natural linkages that exist between upland, riparian, and aquatic ecosystems must also be maintained for these ecosystems to function as they should. Therefore, restoration of riparian vegetation is fundamental to the success of stream rehabilitation projects (Kauffman et al. 1993, Brookes 1987). Kauffman et al. (1993) suggest that 100-foot (30 meter) forested buffers be preserved along both sides of rehabilitated streams.

While the success of any restoration project depends on a number of natural and human variables that must be accounted for in the planning, design, and construction phases, the following phased approach may be used to help avoid, minimize, or mitigate many of the obstacles facing projects. Brookes (1990) recommended a project framework consisting of seven phases: 1) establish detailed project objectives, 2) perform a feasibility/planning study, 3) develop project design and engineering plans, 4) implement project construction, 5) conduct post-construction clean-up, 6) perform on-going maintenance, and 7) perform post-project monitoring. The monitoring phase is critical to evaluating the success of the project as well as contributing to the overall knowledge base on rehabilitation of stream ecosystems (Brookes 1990, 1995; Toth et al. 1995; NRC 1992; Kondolf 1995; Kauffman et al. 1993). Kondolf (1995) also suggests that each project be considered an experiment in which findings may be used to improve subsequent projects.

Restoration is proposed at the following stream reaches:

Bens Branch across from Millime Court: As Bens Branch parallels Lime Kiln Road (i.e., HM2), the stream takes on a braided pattern with eroded vertical banks, which may indicate that the channel is in an unstable state. Historical disturbances, such as direct livestock access to the stream or channel modifications associated with the former limestone quarry may be responsible for this destabilization. Stream conditions at this location should be monitored to further evaluate channel stability, develop possible restoration approaches, and determine feasibility of restoration. Because this section of stream is located in pasture and oldfield habitat, it affords an opportunity to reestablish a riparian buffer and implement bioengineering approaches to stabilize the stream channel.

SCHEDULE:	Complete feasibility evaluation within 3 years of plan approval
	Complete design within 1 year of approved feasibility evaluation
	Complete construction within 1 year of design approval
ESTIMATED COST:	$10,000 – feasibility evaluation
	To be determined in feasibility evaluation – design
	To be determined in feasibility evaluation – construction

Bens Branch at Gas House Pike: A section of Bens Branch (i.e., HM3), downstream from the braided section across from Millime Court and west of MD 75 showed channel instabilities (e.g., downcutting, bank slumping, excess sediment load) and a severe lack of riparian vegetation. This reach extends from approximately Old Lime Plant Road down to where Gas House Pike crosses Bens Branch. As with the upstream braided

section, stream conditions at this location should be monitored to further evaluate channel stability, develop possible restoration approaches, and determine feasibility of restoration. Adjacent land usage, pasture and oldfield habitat, also affords an opportunity to reestablish a riparian buffer and implement bioengineering approaches to stabilize the stream channel.

SCHEDULE:	Complete feasibility evaluation within 3 years of plan approval
	Complete design within 1 year of approved feasibility evaluation
	Complete construction within 1 year of design approval
ESTIMATED COST:	$10,000 – feasibility evaluation
	To be determined in feasibility evaluation – design
	To be determined in feasibility evaluation – construction

5.2.2.3 Further Investigations at Specific Sites

Insufficient information was available to fully assess impacts associated with the following location, therefore further study is recommended.

Countryside Auto Parts: This large automobile scrapyard facility, ICD1, is located in the headwaters of Bens Branch. SWM controls were not apparent at this facility. Although standard illicit discharge tests (i.e., pH, phenol, chlorine, detergent, copper) collected by County inspectors above and below the facility were reported to be within acceptable limits, given the nature of the operation, the potential for fuel, metals, oil and grease, and other contaminants to be washed from the property by stormflows is high. Although not listed in the reviewed MDE and USEPA databases, DPW staff should contact these agencies to determine if additional investigation is warranted.

SCHEDULE:	Complete within 6 months of plan approval
ESTIMATED COST:	Nominal

5.3 MONITORING TO EVALUATE EFFECTIVENESS OF WATER QUALITY IMPROVEMENTS

Outlined here are proposed procedures to monitor and evaluate the effectiveness of water quality improvements as a result of project implementation. As set forth in the Long-Term Monitoring Plan (Southerland et al. 1999), water quality, physical habitat, and biological conditions should be monitored periodically. We recommend that conditions at the ten Lower Linganore Creek watershed monitoring stations (LING-01 to LING-10) be reevaluated approximately every three years using the methods described in Section 2.3.1. Results from these periodic assessments could be documented in a separate study report as well as summarized in the County=s NPDES Annual Report.

In addition to stream monitoring data, we recommend that supplemental visual inspections and photographic documentation of specific site locations be conducted to monitor effectiveness of management actions. Because natural variability may make it difficult to detect trends in stream monitoring data until a long-term data set is amassed, visual inspection results

will help demonstrate whether management actions are beginning to achieve the desired benefit, or whether additional corrective measures are needed. Findings from each round of supplemental visual inspections could be documented in a study report that discusses trends and presents recommendations necessary to address major problems identified during the survey.

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