MEMORANDUM

To: Tim Riley, Manager
Kent Conservation District

From: Michael D'Annucci, Owner,
MSD Associates

Date: October 11, 2005

Re: Murderkill River Watershed Desktop Implementation Plan Cover Letter

---

Murderkill River stream segments are currently threatened by excessive concentrations of nutrients and fecal coliform bacteria, low levels of dissolved oxygen, and stressed aquatic habitats. Nonpoint source pollutant loading is considered a major water quality impairment source. The Kent Conservation District is a primary agency addressing nonpoint source pollution loading in the Murderkill River watershed, and as a result, the District and its agricultural agency partners are charged with the responsibility of meeting the water quality goals of state and federal agencies. An amended Total Maximum Daily Load (TMDL) regulation for the Murderkill River watershed was completed in March 2005 requiring nonpoint source nutrient loading reductions from their 1997 baseline levels of 30 and 50 percent for nitrogen and phosphorous, respectively. The District is currently acting as a valued member of the Murderkill Tributary Action Team, which is attempting to develop a decision-making structure that effectively translates these broad nutrient reduction goals to actual implementation approaches. To facilitate these District and Tributary Action Team nutrient reduction challenges, a detailed and proactive desktop implementation plan was established by Michael D'Annucci of MSD Associates, Phoebe Kilby of Sympoetica, and the planners from the Center for Watershed Protection. The desktop implementation plan includes the following components:

- A land use characterization of current agricultural watershed conditions by Michael D'Annucci that included (i.) the identification of watershed pastures, animal operations, and cropland through the completion of a four-day drive-bye field survey, and (ii.) the spatial identification of existing agricultural BMP and conservation practices in the watershed through the linking of the FSA GIS datalayer of farm fields to the NRCS Customer Service Toolkit database of existing BMPs and conservation practices;
- The development of a land use converstion study by Phoebe Kilby of Sympoetica that projects land use changes, predominately from agriculture to residential, over an extended twenty year planning period;
- The prioritization of subwatershed areas by the Center for Watershed Protection to identify where future urbanization impacts are expected to be the most pronounced. The Kilby land use conversion study was used to assess future

watershed conditions and impervious surfaces;

- The application of a spreadsheet-based Watershed Treatment Model (WTM) by the Center for Watershed Protection to estimate future nutrient loads in the two subwatershed areas where residential development is expected to have its greatest impact. Load estimates derivations included the use and non-use of recommended stormwater urban and agricultural treatment options; and
- The prioritization of farm fields for agricultural BMP and conservation practice implementation by Michael D'Annucci to address existing nutrient loading in the subwatershed areas not evaluated by the WTM.

This desktop implementation plan was designed to support the decision-making framework of local stakeholders (i.e, Tributary Action Team), who are ultimately responsible for ensuring that beneficial uses in the Murderkill River watershed are achieved and the goals of the nutrient TMDL are reached. The desktop implementation plan is included with this final submittal as four technical memorandums that should be reviewed sequentially:

1. Land Use Conversion Study of the Murderkill River completed by Phoebe Kilby of Sympoetica on January 31, 2005;
2. Prioritization of Murderkill River Subwatersheds to Identify Areas for Further Load Reduction Analysis completed by Jennifer Tomlinson, Paul Sturm, and Anne Kitchell of the Center for Watershed Protection on August 1, 2005;
3. Evaluating Future Pollutant Loads and Reduction Opportunities at the Subwatershed Level completed by Anne Kitchell, Paul Sturm, and Ted Brown of the Center for Watershed Protection completed on October 1, 2005; and
4. Farm Field GIS Database Development and Application to the Murderkill River Watershed for Agricultural BMP and Conservation Practice Prioritization completed by Michael D'Annucci of MSD Associates on October 11, 2005.

This final submittal also includes the following GIS datalayers, Figures and Supporting Documents:

- Murderkill River watershed GIS datalayer of farm fields including information gathered during the four-day July 2005 drive-bye field survey of agricultural land uses;
- Murderkill River watershed GIS datalayers of existing agricultural BMPs and conservation practices resulting from the linking of the FSA CLU and NRCS Customer Service Toolkit databases;
- Mapping Graphics found in the CWP Prioritization of Murderkill Watersheds and the Kilby Land Use Conversion Memos;

- CWP Murderkill GIS datalayers;
- Kilby Land Use Conversion GIS datalayers;
- WTM Modeling Spreadsheets supporting CWP Evaluating Future Pollutant Loads Memo.

Memorandum

sympoetica

132 N. Main St. Suite 100
Woodstock, VA
22664

Telephone: 540-459-9590
Toll Free: 800-458-7358

Date: January 31, 2005

To: Mike D'Annucci
MSD Associates

From: Phoebe Kilby
Sympoetica

Re: Task 1. Land Use Conversion Study of the Murderkill Watershed

---

1.0 Introduction

In order to address the non-point source water quality issues in the Murderkill watershed, it is essential to know how land is currently used and how that use might change over time. Stormwater runoff quality from different land uses varies greatly, and the appropriate BMPs to address non-point source pollution vary with land use as well. This land use conversion study attempts to project changes in land use within the Murderkill watershed between 2002 and 2022. Information from the study will be used to model the relative pollution load impact of conversion of the watershed's farms and forests to developed uses and to determine the most effective urban and agricultural BMPs to meet TMDL goals for the watershed.

The prediction of future land use is both a science and an art. One can collect many types of information that help inform the projection, but there are a large number of variables that can change over time and cause the actual conversion of land use to vary from the projected. This analysis attempts to project future land use as accurately as possible, but as will be discussed, many unknown factors exist that could cause the projection to be faulty. Nevertheless, this is a problem with most planning studies and does not prevent the use of our best educated guess to develop water quality improvement plans.

2.0 Data Collection

The goal of this study is to locate and tally existing land use as of 2002 and then project changes to land use by 2022. The following data were collected to carry out the conversion study:

Existing Land Use

The Delaware Spatial Data Implementation Team in the Office of State Planning Coordination obtained aerial photography of the state in 2002. This high resolution photography was good enough to allow aerial photo interpreters to develop existing land use maps for that year. The consultant team obtained the aerials and existing land use maps to use as the basis for determining the existing 2002 land use for this study. Aerial photo interpretation is not

completely accurate, so the consultant carried out some on-the-ground field checking in November 2004 as well as collected existing land use data available at the local level. The field checking uncovered several discrepancies between the actual land use and the photo interpreted land use of some parcels. While Kent County has no existing land use data, the City of Harrington collected existing land use data in and around the city in 2002 for its recent Comprehensive Plan. This more accurate data was used as well to update the existing 2002 land use map for this study (see Figure 1).

Population Estimates

In order to project residential land use conversion for a particular period of time, it is useful to obtain population projections for that period. These projections can then be converted into the number of projected households and thus the number of projected housing units for the period. The University of Delaware's Center for Applied Demography and Survey Research publishes population projections prepared by the Delaware Population Consortium at www.cadsr.udel.edu/demography/consortium.htm. Dated September 23, 2003, this data projects the following population growth for Kent County from 2002 to 2022 in ten-year increments:

Table 1. Population and Household Projections for Kent County, 2002-2012 By the Delaware Population Consortium

Year	Population	Population Growth From 2002	Households	Household Growth From 2002	Household Size*
2002	131,071		49,127		2.6680
2012	143,280	+12,209	55,168	+6,041	2.5971
2022	153,992	+22,921	60,378	+11,251	2.5504

* Household size = # persons per household

Note that the Population Consortium expects household size in the county to decrease over this period from 2.67 persons per household to 2.55 persons per household.

Table 1 shows a lower growth rate than that experienced historically according to the county's Comprehensive Plan. The plan indicates that from 1986 to 2000, the county population increased at an average annual rate (not compounded) of 1.5% or 1,570 persons per year. If this same rate is applied from 2002 to 2022, higher population and household growth is obtained, as shown in Table 2.

Table 2. Population and Household Projections for Kent County, 2002-2012 Based on a Historical Growth Rate of 1,570 persons per year

Year	Population	Population Growth From 2002	Households	Household Growth From 2002	Household Size*
2002	131,071		49,127		2.6680
2012	146,771	+15,700	56,513	+7,386	2.5971
2022	162,471	+31,400	63,704	+14,770	2.5504

* Household size = # persons per household

These population projections are for all of Kent County. The Murderkill watershed represents only a fraction of the total area of Kent County. The Kent County Planning Department was consulted to estimate how much of Kent County's growth would occur in the Murderkill watershed. Planner Kelly Crumpley offered growth location information that the Planning Department had provided to the Delaware Population Consortium for their most recent population estimates. The Planning Department estimated the percentage of the county's growth that might occur within each Census County Division (CCD: a subdivision of a county that is a relatively permanent statistical area established by the Census Bureau and state and local government authorities). The CCDs that cover an area approximating the Murderkill watershed include the Central Kent, Felton, Harrington and North Milford CCDs. The area of these four CCDs is somewhat larger than the Murderkill and was assigned 50% of the County's growth (Central Kent: 15%, Felton: 3%, Harrington: 15% and North Milford: 17%). Kelly Crumpley reviewed the Murderkill watershed area specifically and estimated that it would probably receive about 35% of the County's growth - all of the growth in Felton and Harrington and half of the growth in Central Kent and North Milford. Based on this percentage, Table 3 presents low and high estimates of the growth in population and number of households in the Murderkill watershed from 2002 to 2012.

Table 3. Alternative Growth Scenarios for the Murderkill River Watershed Assuming Murderkill Receives 35% of Kent County Growth

Year	Low Growth Scenario (Table 1)		High Growth Scenario (Table 2)	
	Households	Household Growth From 2002	Households	Household Growth From 2002
2002	17,194		17,194	
2012	19,309	+2,115	19,780	+2,586
2022	21,132	+3,938	22,296	+5,102

Note: The low growth scenario is based on the Delaware Population Consortium estimates for Kent County. The high growth scenario is based on the Kent County historical growth rate.

So for the purposes of this study the number of new housing units expected to be constructed in the Murderkill watershed from 2002 – 2022 is estimated to be between 3,938 and 5,102 units.

The remainder of the data collection focused on the types of housing units, size of lots, and location of this new residential development as well as non-residential development expected. These aspects of projected development are affected by local plans and ordinances, state plans and policies, and recent development approvals in the Murderkill by Kent County and municipalities within Kent County.

Local Comprehensive Plans

A comprehensive plan is a policy document that serves as long-term guide to the growth and development of a locality. It is called comprehensive because it addresses all aspects of the locality's physical development: land use, housing, economic development, transportation, community facilities and infrastructure, agriculture, conservation, etc. Of particular use to this study is the comprehensive plan's future land use map, since it presents the locality's desired future growth patterns.

Kent County adopted its most recent comprehensive plan on March 23, 2002. The Kent County future land use map shows most of the Murderkill watershed as planned for low density residential development at densities of 1 to 2.9 dwelling units per acre. Scattered small areas of medium density residential development at densities of 3 to 5.8 dwelling units per acre and high density residential development at densities of 5.9 to 21 dwelling units per acre are found along Route 13 and Route 1 / 113. There are also small areas of commercial development along Route 13. Most of the medium to high density residentially planned areas have already been developed as have significant portions of the commercially planned areas. A very important feature of the future land use map is its designation of the County's Growth Overlay Zone. As will be discussed under zoning, this is the area where the county has created incentives for new development to locate.

The City of Harrington is the largest municipality in the Murderkill watershed. Harrington adopted its latest plan on January 19, 2004. This plan contains existing and future land use maps for the city and its proposed annexation area. The existing land use maps were used in this study to revise the Murderkill 2002 existing land use map. The future land use maps were used to predict potential changes in land use between 2002 and 2022. The City of Harrington future land use maps show a mix of new uses planned in and around the city, including low, medium and high density residential, commercial, and industrial uses and parks.

Other small towns in the Murderkill watershed include Viola, Felton and Frederica. Viola and Felton are currently almost completely developed except for some platted low density single family residential subdivisions. Fredericka currently retains some significant undeveloped areas, which have recently been proposed for residential development. Comprehensive plans for these localities were not obtained.

Zoning and Subdivision Ordinances

Kent County's zoning ordinance regulates the location and types of land uses permitted within its jurisdiction. The zoning map matches the Comprehensive Plan in that the zoning districts reflect the land uses shown on the future land use map. Most of the Murderkill watershed is zoned AC – Agricultural Conservation or AR- Agricultural Residential. These zones permit only limited development where central water and sewer service is not available. Higher densities, up to 3 dwelling units per acre, are permitted within the Growth Zone Overlay District if central water and sewer service is available. This built-in incentive results in most new residential subdivisions being constructed within the growth zone on central water and sewer. The zoning ordinance requires specific environmental resources to be preserved in open space.

The protections for these environmental resources are outlined in the subdivision ordinance as summarized in Table 4.

Table 4.Protection of Environmental Resources Required in the Kent County Subdivision C				
Resource	Protection Requirement			
Floodplain	All floodplain must remain unsubdivided open space.			
Wetlands	All wetlands must remain unsubdivided. No buildings or impervious surfaces permitted within 25 feet of a delineated wetland.			
Riparian Buffers	No buildings or impervious surfaces permitted within 100 feet of tidal and non-tidal water bodies or U.S.G.S. blue-line streams. Buffer is 50 feet for any non-blue-line stream, creek or drainage ditch.			
Woodlands	Woodlands must be preserved in common open space as follows:			
	Residential		Nonresidential	
	1 to 1.25 dus/ac	60%	1 to 10 acres	20%
	1.25 to 2.5 dus/ac	50%	10 to 25 acres	30%
	2.5 to 5.0 dus/ac	40%	25 to 50 acres	40%
	5.0 to 10.0 dus/ac	30%	50+ acres	50%
	10.0 dus/ac+	20%		

Because the Zoning Ordinance permits cluster subdivision with lot sizes as small as 6,000 square feet, the restrictions on development of environmental resource areas does not generally force an overall reduction in density. Gross residential densities in the AC and AR districts can be as high as 2.8 dwelling units per acre, according to Kelly Crumpley.

The City of Harrington Zoning Ordinance is currently being rewritten so its impact on future development within the city and its annexation area is not known. According to Rebecca Green, Operations Manager, low density single family development will be permitted at 1 dwelling unit per acre, medium density at 2 dwelling units per acre, and high density at as much as 12 dwelling units per acre.

Transfer of Development Rights

Kent County recently adopted a transfer of development rights (TDR) program, effective January 1, 2005, which would allow density to be transferred from areas outside the Growth Zone Overlay District ("sending areas") into specified areas within the Growth Zone Overlay District ("receiving areas"). Two types of receiving areas are designated, primary and secondary. Maximum gross densities permitted within these areas are 7 and 5 dwelling units per acre respectively. In order to achieve these densities, developers would have to buy development rights (density) from landowners in the sending areas, whose land would then be restricted from development. This program is designed to provide even more incentives for development to occur within the Growth Zone Overlay District.

It is impossible to know how this new program could impact development in the Murderkill watershed. It could cause higher density residential development within the Growth Zone Overlay District, though we cannot know whether the development rights transferred in came from sending areas within the Murderkill or elsewhere in Kent County. A transfer of development rights ordinance was adopted in Montgomery County, Maryland, over 20 years ago. Many years elapsed after its passage before a market for development rights emerged and

transfers started to occur. It is possible that little difference in development patterns will occur between 2005 and 2012 in the Murderkill watershed due to the TDR program.

Given that the County's new TDR program is entirely untested, this study does not contemplate higher densities in the Murderkill watershed than have been occurring in recent years.

Delaware Purchase of Development Rights Program

The Delaware Agricultural Lands Preservation Program was established by the State of Delaware in 1991 to protect land for agricultural purposes. Farmers are invited to place their land into and Agricultural Preservation District and agree not to develop their land for at least ten years. In return the farmer receives tax benefits, right-to-farm protection and an opportunity to sell the land's development rights to the state. Approximately 4,253 acres in the Murderkill watershed have been purchased by the state in this PDR program and another 2,657 acres are in Agricultural Preservation Districts. These areas are not expected to develop between 2002 and 2022.

State Infrastructure and Transportation Policies

Delaware has adopted Strategies for State Policies and Spending in order to coordinate land use decision-making with the provision of infrastructure and services. While local governments have control over land use, the state funds the bulk of the infrastructure (roads, schools, etc.) that support the land use decisions. The state strategies document, recently updated in July 2004, maps areas where the state is willing to invest in infrastructure that supports growth and development. The maps identify investment areas 1, 2, 3 and 4 plus areas that are "out of play." Levels 1 – 3 identify the areas where the state supports growth and is willing to make investments in infrastructure. The state fully supports growth in areas 1 and 2. The state will consider investing in area 3 once areas 1 and 2 are substantially built out. Delaware does not plan to invest in area 4. "Out-of-play" lands are those that generally cannot be developed, for example, State and Federally owned lands, parks, PDR lands, etc. The Office of State Planning Coordination reviews development proposals when they are submitted by developers to local governments and provides comments regarding compatibility with its Strategies for State Policies and Spending. This review is not intended to disapprove growth otherwise permitted and within designated growth areas described in the local comprehensive plan, but state decisions on infrastructure can influence the feasibility of a development. This study assumes that future development in the Murderkill will be compatible with the state strategies.

Another important state program that is expected to influence future development in the Murderkill watershed is the Delaware Department of Transportation's Corridor Capacity Preservation Program. This program is designed to maintain the ability of major through roads in Delaware to handle traffic safely and efficiently. Within the Murderkill watershed, the program affects the Route 13 and Route 1 / 113 corridors. Except within mapped community and developing areas in Felton, Frederica and the City of Harrington, this program greatly limits direct access to these corridors. This in effect greatly limits commercial development along these roads outside these towns and city. Planner Kelly Crumply does not anticipate any new commercial development along these roads in the county portions of the Murderkill. Within

Felton, Frederica and Harrington, most of the frontage land along these roads was already developed in 2002, so little new commercial development is expected within the Murderkill watershed.

Recent Trends in Development within the Murderkill Watershed

Kelly Crumpley of Kent County and Rebecca Green of the City of Harrington were interviewed to discover recent and expected future trends in development within the Murderkill. Each was asked to review already platted but undeveloped subdivisions within their jurisdiction and to provide their opinion as to whether the subdivisions were viable and would be built out within our 20-year study horizon. In addition, each was asked to provide information on recently approved subdivisions that had not yet been entered into the locality's GIS system.

Rebecca Green provided information on a large new residential subdivision planned at the western end of the city as well as other potential new residential, commercial and industrial areas. The City's level of growth, however, will be somewhat hindered in the near term due to limited capacity in its existing water and sewer treatment systems.

Kelly Crumpley provided detailed information on new subdivisions recently approved as well as a number of new subdivisions for which applications had been submitted and approvals were pending. There is a great deal of developer interest in the Murderkill watershed area. The total of all the housing units that could be built in the already platted, recently approved, and soon to be approved subdivisions exceeds the number of housing units projected in the high estimate for the Murderkill between 2002 and 2012 and almost reaches the high estimate of housing units for 2022. This could indicate that the Murderkill watershed is experiencing growth at a higher rate than predicted by the population growth estimates. It could also indicate that there is a great deal of development speculation going on in the area. Kelly Crumpley points out that there has been a housing boom in recent years. It is difficult to imagine that this boom will continue through 2022. Development usually occurs in cycles, and the current economic indicators, such as rising interest rates, would tend to show that housing sales could diminish soon. The market for housing is one of the major variables that is difficult to predict and that can greatly affect projected land conversion to housing.

With regard to new commercial and industrial development within the county portion of the Murderkill watershed, Mr. Crumpley did not expect much to occur. This is not an area of the county that is planned for major economic development. There are no industrial parks existing or planned in this area of the county. Also, the Delaware Department of Transportation's Corridor Capacity Preservation Program is effectively preventing commercial development along Routes 13 and 1 / 113 due to its frontage and access limitations. He could not point to any new areas of commercial or industrial development within the county portion of the Murderkill.

Mapping

As part of the data collection process, the consultant team developed a mapped data base specifically for the Murderkill watershed. As described previously, existing land use data from

2002 was obtained from the Office of State Planning Coordination. The team also obtained GIS data from the Kent County Planning Department, including the following:

- parcel boundaries
- parcel numbers
- parcel sizes
- road rights-of-way
- road centerlines
- road names
- zoning
- growth overlay zone
- TDR receiving and sending areas
- jurisdictional boundaries (town and cities)
- streams and water bodies
- floodplains
- wetlands
- county owned sewer districts
- properties purchased under state PDR program

Maps of the watershed were created with following titles to help inform the land conversion maps to be prepared:

- Base Map (showing parcels, roads, streams, and jurisdictional boundaries)
- Existing Land Use (using the state data updated by consultant team)
- Zoning
- TDR Receiving Areas
- Environmental Features and Infrastructure (Floodplains, wetlands, sewer districts)

3.0 Land Conversion

The population estimates, local and state land use policies and ordinances, mapped information and information about recent subdivision activity were used to tabulate and map future conversion of undeveloped land in the Murderkill watershed to developed uses. With regard to non-residential uses, all the planned new commercial and industrial areas recommended by the City of Harrington Comprehensive Plan are projected to be built out by 2012. No new commercial or industrial areas are expected to be built in the county portions of the watershed because no such new uses are planned for the area and because Delaware's Corridor Capacity Preservation Program limits commercial development of land along the major roadways. Since 2002, a new park has been built on Killen's Pond Road northeast of Harrington.

The Murderkill is expected to experience primarily low density residential growth over the next twenty years. Table 5 lists the residential subdivisions that may be built over the next twenty years as well as non-residential lands expected to be developed. The subdivisions are numbered in the table and on the land use conversion map for easy identification.

Table 5. Land Use Conversion / 2002 – 2022 Murderkill Watershed

Site Code	Location	Square Meters	Acres	# Units	Net Density (Units/Ac)
Non-Residential Land Conversion / 2002-2012					
Open Space	Killens Pond Road	199,400	49.3	0	0.0
Commercial Site #1	Dorman Road	17,161	4.2	0	0.0
Commercial Site #2	Tower Hill Road	68,975	17.0	0	0.0
Commercial Site #3	Ronald Rich Road	34,297	8.5	0	0.0
Industrial Site #1	Messicks Road	109,633	27.1	0	0.0
Industrial Site #2	Cluckey Road	75,969	18.8	0	0.0
		Subtotal	124.9	0	
Residential Land Conversion / 2002-2012					
Low Growth Scenario					
High Density Residential	Park Brown Road	51,778	12.8	140	10.9
Low Density Res. Site #1	Lucky Estates	401,064	99.1	197	2.0
Low Density Res. Site #2	Jackson Ditch Road	54,820	13.5	12	0.9
Low Density Res. Site #3	Cloverfield Road	142,925	35.3	39	1.1
Low Density Res. Site #4	Woodview Road	166,911	41.2	45	1.1
Low Density Res. Site #5	Peach Basket Road (S)	191,136	47.2	107	2.3
Low Density Res. Site #6	Peach Basket Road (N)	108,092	26.7	36	1.3
Low Density Res. Site #7	Chimney Hill Road	489,860	121.0	302	2.5
Low Density Res. Site #8	Andrews Lake Road	205,609	50.8	59	1.2
Low Density Res. Site #9	Irish Hill Road	403,660	99.7	187	1.9
Low Density Res. Site #10	Woodfield Road	721,228	178.2	220	1.2
Low Density Res. Site #11	Lambert Road	136,808	33.8	60	1.8
Low Density Res. Site #12	Woodleytown Road	435,063	107.5	103	1.0
Low Density Res. Site #13	McGinnis Pond Road	501,353	123.9	153	1.2
Low Density Res. Site #14	Barretts Chapel Rd	198,219	49.0	53	1.1
Low Density Res. Site #15	Bowers Beach Road	601,695	148.7	111	0.7
Low Density Res. Site #16	Church and Erin Roads	331,922	82.0	142	1.7
Low Density Res. Site #17	Little Mastens Corner	293,077	72.4	168	2.3
		Subtotal	1,343.0	2,134	
High Growth Scenario (Additional)					
Low Density Res. Site #18	Indian Point Road	276,066	68.2	140	2.1
Low Density Res. Site #19	Lexington Phase 1	122,979	30.4	65	2.1
Low Density Res. Site #20	Ash Branch Rd. Phase 1	165,610	40.9	104	2.5
Med. Density Res. Site #1	Frederica Road	180,039	44.5	143	3.2
		Subtotal	184.0	452	
Residential Land Conversion / 2012-2022					
Low Density Res. Site #21	Chimney Hill Road	242,228	59.9	129	2.2
Low Density Res. Site #22	Irish Hill Road	543,543	134.3	290	2.2
Low Density Res. Site #23	Lexington Phase 2	125,866	31.1	65	2.1
Low Density Res. Site #24	Burnite Mill Road	430,784	106.4	270	2.5
Low Density Res. Site #25	Ash Branch Rd. Phase 2	151,134	37.3	104	2.8

Table 5.	Land Use Conversion / 2002 – 2022 Murderkill Watershed				
Site Code	**Location**	**Square Meters**	**Acres**	**# Units**	**Net Density (Units/Ac)**
Low Density Res. Site #26	Roesville Road	577,173	142.6	309	2.2
Low Density Res. Site #27	Waterside Road West	244,826	60.5	121	2.0
Low Density Res. Site #28	Waterside Road East	353,683	87.4	175	2.0
Low Density Res. Site #29	North of Town of Frederica	702,893	173.7	483	2.8
Med. Density Res. Site #2	Town of Frederica	400,211	98.9	302	3.1
		Subtotal	932.1	2,248	
	Residential Grand Total		2,459.2	4,834	
Note: All numbers are rounded and approximate; for planning purposes only.			Acres	Units	

Table 5 shows the subdivisions that are expected to be built under the low and high growth scenarios from 2002 – 2012. The numbers of dwelling units listed in the second to the last column can be related directly to the household projections for 2002 - 2012 for the Murderkill watershed in Table 3. Additional planned subdivisions in Table 5 are shown for the 2012 – 2022 period. The total of 4,834 units for 2002 – 2022 falls between the low and high new household estimates for this period in Table 3. These 4,834 units are at the high end of the range of 3,938 - 5,102 new units by 2022.

All the development projected in Table 5, except for one subdivision, is located within Kent County's Growth Zone Overlay District and within Investment Areas Levels 1, 2 or 3 of the Strategies for State Policies and Spending. Low density residential site #15 is the exception. A subdivision at this location was approved many years ago prior to development of current county and state growth policies.

In conclusion, this study projects the development of land in the Murderkill watershed as displayed in Table 5 and the Land Use Conversion map for the period of 2002 – 2022 (Figure 2). The amount of development projected reflects a relatively high rate of growth, higher than would be expected based on population growth estimates of the Delaware Population Consortium, but slightly less than a straight line projection of historical growth levels from 1986 to 2000. This residential development has either already been approved at state and local levels or will soon be approved. The design of the residential subdivisions is based on existing regulations with regard to stormwater quality controls.

4.0 Build-out Analysis

While Table 5 and the Land Use Conversion maps show expected growth in the Murderkill watershed from 2002 – 2022, current city and county policies would permit a great deal more growth to occur. The comprehensive plan future land use maps of the City of Harrington and Kent County show large areas that could potentially be approved for growth within the Growth Zone Overlay District. This growth is expected to be primarily low density residential development, though higher density residential development could occur of the County's TDR program takes off. The water quality modeling phase of this Murderkill River Watershed Study may test the relative water quality impact of complete watershed build-out, though this build-out would be expected to occur far into the future beyond the 20-year horizon of this study.

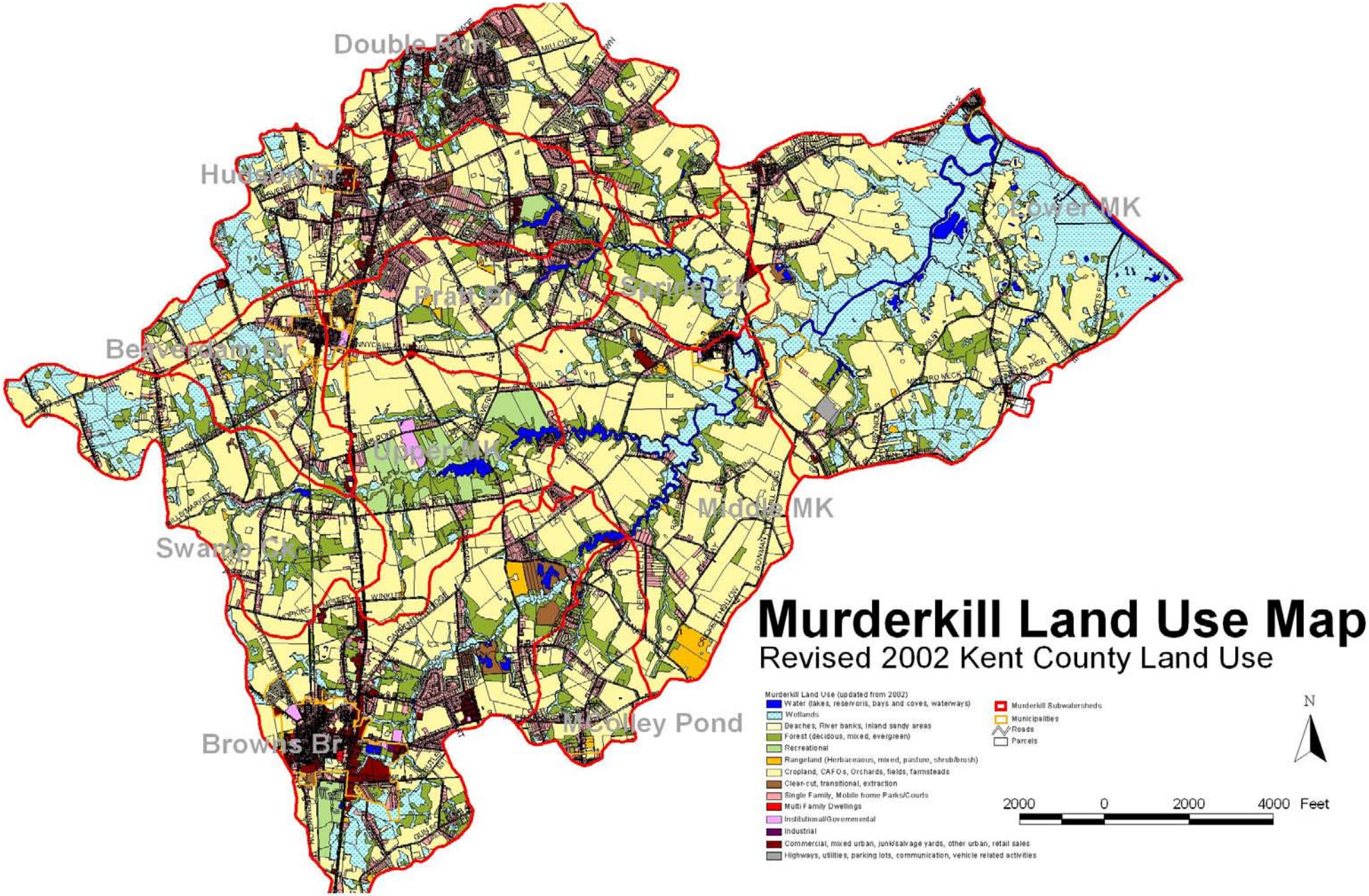


Figure 1. Revise Kent County Land Use Map

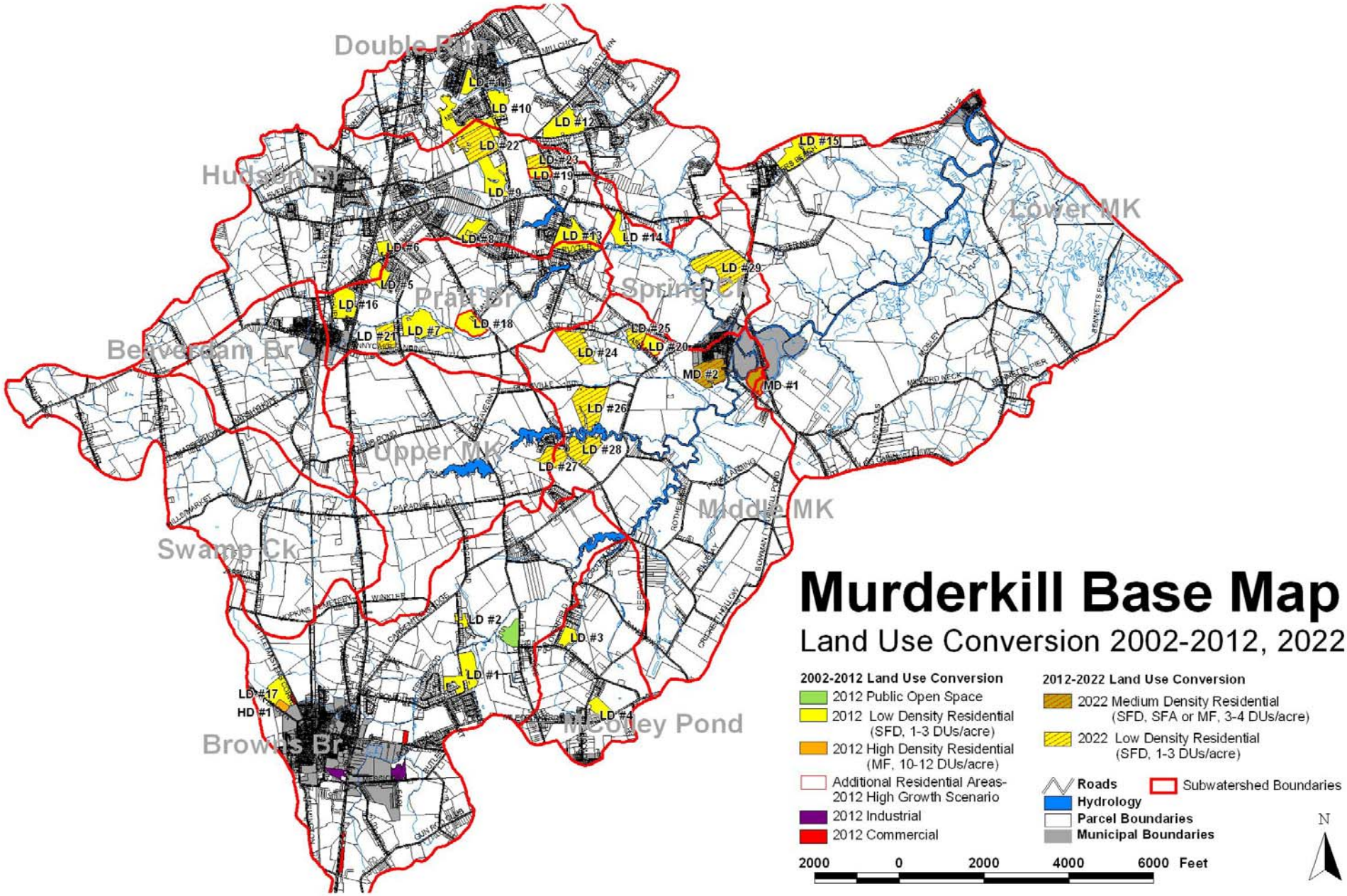


Figure 2. Land Use Conversion Map

Memorandum

8390 Main Street, 2nd Floor
Ellicott City, MD 21043
410.461.8323
FAX 410.461.8324
www.cwp.org
www.stormwatercenter.net

Date: August 1, 2005

To: Mike D'Annucci
MSD Associates

From: Jennifer Tomlinson, Paul Sturm, and Anne Kitchell
Center for Watershed Protection

Re: Task 4.1.3 Prioritization of Murderkill Subwatersheds

This memorandum summarizes existing monitoring and land use data for the Murderkill watershed (Task 4.1.1), presents current and future impervious cover estimates for each subwatershed (Task 4.1.2), and outlines the ranking factors and procedures used to identify priority subwatersheds for subsequent analysis (Task 4.1.3). The Watershed Treatment Model will be applied to priority subwatersheds (Task 4.2); findings from which will be presented in a separate Technical Memorandum.

The purpose of this report is to review what is currently known about watershed conditions to establish baseline watershed conditions and to apply the land use conversion analysis described in Task 1 Technical Memo (Kilby, 2005) to predict future impacts of urbanization. This information will be used to develop a preliminary prioritization of subwatersheds for future planning efforts in the Murderkill watershed. This report is organized in the following sections:

Section 1.0 Introduction—description of basic watershed features and an overview of existing conditions.

Section 2.0 Review of Monitoring Data—summary of water quality monitoring data and known impairments. Also includes review of biological sampling data for aquatic and upland communities, as well as data on instream habitat, flow and riparian buffer quality.

Section 3.0 Land Cover Analysis—summary of available land use information and estimation of current and future impervious cover based on the probable buildout analysis conducted by Kilby (2005)

Section 4.0 Subwatershed Prioritization and Management—describes a ranking process by which subwatersheds are compared using a number of derived metrics.

Section 5.0 Next Steps – Continuation of this project and recommended future actions

This technical memo represents a limited review of existing data for the Murderkill watershed, and no field work was conducted by the project team to verify findings from cited research and studies. This compilation of baseline information should be considered a preliminary step in the watershed planning process, setting the stage for development of watershed goals, subwatershed management strategies, and more detailed restoration and protection approaches. It will be necessary to conduct detailed field assessments to confirm and refine prioritizations and recommendations presented in this memorandum.

1.0 Introduction

The Murderkill watershed, located in southeastern Kent County, drains approximately 68,000 acres (107 sq miles) of coastal plains farmland, forest, wetlands and urban areas (Figure 1). From its headwaters, the Murderkill flows eastward to its confluence with Delaware Bay at Bowers Beach. More than half of the land use within the watershed is considered agricultural, and about a tenth of the watershed is still forested. Harrington, Felton, and Frederica are the largest municipalities within the watershed, however Houston, Bowers Beach, and Viola also have jurisdiction over small portions of the watershed. Based on 2002 land use data, these urban areas account for approximately 14% of overall watershed land use. Kent County's strategic growth area encompasses much of watershed extending from the urban area in the northern portion of the watershed southward towards Milford along the highway corridor. While much of the watershed is considered developable, it is not clear that rapid land conversion from agricultural to urban uses is likely over the next decade (Kilby, 2005).

The watershed is partitioned north to south by US Routes 13 and 113. The lower portion of the Murderkill River (from its mouth at Delaware Bay to just upstream of Rt. 113 Bridge, Frederica) is tidally influenced. The expansive tidal wetlands at the mouth of the watershed contains habitat for many aquatic and avian species and is considered a significant resource management area. A number of lakes and ponds are found within the watershed including McColley Pond, Killen Pond, Courseys Pond, McGinnis Pond, and Andrews Lake. Table 1 summarizes basic watershed characteristics.

Table 1. Basic Profile of the Murderkill Watershed

Total Area	107.0 sq miles (68,461 acres)
Stream Length	252.6 linear miles (includes streams, ponds centerline, tidal)
Lakes and Ponds	5 major ponds(231 total acres) includes McGinnis Pond, McColley Pond, Killian Pond, Coursey Pond, and Andrews Lake
Wetlands	17% of watershed
Dominant Land Use (2002)	Agricultural
Jurisdictions	Kent County plus 6 municipalities: Harrington, Frederica, Felton, Viola, Houston, Bowers Beach
# Subwatersheds	5 (DNREC); 11 (CWP)
Protected parcels (does not include all wetland acres)	9,556 acres or 14% of watershed (parks, open space, preserves, PDR) Additional 5,697 acres proposed for protection; 2,268 acres under AP/10
High Potential Recharge Area	17,401 acres or 25% of watershed
Impervious Cover	8.0% (2002); 8.8% (2022)
Developable Land in Watershed	60% (subtract out wetlands and protected parcels)
Potential Contaminants	High levels of nutrients, high bacteria counts
Major Transportation Routes	U.S. 13 & 113 , State Route 14
Natural/Historic Features	Killens Pond State Park, Milford Neck State Wildlife Area, McGinnis Pond State Wildlife Area, Murderkill River Nature Preserve

The watershed was originally divided into five subwatersheds by DNREC; Center for Watershed Protection (CWP) divided these into 11 smaller subwatershed units for watershed planning purposes (Figure 1). Table 2 provides a brief characterization for each subwatershed.

Table 2. Subwatershed Characterization

Subwatershed		Area (mi^2)	Stream Length (mi)	Description	%IC* (current/ future)	Priority **
DNREC	CWP					
Browns Branch	Browns Branch	15.6	30.2	• Habitat and macroinvertebrates range from degraded to excellent • Listed for Bacteria, Biology, Habitat, Nutrients and DO	12.9/13.8	2
	McColley Pond	3.8	5.9	• Good historical habitat and macroinvertebrates • Listed for Bacteria and Nutrients	7.5/8.1	3
Lower Murderkill	Lower Murderkill	23.2	82.0	• High number of wetlands, special habitat area • Listed for Nutrients and DO	4.5/4.7	3
Spring Creek	Double Run	9.1	17.0	• Elevated nutrient levels • Located within growth area	10.8/12.1	1
	Hudson Branch	11.0	24.6	• Elevated nutrient levels • Located within growth area • Listed for DO, Biology and Habitat	11.4/12.8	1
	Pratt Branch	6.2	10.4	• Elevated nutrient levels • Listed for Biology • Located within growth area	9.7/11.5	1
	Spring Creek	3.6	8.6	• Listed for Bacteria, Nutrients, and DO • Located within growth area	5.8/7.5	3
Swamp Creek	Beaverdam Branch	4.2	14.3	• Some areas with good habitat and WQ • Listed for Biology	8.7/8.7	2
	Swamp Creek	8.9	24.5	• Headwater tributary • Noted degradation of Biology and Habitat	5.1/5.1	3
	Upper Murderkill	8.1	12.5	• Listed for Bacteria, Nutrients, DO, Temperature, Biology and Habitat • Located within growth area	6.6/6.7	2
Upper Murderkill	Middle MK	13.1	22.6	• Listed for Bacteria, Nutrients, Biology and Habitat • Located within growth area	6.1/7.4	2
Total		**107**	**252.6**		**8.0/8.8**	

* IC based on land use analysis presented in Section 3.0 and probable buildout scenario described in Task 1 memo
** Priority ranking detailed in Section 4.0 used to ID subwatersheds with highest restoration potential

The Murderkill River and several of its tributaries and ponds were included on the State's 1996, 1998, and 2000 303(d) lists for impaired water bodies. The main causes of impairment for these waterbodies are generally low dissolved oxygen, high levels of nutrients, high bacteria counts, and/or poor habitat and biology. The main sources of pollution are cropland fertilizers, animal-raising operations and septic systems, which are the predominant method of waste disposal in the Murderkill watershed. Only 13 % of the length of the Murderkill is reported to fully support aquatic life, and none fully supports primary contact recreation (DNREC, 2001). Over 85% of ponds have enough dissolved oxygen to fully support aquatic life, although primary contact recreational use is not recommended (DNREC, 2004a). According to the State's 1998 303(d) list, several miles of the Murderkill are impaired due to poor habitat (DNREC, 2001). Channelization is one of the main forms of physical habitat degradation in the Murderkill watershed (DNREC, 2004b).

A Total Maximum Daily Load (TMDL) for nutrients (nitrogen and phosphorous) and oxygen consuming compounds was approved for the Murderkill in 2001. In 2004 an amended TMDL for the Murderkill was established (DNREC, 2005c) to include load allocations for both point and non-point sources.

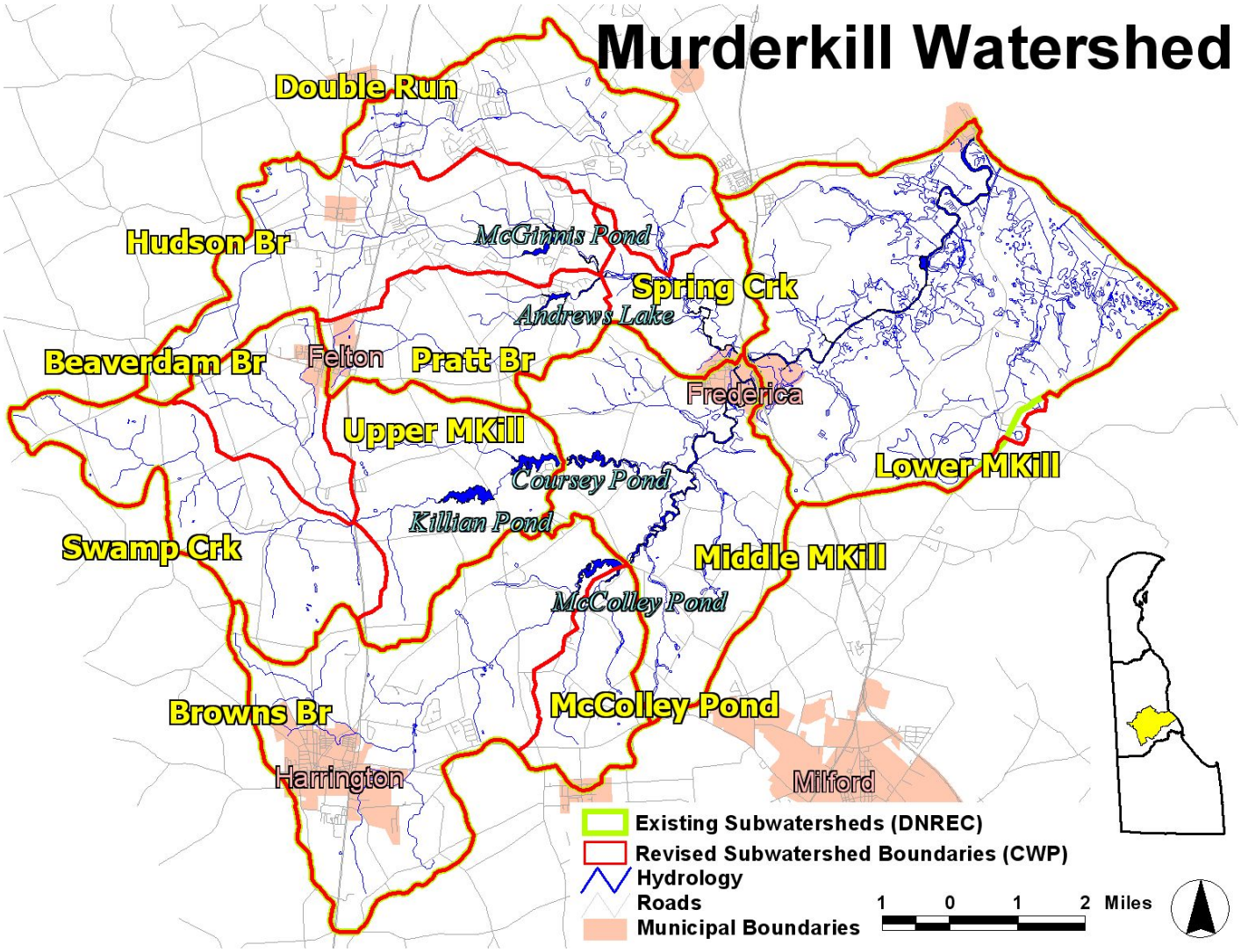


Figure 1. Murderkill Watershed.

2.0 Review of Monitoring Data

This section of the report summarizes existing monitoring data and report findings on water quality, biological sampling, and physical stream habitat assessments. CWP has compiled these data as a preliminary baseline analysis and to develop metrics to be used for prioritizing subwatersheds for further action.

Table 3. Murderkill River Watershed Data reviewed for this Report

Data Type	Brief Description	Form	Source
Fish	1987 Report	Hardcopy	DNREC
	1991 Report, 9 sites		
Macroinvertebrate	1987 & 1991 Report		
Habitat	1987 Report	Unable to acquire	
	1991 Report		
Macroinvertebrate & habitat	14 sites sampled 1991-2003	Excel Spreadsheet	
Riparian Buffer Information	Amount buffer coverage in watershed	GIS Shapefile	
Murderkill TMDL	Impaired segments, nitrogen and other water quality	PDF and hardcopy	
Water quality	66 stations sampled irregularly from 1970-1999	Excel Spreadsheet	DNREC Watershed Assessment Branch
Sediment	2 sites sampled 1996-2004		DNREC (STORET)
Water quality	14 sites sampled 1998-2003 for 2004 305(b)		
Delaware Stream Watch	Narrative macro, chemical, and land use for 2 ponds, several yrs	Hardcopy	Delaware Nature Society
Cropland	Combined CAFO, crop, farmstead, idle fields, and orchard categories	GIS Shapefile	Kent County 2002 land use GIS
Pasture	Combined herbaceous, mixed and shrub/brush rangeland; pasture categories		
Combined Animal Feeding Operations (CAFO)	Only CAFOs		
Growth zones	Kent County growth zone		
Wetlands	Wetlands and water layers combined		
Forest	Combined deciduous, evergreen, and mixed forest		
Recharge	Recharge areas for streams		Delaware Whole Basin
Septic Systems	Only septic systems		
Current Impervious Cover	CWP calculated using Kent county data and data from Draft Land Use Conversion Study (Kilby, 2005)		Kent County 2002 and Kilby (2005)
Breeding Bird	USGS Breeding Bird Survey (BBS)	Digital data and GIS shapefile	USGS (2005)
Amphibian Species	North American Amphibian Mapping Project	Digital Data	NAAMP, 2004

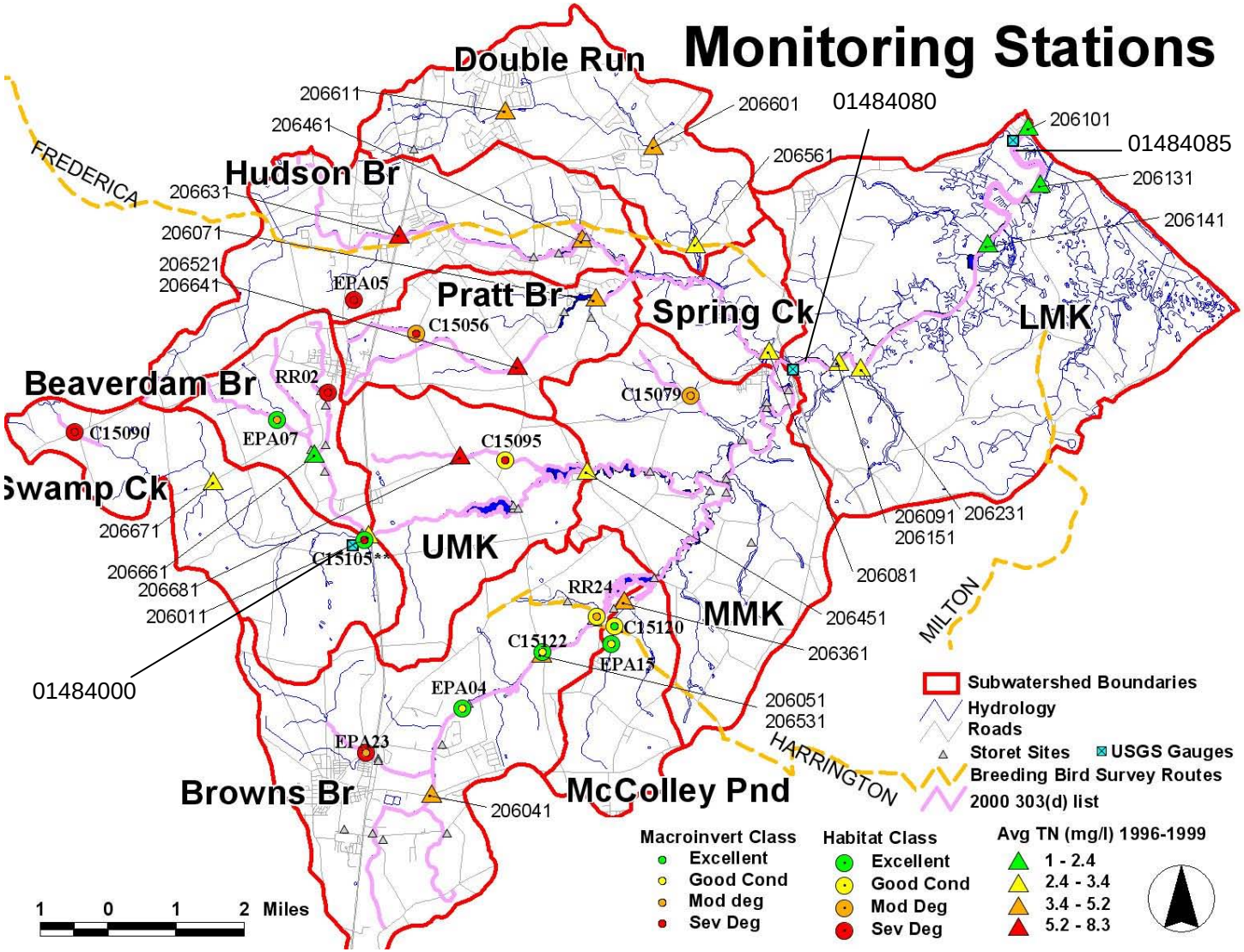


Figure 2. Monitoring stations, survey routes, and impaired waterways

2.1 Water Quality

The Delaware Department of Natural Resources and Environmental Control (DNREC) has identified the Murderkill River and several of its tributaries and ponds as water quality limited waters and has placed them on the State's 1996, 1998, and 2000 303(d) lists (DNREC, 1996, 1998, and 2000). The impairments for these waterbodies are generally due to low dissolved oxygen, high levels of nutrients, high bacteria counts, and/or poor habitat and biology usually as a result of non-point sources (NPS) although point sources (PS) are cited in several instances.

The Murderkill is especially sensitive to these impairments during the summer months when flows are low and stream temperatures are high. This combination results in water quality impairments such as high nutrient concentrations, low oxygen, and algal blooms. The impaired segments of the Murderkill River and the causes of their impairments as identified in the State's 1998 303(d) List are summarized in Table 4 (DNREC, 2001).

Table 4. Segments of the Murderkill River on Delaware's 1998 303(d) List
(from DNREC, 2001)

Segment	Waterbody ID	Length (miles)	Pollutant(s) and / or Stressor(s)	Probable Source(s)
Lower Murderkill	DE220-001 (27.5 miles)	7.6 miles	Nutrients and DO	PS, NPS
Spring Creek	DE220-002 (36.5 miles)	17.6 miles	Bacteria, Nutrients, DO, Biology and Habitat	PS, NPS
Middle Murderkill	DE220-003 (16.2 miles)	10.2 miles	Bacteria, Nutrients, Biology and Habitat	PS, NPS
Browns Branch	DE220-004 (24.1 miles)	10.6 miles	Bacteria, DO, Nutrients, Biology and Habitat	NPS
Upper Murderkill	DE220-005 (21.7 miles)	16.2 miles	Bacteria, Nutrients, DO, Temperature, Biology, and habitat	NPS
McGinnis Pond	DE220-L01 (31.3 acres)	31.3 acres	Bacteria and Nutrients	NPS
Courseys Pond	DE220-L03 (58.1 acres)	58.1 acres	Nutrients	NPS
Killens Pond	DE220-L04 (75.1 acres)	75.1 acres	Bacteria and Nutrients	NPS
McColley Pond	DE220-L05 (49.0 acres)	49.0 acres	Bacteria and Nutrients	NPS

The nutrient threshold levels DNREC uses, and those generally accepted by the scientific community, are 3.0 mg/ for nitrogen (total nitrogen) and 0.1 mg/l for phosphorous (total phosphorous) for inclusion of a stream on the State's list of impaired waters (DNREC, 2001). Nutrient data for the years 1996-1999 is listed in Table 5. Figure 2 shows the sampling locations of the full suite of historic EPA STORET sites though only the more recent nutrient data was evaluated in our analysis.

Table 5. Total Nutrient Summary for the Murderkill River 1996-1999
(From DNREC, 2001)

Subwatershed	STORET Station	Description	Average Total Nitrogen (mg/l)	Average Total Phosphorous (mg/l)
Browns Branch	206041	Browns Branch At De Route 14	4.11	0.099
	206051	Browns Branch At Rd 384 Bridge	4.97	0.071
Pratt Branch	206071	Andrews Lake At Road 380	5.14	0.061
	206641	Pratt Branch At Canterbury Rd.	6.03	0.030
Spring Creek	206081	Spring Creek At Delaware Rt 12	3.25	0.401
Lower Murderkill	206091	Us Rt 113 At Frederica By-Pass	3.05	0.337
	206101	Murderkill River At Bowers Beach Wharf	1.76	0.338
	206131	Murderkill River, 1.25 Miles From Mouth	2.27	0.365
	206141	Murderkill River, 3.25 Miles From Mouth	2.4	0.567
	206231	Confluence of Kent County Stp Trib	2.75	0.645
McColley Pond	206361	McColley Pond Nr Spillway	3.88	0.070
Hudson Branch	206461	Hudson Br, McGinnis Pond @ Road 378	4.55	0.070
	206561	McGinnis Pond;Hudson Branch At Road 371	3.41	0.100
	206631	Hudson Branch At Us Rt. 13	6.39	0.024
Double Run	206601	Double Run At Irish Hill Rd	5.15	0.020
	206611	Double Run At Peachtree Hill Rd	3.94	0.80
Beaverdam Branch	206661	Upper Murderkill @ Little Masten Rd.	1.02	0.130
Swamp Creek	206011	Us Route 13 Below Felton	3.11	0.289
	206671	Black Swamp Crk @ Marshyhope Rd	3.19	0.090
Upper Murderkill	206451	Coursey Pond At County Rd 388	2.9	0.093
	206681	Above Coursey Pnd @ Chimney Hill Rd	8.25	0.300
** Note: No data was available for Middle Murderkill Downstream of McColley and Coursey's Pond				

Concentrations of nutrients in the Murderkill River are generally high and exceed the State's target levels of 1.0-3.0 mg/l for nitrogen and 0.1-0.2 mg/l for phosphorous. The maximum concentration of total nitrogen in the watershed was 19.66 mg/l at Station 206041 (Browns Branch at Rt. 14 Bridge). For phosphorous, the maximum concentration exceeds 2.4 mg/l at several stations in the tidal portions of the Murderkill River (DNREC, 2001). These phosphorus data were not used in the subwatershed prioritization (Section 4) as they were collected during baseflow and may not be reflective of concentrations that move during storm events and ultimately drive phosphorus loads.

For dissolved oxygen (D.O.), the minimum D.O. standard of 4.0 mg/l was violated at all stations located in the tidal Murderkill River. In addition, the minimum D.O. standard was violated at two free flowing tributary stations (stations 206041 and 206661). The minimum D.O. observed at these stations ranged from 1.4 to 3.1 mg/l. The average D.O. standard of 5.5 mg/l (5.0 mg/l for marine waters) was violated at several tidal and non-tidal stations (DNREC, 2001).

Point Sources

A number of point source facilities are located within the Murderkill Watershed; they are primarily wastewater treatment plants. Total nitrogen and total phosphorus loads are reported in Table 6 from the calibration and validation period from 6/97 through 9/98. The nutrient loads for point sources (as per the calibration period) in the Murderkill exceed the combined non-point source load from all other land uses (DNREC, 2001). This is primarily a result of the Kent County facility located on the Lower Murderkill. Locations of the point source facilities are provided in Figure 3.

Table 6. Point Source Facilities in the Murderkill River Watershed
(from DNREC 2001)

Facility Name	NPDES	Size	Type	Receiving Stream	6/97-9/98	
					Total Nitrogen (lbs/day)	Total Phosphorous (lbs/day)
City of Harrington STP	DE0020036	Major	Municipal	Browns Branch	43	0.42
Kent County Facility	DE0020338	Major	Municipal	Lower Murderkill	683.4	262.6
Canterbury Crossing MHP	DE0050075	Minor	Municipal	Double Run (headwaters)	2.2	0.86
Southwood Acres MHP	DE0050172	Minor	Municipal	Double Run	13	5.1
West Farm Inc	N/A	--	Seasonal Operation	Middle Murderkill	54.1	5.2

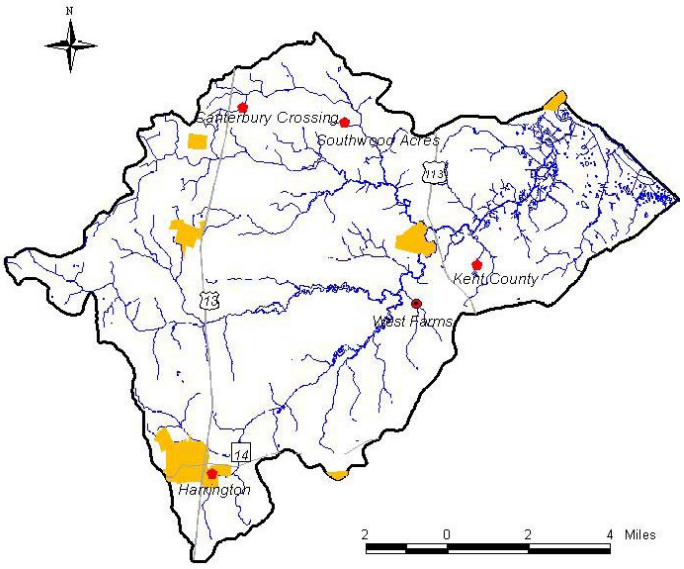


Figure 3. Point source locations in the Murderkill watershed (from DNREC)

Overview of the Total Maximum Daily Load

A TMDL was adopted by EPA Region III and DNREC for the Murderkill River on December 1, 2001. In 2005, an amended TMDL for the Murderkill was published. The TMDLs were published for nutrients and oxygen consuming compounds for the entire Murderkill River watershed, including its tributaries and ponds (DNREC, 2005c). These segments were identified as impaired waters on the Delaware 1996, 1998, and 2000 Section 303 (d) lists for failure to protect aquatic life due to high nutrients and low dissolved oxygen. The proposed amended TMDLs for the Murderkill watershed are listed in Table 7.

Table 7. Proposed Amended TMDLs for the Murderkill River Watershed
(from DNREC, 2005c)

Source			Flow (mgd)	Total Nitrogen (lbs/day)	Total Phosphorous (lbs/day)	CBOD5 (lbs/day)
Load Allocation for Nonpoint Sources			-	560	96	-
Waste Load Allocation for Point Sources	City of Harrington	During no discharge	0	0	0	0
		During seasonal discharge	0.750	140	0.75	37.5
	Kent County Facility		15	751	62.5	1001
	Canterbury Crossing Mobile Home Park		0.05	4.3	0.2	9.6
TMDL *(When Harrington WTTP is not discharging)*			-	**1315.3**	**158.7**	**1010.6**
TMDL *(When Harrington is discharging)*			-	**1455.0**	**159.45**	**1048.1**

In order to meet the amended TMDL targets point source load reduction of 45% for nitrogen and 90% for phosphorous is needed. For the nonpoint source load, a 30% reduction for nitrogen and a 50% for phosphorous is needed. Improvements in municipal sewage treatment and mobile home park septic systems will be needed as well as the enhancement of best management practices for nonpoint sources. An implementation strategy will be finalized by the State, in consultation with the Murderkill River Tributary Action Team and other parties, within 1 year after formal adoption of the TMDL regulation (http://www.tmdls.net/).

2.2 Biological Communities

This section of the report summarizes available data on amphibians, birds, fish, and aquatic macroinvertebrates. Habitat information is presented in Section 2.3. Figure 2 shows the locations within the watershed for macroinvertebrate sampling sites and Breeding Bird Survey Routes.

The Delaware Natural Heritage Program was not able to provide information on freshwater mussels; rare, threatened, or endangered species (RTE); upland forests; wetland quality; or other sensitive habitats within the Murderkill watershed. This information is important for effective

watershed and land use planning, and it absence leaves a gap in the subwatershed prioritization process.

Amphibians

The North American Amphibian Mapping Project (NAAMP) has sampled two routes in the Murderkill watershed: Route 210802**,** which is near Argos Choice, DE and Route 210902, which is in Black Swamp, in the Swamp Creek subwatershed (NAAMP, 2004). Argos Choice is in the McColley Pond subwatershed, northeast of Harrington and southeast of Killens Pond. Maximum calling indices for the Argo's Choice and Black Swamp routes are summarized in Tables 8 and 9, respectively.

Two species of frog are of particular conservation concern in Delaware: Cope's Gray Treefrog and the Green Treefrog. According to the Delaware Natural Heritage Program (DNREC, 2002) Cope's Gray Treefrog is classified as very rare in the state of Delaware and susceptible to extirpation. The Green Treefrog is classified as rare to common.

Table 8. Amphibian Species Observations for Argo's Choice, Route 210802 (NAAMP, 2004)

Species	2001	2003
Fowler's Toad, *Bufo fowleri*	3	3
Green Treefrog, *Hyla cinerea**	0	3
Gray Treefrog, *Hyla versicolor*	0	0
Cope's Gray Treefrog, *Hyla chrysoscelis**	0	3
Spring Peeper, *Pseudacris crucifer*	3	3
Southeastern Chorus Frog, *Pseudacris feriarum*	0	1
-American Bullfrog, *Rana catesbeiana*	0	0
Green Frog, *Rana clamitans*	0	1
Wood Frog, *Rana sylvatica*	2	0
Southern Leopard Frog, *Rana sphenocephala*	0	0
Pickerel Frog, *Rana palustris*	0	2
*Rare species in Delaware		

Table 9. Amphibian Species Observations for Black Swamp, Route 210902 (NAAMP, 2004)

Species	2001	2003	2004
Eastern Spadefoot, *Scaphiopus holbrookii*	0	3	0
American Toad, *Bufo americanus*	0	3	0
Fowler's Toad, *Bufo fowleri*	3	3	3
Northern Cricket Frog, *Acris crepitans*	3	0	0
Green Treefrog, *Hyla cinerea**	0	3	2
Cope's Gray Treefrog, *Hyla chrysoscelis**	2	3	1
Spring Peeper, *Pseudacris crucifer*	3	3	3
Southeastern Chorus Frog, *Pseudacris feriarum*	2	2	0
American Bullfrog, *Rana catesbeiana*	2	0	1
Green Frog, *Rana clamitans*	1	1	2
Wood Frog, *Rana sylvatica*	0	2	0
Southern Leopard Frog, *Rana sphenocephala*	0	0	0
Pickerel Frog, *Rana palustris*	1	3	3
*Rare species in Delaware			

Birds

Three North American Breeding Bird Survey (BBS) routes bisect the Murderkill watershed including Harrington, Frederica and Milton. Current survey data is provided in Appendix A. A map of the survey locations can be accessed directly at the National Atlas of the United States site (http://nationalatlas.gov/natlas/natlasstart.asp) and are shown in Figure 2. A number of the birds noted in the BBS are also listed on Delaware Coastal Zone or the Milford Neck Conservation Area Watch List (see asterisks on Table 10) (DAS, 2004). The BBS routes do not include much of the expansive tidal wetlands at the mouth of the watershed which contains habitat for many breeding and migratory birds of concern (see Delaware Coastal Zone description below).

The Delaware Audubon Society (DAS, 2004) has designated the entire Delaware Coastal Zone as an Important Bird Area as it contains breeding grounds for several WatchListed[1] and endangered/threatened birds. In addition to breeding birds, tens of thousands of WatchListed spring-migrating shorebirds stop along the Delaware coast to consume huge quantities of eggs laid by horseshoe crabs. This has made Delaware one of the most crucial sites for migrating shorebirds on the entire Atlantic Coast of North America. Table 10 provides a list of these bird species of concern for both the Delaware Coastal Zone and the Milford Neck Conservation Area (which overlap). Both the Delaware Coastal area and part of the Milford Neck Conservation Area are in the Lower Murderkill subwatershed. These natural areas alone make the Lower Murderkill one of the top areas for protection within the watershed.

Table 10. Breeding and Migratory Bird WatchList for DE Coastal Zone and Milford Neck Conservation Area

Piping Plover	Wood Thrush*
American Black Duck*	Prairie Warbler*
Black Rail	Prothonotary Warbler*
Least Tern*	Worm eating Warbler*
Red Knot	Kentucky Warbler*
Semipalmated Sandpiper	Saltmarsh Sparrow
Ruddy Turnstones	Sharp-tailed Sparrow*
Sanderlings	Seaside Sparrow*
Dunlin	American Redstarts*
Short-billed Dowitchers	Brown-headed Nuthatch*
Chucks-will's-widow*	

Compiled from DAS 2004 and TNC 2005.
** Species located on BBS Route in the Murderkill watershed*

[1] The WatchList identifies North American bird species that are faced with population decline, limited geographic range, and/or threats such as habitat loss on their breeding and wintering grounds. The WatchList is an early warning system that focuses attention on at-risk bird species before they become endangered.

Fish

Fish communities in Delaware's coastal plain streams, such as the Murderkill, consist of both resident and non-resident species. The lower (tidal) portion of the Murderkill functions as a nursery and seasonal feeding area for a variety of marine and estuarine spawned fishes. Resident species are concentrated primarily upstream in the freshwater tidal areas. This upstream area is also primary spawning area for anadromous species such as the white perch, alewife and blueback herring (DNREC, 1991).

Reported data on fish communities in the Murderkill River is limited. Reports and data exist for two fish studies by DNREC. Fish were first surveyed in the Murderkill in 1986 as part of a ten-watershed study conducted in Delaware. Community data from this study is not in site-specific format; therefore, it was not used for prioritization of subwatersheds within the Murderkill (DNREC, 1987). Site-specific data does exist for approximately nine sites as part of the later study; however, an index of biological integrity (IBI) score was not developed for those sites, making it difficult to compare the quality of fish communities across sites (DNREC, 1991). Habitat data was also collected in both studies, but was not available at the time of this report.

The most common fish caught in both freshwater and tidal areas (for both studies) was the American Eel and white perch. Other common tidal fish include white catfish, hogchoker, and Mummichog, weakfish, and Atlantic Menhaden. Common fish from the freshwater stations included pumpkinseed, bluegill, white perch, and Tessellated darter (DNREC, 1987 & 1991).

Aquatic Macroinvertebrates

Several datasets are available for macroinvertebrates in the Murderkill watershed from the years 1986 through 2003. Both tidal and nontidal macroinvertebrates were sampled in two earlier studies (DNREC, 1987 & 1991), but sites are not well defined and available data is primarily limited to species lists and/or indices that are not described.

More recent (1991-2003) macroinvertebrate and habitat data is site-specific and contains well-defined indices (DNREC 2005a). Macroinvertebrate and habitat indices and metrics are summarized in Table 11 and in Appendix B. Figure 2 shows macroinvertebrate sampling site locations using the most recent data.

The moderately and severely degraded macroinvertebrate sites in Table 11 coincide with segments of the Murderkill on the 1998 - 303(d) list due to poor biology (DNREC, 1998). Nonpoint source pollution from cropland fertilizers, animal-raising operations and septic systems are indicated as the main causes of impairment (DNREC, 2001). Where habitat is also classified as moderately or severely degraded, it is either an additional or primary cause of macroinvertebrate community impairment (see Section 2.3 for more information).

Table 11 . Macroinvertebrate and Habitat Score Summary for the Murderkill

Subwatershed	Stream Name	Site #	Sample Date	HCI (%)	Habitat Class	Taxonomic Richness	BCI (%)	Macro Class
Beaverdam Branch	Fan Tax Ditch	RR02	11/01/91	20	Sev Deg	27	27	Sev Deg
	Beaverdam Branch	EPA07	12/03/96	100	Excellent	30	40	Mod deg
Browns Branch	Browns Branch	C15122	10/29/93	103	Excellent	32	90	Good Cond
		EPA04	10/30/96	111	Excellent	27	70	Good Cond
		RR24	11/01/91	93	Good Cond	20	47	Mod deg
	Trib to Browns Branch	EPA23	10/30/96	33	Sev Deg	30	40	Mod deg
Hudson Branch	Trib to Hudson Branch	EPA05	12/03/96	48	Sev Deg	15	20	Sev Deg
McColley Pond	Trib to McColley Pond	C15120	11/22/93	92	Good Cond	28	100	Excellent
		EPA15	12/04/96	103	Excellent	22	80	Good Cond
Middle Murderkill	Ash Gut	C15079	11/02/93	76	Mod Deg	23	50	Mod deg
Pratt Branch	Trib to Pratt Branch	C15056	11/01/96	78	Mod Deg	13	20	Sev Deg
Swamp Creek	Black Swamp Creek	C15090	11/01/96	57	Sev Deg	18	20	Sev Deg
		C15105*	12/05/96	112	Excellent	13	33	Sev Deg
Upper Murderkill	Spring Branch	C15095	11/22/93	99	Good Cond	19	30	Sev Deg

HCI = Habitat Classification Index
Taxonomic Richness = Number of unique taxa
HBI = Hilsenhoff Biotic Index, measure of tolerance to pollution of community
BCI (%) = Biotic Classification Index, % of reference
Classification = Severely degraded, Moderately degraded, Good condition, Excellent

2.3 Physical Conditions

This section presents available data on flow, instream and sensitive habitats, and riparian buffer quality in the Murderkill watershed.

Flow and Tide: USGS gauging stations

The Murderkill River from its mouth at Bowers Beach up to Courseys Pond is tidal. Similarly, lower segments of Browns Branch, Pratt Branch, Hudson Branch, Spring Creek, and Double Run are tidal. Several United States Geological Survey (USGS) gauging stations exist in the Murderkill Watershed. One tide gauge was installed at Bowers Beach (01484085), in proximity of the confluence of the Murderkill River and Delaware Bay, while the second tide gauge was installed at the Rt. 113 Bridge at Frederica (01484080). These tide gauges were in operation from 1996 through 1999 and recorded tidal elevations every fifteen minutes.

A stream flow gauging station has been periodically used to record data since 1930 at the Rt. 13 Bridge near Felton, Delaware. This gauging station (01484000) monitors drainage from an area of 14.92 square miles and was in operation from 1931 to 1933, 1960 to 1985 and 1996 to 1999.

Instream Habitat

During sampling of tidal rivers completed in 1986 (DNREC, 1987), the Murderkill River was rated as having high habitat richness in comparison to the other rivers sampled at that time. This determination was based on the high relative abundance of infaunal and epifaunal macroinvertebrate species. The overall dominance of crustacean species in the tidal areas (mysid shrimp and amphipods) indicated spatial heterogeneity of the bottom substrate most likely in the form of detritus and shells (DNREC, 1987). According to data from two sediment sampling sites in the tidal portion of the Murderkill, the textural class of the in-stream tidal sediment is mainly silty clay loam, clay, or silty clay (DNREC, 2005b).

Site-specific habitat data from 1991-2003 was collected and analyzed at the macroinvertebrate sampling sites (DNREC 2005a) in the nontidal segment. These data are summarized in Table 11 and in Appendix C. Channelization has been cited as one of the primary causes of physical habitat impairment (DNREC, 2004b) and is possibly the cause of impairment for some of the above moderately and severely degraded sites, especially those segments of the watershed that have been ditched or converted to tax ditches. DNREC, Division of Soil and Water Conservation and Kent Conservation District are responsible for providing planning and organizational assistance for the development and maintenance of tax ditches.

Known tax ditch locations in the Murderkill are Jackson's Tax Ditch in Browns Branch, and Marvel's Crossroads in the McColley Pond subwatershed (Jim Sullivan, Kent County Soil and Water Conservation, personal communication, May 2005). These tax ditches drain 5,157 acres of land in the Murderkill watershed, or 7.6% of the total watershed. This equals roughly 27.36 miles of tax ditches (length). Not all ditches have been mechanically modified, some have only had their vegetation removed. Fan Tax Ditch in Beaverdam Branch is classified as a public ditch, not a tax ditch.

According to CWP (2005) stream reaches in the tax ditch system in the Appoquinimink watershed were characterized by lack of vegetation, mowing to edge, and herbicide application. Both Fan Tax ditch (site RR02 in Beaverdam Branch) and a tributary to Browns Branch (EPA 23) are within ditched areas and were classified has having severely degraded habitat (Table 11). In addition, both of these subwatersheds had the highest percentage of inadequate riparian buffers of all streams, rivers and tax ditches analyzed by DNREC (Krumrine, 2004, Table 12). Lack of forested buffer in combination with the tax ditch maintenance practices such as spraying herbicide likely result in poor instream habitat.

Special Habitat Areas

Little data describing the conditions of remaining upland forests, wetland conditions, or other sensitive areas was available at the time of this report. Much of the special habitat areas discussed below are contained within the Lower Murderkill subwatershed.

The Milford Neck Conservation Area is a network of lands owned by The Nature Conservancy (TNC), Delaware Wildlands, and DNREC. The area is comprised of portions of the Lower Murderkill subwatershed and portions of the Lower Mispillion River watershed to the south.

The Milford Neck Conservation Area is characterized by undeveloped beaches and dunes within the Delaware coastal zone; as well as vast tidal marshlands, swamps, upland forests, and agricultural lands. Milford Neck is home to two extremely rare plant species in Delaware: featherfoil, *Hottonia inflata*, and *Cendric petunia*. To increase the quality of this habitat, TNC is restoring more than 80 acres of agricultural fields to native deciduous forest.

Besides containing habitat for many of the migratory and/or breeding birds that frequent the Delaware coastal zone, Milford Neck also provides prime habitat throughout the year for river otters, wild turkeys, and green treefrogs—a rare state species (TNC, 2005).

The Murderkill River contains high quality smooth cordgrass (*Spartina alterniflora)* communities in estuarine habitat areas of the lower Murderkill, some which are located within the Milford Neck complex and Delaware Coastal Zone. These communities are used extensively by various animal assemblages, including many birds such as Marsh Wrens, Short-eared Owls (*Asio flammeus*), Northern Harrier (*Circus cyaneus*) [2], Willet, Seaside Sparrow, Red-winged Blackbirds (*Agelaius phoeniceus*), Snow Geese (and mammals, such as the marsh rice rat, and muskrat, and numerous invertebrates, especially the fiddler crab, grass shrimp, ribbed mussel, coffee-bean snail, saltmarsh mosquito, and mud snail. Numerous fishes are known to spawn in cordgrass marshes. The state rare plant, *Polygonum ramosissimum* (bushy knotweed), is a rare associate in this community (DNPS 1999).

Riparian Buffers

A GIS analysis of the current status of forested riparian buffers using high-resolution aerial photos was conducted by DNREC (Krumrine, 2004). The analysis revealed that out of the 230 miles of rivers, streams, and tax ditches assessed within the Murderkill watershed, 44% were inadequately protected by forested riparian buffers (Table 12).

Only 130 miles (56%) are adequately buffered along both stream banks; 67 miles (29%) have deficient buffers along either one or both of the stream banks; and 33 miles (15%) have no stream buffers along either stream bank.

Overall, most of the tidal portions of the watershed and the main stem of the Murderkill River are adequately buffered. The areas in most need of attention are the agricultural tax ditches, many of which have no forested riparian buffers. The analysis also emphasizes the importance of working in cooperation with private landowners, since a majority of the waterways flow through privately owned lands. Only 11% of the assessed waterways flow through publicly owned lands. Waterways in public ownership fared much better than those in privately owned lands. Within public lands, 21 miles (81%) are adequately buffered along both stream banks and only 1 mile (4%) had no forested buffer along either stream bank.

Figure 4 shows the location of inadequate stream buffers in the Murderkill watershed.

[2] Both the Short-eared owl and the Northern Harrier are considered Endangered in the State of Delaware. Neither of these species were found in the Breeding Bird Survey but the survey did not include sites in the Lower Murderkill with cordgrass communities.

Table 12. Forested Riparian Buffers in the Murderkill Watershed
(from Krumrine, 2004)

Subwatershed	Stream length* (mi)	DNREC buffer assessment				
		Length of assessed buffer (mi)	No buffer on either side	Buffer deficient on one or both sides**	Inadequate miles *(sum of no and deficient buffer)*	% Inadequate
Beaverdam Br	14.3	13.0	25%	41%	8.6	66%
Browns Br	30.2	29.3	34%	40%	21.6	74%
Double Run	17.0	13.7	10%	44%	7.3	54%
Hudson Br	24.6	20.4	24%	56%	16.4	80%
Lower MK	82.0	77.9	6%	12%	13.9	18%
McColley Pond	5.9	4.2	21%	27%	2.0	48%
Middle MK	22.6	24.4	2%	25%	6.6	27%
Pratt Br	10.4	7.8	10%	42%	4.1	52%
Spring Creek	8.6	7.9	2%	19%	1.7	21%
Swamp Ck	24.5	23.3	25%	35%	13.9	60%
Upper MK	12.5	10.7	15%	35%	5.3	50%
Total Watershed	**252.6**	**232.5**	**15%**	**29%**	**101.4**	**44%**

* Measured by CWP, includes pond/lake centerline
** Deficient means less than 100 ft of riparian forest cover as measured from centerline of stream

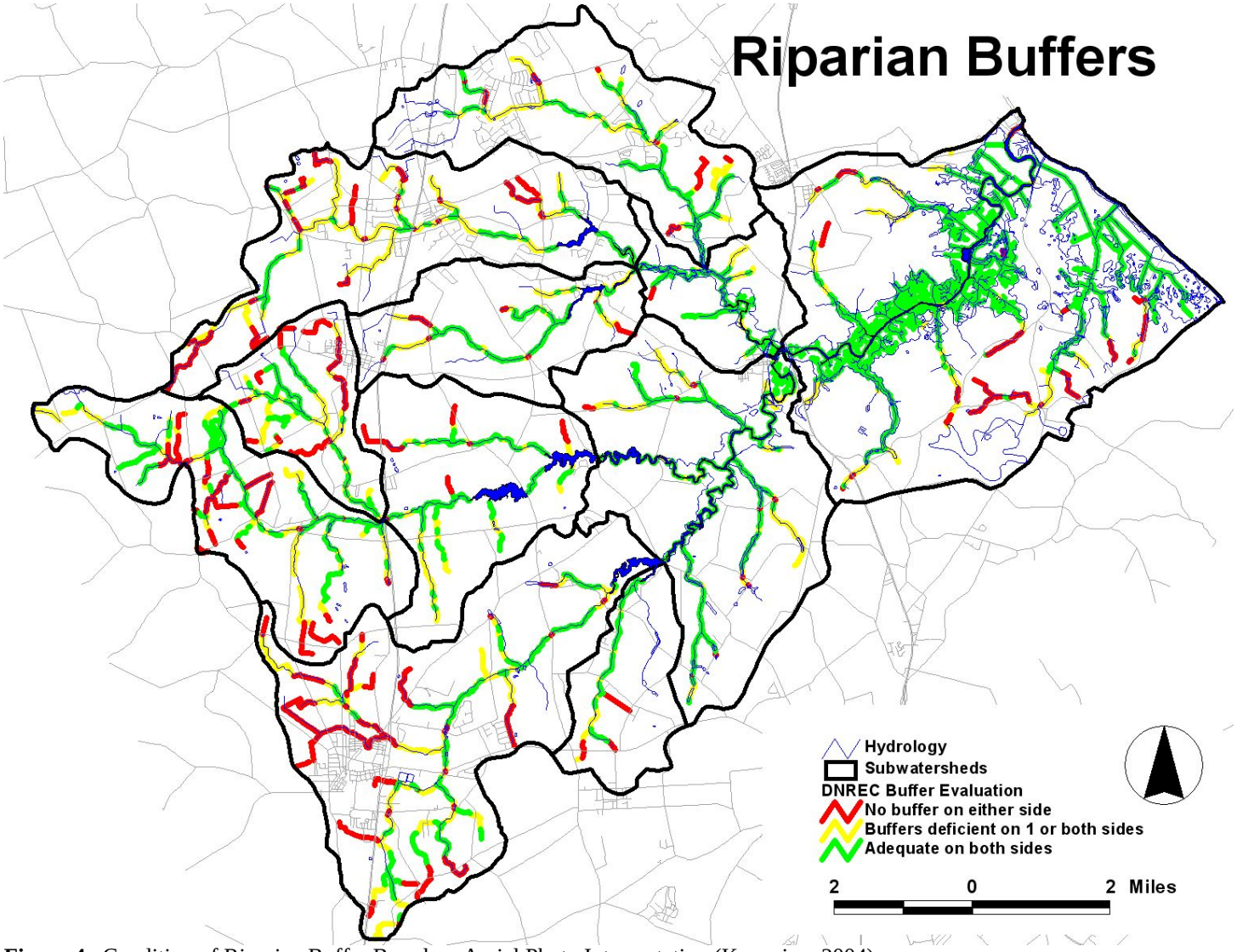


Figure 4. Condition of Riparian Buffer Based on Aerial Photo Interpretation (Krumrine, 2004)

3.0 Land Use Analysis

This section of the report summarizes existing land use, identifies remaining developable areas and growth potential, and uses impervious cover as an indicator of growth and predictor of stream health.

3.1 Existing Land Use

Current watershed land use estimates are based on 2002 land use GIS data provide by Kent County. Minor changes to the land use map were made by Kilby (2005) based on observations in the field. Table 13 summarizes current land use as a percentage for each subwatershed. Refer to Task 1 Technical Memo (Kilby, 2005) for a land use map.

Over half (54%) the watershed is in agricultural use, and approximately 14% of the watershed is classified as urban uses. The Murderkill watershed has a total of 11,830 acres of wetlands, approximately 17% of the total land acreage of the watershed. The predominant wetland type is Palustrine with 60% of the total wetland acreage, and most (86%) of those are forested. There are also extensive estuarine wetlands closer to the confluence with the Delaware Bay. Just over 11% of the watershed remains in forested condition.

Table 13. Murderkill Land Use by Subwatershed

Subwatershed	Area (mi^2)	% Land Use (2002*)												
		Single Family	Multi family	Commercial	Industrial	Transportation	Institutional	Recreational	Agriculture	Rangeland	Forest	Water	Wetlands	Vacant
Beaverdam Br	4.2	15.6		1.3	0.2	0.3			50.4	1.2	12.3	0.1	17.7	0.9
Browns Br	15.6	15.4	0.2	3.9	1.3	0.8	0.4	2.2	47.3	1.0	11.9	1.4	11.0	3.2
Double Run	9.1	24.0		0.6		0.4	0.1		51.1	0.2	12.9	0.3	8.4	2.0
Hudson Br	11.0	21.6		2.2		0.5			51.0	0.5	6.5	0.9	16.2	0.7
Lower MK	23.2	3.7		0.4		0.9		0.2	46.2	0.2	8.2	3.5	36.2	0.4
MColley Pond	3.9	13.8		0.2					62.6	0.6	17.3	0.5	4.4	0.7
Middle MK	13.2	7.1		0.5		0.2	0.1		67.2	2.7	9.6	2.7	9.8	0.2
Pratt Br	6.2	18.0		0.5		0.4	0.6		62.7	0.9	10.5	0.9	4.7	0.8
Spring Creek	3.6	4.2		1.0		0.8	0.1		58.9	0.1	20.9	2.7	11.2	
Swamp Ck	8.9	5.3				0.5			59.9	0.4	13.8	0.3	19.5	0.2
Upper MK	8.1	4.8		0.3		0.7	1.7	3.8	62.3	0.7	16.1	2.8	6.7	
Total Watershed	**107.0**	**11.3**	**0.2**	**1.1**	**0.2**	**0.6**	**0.2**	**0.7**	**54.4**	**0.8**	**11.3**	**1.8**	**16.7**	**0.9**

* Land use based on Kent County GIS file, with corrections based on field observation by Kilby (2005). Categories presented here represent a grouping of Kent County land use categories (see Table 18 for breakdown).

Protected Areas

Almost 14% of the watershed is considered permanently protected open space either through designation as a park or preserve, or through land use techniques such as the PDR/TDR or other conservation easement programs. In addition to these protected parcels, wetland and floodplain provisions also help to protect sensitive habitats. Considering that less than 15% of the watershed is designated as protected open space (not including all wetlands), opportunities still exist for protection and restoration of water resources through the development process. Figure 5 shows designated open space and potential areas of additional protection per Kent County GIS data (i.e., AP/10 and proposed acquisition).

There appear to be other opportunities for protection in the upper watershed in association with wetlands, and contiguous forest. More investigation of these opportunities should be pursued. Special consideration should also be given to protecting areas of high recharge potential. About a quarter of the watershed is characterized as having an excellent recharge potential (Figure 6).

Greenways and recreation

In 1965, the Division of Parks & Recreation began protecting lands along the Murderkill River. To date over 2,028 acres and 3 miles of river corridor have been protected at Killens Pond State Park and the Murderkill River Nature Preserve, stretching from Route 13 to Frederica. A one-half mile pathway was constructed from the park entrance on RD 384 to the Route 13 intersection. The pathway is part of State Bicycle Route 1 and links Lake Forest High School and Killens Pond State Park. A 3.5 mile canoe trail was established from Route 13 to the Coursey Pond spillway.

Stream Crossings

Another indicator of urban impacts to stream systems is stream interruption, as measured by average stream crossings per stream mile in a subwatershed. A rough estimate of number of stream crossings was derived from road and hydrology GIS layers provided by the Whole Basin Program (2000). The number of stream crossings can be used to determine urban fishery resource potential, with an emphasis on potential fish barriers. Number of crossings also may indicate a potential for retrofits opportunities, as well as locate grade control features that may moderate or accelerate local stream bank erosion.

The Murderkill has at least 136 stream crossings; Beaverdam and Hudson Branches have the highest density of crossings at 3.6 and 2.3 crossings per square mile, respectively (Table 14).

Pollutant Sources (point sources)

The Delaware Whole Basin Program provided 2000 data on recharge potential, septic systems and potential contaminants such as wastewater outfalls, underground storage tanks, and land fills. Subwatersheds with high densities of septics, CAFO's, or other potential pollution hotspots may be priorities for education and restoration efforts (see Table 14).

A total of 138 potential contaminant locations were identified in the watershed, 78% of which are underground storage tanks. A list of potential contaminants by subwatershed can be found in Appendix D. More than 50 of these potential contaminants are located in Browns Branch, including a landfill and two Super Fund sites. There are over 5,000 individual septic tanks in the watershed. Double Run and Hudson Branch have the highest density of on-site septic systems, 130 and 100 per square mile, respectively.

Twenty-seven confined animal feedlots (CAFOs) were identified in the Murderkill watershed based on land use data. The type, animal density, and management practices at these locations was not investigated. The locations of these operations, as well as recharge areas and other potential contaminants can be located in Figure 6.

There are four municipal wastewater treatment plants in the Murderkill River watershed. These facilities include the city of Harrington, Kent County facility, Canterbury Crossing mobile home park, and Southwood Acres mobile home park.

Table 14. Stream Crossings and Potential Pollutant Sources

Subwatershed	CAFO's		Septics		Potential Contaminants			Stream Crossings	
	#	acres	#	#/sq mi	Large On-site Septic Systems	Hotspots*	Underground Storage Tanks	#	#/sq mi
Beaverdam Br	2	23	290	69.9	1	1	6	15	3.6
Browns Br	3	23	855	54.7		5	49	19	1.2
Double Run	0	0	1183	129.9	2	2	4	16	1.8
Hudson Br	2	16	1106	100.7	2	2	8	25	2.3
Lower MK	8	63	420	18.1		5	11	13	0.6
McColley Pond	4	25	232	60.3		1	3	5	1.3
Middle MK	3	23	297	22.6		1	10	17	1.3
Pratt Br	1	21	363	58.5		2	5	10	1.6
Spring Creek	0	0	44	12.3			3	1	0.3
Swamp Ck	2	13	221	24.7			2	10	1.1
Upper MK	2	40	231	28.4	1	1	6	5	0.6
Total Watershed	27	247	5242	49.0	6	20	107	136	1.3

* Hotspots include Super fund sites, Toxics Release Inventory Sites; Landfills, Dumps, Tires; Pesticide Loading, Mixing & Storage; and Sludge Application Sites (from Whole Basin Program, 2000)

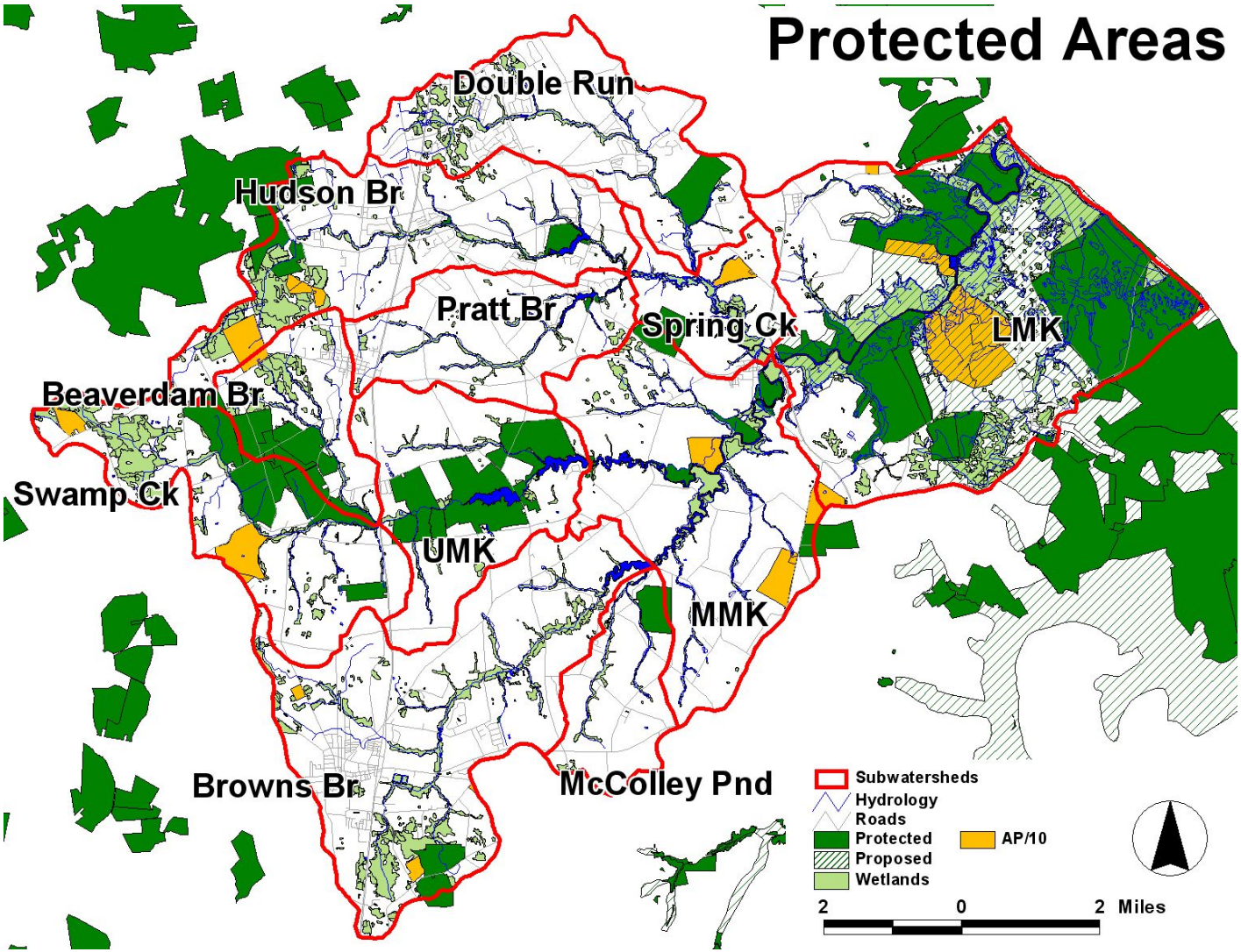


Figure 5. Designated and Potential Protected Areas

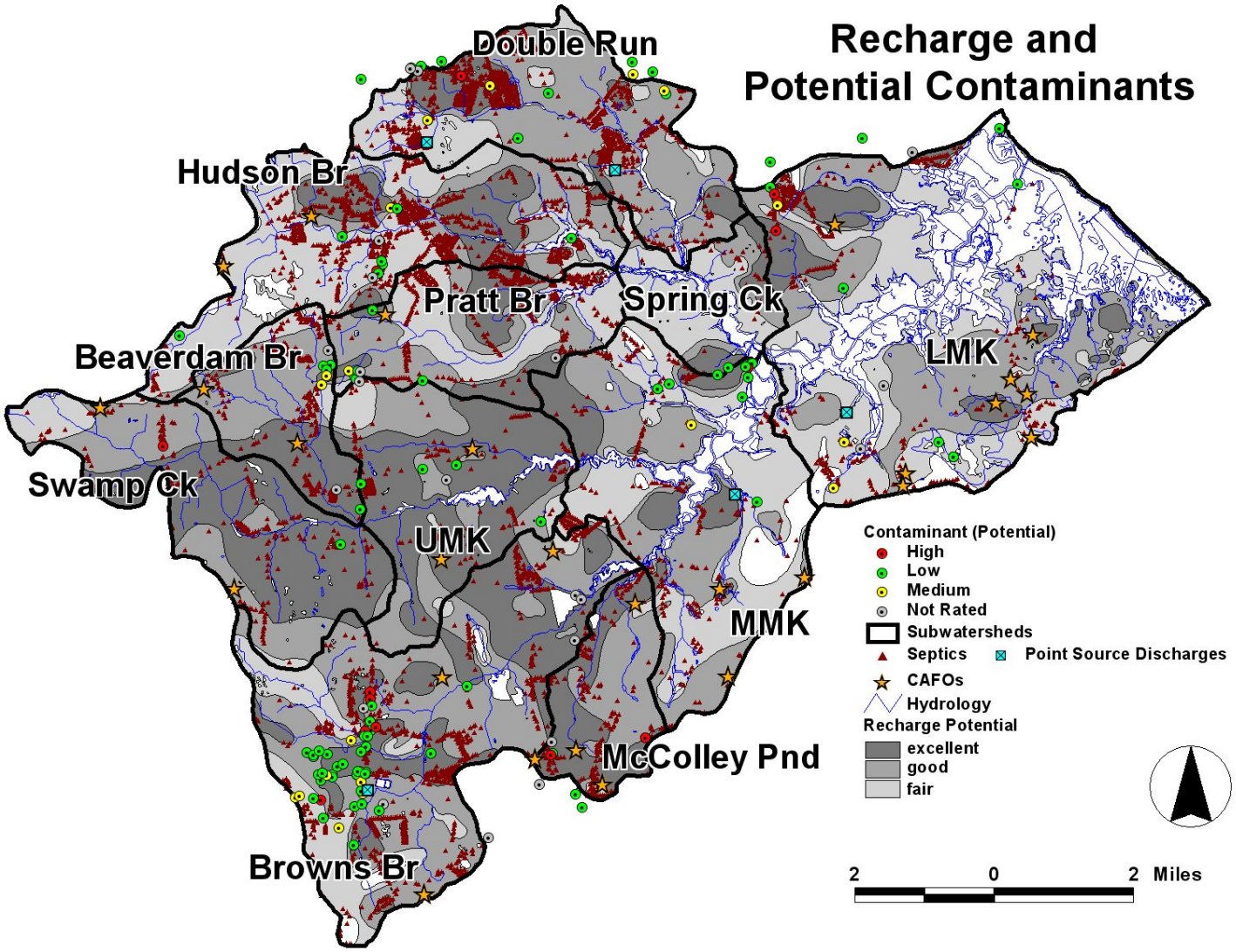


Figure 6. Recharge Areas and Potential Contaminant Source

Storm Water Treatment Practices

Approximately 85 individual stormwater treatment practices are located in the watershed (Table 15), the majority of which are in Brown's Branch. The most common practices appear to be wet or dry detention ponds. Existing practices can be indicative of local stormwater management experience, extent of treatment, and potential retrofit opportunities (particularly dry pond). Unfortunately, the GIS data sets are incomplete, and do not contain information on drainage area, sizing, and practice age. This data is currently being updated by Kent County.

Table 15. Number of Stormwater Treatment Practices (Kent County, 2005)

Subwatershed	Stormwater Treatment Practices*					
	Wet Pond	Dry Pond	Infiltration	Filter Strips	Swales	Total
Beaverdam Br	1	1	1	0	0	3
Browns Br	32	5	1	0	6	44
Double Run	5	4	3	0	0	12
Hudson Br	8	3	0	0	0	11
Lower MK	0	0	0	0	1	1
MColley Pond	2	1	0	0	0	3
Middle MK	0	0	0	1	0	1
Pratt Br	4	3	0	0	0	7
Spring Creek	0	0	0	0	0	0
Swamp Ck	0	0	0	0	0	0
Upper MK	2	1	0	0	0	3
Total Watershed	54	18	5	1	7	85

* Combination of two GIS data sets from the County. Neither data set is completely accurate, the County is in the process of refining and updating STP location and maintenance information,

Agricultural Best Management Practices are being evaluated by MSD in conjunction with Task 4 of this project and will be reported on separately.

3.2 Development Potential

Zoning for the Murderkill was supplied by Kent County and does not contain information for parcels within municipal jurisdictions. Figure 7 shows zoning categories for the remaining developable parcels in the watershed. Developable areas include existing farms, forests and vacant parcels (based on 2002 land use) that were considered eligible for development. Wetlands and designated protected areas were subtracted from potential developable areas. Steep slopes, buffers, and other restrictions on developable areas were not accounted for.

More refined future growth predictions are derived from the land conversion analysis performed during Task 1 (Kilby, 2005). General findings from that analysis suggest:

- The Murderkill watershed area will probably receive about 35% of the County's growth - all of the growth in Felton and Harrington and half of the growth in Central Kent and North Milford.

- Most of the medium to high density residentially planned areas in the watershed have already been developed as have significant portions of the commercially planned areas. Harrington has some remaining developable areas, however, the City's level of growth, however, will be somewhat hindered in the near term due to limited capacity in its existing water and sewer treatment systems. Viola and Felton are currently almost completely developed except for some platted low density single family residential subdivisions. Frederica currently retains some significant undeveloped areas, which have recently been proposed for residential development.

- The total number of housing units that could be built in the already platted, recently approved, and soon to be approved subdivisions exceeds the number of housing units projected in the high estimate for the Murderkill between 2002 and 2012 and almost reaches the high estimate of housing units for 2022. This could indicate that the Murderkill watershed is experiencing growth at a higher rate than predicted by the population growth estimates. It could also indicate that there is a great deal of development speculation going on in the area.

- With regard to new commercial and industrial development within the county portion of the Murderkill watershed, the county does not expect much to occur. This is not an area of the county that is planned for major economic development. There are no industrial parks existing or planned in this area of the county.

- Future development in the Murderkill is assumed to be compatible with the state growth strategies, including the DelDOT Corridor Capacity Preservation Program. Within the Murderkill watershed, this program greatly limits direct access to the Route 13 and Route 1 / 113 corridors. The County does not anticipate any new commercial development along these roads in the county portions of the Murderkill. Within Felton, Frederica and Harrington, most of the frontage land along these roads was already developed in 2002, so little new commercial development is expected within the Murderkill watershed.

- The County has established incentives for development in the Growth Zone Overlay District (i.e., density bonuses, sewer service). The PDR and TDR programs provide even more incentives for development to occur within the overlay. Given that the County's new TDR program is entirely untested, this study does not contemplate higher densities in the Murderkill watershed than have been occurring in recent years.

- Approximately 4,253 acres in the Murderkill watershed have been purchased by the state in this PDR program and another 2,657 acres are in Agricultural Preservation Districts. These areas are not expected to develop between 2002 and 2022.

Based on this analysis, 35 parcels expected to be developed within the next 20 years were identified by Kilby (2005). These parcels can be seen in Figure 7, and are predominantly low density residential development.

While this level of development represents expected growth in the Murderkill watershed from 2002 – 2022, current city and county policies would permit a great deal more growth to occur. The comprehensive plan future land use maps of the City of Harrington and Kent County show large areas that could potentially be approved for growth within the Growth Zone Overlay District. This growth is expected to be primarily low density residential development—though higher density residential development could occur if the County's TDR program takes off—and would be expected to occur far into the future beyond the 20-year horizon of this study.

Table 16 summarizes additional subwatershed characteristics related to potential growth including estimated developable areas, % of area within the growth zone overlay district, amount of protected land, and area of high recharge value.

Table 16. Developable and Protected Lands

Subwatershed	Area (Acres)	% Developable[1]	% Likely to be Developed[2]	% Growth Zone[3]	% Wetlands[4]	% Protected[5]	% Excellent Recharge Potential[6]
Beaverdam Br	2656	46%	0%	60%	17.7%	26%	40%
Browns Br	10009.6	58%	2.7%	53%	11.0%	3%	28%
Double Run	5830.4	61%	7.2%	96%	8.4%	5%	16%
Hudson Br	7027.2	55%	7.9%	80%	16.2%	6%	19%
Lower MK	14873.6	42%	1.1%	3%	36.2%	31%	8%
McColley Pond	2464	73%	3.1%	0%	4.4%	7%	49%
Middle MK	8416	75%	6.8%	73%	9.8%	5%	12%
Pratt Br	3968	74%	10.2%	100%	4.7%	1%	24%
Spring Creek	2291.2	75%	9.6%	94%	11.2%	5%	15%
Swamp Ck	5721.6	61%	0.0%	0%	19.5%	17%	56%
Upper MK	5203.2	59%	0.6%	69%	6.7%	29%	63%
Total Watershed	**68460.8**	**58%**	**4.0%**	**50%**	**16.7%**	**14%**	**25%**

[1] Developable lands are non-protected, un developed parcels currently listed as agricultural or forested land use.
[2] Parcels likely to be developed based on Kilby 2005 analysis (depicted on Figure 7)
[3] Growth zone is area designated by County for future growth (depicted on Figure 7)
[4] Wetland percentages were derived from the wetlands land use classification (Kent County, 2002). See Figure 5.
[5] Protected lands (see Figure 5) include parcels designated as parks, preserves, open spaces, PDR or other permanently protected area. These estimates do not include all wetland areas or temporary easements (i.e, AP/10).
[6] Recharge Potential is defined by Delaware Whole Basin Program (2000). See Figure 6.

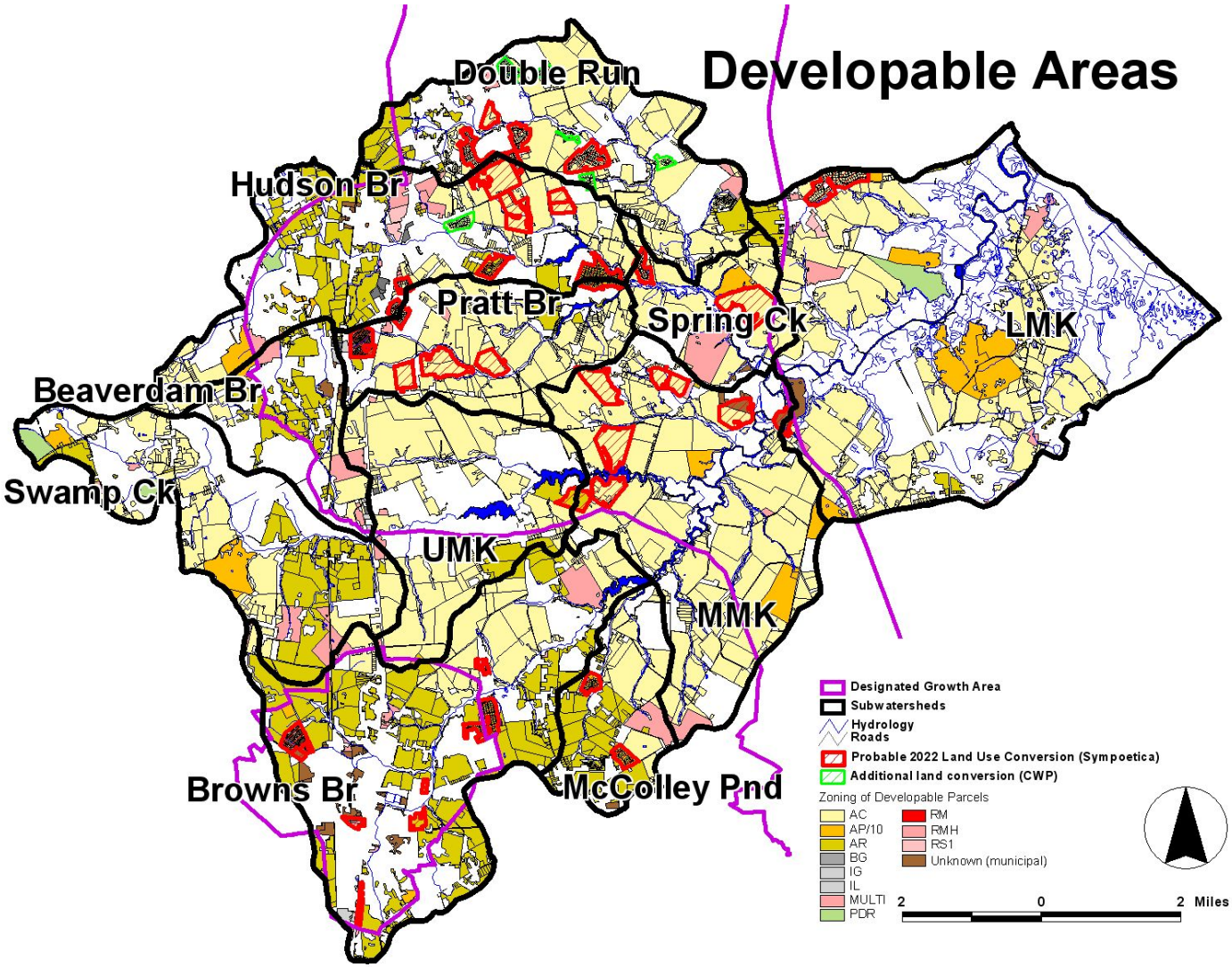


Figure 7. Zoning Classifications of Developable Parcels

3.3 Current and Future Impervious Cover

Watershed impervious cover (IC) is a typical indicator of stream conditions. Percent imperviousness can be easily estimated based on land use, and can be used to predict the impact of future urbanization on stream conditions based on zoning or probable development scenarios. This section describes an impervious cover analysis of the Murderkill watershed based on three scenarios: current, future buildout (high), and a refined estimate of expected future growth (low).

The Impervious Cover Model

Recent research has revealed a strong relationship between IC and various indicators of stream quality. When porous land cover is converted to IC, a greater fraction of annual rainfall is converted to surface runoff and a smaller volume recharges the groundwater. This increased surface runoff volume causes higher peak flows that erode stream channels, and lower baseflow, resulting in in-stream habitat degradation. In addition, surface runoff carries a suite of pollutants that degrade water quality. Studies also suggests a link between IC and the diversity, richness and abundance of aquatic life (CWP, 2003).

Stream research generally indicates that certain zones of stream quality exist, most notably at about 10% watershed imperviousness, where sensitive stream elements are lost from the system. A second threshold appears to exist at around 25 to 30% impervious cover, where most indicators of stream quality consistently shift to a poor condition (e.g., diminished aquatic diversity, water quality and habitat scores). Based on the relationship between IC thresholds and stream quality, a simple urban stream classification model can be used to screen subwatershed conditions, provide a classification system with management options to address the protection and mitigation needs of a watershed, and predict the existing and future quality of streams based on the measurable change in impervious. The model classifies streams into one of three categories: sensitive, impacted, and non-supporting (Table 17).

Table 17. Impervious Cover Classifications

Classification	Description
Sensitive (≤10% IC)	• Typically high quality streams (though rurally-impacted watersheds will have low IC) • Generally have stable channels, excellent habitat structure, good to excellent water quality, diverse communities of both fish and aquatic insects • Do not see frequent flooding and other hydrological changes associated with urbanization
Impacted (11%-25% IC)	• Show clear signs of degradation due to watershed urbanization • Greater storm flows begin to alter the stream geometry • Both erosion and channel widening are clearly evident • Stream banks become unstable, and physical habitat in the stream declines noticeably • Stream water quality shifts into the fair/good category during storms and dry weather • Stream biodiversity declines to fair levels, fewer sensitive fish and aquatic insects
Non-supporting (>25% IC)	• Streams essentially conduits for conveying stormwater flows • Channel becomes highly unstable, many reaches experience severe widening, incision and erosion • Pool and riffle structure diminished or eliminated; stream substrate can no longer provide habitat for aquatic insects, or spawning areas for fish • Water quality often rated fair to poor; water contact recreation not possible • Subwatersheds generally display increases in nutrient loads to downstream receiving waters • Biological quality is generally considered poor, dominated by pollution tolerant species

Caveats
Although the IC model is supported by research, there are several limitations that need to be clearly understood, particularly in relation to the Murderkill. Clearly, the model fails to account for agricultural impacts, which are likely the sources of many stream impairments in the Murderkill. In these cases, additional indicators such as riparian buffer continuity, % pasture and cropland, # of CAFOs, and # of agricultural BMPs should be considered when establishing subwatershed management classifications.

The model recognizes that individual stream may depart from the model for various reasons. It is intended to predict potential rather than actual stream quality based on urbanizing conditions, thus modification should be made based on on-the ground conditions. The model should be applied to first to third order streams. Thresholds may be shifted up for coastal systems where tidal influences may dampen impacts (15% for sensitive threshold for example). Further research is needed regarding the influence of stormwater treatment practices, pervious areas, and riparian forest cover, as well as the threshold between impacted and non-supporting streams. Despite these limitations, the impervious is still one of the best tools for rapidly evaluating and managing a watershed (CWP, 2003).

Estimating Impervious Cover
Current IC was estimated using GIS for each subwatershed for three scenarios:

- Current—using 2002 land use data from the county that was revised by Kilby (2005) based on field observations.
- Full buildout—based purely on Kent County zoning data
- Refined buildout—based on a more probable land use conversion analysis (Kilby, 2005).

For each scenario, IC was estimated by applying an average IC coefficient to each land use category, zoning district, or development density (see Table 18). Coefficients derived from similar DE land uses in the Christina Basin (Greig et al. 1998) and from the Chesapeake Bay (Cappiella and Brown, 2001) were applied in the Murderkill.

Under the full buildout scenario, it was assumed that full build out of current zoning would occur in the future, and that the most densely allowable development within a zoning district would occur. Consequently, future IC estimates represent the <u>maximum</u> level of development that can be expected in the watershed, especially since not all parcels that are zoned for a particular land use will ultimately be built out (i.e., economic conditions, access, lack of infrastructure). Areas zoned Agricultural Conservation (AC) that are within the designated growth zone were assumed to buildout to maximum density of 3 units per acre. These assumptions do not account for the absence of zoning information for developable areas within municipal jurisdiction.

To project future IC, developable parcels were identified based on current 2002 land use. Developable parcels include all agricultural, forested, rangeland, transitional areas, and vacant lots (exclude developed parcels, wetlands, and protected areas). IC coefficients were applied to developable parcels based on their zoning classifications to obtain future IC acreage. Future IC acreage was added to current IC area for a total estimate of current IC for each subwatershed (corrections were made for converted lands).

Table 18. IC Coefficients and Land Use, Zoning, and Density Districts

Category	Kent Co. Land Use District	Future Classification		IC Coefficient
		Kent Co. Zoning	Refined (Kilby, 2005)	
Water / wetlands	Bays and coves; Man-made reservoirs; Natural lakes and ponds; Wetlands; Waterways/streams/canals	--	--	0%
Forest	Deciduous forest; Evergreen forest; Mixed forest	--	--	0%
Rangeland	Pasture; Shrub/brush rangeland; Herbaceous and Mixed rangeland	--	--	0%
Public Open Space	Recreational	--	--	5%
Vacant	Clear-cut; Inland natural sandy areas; Extraction; Transitional	--	--	5%
Agriculture	Confined animal feeding operations; Cropland; Farmsteads and farm related buildings; Other agriculture; Idle Fields Orchards/nurseries/hort; Truck crops;	AC (not in growth zone)	--	5%
Single Family Res. *(Low Density)*	--	AC (in growth zone); AR, RS1	LDR	22%
Single family Res. *(Med. Density)*	Single family dwellings; Mobile home parks/courts	RS-5, RMH, BN	MDR	30%
Multi-family Res. *(High density)*	Multi family dwellings	RM	HDR	65%
Institutional	Institutional/governmental	--	--	55%
Industrial	Industrial	IL. IG	Industrial	72%
Commercial	Retail sales/wholesale/prof. services; Other commercial; Junk/salvage yards; Mixed/Other urban land	BC, BG	Commercial	85%
Transportation/Utility	Highways/roads/freeways; Utilities; Communication-antennas; Other transportation/communication; Parking lots; Railroads; Vehicle related activity	--	--	90%

* Based on Kent County 2002 land use and zoning GIS
** All coefficients based on estimates used by DE Water Resources Agency as outlined in Greig et al. (1998) except for low density residential which is based on Cappiella and Brown (2000)

Under the refined future scenario, Kilby's (2005) land conversion analysis was used to predict where actual development was likely to occur over a 20-year horizon (2022). It assumes less development than full buildout by taking into account population trends, housing market, strategic growth plans, and restrictions associated with transportation corridors. In this scenario, the procedure for estimating future IC is similar to the buildout scenario, except developable parcels are limited to the 35 residential, commercial, and industrial parcels identified for development (see Figure 7). IC coefficients were assigned based on the density and type of probable development. Refer to the Task 1 Tech Memo for more detail on the land conversion analysis and assumptions made.

IC spreadsheet calculations for each scenario can be found in Appendix E.

Classifying Subwatersheds

In 2002, watershed impervious cover was estimated to be 8%. Based on the analysis of future conditions, maximum buildout is predicted to result in a watershed impervious estimate of 16%, and the refined buildout is predicted to result in a modest increase to 9% IC. Based on the IC model, three subwatersheds are classified as borderline sensitive/impacted, only one is classified as impacted, and the remaining are considered sensitive. Note that these classifications are solely based on IC and should be refined based on agricultural impacts, riparian indicators, and on the ground monitoring and assessment data before management classifications are finalized.

Based on probable growth in the watershed over the next 20 years (Kilby scenario), it is likely that two subwatersheds (Hudson and Pratt Branches) will shift to the impacted categories in the coming decades (see Table 19). All subwatersheds, with the exception of Lower Murderkill have the potential to shift to impacted if buildout falls more in line with allowable zoning. In particular, Pratt Br, Hudson Br, Brown Br , Double Run, and Spring Branch may begin to approach the non-supporting category.

As part of watershed planning effort, protection measures such as increased land conservation, strengthening environmental regulations (i.e. buffers, open space, erosion and sediment control), more stringent development criteria (i.e. better site design, stormwater criteria) are recommended for sensitive subwatersheds. For impacted subwatersheds, more emphasis on water quality improvements, stormwater retrofitting, stream restoration and pollution prevention may be emphasized.

Table 19. Current and Future Impervious Cover

Subwatershed	Total Acres	% IC				
		Current[1] (2002)	Future[2]		Classification[3]	
			Kent Co Zoning	Kilby (2004)	Current	Future Shift
Beaverdam Br	2656	8.7%	17.7%	8.7%	Sensitive	Potential
Browns Br	10009.6	12.9%	21.4%	13.8%	Impacted	Potential
Double Run	5830.4	10.8%	21.7%	12.1%	Sensitive/Impacted	Likely
Hudson Br	7027.2	11.4%	20.9%	12.8%	Sensitive/Impacted	Likely
Lower MK	14873.6	4.5%	5.6%	4.7%	Sensitive	No shift
McColley Pond	2464	7.5%	17.6%	8.1%	Sensitive	Potential
Middle MK	8416	6.1%	15.5%	7.4%	Sensitive	Potential
Pratt Br	3968	9.7%	22.6%	11.5%	Sensitive/Impacted	Likely
Spring Creek	2291.2	5.8%	21.9%	7.5%	Sensitive	Potential
Swamp Ck	5721.6	5.1%	11.3%	5.1%	Sensitive	Potential
Upper MK	5203.2	6.6%	13.9%	6.7%	Sensitive	Potential
Total Watershed	**68460.8**	**8.0%**	**15.6%**	**8.8%**	**Sensitive**	**Potential**

[1] Current IC based on average IC coefficients for a given land use (see Table 18). Land use based on Kent County 2002 data with modifications made by Kilby (2005) based on field observation.
[2] Future IC initially determined based on Kent County zoning classifications for remaining developable parcels. These estimates were refined based on the probable land use conversion study (Kilby, 2005) which identified probable residential and commercial development over the next two decades given land use plans, development trends, and population projections.
[3] Subwatershed classifications based on impervious cover only (does not take agricultural impacts into account). Future shifting of classification based on ICM thresholds where "no shift" indicates no predicted shifting from sensitive to impacted; "potential" indicates based on zoning scenario that there may be a shift; and "Likely" indicates a probable shift based on Kilby (2005) analysis.

4.0 Subwatershed Prioritization

A prioritization of subwatersheds was completed in order to choose one or two subwatersheds for the Watershed Treatment Analysis (Task 4.2), and to provided preliminary guidance for future watershed restoration and protection efforts. A prioritization enables watershed planners to focus limited resources on areas most in need of management. In the prioritization for the Murderkill subwatersheds, factors negatively affecting either current or future water quality were assessed in order to choose initial subwatersheds for early (preventative) actions and restoration assessment. An important factor in the analysis was on subwatersheds that will likely experience additional development in the near future, so that cost effective policies and/or restoration measures could be enacted to reduce both current and future impacts (Kilby, 2005).

Table 20 provides a description of the factors used to prioritize Murderkill subwatersheds for restoration and prevention of additional impacts.

Table 20. Criteria to Prioritize Murderkill Subwatersheds for Restoration

Factor	Data
Low % of wetlands	% Wetland by subwatershed
Low % forest	% forest by subwatershed
Presence of CAFOs	# Confined animal feeding operations per subwatershed acres
High % of inadequate buffer	% of inadequate buffer by subwatershed
High density of septic systems	3 septics per sq mile per watershed
High recharge potential	% subwatershed with recharge potential
High # stream crossing	# stream crossings per subwatershed
High growth	High % subwatershed in growth area
High % impervious cover	% impervious cover by subwatershed
High future loss of Agricultural/forest land	Future land use (Kilby, 2005)
High total nitrate concentrations	Stations with high nitrates
Presence of poor macroinvertebrate diversity	IBI stations with low scores
Presence of poor in-stream habitat	IBI stations with low scores
High current or future IC	Current and future IC numbers by subwatershed

Subwatersheds were scored on the above factors using the criteria set forth in Table 21. Subwatersheds in all categories were given an initial score of 0, 1, or 2 based on the level (percentage or number) of impact in each category (and in the watershed as a whole). Several categories were weighted by a factor of two based on their potential importance relative to TMDLs for nutrients and CBOD. The categories receiving additional weighting included riparian buffers, number of septic systems, and percent area in growth zone. The final scores were normalized due to data limitations in some of the subwatersheds such as nutrients, macroinvertebrates and habitat (Table 22).

Table 21. Watershed Prioritization Scoring Scheme			
Metric	Prioritization score		
	2	1	0
Percent of Total CAFOs in watershed	> 20%	9-20%	< 9%
% Inadequate Buffer	≥ 60%	40-59%	<40 %
Density of stream crossings	>3 / sq mi	> 2 / sq mi	<2 /sq mi
Density septic systems	>80 / sq mi	50-80 / sq mi	<50 /sq mi
Current Impervious Cover	>12%	8-12%	<8
Future loss of Agricultural and forest land	> 400 acres	200-400 acres	< 200
% Subwatershed area in Growth Zone	> 70%	50-70%	< 50%
Wetlands	4-8%	9-14%	>15%
Forest	4-8%	9-13%	>14%
Average Nitrogen (mg/l)	5.2-8.3	3.4-5.2	1-3.4
Macroinvertebrate Classification	Severely degraded	Moderately degraded	Excellent or Good
Habitat Classification	Severely degraded	Moderately degraded	Excellent or Good

The three subwatersheds that scored highest for restoration priority included (in order of priority): Hudson Branch, Pratt Branch, and Double Run. These three priority subwatersheds have a number of characteristics that caused them to rank as strong candidates for restoration.

- They all expect to receive development pressure based on zoning and development projects that are in the "pipeline" (Kilby, 2005).
- There are opportunities for improvements in riparian buffers, wetland creation, and forest cover based on our preliminary analysis.
- All three subwatersheds have elevated nutrient concentrations based on the field data that was assessed.

The analysis was completed to assist with prioritizing restoration candidates from a subwatershed scale; however there are other factors that may be worth considering in the management of the subwatersheds. It should not be concluded that other subwatersheds do not also contain ample restoration opportunities, nor should one infer that other subwatersheds are not important for protection based on factors such as sensitive natural resources.

We recommend additional effort to identify areas, particularly in the headwaters, for natural resource protection. As stated previously, additional fieldwork to identify specific protection and restoration opportunities should be conducted as part of a comprehensive watershed planning process.

Table 22. Subwatershed Prioritization with Weighting on Buffer, Septics, and Area in Growth Zone

Subwatershed	CAFOs	Inadequate buffer	Septics	Stream crossings	IC	Loss of Ag/forest	% area in Growth Zone	Wetlands	Forest	High Nutrients*	Habitat**	Macro**	TOTAL	Total possible score w/ weight	Normalized weighted score
Beaverdam Br	0	4	2	2	1	0	2	0	1	0	2	2	16	30	0.53
Browns Br	1	4	2	0	2	1	2	1	1	1	0	1	16	30	0.53
Double Run	0	2	4	0	1	1	4	1	1	1	NS	NS	15	26	0.58
Hudson Br	0	4	4	1	1	2	4	0	2	1	2	2	23	30	0.77
Lower MK	2	0	0	0	0	0	0	0	2	0	NS	NS	4	26	0.15
McCaulley Pd	1	2	2	0	0	0	0	2	0	1	0	0	8	30	0.27
Middle MK	1	0	0	0	0	2	4	1	1	NS	1	1	11	28	0.39
Pratt Br	1	2	2	0	1	1	4	2	1	2	NS	NS	16	26	0.62
Spring Creek	0	0	0	0	0	0	4	1	0	0	NS	NS	5	26	0.19
Swamp Ck	1	4	0	0	0	0	0	0	0	0	0	2	7	30	0.23
Upper MK	0	2	0	0	0	0	4	1	0	2	0	2	11	30	0.37

NS = no score due to absence of data
High priority sites >0.55 are shaded
Med priority sites: 0.30 – 0.55
Low priority sites: 0.00 – 0.29

5.0 Next Steps

There are a series of next steps planned as part of the larger overall Murderkill project and a number of proposed future steps that would be beneficial in beginning to address some of the critical watershed issues. These recommendations are based solely on existing data (not field verified), land use analysis from Kilby (2005), and our experience in watershed planning.

Planned next steps

1. The Center for Watershed Protection will utilize the Watershed Treatment Model (WTM) to evaluate priority subwatersheds identified in this report. The assessment will look at current and expected future nutrient loads in two ~~three~~ designated subwatersheds based on the growth scenario discussed in the Draft Land Use Conversion Study of the Murderkill Watershed (Kilby, 2005).

2. MSD Associates will complete a farm field~~-~~ inventory of BMPs and field verification of existing crop type and animal feedlots.

Recommended Future Steps

1. Assess existing regulations protecting natural resources and existing development standards to identify opportunities to reduce impacts from new development. Opportunities for improvement may include stream buffer standards ~~(I think buffers are 100 ft already~~), septic inspection requirements, reduced road widths (development standards that influence impervious cover), reforestation requirements and enhanced stormwater treatment requirements.

2. Acquire natural heritage data for the watershed to identify key locations with rare species, contiguous forest and other sensitive areas including important wetlands. Work on land preservation efforts to protect these areas.

3. Perform a similar subwatershed prioritization for conservation; identify the subwatersheds most in need of protection and preservation.

4. Conduct stream and upland assessments to identify restoration and pollution prevention opportunities in the prioritized subwatersheds. Consider expanding the assessments to include areas with high nutrient concentrations or poor biological conditions and ultimately the entire watershed. The assessments should also help to identify additional outstanding natural resource areas.

~~4.~~5. Integrate watershed protection and sensitive land conservation into the comprehensive plan and growth scenarios for the County and local jurisdictions.

Formatted: Bullets and Numbering

~~5.~~6. Consider AP/10 (agricultural areas with temporary farmland protection) and recharge areas for permanent protection programs. Develop a list of priority conservation sites in the watershed.

~~6.~~7. Continue to update GIS stormwater treatment practice (STP) layer and farm BMP (Best Management Practice) layer. Include existing area treated in data on each practice.

~~7.~~8. Identify potential retrofit opportunities.

~~8.~~9. Sponsor a watershed group to take the lead on watershed education and community projects (stenciling, stream cleanups, tree planting etc). Increase opportunities for low impact recreational uses by establishing new or enhancing existing canoe/kayak trails and environmental educational programs.

~~9.~~10. Work with municipalities, County, and DNREC to update existing land use layer based on Kilby (2005) field verification, as well as farm specific data based on D'Annucci's field assessment. C~~c~~reate more complete and thorough GIS data coverage for the watershed. This could include complete zoning coverage for all jurisdictions in the watershed as well as the recommendations in #6 on BMP layers.

~~10.~~11. Consider biological nitrogen reduction at larger sewage treatment plants to further reduce nitrogen loading to the watershed.

12. Pursue broader septic impact study and associated education program promoting proper upkeep, maintenance, and replacement.

13. Perform additional water quality monitoring to isolate catchments responsible for localized high nutrient concentrations.

Formatted: Bullets and Numbering

Formatted: Bullets and Numbering

Formatted: Bullets and Numbering

Formatted: Bullets and Numbering

Formatted: Bullets and Numbering

References

Cappiella and Brown. 2001. Impervious Cover and Land Use in the Chesapeake Bay Watershed. Ellicott City, MD.

Center for Watershed Protection (CWP). 2005. *Appoquinimink Watershed Implementation Plan*. Ellicott City, MD.

CWP. 2003. Impacts of Impervious Cover on Aquatic Systems. Ellicott City, MD.

Delaware Audubon Society (DAS). 2004. *Important Bird Areas in Delaware.* DAS. Wilmington, DE. Accessed 5/10/05 at http://www.delawareaudubon.org/birding/globaliba.html

Department of Natural Resources and Environmental Control (DNREC). 1987. *Annual Report: Stream and Inland Bays Fish Survey*. DNREC, Division of Fish and Wildlife. Dover, DE.

DNREC. 1991. *Stream and Inland Bays Fish Survey: An Inventory of Fishes and Macroinvertebrates in Delaware's Streams*. DNREC, Division of Fish and Wildlife. Dover, DE.

DNREC. 1996. *Final Determination for the State of Delaware 1996 Clean Water Act Section 303(d) List of Waters Needing TMDLs*. DNREC. Dover,DE.

DNREC. 1998. *Final Determination for the State of Delaware 1998 Clean Water Act Section 303(d) List of Waters Needing TMDLs*. DNREC. Dover, DE.

DNREC. 2000. *Preliminary Determination for the State of Delaware 2000 Clean Water Act Section 303(d) List of Waters Needing TMDLs.* DNREC. Dover, DE.

DNREC. 2001. Technical Analysis for the Murderkill River TMDLS. Watershed Assessment Section, Division of Water Resources, DNREC. Dover, DE.

DNREC. 2002. Delaware's Rare Animal Species of Conservation Concern. The Delaware Natural Heritage Program. Accessed 5/20/05 at http://www.dnrec.state.de.us/fw/animal.htm

DNREC. 2004a. Delaware's Pollution Control Strategy: Murderkill Tributary Action Team (Impaired Water Bodies). Accessed 5/11/05 at http://www.dnrec.state.de.us/water2000/Sections/Watershed/ws/mk_impaired.htm

DNREC. 2004b. Delaware's Pollution Control Strategy: Murderkill Tributary ActionTeam (Location and Issues). Accessed 5/11/05 at http://www.dnrec.state.de.us/water2000/Sections/Watershed/ws/mk_location.htm

DNREC. 2005a. Spreadsheet of macroinvertebrate and habitat assessment data forstations in the Murderkill Watershed 1991-2003.

DNREC. 2005b. Spreadsheet of Sediments Data for stations on the Murderkill Watershed 1996-2004.

DNREC. 2005c. Draft Technical Analysis for Amendment of the 2001 Murderkill River TMDls Watershed Assessment Section, Division of Water Resources, DNREC. Dover, DE

Delaware Native Plant Society (DNPS). 1999. Natural Community Highlight: Smooth Coordgrass. *The Turk's Cap* Vol.2(3). http://www.delawarenativeplants.org/dnps-natcomm23.htm

Greig, Bowers, and Kauffman. 1998. Final Phase I and II Report: Christina River Basin Water Quality Management Strategy. Christina Basin Water Quality Management Committee. DE

Kilby, Phoebe. 2005. Draft Land Use Conversion Study of the Murderkill Watershed. Sympoetica. Woodstock, VA.

Krumrine, Mike. 2004. An Evaluation of Forested Buffers in the Murderkill Watershed. *ributary Times.* Accessed 4/28/05 at http://www.dnrec.state.de.us/water2000/Sections/Watershed/ws/trib_times_2004_5_mk_riparian_buffers.htm

North American Amphibian Monitoring Program (NAAMP). 2004. Patuxent Wildlife Research Center http://www.pwrc.usgs.gov/NAAMP/database/

National Atlas of the United States, March 5, 2003, http://nationalatlas.gov

Sauer, J. R., J. E. Hines, and J. Fallon. 2004. *The North American Breeding Bird Survey, Results and Analysis 1966 - 2003. Version 2004.1. USGS Patuxent Wildlife Research Center, Laurel, MD.* Frederica List accessed at http://www.mbr-pwrc.usgs.gov/cgi-bin/rtena23.pl?21004

Stribling, J.B., B.K. Jessup, J.S. White. 1998. *Development of an Index of Biotic Integrity for Maryland Streams*. MD DNR. Annapolis, MD.

Sullivan, J. 2005. Personal Communication. Kent County Soil and Water Conservation. May 2005.

The Nature Conservancy (TNC). 2005. Delaware Preserves: Milford Neck. http://www.nature.org/wherewework/northamerica/states/delaware/preserves/art10710.html Accessed 5/10/05.

Appendix A
Species List for the North American Breeding Bird Survey for Frederica, Harrington and Milton

Route: FREDERICA
(Sauer et al. 2004)

Species	Birds/ route	Species	Birds/ route
Great Blue Heron *Ardea herodias*	0.58	Hairy Woodpecker *Picoides villosus*	0.11
Cattle Egret *Bubulcus ibis*	1.03	Northern Flicker *Colaptes spp.*	3.44
Green Heron *Butorides virescens*	0.89	Pileated Woodpecker *Dryocopus pileatus*	0.08
Black Vulture *Coragyps atratus*	0.03	Eastern Wood-Pewee *Contopus virens*	5.17
Turkey Vulture *Cathartes aura*	7.64	Acadian Flycatcher *Empidonax virescens*	0.67
Canada Goose *Branta canadensis*	1.19	Willow Flycatcher *Empidonax traillii*	0.03
Wood Duck *Aix sponsa*	0.28	Willow/Alder Flycatcher *Empidonax spp.*	0.03
American Black Duck *Anas rubripes*	0.03	Eastern Phoebe *Sayornis phoebe*	2.03
Mallard *Anas platyrhynchos*	0.92	Grt. Crested Flycatcher *Myiarchus crinitus*	2.61
Osprey *Pandion haliaetus*	0.03	Eastern Kingbird *Tyrannus tyrannus*	2.25
Cooper's Hawk *Accipiter cooperii*	0.03	White-eyed Vireo *Vireo griseus*	4.08
Broad-winged Hawk *Buteo platypterus*	0.06	Yellow-throated Vireo *Vireo flavifrons*	0.14
Red-tailed Hawk *Buteo jamaicensis*	0.28	Warbling Vireo *Vireo gilvus*	0.06
American Kestrel *Falco sparverius*	0.56	Red-eyed Vireo *Vireo olivaceus*	5.89
Ring-necked Pheasant *Phasianus colchicus*	0.22	Blue Jay *Cyanocitta cristata*	9.08
Wild Turkey *Meleagris gallopavo*	0.03	American Crow *Corvus brachyrhynchos*	29.03
Northern Bobwhite *Colinus virginianus*	36.03	Fish Crow *Corvus ossifragus*	0.33
Killdeer *Charadrius vociferus*	6.28	Horned Lark *Eremophila alpestris*	2.78
American Woodcock *Scolopax minor*	0.03	Purple Martin *Progne subis*	25.53
Laughing Gull *Larus atricilla*	0.03	Tree Swallow *Tachycineta bicolor*	0.53
Ring-billed Gull *Larus delawarensis*	0.08	N. Rough-winged Swallow *Stelgidopteryx serripennis*	2.25
Rock Dove *Columba livia*	9.50	Bank Swallow *Riparia riparia*	0.03
Mourning Dove *Zenaida macroura*	26.25	Barn Swallow *Hirundo rustica*	18.89
Black-billed Cuckoo *Coccyzus erythropthalmus*	0.14	Carolina Chickadee *Poecile carolinensis*	3.97
Yellow-billed Cuckoo *Coccyzus americanus*	2.75	Tufted Titmouse *Baeolophus bicolor*	7.67
Great Horned Owl *Bubo virginianus*	0.33	White-breasted Nuthatch *Sitta carolinensis*	0.03
Chuck-will's-widow *Caprimulgus carolinensis*	0.03	Carolina Wren *Thryothorus ludovicianus*	5.64
Whip-poor-will *Caprimulgus vociferus*	0.08	House Wren *Troglodytes aedon*	1.28
Chimney Swift *Chaetura pelagica*	8.19	Blue-gray Gnatcatcher *Polioptila caerulea*	0.61
Ruby-thr. Hummingbird *Archilochus*	0.08	Eastern Bluebird *Sialia sialis*	1.81

colubris			
Belted Kingfisher *Ceryle alcyon*	0.19	Wood Thrush *Hylocichla mustelina*	14.61
Red-bellied Woodpecker *Melanerpes carolinus*	9.42	Chipping Sparrow *Spizella passerine*	18.56
Downy Woodpecker P*icoides pubescens*	1.44	Field Sparrow *Spizella pusilla*	12.31
Northern Mockingbird *Mimus polyglottos*	29.14	Vesper Sparrow *Pooecetes gramineus*	0.25
Brown Thrasher *Toxostoma rufum*	2.72	Grasshopper Sparrow *Ammodramus savannarum*	2.50
European Starling *Sturnus vulgaris*	95.67	Henslow's Sparrow *Ammodramus henslowii*	0.03[3]
Cedar Waxwing *Bombycilla cedrorum*	0.31	Song Sparrow *Melospiza melodia*	11.19
Yellow Warbler *Dendroica petechia*	0.89	Northern Cardinal *Cardinalis cardinalis*	18.86
Yellow-throated Warbler *Dendroica dominica*	0.03	American Robin *Turdus migratorius*	60.53
Pine Warbler *Dendroica pinus*	0.92	Gray Catbird D*ametella carolinensis*	5.19
Prairie Warbler *Dendroica discolor*	0.44	Blue Grosbeak *Guiraca caerulea*	7.89
Black-and-white Warbler *Mniotilta varia*	0.14	Indigo Bunting *Passerina cyanea*	20.53
American Redstart *Setophaga ruticilla*	0.17	Dickcissel *Spiza americana*	0.03
Prothonotary Warbler *Protonotaria citrea*	0.14	Red-winged Blackbird *Agelaius phoeniceus*	47.03
Worm-eating Warbler *Helmitheros vermivorus*	0.06	Eastern Meadowlark *Sturnella magna*	8.78
Ovenbird *Seiurus aurocapillus*	4.11	Common Grackle *Quiscalus quiscula*	214.5
Louisiana Waterthrush *Seiurus motacilla*	0.03	Brown-headed Cowbird *Molothrus ater*	4.50
Kentucky Warbler *Oporornis formosus*	1.06	Orchard Oriole *Icterus spurius*	3.00
Common Yellowthroat *Geothlypis trichas*	9.78	Baltimore Oriole *Icterus galbula*	2.33
Yellow-breasted Chat *Icteria virens*	3.53	House Finch *Carpodacus mexicanus*	4.53
Summer Tanager *Piranga rubra*	0.03	American Goldfinch *Carduelis tristis*	4.06
Scarlet Tanager *Piranga olivacea*	1.61	House Sparrow *Passer domesticus*	55.36
Eastern Towhee *Pipilo erythrophthalmus*	7.64		

[3] Delaware Endangered Species according to DNREC, Division of Fish and Wildlife, Natural Heritage and Endangered Species Program

Species List for the North American Breeding Bird Survey - Route:HARRINGTON
(Sauer et al. 2004)

Species	Birds/ route	Species	Birds/ route
Pied-billed Grebe *Podilymbus podiceps*	0.03	Great Horned Owl *Bubo virginianus*	0.17
Double-crest. Cormorant *Phalacrocorax auritus*	1.17	Barred Owl *Strix varia*	0.14
American Bittern *Botaurus lentiginosus*	0.03	Common Nighthawk *Chordeiles minor*	0.06
Least Bittern *Ixobrychus exilis*	0.03	Chuck-will's-widow *Caprimulgus carolinensis*	0.22
Great Blue Heron *Ardea herodias*	3.53	Whip-poor-will *Caprimulgus vociferus*	0.39
Great Egret *Ardea alba*	0.56	Chimney Swift *Chaetura pelagica*	12.14
Snowy Egret *Egretta thula*	1.08	Ruby-thr. Hummingbird *Archilochus colubris*	0.53
Cattle Egret *Bubulcus ibis*	1.97	Belted Kingfisher *Ceryle alcyon*	0.25
Green Heron *Butorides virescens*	2.11	Red-headed Woodpecker *Melanerpes erythrocephalus*	0.03
Black-crn. Night Heron *Nycticorax nycticorax*	0.22	Red-bellied Woodpecker *Melanerpes carolinus*	9.00
Glossy Ibis *Plegadis falcinellus*	2.19	Downy Woodpecker *Picoides pubescens*	2.25
Black Vulture *Coragyps atratus*	1.78	Hairy Woodpecker *Picoides villosus*	0.72
Turkey Vulture *Cathartes aura*	18.44	Northern Flicker *Colaptes spp.*	3.67
Canada Goose *Branta canadensis*	5.92	Pileated Woodpecker *Dryocopus pileatus*	0.03
Wood Duck *Aix sponsa*	0.58	Eastern Wood-Pewee *Contopus virens*	7.03
Gadwall *Anas strepera*	0.06	Acadian Flycatcher Empidonax virescens	2.25
American Black Duck *Anas rubripes*	0.75	Willow Flycatcher Empidonax traillii	0.78
Mallard *Anas platyrhynchos*	2.33	Willow/Alder Flycatcher Empidonax spp.	0.78
Blue-winged Teal *Anas discors*	0.11	Eastern Phoebe Sayornis phoebe	0.72
Osprey *Pandion haliaetus*	0.67	Grt. Crested Flycatcher Myiarchus crinitus	5.36

Bald Eagle *Haliaeetus leucocephalus*	0.14	Eastern Kingbird Tyrannus tyrannus	3.89
Northern Harrier *Circus cyaneus*	0.33	White-eyed Vireo Vireo griseus	3.08
Cooper's Hawk *Accipiter cooperii*	0.08	Yellow-throated Vireo Vireo flavifrons	0.42
Red-tailed Hawk *Buteo jamaicensis*	1.19	Warbling Vireo Vireo gilvus	0.06
American Kestrel *Falco sparverius*	0.33	Red-eyed Vireo Vireo olivaceus	14.61
Ring-necked Pheasant *Phasianus colchicus*	0.31	Blue Jay Cyanocitta cristata	10.14
Wild Turkey *Meleagris gallopavo*	0.03	American Crow Corvus brachyrhynchos	27.75
Northern Bobwhite *Colinus virginianus*	33.22	Fish Crow Corvus ossifragus	8.39
Clapper Rail *Rallus longirostris*	1.00	Horned Lark Eremophila alpestris	12.19
Virginia Rail *Rallus limicola*	0.06	Purple Martin Progne subis	25.00
Killdeer *Charadrius vociferus*	6.78	Tree Swallow Tachycineta bicolor	2.00
Black-necked Stilt *Himantopus mexicanus*	0.03	N. Rough-winged Swallow *Stelgidopteryx serripennis*	1.31
Willet *Catoptrophorus semipalmatu*	25.69	Bank Swallow *Riparia riparia*	5.39
Spotted Sandpiper *Actitis macularia*	0.03	Barn Swallow *Hirundo rustica*	42.33
American Woodcock *Scolopax minor*	0.06	Carolina Chickadee Poecile carolinensis	4.50
Laughing Gull *Larus atricilla*	73.94	Tufted Titmouse Baeolophus bicolor	9.61
Ring-billed Gull *Larus delawarensis*	16.25	White-breasted Nuthatch Sitta carolinensis	0.08
Herring Gull *Larus argentatus*	11.06	Carolina Wren *Thryothorus ludovicianus*	15.19
Great Black-backed Gull *Larus marinus*	1.06	House Wren *Troglodytes aedon*	1.42
Forster's Tern *Sterna forsteri*	0.86	Sedge Wren *Cistothorus platensis*	0.03
Least Tern *Sterna antillarum*	0.11	Marsh Wren *Cistothorus palustris*	2.69
Black Skimmer *Rynchops niger*	0.25	Blue-gray Gnatcatcher *Polioptila caerulea*	1.03
Rock Dove *Columba livia*	18.17	Eastern Bluebird *Sialia sialis*	1.81

Mourning Dove *Zenaida macroura*	42.28	Veery *Catharus fuscescens*	0.03
Black-billed Cuckoo *Coccyzus erythropthalmus*	0.19	Wood Thrush Hylocichla mustelina	13.14
Yellow-billed Cuckoo *Coccyzus americanus*	1.64	American Robin Turdus migratorius	57.81
Eastern Screech-Owl *Otus asio*	0.03	Gray Catbird Dumetella carolinensis	6.08
Northern Parula *Parula americana*	0.08	Northern Mockingbird *Mimus polyglottos*	30.39
Yellow Warbler *Dendroica petechia*	2.31	Brown Thrasher *Toxostoma rufum*	2.81
Yellow-throated Warbler *Dendroica dominica*	0.42	European Starling *Sturnus vulgaris*	162.47
Pine Warbler *Dendroica pinus*	1.00	Cedar Waxwing *Bombycilla cedrorum*	4.75
Prairie Warbler *Dendroica discolor*	0.03	Grasshopper Sparrow *Ammodramus savannarum*	2.36
Black-and-white Warbler *Mniotilta varia*	0.03	Seaside Sparrow *Ammodramus maritimus*	6.28
American Redstart *Setophaga ruticilla*	0.28	Song Sparrow *Melospiza melodia*	27.17
Prothonotary Warbler *Protonotaria citrea*	0.86	Swamp Sparrow *Melospiza georgiana*	4.33
Worm-eating Warbler *Helmitheros vermivorus*	0.11	Northern Cardinal *Cardinalis cardinalis*	23.28
Ovenbird *Seiurus aurocapillus*	2.72	Blue Grosbeak *Guiraca caerulea*	12.19
Louisiana Waterthrush *Seiurus motacilla*	0.25	Indigo Bunting *Passerina cyanea*	23.53
Kentucky Warbler *Oporornis formosus*	1.36	Dickcissel *Spiza americana*	0.19
Common Yellowthroat *Geothlypis trichas*	17.11	Red-winged Blackbird *Agelaius phoeniceus*	118.61
Yellow-breasted Chat *Icteria virens*	1.17	Eastern Meadowlark Sturnella magna	7.94
Summer Tanager *Piranga rubra*	0.06	Common Grackle Quiscalus quiscula	323.11
Scarlet Tanager *Piranga* olivacea	2.97	Boat-tailed Grackle Quiscalus major	6.69
Eastern Towhee Pipilo erythrophthalmus	6.64	Brown-headed Cowbird Molothrus ater	8.47
Chipping Sparrow Spizella passerina	14.11	Orchard Oriole Icterus spurius	3.92
Field Sparrow Spizella pusilla	3.92	Baltimore Oriole Icterus galbula	0.69

Vesper Sparrow Pooecetes gramineus	0.92	House Finch Carpodacus mexicanus	14.14
House Sparrow Passer domesticus	82.42	American Goldfinch Carduelis tristis	9.61

Species List for the North American Breeding Bird Survey - Route: MILTON
(Sauer et al. 2004)

Species	Birds/route	Species	Birds/route
Double-crest. Cormorant *Phalacrocorax auritus*	1.15	Purple Martin *Progne subis*	15.55
Great Blue Heron *Ardea herodias*	0.55	Tree Swallow *Tachycineta bicolor*	0.36
Little Blue Heron *Egretta caerulea*	0.03	N. Rough-winged Swallow *Stelgidopteryx serripennis*	0.21
Cattle Egret *Bubulcus ibis*	0.09	Bank Swallow *Riparia riparia*	0.12
Green Heron *Butorides virescens*	1.03	Barn Swallow *Hirundo rustica*	23.00
Glossy Ibis *Plegadis falcinellus*	0.15	Carolina Chickadee *Poecile carolinensis*	2.91
Black Vulture *Coragyps atratus*	0.64	Tufted Titmouse *Baeolophus bicolor*	9.27
Turkey Vulture *Cathartes aura*	10.91	Carolina Wren *Thryothorus ludovicianus*	11.61
Canada Goose *Branta canadensis*	1.94	House Wren *Troglodytes aedon*	0.58
Wood Duck *Aix sponsa*	0.21	Marsh Wren *Cistothorus palustris*	0.88
Mallard *Anas platyrhynchos*	0.06	Blue-gray Gnatcatcher *Polioptila caerulea*	0.30
Blue-winged Teal *Anas discors*	0.21	Eastern Bluebird *Sialia sialis*	0.82
Osprey *Pandion haliaetus*	0.12	Wood Thrush *Hylocichla mustelina*	14.67
Red-tailed Hawk *Buteo jamaicensis*	0.91	American Robin *Turdus migratorius*	43.82
American Kestrel *Falco sparverius*	0.39	Gray Catbird *Dumetella carolinensis*	2.91
Ring-necked Pheasant *Phasianus colchicus*	0.03	Northern Mockingbird *Mimus polyglottos*	26.58
Wild Turkey *Meleagris gallopavo*	0.06	Brown Thrasher *Toxostoma rufum*	2.09
Northern Bobwhite *Colinus virginianus*	33.85	European Starling *Sturnus vulgaris*	152.88

Clapper Rail *Rallus longirostris*	0.18	Cedar Waxwing *Bombycilla cedrorum*	2.48
King Rail *Rallus elegans*	0.03	Yellow Warbler *Dendroica petechia*	0.76
Killdeer *Charadrius vociferus*	3.36	Pine Warbler *Dendroica pinus*	2.12
Willet *Catoptrophorus semipalmatu*	0.91	Prairie Warbler *Dendroica discolor*	0.21
Laughing Gull *Larus atricilla*	4.82	Black-and-white Warbler *Mniotilta varia*	0.09
Ring-billed Gull *Larus delawarensis*	1.82	Prothonotary Warbler *Protonotaria citrea*	0.06
Herring Gull *Larus argentatus*	0.33	Worm-eating Warbler *Helmitheros vermivorus*	0.09
Great Black-backed Gull *Larus marinus*	0.12	Ovenbird *Seiurus aurocapillus*	3.76
Common Tern *Sterna hirundo*	0.24	Louisiana Waterthrush *Seiurus motacilla*	0.03
Least Tern *Sterna antillarum*	0.06	Kentucky Warbler Oporornis formosus	0.82
Rock Dove Columba livia	7.55	Common Yellowthroat Geothlypis trichas	8.82
Mourning Dove Zenaida macroura	28.67	Yellow-breasted Chat Icteria virens	1.36
Black-billed Cuckoo Coccyzus erythropthalmus	0.42	Summer Tanager Piranga rubra	0.06
Yellow-billed Cuckoo Coccyzus americanus	1.91	Scarlet Tanager Piranga olivacea	2.42
Eastern Screech-Owl Otus asio	0.09	Eastern Towhee Pipilo erythrophthalmus	5.06
Great Horned Owl Bubo virginianus	0.09	Chipping Sparrow Spizella passerina	12.36
Common Nighthawk Chordeiles minor	0.03	Field Sparrow Spizella pusilla	4.88
Chuck-will's-widow Caprimulgus carolinensis	1.24	Vesper Sparrow Pooecetes gramineus	0.45
Whip-poor-will Caprimulgus vociferus	0.45	Grasshopper Sparrow Ammodramus savannarum	1.33
Chimney Swift Chaetura pelagica	17.36	Seaside Sparrow Ammodramus maritimus	0.09
Ruby-thr. Hummingbird Archilochus colubris	0.27	Song Sparrow Melospiza melodia	13.73
Belted Kingfisher Ceryle alcyon	0.12	Swamp Sparrow Melospiza georgiana	0.67
Red-bellied Woodpecker Melanerpes carolinus	6.55	Northern Cardinal Cardinalis cardinalis	17.00

Downy Woodpecker Picoides pubescens	1.15	Blue Grosbeak Guiraca caerulea	9.79
Hairy Woodpecker Picoides villosus	0.21	Indigo Bunting Passerina cyanea	19.15
Northern Flicker Colaptes spp.	2.94	Red-winged Blackbird Agelaius phoeniceus	45.24
Pileated Woodpecker Dryocopus pileatus	0.03	Eastern Meadowlark Sturnella magna	3.79
Eastern Wood-Pewee Contopus virens	5.21	Common Grackle Quiscalus quiscula	250.21
Acadian Flycatcher Empidonax virescens	1.33	Boat-tailed Grackle Quiscalus major	0.12
Eastern Phoebe Sayornis phoebe	0.91	Brown-headed Cowbird Molothrus ater	5.73
Grt. Crested Flycatcher Myiarchus crinitus	3.03	Orchard Oriole Icterus spurius	1.61
Eastern Kingbird Tyrannus tyrannus	1.76	Baltimore Oriole Icterus galbula	0.52
White-eyed Vireo Vireo griseus	3.09	House Finch Carpodacus mexicanus	6.45
Yellow-throated Vireo Vireo flavifrons	0.33	American Goldfinch Carduelis tristis	4.79
Warbling Vireo Vireo gilvus	0.12	House Sparrow Passer domesticus	47.85
Red-eyed Vireo Vireo olivaceus	13.39	Fish Crow Corvus ossifragus	7.55
Blue Jay Cyanocitta cristata	12.36	Horned Lark Eremophila alpestris	7.67
American Crow Corvus brachyrhynchos	36.33		

Appendix B.
Macroinvertebrate Assessments

Table B. Murderkill Macroinvertebrate Assessment (DNREC 2005)

Site #	Survey Date	Taxonomic Richness	EPT Richness	% Ephem	HBI	% Clingers	BCI (%)	Class
C15056	11/01/96	13	1	0.0	6.0	20.0	20	Sev Deg
C15079	11/02/93	23	3	3.1	5.0	29.2	50	Mod deg
C15090	11/01/96	18	1	0.0	5.3	1.0	20	Sev Deg
C15095	11/22/93	19	7	1.1	6.6	17.8	30	Sev Deg
C15105	10/26/93	27	10	15.7	4.4	35.3	80	Good Cond
C15105	05/04/95	21	11	28	5.5	22	67	Good Cond
C15105	10/25/95	16	4	0.0	3.1	9.4	33	Sev Deg
C15105	12/05/96	13	5	1.0	2.6	4.0	33	Sev Deg
C15105	12/02/03	26	8	13.9	5.1	32.7	60	Mod deg
C15105 rep	12/02/03	26	7	13.2	3.8	28.8	60	Mod deg
C15120	11/22/93	28	9	37.4	3.2	66.7	100	Excellent
C15122	10/29/93	32	12	17.5	5.0	55.7	90	Good Cond
EPA04	10/30/96	27	8	20.4	4.9	40.8	70	Good Cond
EPA05	12/03/96	15	0	0.0	6.2	17.3	20	Sev Deg
EPA07	12/03/96	30	7	8.2	5.3	11.3	40	Mod deg
EPA15	12/04/96	22	10	21.0	4.0	51.0	80	Good Cond
EPA23	10/30/96	30	3	1.0	5.8	41.0	40	Mod deg
RR2	11/01/91	27	2	15	7.5	0.9	27	Sev Deg
RR24	11/01/91	20	5	2	5.8	34	47	Mod deg

Taxonomic Richness = Number of unique taxa
EPT Richness = Number of taxa in the orders Ephemeroptera, Plecoptera and Trichoptera
% Ephem = Percent composition of Ephemeroptera
HBI = Hilsenhoff Biotic Index, measure of tolerance to pollution of community
% Clingers = Percent composition of clingers
BCI (%) = Biotic Classification Index, % of reference
Class = Classification: Severely degraded, Moderately degraded, Good condition, Excellent

Appendix C. Habitat Sampling data from DNREC (2005)

Site #	Stream Name	Survey Date	CM	IH	P	BSL*	BSR	BVL	BVR	S	RZL	RZR	Total Score	HCI (%)	Class
C15056	Trib Pratt Branch	11/01/96	7	9	2	10	10	7	7	18	10	10	90	78	Mod Deg
C15079	Ash Gut	11/02/93	18	6	4	19		9	9	16	1	5	87	76	Mod Deg
C15090	Black Swamp Creek	11/01/96	3	8	2	4	4	5	5	16	10	9	66	57	Sev Deg
C15095	Spring Branch	11/22/93	16	16	15	14		10	9	16	10	8	114	99	Good Cond
C15105	Black Swamp Creek	10/26/93	19	16	20	20		9	9	19	10	10	132	115	Excellent
C15105	Black Swamp Creek	05/04/95	16	16	16	20		9	9	5	10	10	111	97	Good Cond
C15105	Black Swamp Creek	10/25/95	18	19	16	18	8	8	18	10	10	10	135	117	Excellent
C15105	Black Swamp Creek	12/05/96	19	12	19	10	10	10	10	19	10	10	129	112	Excellent
C15105	Black Swamp Creek	12/02/03	16	7	17	8	8	4	4	13	10	10	97	84	Mod Deg
C15105 rep	Black Swamp Creek	12/02/03												84	Mod Deg
C15120	Trib McCaulley Pond	11/22/93	19	16	16	15		5	5	18	10	2	106	92	Good Cond
C15122	Browns Branch	10/29/93	16	15	18	15		8	8	18	10	10	118	103	Excellent
EPA04	Browns Branch	10/30/96	16	18	20	10	10	8	8	18	10	10	128	111	Excellent
EPA05	Trib Hudson Branch	12/03/96	5	3	0	8	9	6	6	15	1	2	55	48	Sev Deg
EPA07	Beaverdam Branch	12/03/96	20	16	8	10	10	8	8	15	10	10	115	100	Excellent
EPA15	Trib McColley Pond	12/04/96	20	15	10	10	10	8	8	18	10	10	119	103	Excellent
EPA23	Trib Browns Branch	10/30/96	2	5	5	10	10	3	3	0	0	0	38	33	Sev Deg
RR2	Fan Tax Ditch	11/01/91	1	8	3	9		1	1	0	0	0	23	20	Sev Deg
RR24	Browns Branch	11/01/91	16	17	16	15		9	2	18	10	4	107	93	Good Cond

CM - Channel modification
IH - Instream habitat
P - Pools
BSL - Bank stability (left bank); BSR - Bank stability (right bank)
BVL - Bank vegetative type (left); BVR - Bank vegetative type (right)
S - Shading
RZL - Riparian zone width (left)
RZR - Riparian zone width (right)
HCI (%) - Habitat Classification Index, % of reference
Class = Classification: Severely degraded, Moderately degraded, Good condition, Excellent

Appendix D. Potential Contaminants (Whole Basin Program, 2000)

	SITENAME	Priority
Browns Branch		
Hazardous Waste Generators	Huntsman Packaging	Low
Landfills & Dumps	Porter Landfill (closed)	Not Rated
Pesticide Loading, Mixing & Storage	Milford Fertilizer-Harrington (active)	Medium
Superfund Sites	PORTERS LANDFILL (HSCA)	Not Rated
	KENT COUNTY LANDFILL/HOUSTON (HSCA O &M)	Not Rated
Underground Storage Tanks	Harrington Service Center	High
	Burris Foods	High
	Harrington Tru Blu	High
	UPS United Parcel Service	High
	Deldot Harrington Yard	High
	Schiff Farms, Incorporated	High
	Harrington Shell Mart	High
	LIFT Parts & Service/DIV OF AP ISAKSON Inc	Low
	TOWERS Auto Service	Low
	ATLANTIC Concrete CO	Low
	James Julian Inc	Low
	HIGRADE Dairy	Low
	Kirby & Holloway	Low
	Super Soda Center	Low
	Jays Quality Market	Low
	Irabak & Company	Low
	Butler Fuel Inc	Low
	McCulloughsTire Service	Low
	Charles Corbit Armory	Low
	Delmarva Power Harrington	Low
	#1-000188 Re-Assign Peoples Oil or Restaurant	Low
	Shore Stop #123	Low

	Lake Forest South Elementary School	Low
	Stellars Market	Low
	Joseph T Richardson Inc	Low
	MCDONALDS Robert G REVE	Low
	Shore Stop #154	Low
	Harrington Texaco	Low
	CONSOLIDATED THERMOPLASTIC	Low
	Exxon CASHWellS #23892	Low
	Ken Meredith & Son	Low
	Burris Foods	Low
	Bell Atlantic TELEPHONE	Low
	LAGARELLI Property JAM	Low
	Harrington Motor CO	Low
	Joseph T Richardson Inc	Low
	JC PENNEY NATIONAL Bank	Low
	Marcus Cable	Low
	Harrington POST Office	Low
	DTS CALLIS Thompson	Low
	Deldot -Right of Way Harrington	Low
	Coastal Pump and Tank Inc	Medium
	Peoples Service Oil or Restaurant	Medium
	Hendricks and Son, Incorporated	Medium
	Taylor & Messick Inc	Medium
	Delaware State FAIRGROUND	Medium
	DTS Callis Thompson	Medium
	Citgo Harrington Empty File	Medium
	Kemps Frozen Foods	Medium
Waste Water Outfalls	United Parcel Service	Not Rated
	Huntsman Packing Corp.	Not Rated
Beaverdam Branch		
Large On-site Septic Systems	J & J MHP	Not Rated

Pesticide Loading, Mixing & Storage	Agway, Inc.-Felton (Inactive)	Medium
Underground Storage Tanks	Felton Fire Company	Low
	First State Crane	Low
	Felton Hardware	Low
	Milford Fertilizer Co	Low
	Agway Inc Milford Fertilizer	Low
	First State Crane	Low
Waste Water Outfalls	Felton Aggregate Depot	Medium
	BFI Waste Systems of N. Americ	Not Rated
Double Run		
Combined Sewer Overflow	Wilmington #17	High
Hazardous Waste Generators	Polytech High School	Low
Large On-site Septic Systems	Kent County PolyTech (Active)	Medium
	Savannah Road Center	Not Rated
Pesticide Loading, Mixing & Storage	Air Enterprises-Magnolia (Active_	Medium
Underground Storage Tanks	REICHHOLD CHEMICALS Inc Dover Lab	Low
	Fifer Farms	Low
	Air Enterprises Inc	Low
	Ernie's Country Store	Medium
Hudson Branch		
Hazardous Waste Generators	Delaware Solid Waste Authority	Low
Large On-site Septic Systems	Woodand Manor MHP (Active)	Not Rated
	Seafood City (Active)	Not Rated
Tire Piles	MR TIRE	Low
Underground Storage Tanks	Blades Bus Service, Incorporated	High
	Henrys Market	Low
	Shore Stop #60 Canterbury	Low
	Pit Stop Deli	Low
	Martin Limestone Warehouse	Low
	MCGINNIS POND HDQTRS CANT	Low
	McGinnis Pond Shop	Low

	CHAMBERS DODGE TRUCK CENT	Medium
Lower Murderkill		
Hazardous Waste Generators	I L C - Dover Inc.	Low
	Litton Systems Inc-Clifton Pre	Low
	I L C - Dover, Inc	Low
Sludge Application Sites	Kent County Frederica Sludge F (Inactive)	Not Rated
	Kent County Pennuel Tract (Inactive)	Not Rated
Underground Storage Tanks	Del Gas	High
	Shore Stop #110	High
	Appels Marine Incorporated	High
	Cains Furniture Little Heaven	High
	Faulkners Pier	Low
	Kamar Bus Service Inc	Low
	Shahan Property of Dewey & Anna	Low
	Island Field Archeological Research	Low
	Kent County Waste Water Treatment Facility	Medium
	LITTON SPECIAL DEVICES	Medium
	WILLIAM ROOP	Medium
McColley Pond		
Sludge Application Sites	Kent County Blessing Farm (InActive)	Not Rated
Underground Storage Tanks	Blakes Garage	High
	HOUSTON MINI Market	High
	IA Construction Corp	Low
Middle Murderkill		
Toxics Release Inventory Sites	ILC Dover (Active)	Medium
Underground Storage Tanks	RobertS Construction CO	High
	Nashold Mini Market	Low
	George Rothwell Grainary	Low
	George E. Effinger	Low
	Former S/S #24637	Low
	ILC Dover, Incorporated	Low

	North Bowers Fire Company	Low
	ILC Dover IncBuilding 37 FUE	Low
	FREDERICA Pump Station 13	Low
	Delbert Mills Jr & Son	Low
Pratt Branch		
Sludge Application Sites	Kent County Torbert Farm (Inactive)	Not Rated
Superfund Sites	ALL RITE RUBBISH INC 11 (OLD)	Not Rated
Underground Storage Tanks	Goose Creek Food Store	Low
	Felton Mobil	Low
	Moxleys Service Center	Low
	All Rite Rubbish	Low
	Lake Forest North Elementary School	Medium
Spring Creek		
Underground Storage Tanks	Morris Grocery	Low
	Lake Forest East Elementary School	Low
	#1000327 ReAssigned John Morris or Carl King	Low
Swamp Branch		
Underground Storage Tanks	Reynolds Property	High
	TODD Property	Low
Upper Murderkill		
Large On-site Septic Systems	Killens Pond State Park	Not Rated
Superfund Sites	ALL RITE RUBBISH REMOVAL (NEW) (HSCA)	Not Rated
Underground Storage Tanks	All Rite Rubbish Removal	Low
	Uncle Willies #13	Low
	Byfield Farms	Low
	Winkler Brothers	Low
	Lake Forest High School	Low
	KILLENS POND State Park	Low

Appendix E. Impervious Cover Calculations

Scenario 1: Current IC (2002 Land Use)

Subwatershed	Area (acres)	2002 Land Use (acres)													
		Single Family	Multi fam	Commercial	Industrial	transportation	institutional	recreational	Ag	rangeland	forest	water	wetlands	vacant	total
Beaverdam Br	2656	415.00		33.38	4.97	7.18			1340.25	30.88	327.45	3.98	471.12	22.78	2656.99
Browns Br	10009.6	1541.32	22.62	404.56	137.88	78.43	64.87	217.85	4695.50	103.16	1184.28	144.67	1097.77	317.72	10010.63
Double Run	5830.4	1400.87		37.22		24.36	3.45		2978.29	10.87	751.85	18.26	488.18	116.42	5829.77
Hudson Br	7027.2	1514.66		154.44		35.57			3580.05	37.88	455.51	60.26	1140.68	45.78	7024.85
Lower MK	14873.6	539.90		57.17		127.57		30.38	6831.72	34.41	1217.82	514.97	5354.16	63.60	14771.70
MColley Pond	2464	339.82		5.15			0.02		1541.75	13.88	425.03	11.43	107.20	18.16	2462.45
Middle MK	8416	596.36		44.12		15.46	4.95		5658.05	227.95	808.27	224.09	822.02	13.85	8415.12
Pratt Br	3968	714.73		21.70		16.90	23.16		2488.65	36.83	415.23	36.08	188.08	29.83	3971.19
Spring Creek	2291.2	96.64		22.12		18.39	1.66		1348.49	2.89	478.40	62.67	256.87		2288.14
Swamp Ck	5721.6	302.07		2.40		30.96			3430.34	21.00	791.27	18.58	1114.52	11.84	5722.97
Upper MK	5203.2	250.42		17.45		37.13	90.69	196.33	3242.32	37.32	840.09	145.83	346.67		5204.25
Watershed	68460.8	7711.81	22.62	799.71	142.85	391.95	188.79	444.55	37135.41	557.06	7695.20	1240.83	11387.27	639.99	68358.05

		Current IC Acres *(Land use area * IC Coefficient)*														% IC
IC Coefficients		0.30	0.65	0.85	0.72	0.90	0.55	0.05	0.05	0.00	0.00	0.00	0.00	0.05		
Beaverdam Br	2656	124.50	0.00	28.37	3.58	6.46	0.00	0.00	67.01	0.00	0.00	0.00	0.00	1.14	231.06	8.7%
Browns Br	10009.6	462.40	14.70	343.88	99.27	70.59	35.68	10.89	234.77	0.00	0.00	0.00	0.00	15.89	1288.07	12.9%
Double Run	5830.4	420.26	0.00	31.64	0.00	21.92	1.90	0.00	148.91	0.00	0.00	0.00	0.00	5.82	630.45	10.8%
Hudson Br	7027.2	454.40	0.00	131.28	0.00	32.02	0.00	0.00	179.00	0.00	0.00	0.00	0.00	2.29	798.98	11.4%
Lower MK	14873.6	161.97	0.00	48.59	0.00	114.81	0.00	1.52	341.59	0.00	0.00	0.00	0.00	3.18	671.66	4.5%
MColley Pond	2464	101.95	0.00	4.38	0.00	0.00	0.01	0.00	77.09	0.00	0.00	0.00	0.00	0.91	184.33	7.5%
Middle MK	8416	178.91	0.00	37.50	0.00	13.91	2.72	0.00	282.90	0.00	0.00	0.00	0.00	0.69	516.64	6.1%
Pratt Br	3968	214.42	0.00	18.44	0.00	15.21	12.74	0.00	124.43	0.00	0.00	0.00	0.00	1.49	386.73	9.7%
Spring Creek	2291.2	28.99	0.00	18.81	0.00	16.55	0.91	0.00	67.42	0.00	0.00	0.00	0.00	0.00	132.69	5.8%
Swamp Ck	5721.6	90.62	0.00	2.04	0.00	27.86	0.00	0.00	171.52	0.00	0.00	0.00	0.00	0.59	292.63	5.1%
Upper MK	5203.2	75.13	0.00	14.83	0.00	33.41	49.88	9.82	162.12	0.00	0.00	0.00	0.00	0.00	345.19	6.6%
Watershed	**68460.8**	**2313.54**	**14.70**	**679.76**	**102.85**	**352.75**	**103.84**	**22.23**	**1856.77**	**0.00**	**0.00**	**0.00**	**0.00**	**32.00**	**5478.44**	**8.0%**

Scenario 2: Full Buildout IC (Kent County Zoning)

Subwatershed	Area (acres)	Zoning (acres) for Developable Parcels													
		AC (GZ)	AC (no GZ)	AC/AR	AP/10	AR	BG	BN	IG	IL	MULTI	RM	RMH	RS1	Total
Beaverdam Br	2656	207.63	89.25		31.52	623.31	10.71	0.14	10.11	11.55	141.3		0.89		1126.41
Browns Br	10009.6	268.37	1351.87		41.82	3410.52	3.5		1.9	35.7	276.56			0.03	5390.27
Double Run	5830.4	2841.57	0			484.32	4.03	0.45			22.19	0.26	94.84		3447.66
Hudson Br	7027.2	1419.16	324.45		135.59	1474.92	47.62	7.63			205.09		2.39	59.85	3676.7
Lower MK	14873.6	117.1	4423.17	49.34	762.66	163.52	25.7	1.01	2.89	6.76	198.31		9.48	33.82	5793.76
MColley Pond	2464		698.88			879.14	0				151.56				1729.58
Middle MK	8416	4121.62	1496.26		311.25	34.85			1.51		98.27			13.9	6077.66
Pratt Br	3968	2537.6	0.13			191.32	7.55			12.13	29.66			1.31	2779.7
Spring Creek	2291.2	1217.27	100.37		81.84	42.32					229.74				1671.54
Swamp Ck	5721.6		1537.47		271.93	1226.97	2.63				252.69				3291.69
Upper MK	5203.2	1691.02	960.97			287.74	8.81	0.17			76.88		0.22	0.03	3025.84
Watershed	68460.8	14421.34	10982.82	49.34	1636.61	8829.13	110.55	9.4	16.41	66.14	1682.25	0.26	107.82	108.94	38160.44

Full Buildout IC Acres *(Developable area * IC Coefficient)*															Current IC (corrected)	Total IC	% IC
IC Coefficients		0.22	0.05	0.22	0.05	0.22	0.85	0.30	0.72	0.72	0.65	0.65	0.35	0.20			
Beaverdam Br	2656	45.68	4.46	0.00	1.58	137.13	9.10	0.04	7.28	8.32	91.85	0.00	0.31	0.00	164.05	469.79	17.7%
Browns Br	10009.6	59.04	67.59	0.00	2.09	750.31	2.98	0.00	1.37	25.70	179.76	0.00	0.00	0.01	1053.30	2142.15	21.4%
Double Run	5830.4	625.15	0.00	0.00	0.00	106.55	3.43	0.14	0.00	0.00	14.42	0.17	33.19	0.00	481.54	1264.58	21.7%
Hudson Br	7027.2	312.22	16.22	0.00	6.78	324.48	40.48	2.29	0.00	0.00	133.31	0.00	0.84	11.97	619.98	1468.56	20.9%
Lower MK	14873.6	25.76	221.16	10.85	38.13	35.97	21.85	0.30	2.08	4.87	128.90	0.00	3.32	6.76	330.08	830.04	5.6%
MColley Pond	2464	0.00	34.94	0.00	0.00	193.41	0.00	0.00	0.00	0.00	98.51	0.00	0.00	0.00	107.24	434.11	17.6%
Middle MK	8416	906.76	74.81	0.00	15.56	7.67	0.00	0.00	1.09	0.00	63.88	0.00	0.00	2.78	233.73	1306.28	15.5%
Pratt Br	3968	558.27	0.01	0.00	0.00	42.09	6.42	0.00	0.00	8.73	19.28	0.00	0.00	0.26	262.30	897.36	22.6%
Spring Creek	2291.2	267.80	5.02	0.00	4.09	9.31	0.00	0.00	0.00	0.00	149.33	0.00	0.00	0.00	65.27	500.82	21.9%
Swamp Ck	5721.6	0.00	76.87	0.00	13.60	269.93	2.24	0.00	0.00	0.00	164.25	0.00	0.00	0.00	121.11	648.00	11.3%
Upper MK	5203.2	372.02	48.05	0.00	0.00	63.30	7.49	0.05	0.00	0.00	49.97	0.00	0.08	0.01	183.07	724.04	13.9%
Watershed	**68460.8**	3172.69	549.14	10.85	81.83	1942.41	93.97	2.82	11.82	47.62	1093.46	0.17	37.74	21.79	3621.67	10688	**15.6%**

Correct Current IC is the current IC minus IC associated with converted ag, forest, or transitional lands.

Scenario 3: Refined 2022 IC (based on Kilby, 2005)

Subwatershed	Area (acres)	Corrected land use Acres (shaded) and Likely Development Parcels (in red)																		
		Single Family	Multi fam	LDR	MDR	HDR	Commercial	COM	Industrial	IND	transport	institutional	recreational	Ag	Range	forest	water	wetlands	vacant	total
Beaverdam Br	2656	415.0					33.4		5.0		7.2			1340.2	30.9	327.5	4.0	471.1	22.8	2657.0
Browns Br	10009.6	1541.3	22.6	185.0		12.8	404.6	29.7	137.9	45.9	78.4	64.9	217.8	4471.5	103.2	1175.4	144.7	1097.8	283.2	10016.6
Double Run	5830.4	1400.9		415.4			37.2				24.4	3.4		2682.7	10.9	722.8	18.3	488.2	26.0	5830.1
Hudson Br	7027.2	1514.7		554.0			154.4				35.6			3134.7	37.9	392.5	60.3	1140.7	2.0	7026.6
Lower MK	14873.6	539.9		139.4	16.2		57.2				127.6		30.4	6685.7	34.4	1208.3	515.0	5354.2	63.6	14771.8
MColley Pond	2464	339.8		77.0			5.1					0.0		1489.8	13.9	405.1	11.4	107.2	13.9	2463.3
Middle MK	8416	596.4		443.0	127.2		44.1				15.5	4.9		5148.1	228.0	765.2	224.1	822.0	0.1	8418.4
Pratt Br	3968	714.7		394.0			21.7				16.9	23.2		2192.7	36.8	344.9	36.1	188.1	0.8	3969.9
Spring Creek	2291.2	96.6		220.0			22.1				18.4	1.7		1161.5	2.9	446.6	62.7	256.9		2289.3
Swamp Ck	5721.6	302.1					2.4				31.0			3430.3	21.0	791.3	18.6	1114.5	11.8	5723.0
Upper MK	5203.2	250.4		30.0			17.5				37.1	90.7	196.3	3212.3	37.3	840.1	145.8	346.7		5204.2
Watershed	68460.8	7711.8	22.6	2457.8	143.4	12.8	799.7	29.7	142.9	45.9	391.9	188.8	444.6	34949.4	557.1	7419.6	1240.8	11387.3	424.2	68370.2

		Refined IC Acres *(Land Use + Probable developments * IC Coefficient)*																			% IC
IC Coefficients		0.30	0.65	0.22	0.30	0.65	0.85	0.85	0.72	0.72	0.90	0.55	0.05	0.05	0.00	0.00	0.00	0.00	0.05		
Beaverdam Br	2656	124.50	0.00	0.00	0.00	0.00	28.37	0.00	3.58	0.00	6.46	0.00	0.00	67.01	0.00	0.00	0.00	0.00	1.14	231.06	8.7%
Browns Br	10009.6	462.40	14.70	40.70	0.00	8.32	343.88	25.25	99.27	33.05	70.59	35.68	10.89	223.57	0.00	0.00	0.00	0.00	14.16	1382.46	13.8%
Double Run	5830.4	420.26	0.00	91.39	0.00	0.00	31.64	0.00	0.00	0.00	21.92	1.90	0.00	134.13	0.00	0.00	0.00	0.00	1.30	702.54	12.1%
Hudson Br	7027.2	454.40	0.00	1219	0.00	0.00	131.28	0.00	0.00	0.00	32.02	0.00	0.00	156.73	0.00	0.00	0.00	0.00	0.10	896.40	12.8%
Lower MK	14873.6	161.97	0.00	30.67	4.86	0.00	48.59	0.00	0.00	0.00	114.81	0.00	1.52	334.29	0.00	0.00	0.00	0.00	3.18	699.89	4.7%
MColley Pond	2464	101.95	0.00	16.94	0.00	0.00	4.38	0.00	0.00	0.00	0.00	0.01	0.00	74.49	0.00	0.00	0.00	0.00	0.69	198.46	8.1%
Middle MK	8416	178.91	0.00	97.46	38.16	0.00	37.50	0.00	0.00	0.00	13.91	2.72	0.00	257.40	0.00	0.00	0.00	0.00	0.00	626.07	7.4%
Pratt Br	3968	214.42	0.00	86.68	0.00	0.00	18.44	0.00	0.00	0.00	15.21	12.74	0.00	109.63	0.00	0.00	0.00	0.00	0.04	457.16	11.5%
Spring Creek	2291.2	28.99	0.00	48.40	0.00	0.00	18.81	0.00	0.00	0.00	16.55	0.91	0.00	58.07	0.00	0.00	0.00	0.00	0.00	171.74	7.5%
Swamp Ck	5721.6	90.62	0.00	0.00	0.00	0.00	2.04	0.00	0.00	0.00	27.86	0.00	0.00	171.52	0.00	0.00	0.00	0.00	0.59	292.63	5.1%
Upper MK	5203.2	75.13	0.00	6.60	0.00	0.00	14.83	0.00	0.00	0.00	33.41	49.88	9.82	160.62	0.00	0.00	0.00	0.00	0.00	350.29	6.7%
Watershed	68460.8	2313.54	14.70	540.72	43.02	8.32	679.76	25.25	102.85	33.05	352.75	103.84	22.23	1747.47	0.00	0.00	0.00	0.00	21.21	6008.70	**8.8%**

Appendix F. Subwatershed Prioritization: Restoration - NO WEIGHTING

Subwatershed	CAFOs	Inadequate buffer	Septics	Stream xings	IC	Loss of Ag/forest	Growth	Wetlands	Forest	High Nutrients*	Habitat**	Macro**	**TOTAL**	total possible score	Normalized (score/total possible score)
Beaverdam Br	0	2	1	2	1	0	1	0	1	0	2	2	12	24	0.50
Browns Br	1	2	1	0	2	1	1	1	1	1	0	1	12	24	0.50
Double Run	0	1	2	0	1	1	2	1	1	1	NS	NS	10	20	0.50
Hudson Br	0	2	2	1	1	2	2	0	2	1	2	2	17	24	0.71
Lower MK	2	0	0	0	0	0	0	0	2	0	NS	NS	4	20	0.20
McColley Pond	1	1	1	0	0	0	0	2	0	1	0	0	6	24	0.25
Middle MK	1	0	0	0	0	2	2	1	1	NS	1	1	9	22	0.41
Pratt Br	1	1	1	0	1	1	2	2	1	2	NS	NS	12	20	0.60
Spring Creek	0	0	0	0	0	0	2	1	0	0	NS	NS	3	20	0.15
Swamp Ck	1	2	0	0	0	0	0	0	0	0	0	2	5	24	0.21
Upper MK	0	1	0	0	0	0	2	1	0	2	0	2	8	24	0.33
	*nitrogen values for subwatersheds with multiple sampling sites were averaged first and then scored.														
	** Macroinvertebrate and habitat sites were scored and then averaged.														

Subwatershed Prioritization with Weighting on Buffer, Septics, and Area in Growth Zone															
Subwatershed	CAFOs	Inadequate buffer	Septics	Stream crossings	IC	Loss of Ag/forest	% area in Growth Zone	Wetlands	Forest	High Nutrients*	Habitat**	Macro**	**TOTAL**	Total possible score w/ weight	Normalized weighted score
Beaverdam Br	0	4	2	2	1	0	2	0	1	0	2	2	16	30	0.5333333
Browns Br	1	4	2	0	2	1	2	1	1	1	0	1	16	30	0.5333333
Double Run	0	2	4	0	1	1	4	1	1	1	NS	NS	15	26	0.5769231
Hudson Br	0	4	4	1	1	2	4	0	2	1	2	2	23	30	0.7666667
Lower MK	2	0	0	0	0	0	0	0	2	0	NS	NS	4	26	0.1538462
McColley Pd	1	2	2	0	0	0	0	2	0	1	0	0	8	30	0.2666667
Middle MK	1	0	0	0	0	2	4	1	1	NS	1	1	11	28	0.3928571
Pratt Br	1	2	2	0	1	1	4	2	1	2	NS	NS	16	26	0.6153846
Spring Creek	0	0	0	0	0	0	4	1	0	0	NS	NS	5	26	0.1923077
Swamp Ck	1	4	0	0	0	0	0	0	0	0	0	2	7	30	0.2333333
Upper MK	0	2	0	0	0	0	4	1	0	2	0	2	11	30	0.3666667

Memorandum

8390 Main Street, 2nd Floor
Ellicott City, MD 21043
410.461.8323
FAX 410.461.8324
www.cwp.org
www.stormwatercenter.net

Date: October 1, 2005

To: Mike D'Annucci
MSD Associates

From: Anne Kitchell, Paul Sturm, and Ted Brown
Center for Watershed Protection

Re: Task 4.2 Evaluating Future Pollutant Loads and Reduction Opportunities at the Subwatershed Level

---

This memorandum provides a summary of a model pollutant load assessment conducted by the Center for Watershed Protection (CWP) in association with MSD Associates for the Murderkill River Watershed Study. The spreadsheet-based Watershed Treatment Model (WTM) was used to estimate existing and future nutrient loads in two priority subwatersheds—Hudson and Pratt Branches—from both agricultural and urban land uses. Potential load reductions were also evaluated based on the application of a suite of both structural and nonstructural treatment practices.

Land use in Hudson and Pratt Branches is dominated by active cropland, though both subwatersheds were identified as prominent areas for residential growth over the next twenty years. The WTM was applied to see how nutrient loading will change as the subwatershed develops and as management practices are implemented. The model input relies on future growth information presented in a land use conversion study by Kilby (2005), watershed information presented in Task 4.1 Baseline Technical Memo (CWP, 2005), and a farm BMP assessment (D'Annucci, 2005).

The WTM found that the majority of the nutrient load is from cropland, and the most effective reductions in this load can be obtained from extensive application of agricultural management practices such as cover crops in both subwatersheds. Urban loads are minor when compared to agricultural loads, however septic systems and lawn runoff appear to be the major sources of urban nutrients. Based on the model, current treatment practices result in only 4% TN and 8% TP reductions in Hudson Branch, and 13% TN and 15% TP reductions in Pratt Branch. Application of additional future treatment practices were able to further reduce uncontrolled loads up to 45% TN and 28% TP reduction in Hudson Branch, and 49% TN and 30% TP reductions in Pratt Branch. Reductions associated with future practices are similar to goals of the Murderkill TMDL, which are 50% TN and 30% TP reduction across the entire watershed.

Predicted land use conversions from cropland and forest cover to residential neighborhoods over the next 20 years did not result in significant changes in loads based when future practices were applied.

This memo includes the following sections:

1.0 Description of the WTM
2.0 Input Data and Assumptions
  2.1 Pollutant Sources
  2.2 Treatment Options
  2.3 Future Development
3.0 Results
4.0 Conclusions

More detailed information is tabularized in the Appendix. A digital copy of the WTM spreadsheet used in this modeling exercise is provided for each subwatershed.

1.0 Description of the WTM

The Watershed Treatment Model (WTM), version 3.1 (Caraco, 2002) is a simple spreadsheet model typically used to:

- Estimate pollutant loading under current watershed conditions
- Determine the effects of current management practices
- Estimate load reductions associated with implementation of structural and non-structural management practices
- Evaluate the effects of future development

The model has two basic components: Pollutant Sources and Treatment Options. The *Pollutant Sources* component of the WTM estimates the load from primary land uses (i.e. residential, commercial, agriculture) and secondary sources (i.e. active construction, managed turf, channel erosion, illicit connections) in a watershed without treatment measures in place. The *Treatment Options* component of the model estimates the potential reduction in this uncontrolled load if various treatment measures (both structural and nonstructural) are used. The WTM can examine a wide suite of treatment measures that are not typically tracked in models such as SLAMM and SWMM (see Table 1). The WTM allows the user to quantitatively examine how these practices can most effectively be combined to reduce pollutant loads.

Table 1. Menu of Treatment Options Evaluated in WTM
Rural Treatment Options • Agricultural BMPs—Cover crops, nutrient management plans, filter strips, buffers, settling basins, water control structures, tree planting, crop rotation, grazing management, etc • Forestry BMP Urban Treatment Options • Stormwater treatment practices (STP): STPs for new development, retrofits • Stormwater management program practices: lawn care education, pet waste education, street sweeping, impervious cover disconnection, riparian buffers, catch basin cleanouts, CSO/SSO repair/abatement, illicit connection removal • Erosion and sediment control • Better site design • Non-Stormwater—Septic system education, septic repair/inspection, septic system upgrade, marina pumpout, point source treatment

The model is based on the Simple Method (Schueler, 1987) for pollutant load calculations where impervious cover is used to estimate primary loads from various urban land uses. Loading for rural areas uses literature reported values and is primarily based on the area dedicated to row crops. Specific concentration assumptions used for urban/suburban loading estimates in the WTM model are based on values for different land uses summarized in the National Stormwater Quality Database (NSQD), a summary of national stormwater data from over 200 communities nationwide (Pitt et. al., 2003). Estimated runoff volumes are multiplied by pollutant concentration data to compute stormwater loads. All loads are computed based on an annual time step.

The ***existing management practices*** and ***future management practices*** components of the WTM assess the ability of the treatment options in a watershed to reduce the uncontrolled pollutant loads from primary and secondary sources. The pollutant removal efficiencies associated with various structural and nonstructural urban stormwater management practices are based on existing research and studies in the National Pollutant Removal Performance Database for Stormwater Treatment Practices (Winer, 2000) and research compiled in the WTM (Caraco, 2002). Pollutant removal efficiencies for agricultural practices are based on information from the Delaware Department of Natural Resources and Environmental Control (DNREC) and additional research conducted when developing the agricultural component of the WTM. Existing practice application is based on GIS data provided by Kent County (septics, sewered areas, and stormwater BMPs), DNREC (buffer analysis), MSD Associates (farm BMPs), and CWP observations in other Delaware watersheds.

A unique feature of the WTM is the inclusion of ***treatability*** and ***discount*** factors. Treatability is the fraction of a source that can be treated by a practice. For structural practices, treatability is best defined as the area that can be treated, while for education programs, it may reflect the fraction of the population that can be reached. The model uses discount factors to account for various levels of implementation, maintenance, and design criteria, in order to provide a more realistic implementation scenario and to avoid double counting management practices that occur in series or on the same site. Discount factors are applied to potential load reductions to account for imperfect practice application and upkeep, inability of educational programs to reach all citizens, and inadequate funding to implement all practices, to name a few.

Caveats

Rural watershed features have been integrated into model to accommodate implementation of agricultural treatment practices, however the WTM is a planning level model primarily for urban/suburban applications. There are many simplifying assumptions made by the WTM, and the model results are not calibrated. Therefore, the results of the model simulations should be compared on a relative basis rather than used as absolute values.

The application of existing and future treatment practices in the Murderkill is based on limited GIS data, best professional judgment, and default values associated with the WTM. No field verification of practice implementation was conducted as part of this project.

A series of modeling assumptions were made on loading rates, existing and current practice application, and stormwater program implementation that may or may not be valid for the

Murderkill watershed. These assumptions will be highlighted throughout the memo so further model refinement can occur.

Modeling was only performed for nutrient loads and does not look at sediment, bacteria, or other pollutants of concern.

2.0 INPUT DATA AND ASSUMPTIONS

This section provides a brief summary of the input data used in the WTM for both Pratt and Hudson Branches. It is organized by pollutant sources (primary and secondary sources), treatment options (existing and future practices), and future development. Data assumptions for each section are also listed.

2.1 Pollutant Sources

Primary sources are based on updated 2002 Kent County land use data (Kilby, 2005). Table 2 summarizes existing land use and associated loading rates applied in Hudson and Pratt Branches. See Watershed Baseline Technical Memo (CWP, 2005) for information on land use derivations and impervious cover estimates. Concentrations and annual loading rates for various land uses are based on Pitt (2003), Winer (2000), and Caraco (2002).

Table 2. Primary Sources and Loading Assumptions

Existing Land Use	Area (acres)		% IC	Concentration (mg/l)		Annual Loading Rates (lbs/acre/yr)	
	Hudson	Pratt		TN	TP	TN	TP
Single Family Residential	1514.7	714.7	22%	1.9	0.3	4	1.5
Institutional	0	23.2	55%	2.0	0.26	9.9	1.3
Commercial	154.4	21.7	85%	2.0	0.25	13.3	1.7
Transportation	35.6	16.9	90%	2.3	0.25	14.0	1.8
Cropland (Ag, farmsteads, CAFOs, orchards)	3580.1	2488.7	5%	--		17.1	1.2
Pasture (rangeland)	37.9	36.83	0%			4.6	0.7
Forest	1596.2	603.31	0%			2.5	0.2
Open Water	60.3	36.08	0%			45	0.5
Active Construction	45.8	29	5%			--	
Total Subwatershed Area	**7025**	**3970**	--				

Assumptions for primary sources include:

- An annual average precipitation of 44.8 inches (worldclimate.com for Dover, Kent County).
- Half of rural TN load is from storm vs non-storm flow, 70% of TP, respectively
- Hudson has 7.4 miles of urban stream; Pratt has 2.42 miles of urban stream
- Existing land use was updated to incorporate field observations by Kilby (2005)

- Planning horizon is 20 years (per Kilby, 2005)
- The impervious cover coefficient used for Single Family Residential in CWP (2005) was reduced from 30% (used by Delaware Waters Resource Agency in New Castle County) to 22% for the purposes of this model. Consider verifying these coefficients by direct measurement of randomly selected land use areas using recent aerial photos.
- A single loading rate for cropland was applied, though different loads may be associated with various crop types. If loading information is available (see DNREC), there is a potential to apply separate rates for soy versus corn field using data provided by D'Annucci (2005)

Secondary source loads are basically calculated as a product of flow and concentration. Refer to Caraco (2002) for detail on how loads are specifically calculated for each type of secondary source. Secondary sources that were present in the watershed and quantifiable based on existing data were considered. In most cases, this involved using GIS data provided to CWP by Kent County or based on default values of the WTM. Table 3 describes input data and assumptions for secondary sources in both subwatersheds.

Based on these assumptions, the following are suggestions for model refinement:

- None of the data used here was field verified, though the livestock estimates were based on a quick watershed drive by with herd counts (D'Annucci, 2005). Because flows from secondary sources are location-specific, the accuracy of estimates improves with additional information about the system being studied. For example, estimates on the flow generated from septic systems within a watershed will depend on the accuracy of septic inventories available to the watershed manager. Local data may substantially improve these estimates.
- Updated wastewater infrastructure information would be helpful in determining actual septic and wastewater assumptions (we ignored SSO) and an illicit discharge survey would help refine illicit loading. Also, we assumed that residential and commercial areas inside of the sewered area boundary are the only dwellings/businesses on sewer.
- County NRCS office should provide estimates on livestock densities and tile drainage
- Secondary sources such as SSO and channel erosion are not included or are minimized in the model run due to insufficient data. Built in model defaults for channel erosion result in minimal contribution to overall load when input values for eroded stream miles are zero. A stream survey could provide realistic channel erosion estimates. In fact, model output associated with the treatment option for channel protection is largely ignored as part of this project effort since no field observations were made. Channel erosion is highly variable across watersheds and geologies, which makes its estimation using the WTM particularly challenging.

Table 3. Secondary Sources and Data Assumptions			
Source	**Assumption**	**Hudson**	**Pratt**
General sewage usage	Counted existing residential parcels (one dwelling per parcel) inside and outside the Kent County sewered area boundaries. If outside, the parcel counted as on septic. Also used septic database, but added to that number based on sewer boundaries. Default value of 2.7 persons/dwelling. Estimated fraction of septic failing at 15% (probably low).	1386 dwelling units where 30 on sewer and 1356 on septic (1106 in septic database)	741 total; 314 not on septic; approx 427 with septics (363 septics in GIS layer)
Active construction	Based on transitional land use and parcel layer showing platted residential. Assume ½ of site cleared. N and P runoff data from active construction based on soil content (% weight) of 0.0005 N and 0.0002 P in soil (Haith et al 1992)	45 acres; with average disturbed area of 20 acres	29 acres; average site size 15 acres
Illicit discharges	Based on assumption that 0.2% of residents and 1% of businesses illicitly connected	2.7 connections	1.5 connections
Lawn soils	Simplified assumption of 100% B soils. A more detailed soil breakdown could be determined using soil and recharge data layers		
Road sanding	Probably not much of this in coastal DE, however we used nominal assumption of 300 lbs/yr with 80% of roads being open section		
Channel Erosion	Due to insufficient data, this parameter is largely ignored in the model, with an input of 0 eroded stream miles		
Tile drainage	TN loads range from 5-13 lb/acre/yr TN for unfertilized and fertilized corn (see Caraco 2002); we use average of 9 for TN and 0.17 for TP. Area of tile drainage based on D'Annucci (2005) farm BMP layer (practice #606). Alternatively, tile drainage can be estimated using poorly drained soils in crop areas	23.7 acres	165.4 acres
Livestock	Loads for cattle 175 TN and 30 TP ; and 0.9 and 0.4 respectivelly for layers. Using D'Annucci (2005) farm BMP data, we lumped horses and goats/mules/ponies from with cattle. When no densities provided, we assumed 2 head/horse farm; 50 head/cattle operation, 200 layers/poultry house	90 cattle (22 cattle; 20 goats/mules/ponies; 36 horses plus 6 horse farms with no density) 200 layers	33 cattle, 6 goats; cattle operation at 50 head; 400 layers each
Sanitary sewer overflows are not included in this modeling effort due to insufficient data. Other secondary sources such as point sources, marinas, and CSOs are not present in either subwatershed			

2.2 Treatment Options

The WTM models load reductions from primary and secondary sources associated with the application of treatment practices. Existing practices and future reductions associated with potential practice implementation can both be modeled. The existing management practices included in the WTM were primarily based on farm BMP data (D'Annucci, 2005), stormwater practice database (Kent County, currently being updated), and CWP observations in other Delaware watersheds. CWP used best professional judgment when applying discount factors to adjust the load reduction of each practice. For this modeling exercise, the same treatment options are applied evenly in both Hudson and Pratt subwatersheds.

Table 4 summarizes the assumptions used for applying current and future treatment practices. There are numerous combinations of practices and discounts that can be applied using the WTM, however future practices for treating existing uncontrolled loads are limited to those described here. For a detailed breakdown of agricultural practices applied on each farm tract, see Appendix A.

Table 4. Treatment Practice Input Data Used

Input	Existing Practices	Future Practices
Agricultural BMPs	Acres under nutrient management plans, cover crop, residue management, water control structure, tree planting/upland wildlife, and filter strips as reported by D'Annucci (2005). Tracts with multiple practices were modeled in series. See Table 6 for BMP efficiencies	Existing practices plus 100% implementation of cover crop and nutrient management plan on all currently unmanaged cropland acres.
Riparian Buffers (rural)	Use DNREC buffer analysis in ag areas only. Acres (buffer length*100 ft width—both sides) with an applied efficiency (see Table 6) Hudson currently has 18 acres in adequate buffer; Pratt has 69 acres in adequate buffer	Adequate 100ft forested buffer on all rural streams with applied efficiency. Hudson has 228 total available buffer acres at 100ft width, and Pratt has 135 acres.
Pet waste education	No program in place for watershed residents. No watershed group.	Yes. Awareness of 0.25 was chosen based the many types of education messages used; awareness of 0.25
Lawn care education	No program in place for watershed residents where 78% of residents fertilize and 65% of those over-fertilize.	Yes, ed campaign reaches 30% of residents and 70% change behavior.
Erosion and Sediment Control Program	Assumed 70% program efficiency where 80% of building permits regulated. Used a compliance factor of 0.7 (monthly inspections) and installation/maintenance factor of 0.6	Assume future improvement in the enforcement of erosion and sediment control regulations., therefore 90% efficiency where 80% of building permits regulated; compliance factor of .8 (weekly inspections and increased inspector ed) and installation/maintenance factor of 0.9
Streets Swept (Acres)	Assumed that no residential or commercial streets are swept.	Assumes 25% of roads swept with mechanical sweeper. A 0.5 discount was used to reflect an absence of parking restrictions.
IC disconnected	75% of residential rooftops disconnected based on high open section road estimates. No businesses disconnected.	Assumes 25% of rooftops can be disconnected; 30% of residents reached via newspaper, and 25% of those reached are willing to participate. For businesses, 100% are reached (targeted ed campaign) and 10% participate with no incentive offered.

Table 4. Treatment Practice Input Data Used		
Input	**Existing Practices**	**Future Practices**
Structural Stormwater Management Practices	Based on Kent County STP database, which is in the process of being updated. Database is not considered complete and also provides no information on drainage areas for existing practices. Data used includes 13 and 4 wetponds and 9 and 3 dry ponds in Hudson and Pratt, respectively. See Table 7 for BMP efficiencies	Since no field work, assume existing dry ponds are converted to wet ponds and infiltration practices.
Riparian Buffers (Urban)	Used DNREC buffer assessment to identify good and inadequate buffer (<100 ft forested considered inadequate). Used a 0.5 factor for design, which represents voluntary criteria, and a 0.6 factor for maintenance, indicating that an ordinance calls for the buffers to be maintained but no enforcement or education effort ensures their preservation. Currently, 1.8 of total 7.4 urban miles (Hudson) and 0.9 out of total 2.42 (Pratt) in adequate condition.	Assumed all urban buffer miles >100 ft forested on each side. Used a 0.9 factor for design, which represents enforceable design criteria, and a 0.8 factor for maintenance, indicating that an ordinance calls for the buffers to be maintained but no enforcement or education effort ensures their preservation.
Septic system education	No program in place.	Yes. Reaches 25% of residents and 40% willing to change behavior
Septic system repair and upgrade	No program in place.	Yes, programs in place to require mandatory inspection and 90% willing to repair (die to fines and cost share programs). 10% are willing to upgrade to more efficient system.
Illicit Discharge	No program in place.	50% of infrastructure investigated; 100% of repairs made

Agricultural practice efficiencies used were those reported by the Chesapeake Bay Program and by DNREC. The WTM applies treatment practices in series, and assumes that each successive practice can treat only the remaining load after previous practices have been applied. For example, 100 lb load is treated by a practice with an 80% removal efficiency. The next practice in series will have a reduced load of 20 lbs left to remove. If the second practice is 50% efficient, then the total remaining load will be 10 lbs, or 10% of the original load.

In addition, the WTM applies two discount factors to agricultural practices. The first is an implementation factor which accounts for the level of implementation on targeted farms. The second is a discount factor applied to practices in series, which reduces efficiencies by 50% when applied as the second, third or fourth in a series. Efficiencies for practices extracted from D'Annucci (2005) and used in the model are listed in Table 5.

Urban storm water treatment practice efficiencies are based on the National Pollutant Removal Performance Database for Stormwater Treatment Practices (Winer, 2000) and research compiled in the WTM (Caraco, 2002). Discount factors are applied to practices to reflect the level of implementation and long-term maintenance of the various practices. In this model scenario, no urban practices were applied in series. Table 6 provides efficiencies for practices used in this effort.

Table 5. Efficiencies for Agricultural Practices				
Practice	**Pollutant Removal Efficiency (%)***			
	WTM		DNREC**	
	TN	TP	TN	TP
Cover Crop	58	10	59	5
Nutrient Management	20	20	13-21	24
Water control structure	--	--	33	44
Grass Filter strip	45	40	46	54
Buffer (tree)	55	70	62	62
Tree planting/upland wildlife habitat/wetlands***	85	84	--	--

*Shaded cells indicate values used in model scenario
** personal communication Lyle Jones with DNREC
*** In this model, tree planting is counted as a treatment practice, however, future modeling should consider this practice as land use conversion

Table 6. STPs Pollutant Removal Efficiencies		
BMP Type	**TN**	**TP**
Dry Water Quantity Pond	5%	19%
Dry Extended Detention Pond	31%	20%
Wet Pond	33%	51%
Wetland	30%	49%
WQ Swale	38%	34%
Filters	38%	59%
Infiltration	51%	70%

Based on the National Pollutant Removal Performance Database for Stormwater Treatment Practices (Winer, 2000) and research compiled in the WTM (Caraco, 2002).

Future practices were quantified to the extent possible and full implementation was assumed, which was challenging given the lack of field data. The values used as discount factors were generous, signifying that the practices would be adopted and maintained. Realistically, not all future practices would be implemented; therefore the load reductions seen with the application of future management practices are considered a best-case scenario.

Suggestions for refining the WTM based on updated or more specific local information include:

- Test a variety of practice combinations to see what gets the most reduction for the least effort
- Including other important agricultural practices that may also reduce nutrient loads (i.e. animal waste management).
- Conduct retrofit inventory to see what type of future storm water practices can be added to the watershed
- Obtain a better understanding of application of multiple practices on the same area
- Instead of applying a removal efficiency for tree planting, consider this practice as a land conversion or reclamation.

- Use local removal efficiencies when available and appropriate

2.3 Future Development

Future land use was determined vis-à-vis a land conversion study conducted by Kilby (2005), which predicted probable growth in the Murderkill watershed over the next 20 years. Refer to previous technical memos for a discussion of probable development and buildout scenarios. Table 7 shows future land uses for Hudson and Pratt Branches and shows the change in land use (primary sources) based on these growth predictions. Both subwatersheds show a conversion of agricultural and forested areas to residential use. Impervious cover estimates and loading rates for future development are the same as existing primary sources (see Table 2).

Table 7. Future Land Use (2022)

Single Family	Hudson		Pratt	
	2022 (acres)	Change (acres)	2022 (acres)	Change (acres)
Residential Land Use	2069	554.0	1108.7	394.0
Commercial	154.44		21.7	
Transportation	35.6	.03	16.9	
Cropland	3134.7	-445.4	2192.7	-296.0
Pasture	37.9		36.8	-.03
Forest	1533.2	-63.0	533	-70.3
Open water	60.3		36.1	
Construction sites	500		365	
Change in acreage represents gains and loses in land use types from existing land use to future growth scenario.				

Future loads associated with additional growth include the applications of future (rather than existing treatment practices). Other factors the model takes into account when considering future pollutant loads associated with growth are explained in Table 8 below.

Table 8. New Development Input Data Used

New wastewater customers	Estimates were based on the number of parcels/homes in each new development using Kilby (2005) land use conversion. Parcels outside the sewered area boundaries were considered new septic customers. Parcels inside the sewer area were considered new sewer customers. This assumes no changes in planned wastewater infrastructure over the next 20 years. Hudson is estimated to gain 403 new sewer and 245 new septic customers. Pratt is expected to pick up an additional 766 sewer customers and 52 new septics.
New Construction	Hudson will have at least 452 acres of active construction and Pratt will have 336 acres. Over a planning Horizon of 20 years, this results in an average of 23 and 17 acres of active construction per year.
Stormwater Control on New Development	The controls on new development inputs were based on the current stormwater program and the assumption of more rigorous design standards and on-site load calculations are required for 90% of new development. Discount factors for capture, design, and practice maintenance are 0.8, 1.0, and 0.6, respectively. Assumptions were made regarding the percentage of each type of structural practice that would be built to control new development (25%wet ponds, 25% wetlands, 25% infiltration, and 25% filters.

As modeled, this future scenario does not take into account potential application of better site design or open space development. This could be accounted for by reducing impervious cover coefficients associated with new residential or commercial areas to reflect this change in development pattern.

3.0 Results

Results are presented for uncontrolled nutrient loads (primary and secondary sources), treatment option effects on existing uncontrolled and future growth scenarios, and a breakdown of relative reductions associated with treatment types.

3.1 Uncontrolled Load Estimates

Uncontrolled nutrient loads from primary and secondary sources are summarized in Table 9. Based on the model, the overwhelming majority of nutrients are coming from cropland in both subwatersheds. Septic systems are also likely to contribute a significant amount of TN. Single-family residential land use, lawns, animal waste and active construction also register as minor contributors.

Table 9. Uncontrolled Nutrient Loads from Primary and Secondary Sources

Source		**Annual Loading Rates** (lbs/acre/yr)			
		Hudson		Pratt	
		TN	TP	TN	TP
Primary Sources	Single Family Res.	6,504	1,027	3,069	485
	Institutional	0	0	230	30
	Commercial	2,294	287	322	40
	Transportation	641	70	305	33
	Cropland	61,219	4,332	42,556	3,011
	Pasture	174	27	169	26
	Forest	3,990	319	1,508	121
	Open Water	2,712	30	1,624	18
	Total Primary Load	**77,534**	**6,091**	**49,783**	**3,764**
Secondary Load	Septic Systems	17,101	117	5,385	37
	Illicit Connections	303	137	93	33
	Active Construction	2,788	1,115	1,348	539
	Channel Erosion	178	71	58	23
	Lawns (subsurface)	5,742	86	2,760	41
	Tile Drainage	213	4	1,489	28
	Animal Waste	2,460	249	2,490	256
	Total Secondary Load	**28,786**	**1,780**	**13,623**	**958**
Total Load		**106,320**	**7,871**	**63,407**	**4,722**

Table 10 shows additional loads associated with the 2020 future growth scenario described by Kilby (2005). The shift from existing to future land use increases the loads from urban sources while decreasing those from rural sources.

Table 10. Additional Uncontrolled Load from Primary and Secondary Sources Associated with New Development

Source		Annual Loading Rates (lbs/acre/yr)			
		Hudson		Pratt	
		TN	TP	TN	TP
Primary Sources	Single Family Res.	2,293	362	1,692	267
	Transportation	1	0	0	0
	Cropland	(7,615)	(539)	(1,660)	(272)
	Forest	(157)	(13)	(176)	(14)
Secondary Load	Septic Systems	2,711	212	575	45
	Active Construction	586.55	234.62	433.89	173.55
	Channel Erosion	208.09	83.24	73.36	29.34
	Lawns (subsurface)	1,498	23	1,052	16
Total Load		**(476)**	**363**	**1,990**	**245**

3.2 Effect of Treatment Options

Overall results from the model are presented below for uncontrolled and for existing loads controlled by current and future treatment options. While a numerical value in lbs/year is generated by the WTM (Table 11), it is more appropriate to evaluate relative load changes via percent of total reduction from uncontrolled loads (Table 12).

Table 11. Load Summary for Various Treatment Scenarios and Future Growth

	Uncontrolled Loads (lbs/yr		Controlled Loads (lbs/yr)					
	(Primary + Secondary Sources)		Existing Practices		Future Practices		Future Growth	
	TN	TP	TN	TP	TN	TP	TN	TP
Hudson Branch								
Total Load	**106,320**	**7,871**	**101,565**	**7,241**	**58,008**	**5,631**	**57,493**	**5,994**
Storm Load	47,770	6,097	44,560	5,531	23,986	4,594	22,939	5,190
Non-Storm Load	58,550	1,774	57,005	1,710	34,022	1,037	34,553	804
Pratt Branch								
Total Load	**63,407**	**4,722**	**55,237**	**4,032**	**32,042**	**3,307**	**34,003**	**3,552**
Storm Load	31,428	3,645	26,923	3,101	15,786	2,665	16,964	3,105
Non-Storm Load	31,979	1,077	28,314	932	16,256	642	17,038	447

Non-storm loads derived from fraction of rural land use loads and total contributions of secondary sources such as septic, illicit discharge and subsurface lawn drainage.

Table 12. Load Reduction Summary for Treatment Scenarios and Future Growth						
	% Load Reductions					
	Existing Practices		Future Practices		Future Growth	
	TN	TP	TN	TP	TN	TP
Hudson Branch						
Total Load	**4%**	**8%**	**45%**	**28%**	**46%**	**24%**
Storm Load	7%	9%	50%	25%	52%	15%
Non-Storm Load	3%	4%	42%	42%	41%	55%
Pratt Branch						
Total Load	**13%**	**15%**	**49%**	**30%**	**46%**	**25%**
Storm Load	14%	15%	50%	27%	46%	15%
Non-Storm Load	11%	13%	49%	40%	47%	59%
Non-storm loads derived from fraction of rural land use loads and total contributions of secondary sources such as septic, illicit discharge and subsurface lawn drainage (fraction of CSO and SSO not used in this scenario). Murderkill TMDL goals for watershed-wide TN and TP reductions of 50% and 30%, respectively.						

A number of management practices are currently in place and can be assumed to reduce the uncontrolled TN loading by 4% and 13% and 8% and 15% for TP in Hudson and Pratt Branches, respectively. The application of future management practices results in more significant load reductions in each subwatershed; 45% TN reduction for Hudson Branch, 49%TN for Pratt Branch).

The impact of future development on overall nutrient loading when compared to the Future Practices scenario appears negligible. Pratt and Hudson Branches show relatively no change in loading as the subwatershed develops over the next 20 years, though a slight increase in nutrient loads are seen in Pratt Branch under the development scenario. While minor differences are within the WTM margin of error, drops in load reduction potential as the watershed develops may be a result of the relative focus of the model on applying future agricultural practices rather than the extensive application of urban treatment practices.

3.3 Relative Reductions Associated with Treatment Types

Based on the assumptions summarized in section 2.2, the load reductions (lbs/yr) for combined agricultural and urban treatment options are presented in Table 13. Load reductions for each group of practices are also presented as a percentage of the total combined load reduction. Not surprisingly, it is the application of future agricultural BMPs that results in the largest load reductions, which makes sense given the dominance of agricultural land uses (and nutrient loading) in the subwatersheds.

For a more detailed breakdown of reductions associated with individual practices see Tables A2-3 in the Appendix.

Table 13. Nutrient Load Reductions from Existing and Future Treatment Practices								
	Hudson				Pratt			
	Existing		Future		Existing		Future	
	TN (lb/yr)	TP (lb/yr)	TN (lb/yr)	TP (lb/yr)	TN (lb/yr)	TP (lb/yr)	TN (lb/yr)	TP (lb/yr)
Agricultural BMPs	3,090	211	40,845	1,202	7,330	482	28,236	942
Urban practices	1,665	419	5,802	619	840	207	2,289	265
Total Reduction	4,755	630	46,647	1,821	8,170	689	30,525	1,208
% of total reduction	% TN	% TP	% TN	% TP	% TN	% TP	% TN	% TP
Agricultural BMPs	65%	33%	88%	66%	90%	70%	93%	78%
Urban practices	35%	67%	12%	34%	10%	30%	7%	22%
total	100%	100%	100%	100%	100%	100%	100%	100%

4.0 CONCLUSIONS AND NEXT STEPS

This modeling exercise was intended to show a relatively simple method for evaluating current nutrient loads and treatment potential for individual subwatersheds within the Murderkill watershed. This is particularly important in light of the current Murderkill TMDL, which sets reduction goals for TN and TP of 50% and 30%, respectively. If we apply these same reduction goals at the subwatershed scale, the WTM can roughly predict our ability to meet those goals.

Table 14 shows the capacity to meet these relative TMDL goals in the two subwatersheds based on the WTM analysis (shading indicates goal is met). If the established TMDL took existing practices into account when deriving base loading estimates (A), then reduction goals cannot be met based on the future practices modeled here. If the TMDL does not take existing practices into account (B), then reduction goals can almost be met in Hudson and Pratt Branches using future practices modeled here. Future development as modeled here gets us further from these goals.

This should not be interpreted to mean that application of additional practices would not result in 50 % TN reductions. Nor should it be assumed that these reductions would prohibit sufficient watershed wide reductions, as some subwatersheds may have more reduction opportunity or less uncontrolled loading than Hudson or Pratt.

Table 14. TMDL Target Reductions							
TMDL	Subwatershed	% Load Reduction					
		Existing Practices		Future Practices		Future Growth	
		TN	TP	TN	TP	TN	TP
A	Hudson	n/a		43%	22%	43%	17%
	Pratt			42%	18%	38%	12%
B	Hudson	4%	8%	45%	28%	46%	24%
	Pratt	13%	15%	49%	30%	46%	25%

TMDL reduction goals set for 50% TN and 30% TP. Alternative A assumes TMDL took reductions associated with existing treatment practices into account when it was established
Alternative B assumes TMDL based solely on land use and primary sources

Based on this modeling exercise, we recommend Kent County:

- Make a concerted effort to work with local farmers to implement agricultural practices on farms currently not applying appropriate nutrient management tools. Agricultural drainage is the dominant source of nutrients in Hudson and Pratt Branches, yet agricultural management practices to control nutrients are currently applied to less than 20% and 50% of total cropland in Hudson and Pratt Branches, respectively. The application of future practices in the WTM to remaining farm lands resulted in the majority of load reductions. Next to tree planting, cover crops may be the most effective tool for reducing nutrient loads.

- Identify areas to be reforested. Converting nutrient source areas (ag, residential, etc) back to forested conditions will help reduce primary loads.

- Develop septic education and inspection program. The WTM highlighted septics as the second largest source of nutrient loading in both subwatersheds, and the model used an estimated failure rate of 15%. A 30-37% of the modeled urban TN load reduction in Pratt and Hudson, respectively was related to combined future septic education, repair, and upgrade program implementation. A septic inventory could be conducted to verify condition and location of existing septic systems. Septic repair and upgrade program should be established, and consider adopting regulatory standards to require proper maintenance.

- Implement a targeted residential lawn care education program. Forty- 33% of the future urban TN load reduction modeled for Pratt and Hudson, respectively, was associated with lawn care education. The model highlighted lawn runoff as a significant urban source of nutrients. Conduct a neighborhood assessment to determine which areas are the worst offenders and educated them on proper fertilizer application procedures, soil testing, etc.

- Conversion of farm fields to residential areas will not likely result in nutrient load reductions if modeled assumptions are accurate. Much of the new development will be on septic (according to GIS data) and the model run did not account for the application of open space or better site design alternatives for new development. Consider running sewer to new developments within the priority growth area. Sewer expansion should coincide with upgrades to sewage treatment plants to the limit of technology nutrient removal processes including Biological Nitrogen Reduction (BNR) and advanced phosphorus removal. Infrastructure maintenance and upgrades should also be assessed and considered in order to reduce inflow and infiltration (I&I) and overflows. Using better site design to reduce impervious cover and to encourage disconnection are recommended. Estimated rooftop disconnection as an existing practice resulted in the largest reduction of existing uncontrolled loads.

- Erosion and sediment control (ESC) practices accounted for some of the existing and future urban area load reductions. WTM nitrogen load reduction estimates associated with ESC practices may be higher than expected, as some research suggests that in humid regions, most nitrogen is in the soluble form and moves through the soil into the shallow groundwater, which subsequently moves to drainage ditches and streams (Mitsch et al., 1999; Gilliam et

al., 1985). ESC is a critical practice in reducing TSS loads, which was not modeled in this effort. If the current program does not require weekly inspections, practice maintenance, or inspector/contractor education, consider updating the program, particularly given the increase construction activity slated in these two subwatersheds.

- Riparian buffers did not stand out as a big practice for nutrient reduction, however there are many other benefits associated with healthy riparian buffers not captured during this modeling exercise. We recommend continuing efforts to maintain and restore the riparian corridor. Research shows a natural stream system with a well-functioning riparian corridor is more efficient at in stream-processing and retaining of nutrients compared to edge of field buffers (Meyer and Wallace, 2001).

- Consider running the WTM for the entire watershed for planning purposes in order to determine which subwatersheds contribute the most uncontrolled load, identify which subwatersheds have the greatest potential for pollutant load reduction/meeting TMDL, and develop a strategy for implementing the most efficient treatment practices to reduce loads. Prior to running the model, users should:
    - reconcile loads, removal efficiencies, and land use assumptions with those of the TMDL prior to conducting analysis
    - Conduct field assessments (i.e. septic inventory, stream walk, stormwater inventory, municipal operations assessment) to verify secondary sources (i.e channel erosion and illicit discharges, rooftop disconnections, failing systems, and street sweeping)
    - Update storm water practice information with drainage areas and design information
    - Revisit assumptions made during modeling scenario and refine them based on local knowledge (IC coefficients, soils, sewered areas, tile drains, etc)

REFERENCES

Caraco, D. 2002. The Watershed Treatment Model. Version 3.1. Center for Watershed Protection. Ellicott City, MD.

Center for Watershed Protection (CWP). 2005 Murderkill Baseline Assessment Technical Memo. Ellicott City, MD

D'Annucci. 2005. Murderkill Farm BMP database and technical Memo. MSD Associates. Virginia Beach, VA

Gilliam, J.W., T.J. Logan and F.E. Broadbent. 1985. Fertilizer use in relation to the environment. p. 561-588. In: O.P. Engelstad (Ed.) Fertilizer Use and Technology. Am. Soc. Agron., Madison, WI

Kilby. 2005. Murderkill Land Use Conversion Study. Technical Memo. Sympoetica

Meyer, J. L. and J. B. Wallace. 2001. Lost linkages and lotic ecology: rediscovering small streams. Pages 295-317 *in* M.C. Press, N.J. Huntly, and S. Levin, editors. Ecology: achievement and challenge. Blackwell Science.

Mitsch, W.J., J.W. Day, J.W. Gilliam, P.M. Groffman, D.L. Hey, G.W. Randall, and N. Wang. 1999. Reducing nutrient loads, especially nitrate-nitrogen, to surface water, ground water and the Gulf of Mexico. Topic 5 Rep. of the Integrated Assessment on Hypoxia in the Gulf of Mexico. NOAA Coastal Ocean Program Decision Analysis Ser. no. 19. NOAA Coastal Ocean Program, Silver Spring, MD.

Line, Dan et al. 2002. "Pollutant Export from Various Land Uses in the Upper Neuse River Basin." Water Environment Research, Vol. 74, Number 1.

Pitt, R., Maestre A., and R. Morquecho. The National Stormwater Quality Database (NSQD), Version 1.0. Water Environment Federation Technical Exposition and Conference, Los Angeles. October 2003.

World Climate website. www.worldclimate.com. Accessed Sept 2005/

Schueler, T. 1987. Controlling Urban Runoff. MWCOG.

Tetra Tech. 2004. Memorandum to Upper Neuse Task Force. "Translation of SET Loading Estimate to Upper Neuse Performance Targets".

Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices: 2nd Edition. Center for Watershed Protection. Ellicott City, MD.

Appendix A

Table A1a. Pratt Branch Farm BMPs							
Tract #	Acres Applied Agricultural BMP (NRCS Code)						
	Cover Crop (340)	Filter Strip (393)	Nutrient Mngt Plan (590)	Subsurface Drain (606)	Tree planting (612)	Water Control Structure (587)	Upland Habitat (645)
1261		393	76.6				645
1285			43.19				
1286	103.09		203.99	100.9	100.9	100.9	
1430			124.17				
1520			30.06				
1551			10.35				
2701			20.16				
2702			15.91				
2708			45.81				
2870			64.54	64.54			
2894		64.54	55.6				17.6
2895			5.1				
2896			20.79				
2897			37.82				
2898			5.98				
2899			29.77				
2901			17.21				
2902			41.7				
2904			71.71				
2929			113.93				
Grand Total	103.09	457.54	1034.39	165.44	100.9	100.9	82.1

Table A1b. Hudson Branch Farm BMPs								
Tract #	Acres Applied Agricultural BMP (NRCS Code)							
	Cons Cover (327)	Critical Area Planting (342)	Filter Strip (393)	Nutrient Mngt Plan (590)	Sub-surface Drain (606)	Tree planting (612)	Wetland Habitat (644)	Upland Habitat (645)
75				13.18				
127	2.63							2.63
244				2.33				
1307				54.98				
1324				41.5				
1325				175.2				
2206			3.43	9.58		2.21	1.08	2.21
2227								13.28
2362				4.23				
2386	9.93	6.29		1.91			6.29	10.64
2424								4.83
2444				37.9				
2445				14.51				
2498				19.64				
2893				144.14				
2906					23.04			
2978						3.2		3.2
7050				35.26				
7130								5.44
Grand Total	12.56	6.29	3.43	554.36	23.04	5.41	7.37	42.23

Table A2a. Pratt Branch Agricultural BMPs Applied in Series

Current Practices									Reduction from Ag Practices			
Total Area	Area Applied	BMP-1	Efficiencies (%)		BMP-2	Efficiencies (%)		Implementation	TN	TP		
(Acres)	(Acres)		TN	TP		TN	TP		lb/year	lb/year		
2,489	680	nutrient management	20%	20%				100%	2,327	163		
	103	cover crop	59%	5%	nutrient management plan	20%	20%	100%	1,185	30		
	100	nutrient management	20%	20%	water control structure	33%	40%	100%	794	62		
	120	tree planting	85%	83%				100%	1,753	120		
	69	Buffers	55%	70%				100%	649	58		
	64	Nutrient Management Plan	20%	20%	filter strip	46%	54%	100%	622	49		
								Total Reduction for Existing Ag Practices	**7,330**	**482**		
Future Practices											**Net Benefit**	
											TN lb/yr	TP lb/yr
2,489	680	nutrient management	20%	20%	Future cover crop	59%	5%	100%	7,814	197	5,487	34
	103	cover crop	59%	5%	nutrient management plan	20%	20%	100%	1,185	30	0	0
	100	nutrient management	20%	20%	water control structure	33%	40%	100%	794	62	0	0
	120	tree planting	85%	83%	-	0%	0%	100%	1,753	120	0	0
	69	Buffers	55%	70%	-	0%	0%	100%	649	58	0	0
	64	Nutrient Management	20%	20%	filter strip	46%	54%	100%	622	49	0	(0)
	1,287	Future Cover crop	59%	5%	Future nutrient management	20%	20%	100%	14,798	371	14,798	371
	66	Future Buffers	55%	70%	-	0%	0%	100%	621	55	621	55
								Total Reduction for Future Ag Practices	**28,236**	**942**	**20,907**	**460**

Shaded cells indicate additional practice applications

Table A2b. Hudson Branch Agricultural BMPs Applied in Series

Current Practices									Reduction from Ag Practices			
Total Area	Area Applied	BMP-1	Efficiencies (%)		BMP-2	Efficiencies (%)		Implementation	TN	TP		
(Acres)	(Acres)		TN	TP		TN	TP		lb/year	lb/year		
3,580	554	nutrient management	20%	20%				100%	1,895	133		
	59	tree planting	85.4%	83.5%				100%	862	59		
	13	cover crop	59%	5%				100%	131	1		
	3	filter strip	46%	54%	nutrient management plan	20%	20%	100%	33	3		
	18	Buffers	55%	70%				100%	169	15		
								Total Reduction for Existing Ag Practices	**3,090**	**211**		
Future Practices											**Net Benefit**	
											TN lb/yr	TP lb/yr
3,580	554	nutrient management	20.00%	20.00%	Future cover crop	59%	5%	100%	6,366	160	4,471	27
	59	tree planting	85.40%	83.50%	-	0%	0%	100%	862	59	0	0
	13	cover crop	59.00%	5.00%	Future nutrient management plan	20%	20%	100%	149	4	18	3
	3	filter strip	46.00%	54.00%	nutrient management plan	20%	20%	100%	33	3	0	0
	18	Buffers	55.00%	70.00%	-	0%	0%	100%	169	15	0	0
	2,723	Future cover crop	59.00%	5.00%	Future nutrient management plan	20%	20%	100%	31,291	784	31,291	784
	210	Future Buffers	55.00%	70.00%	-	0%	0%	100%	1,975	178	1,975	178
								Total Reduction for Future Ag Practices	**40,845**	**1,202**	**37,755**	**992**

Table A3a. Pratt Branch Load Reductions Associated with Various Urban Treatment Practices

Urban Practices	Load Reduction (lb/yr)				% of Total Reduction			
	Existing		Future		Existing		Future	
	TN	TP	TN	TP	TN	TP	TN	TP
Lawn Care Education	0	0	907	18	-	-	40%	7%
Pet Waste Education	0	0	36	5	-	-	2%	2%
Erosion and Sediment Control	317	127	469	188	38%	61%	20%	71%
Street Sweeping	0	0	29	5	-	-	1%	2%
Impervious Cover Disconnection	495	77	29	2	59%	37%	1%	1%
Structural Stormwater Management Practices	7	2	4	1	1%	1%	-	-
Riparian Buffers	20	1	117	6	2%	-	5%	2%
Septic System Education	N/a		48	0	N/a		2%	-
Illicit Connection Removal			23	8			1%	3%
Septic System Inspection/Repair			383	33			17%	12%
Septic System Upgrade			244	0			11%	-
Total Benefit	**840**	**207**	**2,289**	**265**	**100%**	**100%**	**100%**	**100%**

Table A3b. Hudson Branch Load Reductions Associated with Various Urban Treatment Practices

Urban Practices	Load Reduction (lb/yr)				% of Total Reduction			
	Existing		Future		Existing		Future	
	TN	TP	TN	TP	TN	TP	TN	TP
Lawn Care Education	0	0	1,887	38	-	-	33%	6%
Pet Waste Education	0	0	67	9	-	-	1%	1%
Erosion and Sediment Control	656	262	970	388	39%	63%	17%	63%
Street Sweeping	0	0	63	10	-	-	1%	2%
Impervious Cover Disconnection	931	147	54	6	56%	35%	1%	1%
Structural Stormwater Management Practices	29	7	15	3	2%	2%	-	-
Riparian Buffers	49	2	527	26	3%	1%	9%	4%
Septic System Education	N/A		152	0	N/A		3%	-
Illicit Connection Removal			76	34			1%	6%
Septic System Inspection/Repair			1,215	105			21%	17%
Septic System Upgrade			775	0			13%	-
Total Benefit	**1,665**	**419**	**5,802**	**619**	**100%**	**100%**	**100%**	**100%**

MEMORANDUM

To: Tim Riley, Manager
Kent Conservation District

From: Michael D'Annucci, Owner,
MSD Associates

Date: October 11, 2005

Re: Farm Field GIS Database Development and Application to the Murderkill River Watershed

---

The Kent Conservation District has elected to develop a Geographic Information System database of farm fields to improve their ability to coordinate and effectively manage agricultural NPS pollutant reductions. The spatial database will facilitate a more efficient:

- Consolidation of information from the numerous agricultural agencies that develop and administer BMP and conservation practices;
- Approach to highlighting the geographic location of all existing BMP and conservation practice locations in a designated watershed; and
- Utilization of watershed planning tools capable of targeting and ranking farm field properties for various BMP and conservation practice implementation.

This technical memorandum describes the methodology used to create this GIS database of farm fields in the Murderkill River watershed (Proposal Task 2), and to utilize this GIS database for the identifying and targeting farm field sites for potential enrollment in various state and federal agricultural voluntary cost-share programs that address nutrient nonpoint source pollutant loading (Proposal Task 5). The targeting of farm fields was applied to those Murderkill River subwatershed areas not prioritized for land use conversion from agriculture to urban/residential (Center for Watershed Protection, ***Prioritization of Murderkill Subwatersheds***, 2005). The following list of subwatershed areas was included in the farm field targeting effort: Double Run, Beaverdam Branch, Swamp Creek, Browns Branch, Upper Murderkill River, Middle Murderkill River, Lower Murderkill River, McColley Pond, and Spring Creek.

MSD Associates, 103 46th Street, Virginia Beach, VA 23451, (757) 469-0546

1 INTRODUCTION

The Clean Water Act requires that impaired water bodies be listed under Section 303(d) of the Act. Waters that are placed on the 303(d) list must have a Total Maximum Daily Load (TMDL) study developed for the pollutant of concern. A proposed amended Murderkill River TMDL for nutrients and oxygen consuming compounds was published in 2005. It requires nonpoint source (NPS) load reductions of 30 percent for nitrogen and 50 percent for phosphorous. The ***Delaware Nonpoint Source Management Plan*** (2000) states that the Murderkill River was placed on the high priority watershed list for reasons that include high agriculture and high groundwater concerns. Moreover, the Murderkill River Tributary Action Team, formed to implement practices supporting the TMDL loading reduction requirements, states that the Murderkill River's main sources of pollution include cropland fertilizers and animal-raising operations.

District Agricultural Challenges. These NPS pollutant loading sources of cropland fertilizers and animal-raising operations are a primary concern of the Kent Conservation District (District). The District provides state cost-share funds to cooperating landowners for agricultural Best Management Practice (BMP) and conservation practice implementation, and they work directly with their federal technical partner, the USDA Natural Resources Conservation Service (NRCS), to disperse federal funds for agricultural BMP and conservation practice implementation. In addition, the District has a staff of three certified nutrient management planners. The Delaware Nutrient Management Commission requires the development of nutrient management plans for:

- All persons who operate an animal feeding operation in excess of 8 animal units (1 animal unit = 1,000 pounds);
- All persons who control or manage property in excess of 10 acres where nutrients are applied.

Furthermore, any farm operator not requiring a nutrient management plan, but would like one created for them, can be placed on a first-come first-serve list.

As the Murderkill Tributary Action Team makes recommendations for nutrient pollutant reductions, it is expected that specific agricultural land use activities will be identified as major sources of nutrient loading. The District and its state and federal partner agencies will, therefore, be required to utilize considerable resources to implement the necessary 'on the ground' nutrient pollutant control measure solutions, and will be confronted with the challenge of how best to maximize the limited implementation funds and planning resources earmarked for potential agricultural NPS loading sources.

Farm Field GIS Database Development. To assist the District meet these challenges associated with agricultural BMP and conservation practice implementation, a Geographic Information System (GIS) Database was developed to identify the geographic location of existing agricultural BMPs, conservation practices, and nutrient management plans, and characterize potential pollutant loading sources from agricultural land uses in the Murderkill River watershed. This farm field GIS database includes an ArcView GIS datalayer of USDA Farm Service Agency (FSA) Common Land Units for Kent County. This 'Common Land Unit' datalayer was created by the FSA from existing hardcopy aerial photographs where the boundaries of thousands of farm fields and other land use areas were defined by the landowners themselves. The Common Land Unit (CLU) datalayer attribute information was incomplete during the development of the farm field GIS database, and MSD Associates referred to the hardcopy aerial photographs to enter FSA identification numbers (FSA Tract and CLU Numbers) directly into the database. This FSA CLU datalayer of spatial farm field information was subsequently linked to the NRCS Customer Service Toolkit (Toolkit) database of existing BMP, conservation practice, and nutrient management planning information in Kent County. This Toolkit database includes agricultural cost-share information for those farm fields possessing existing agricultural BMPs and conservation practices implemented through the application of state and federal funding sources. The CLU GIS datalayer and the Toolkit database were combined with other readily available GIS datalayers including soils, wetlands, hydrology, and roads to form the farm field GIS database.

Watershed Assessment. The farm field GIS database was utilized to conduct a desktop assessment of potential nutrient loading sources and to assist with the future prioritization of agricultural BMP and conservation practice implementation in the specified subwatershed areas of the Murderkill River. Agricultural BMP and conservation practices addressing three nutrient loading pathways were reviewed: Nutrient (nitrogen) loading from cropland in high groundwater recharge areas; nutrient (nitrogen and particulate phosphorous) loading into stream areas lacking appropriate riparian buffering; and nutrient (nitrogen and phosphorous) loading from farm animal waste sources. A number of farm fields were prioritized for potential voluntary enrollment in the existing state and federal agricultural cost-share programs. Lists and figures of farm fields are included in this technical memorandum to provide the District and their state and federal agency partners with an ability to initiate a proactive approach to farm field enrollment in available agricultural BMP and conservation practice cost-share programs.

2 FARM FIELD GIS DATABASE DEVELOPMENT

A GIS database of farm fields located in the Murderkill River watershed was developed. The database houses animal operation information collected during a four-day drive-bye field survey, and existing BMP and conservation practice information extracted from the NRCS Toolkit database for Kent County.

FSA CLU Database of Farm Fields. The FSA is in the process of providing a desktop tool for all FSA field service center offices located throughout the nation. They are digitizing all Common Land Units (CLUs), including farm fields, rangeland, and pastureland. The FSA has established the CLU as a standardized GIS data layer that includes the following definition for this "smallest unit of land:"

- Permanent, contiguous boundary;
- Common land cover and land management;
- Common owner; and
- Common producer association.

Historically, landowners and farming operators have provided the boundary locations of their farm fields directly to FSA personnel while enrolling in FSA designated programs. These boundaries were delineated and kept up-to-date on hand-marked hardcopy aerial photographs. The farm field boundaries have been referenced as CLU GIS data layer polygons and digitized using available electronic and geo-referenced Digital Orthoquad (DOQ) aerial photographs. Although the CLU data layer was completed for Kent County, attribute information was lacking. No administrative information (i.e., farm tract and CLU numbers) for the farm field CLUs were included in the database. To separate and differentiate FSA recognized farm field CLUs, MSD Associates accessed the Kent County FSA hand-marked hardcopy aerial photographs for this vital administrative information and included it in the database. Only those farm fields (cropland and pastureland) enrolled in FSA programs were provided farm tract and CLU numbers. A total of 1,605 of these CLU types were identified in the Murderkill River watershed by MSD Associates.

Drive-Bye Field Survey of Farm Fields. A four-day drive-bye field survey of farm fields was conducted by MSD Associates in July 2005. A Geographic Positioning System (GPS) was linked to a laptop containing the GIS data layer of CLUs (those with and without FSA designated administrative information). The GPS provided a real-time display of the vehicle's exact location, movements, and direction of movement on the laptop screen. In addition a GIS shapefile record of all roads traveled was maintained so that routes through the watershed would not be duplicated. The location of all cropland, pastureland, and farms that had gone idle, animal sitings, poultry houses, and other noteworthy information related to nutrient loading was added to the CLU data layer. In addition to the FSA recognized CLUs possessing farm tract and CLU numbers, information was

collected for an additional 55 CLUs (mainly small animal operations that were not reported to the FSA). As a result, 1,660 CLUs were designated as 'farm fields' by MSD Associates. These farm fields were extracted from the CLU data layer. Figure 2-1 shows the location of these farm fields (croplands and pasturelands) in the predominately agrarian Murderkill River watershed. The results of the drive-bye field survey are provided in Appendix B.

NRCS Customer Service Toolkit Information. The NRCS has developed a standardized database application for conservation planning and design, establishing contracts with customers (i.e., growers), and the delivery of technical assistance documents. This Toolkit database features desktop GIS integrated with Microsoft Office. Individual customer files are created for conservation plans and contractual documents. Information entered into Toolkit by District and NRCS field personnel includes Customer IDs and Enterprise Names, GIS polygons of Planned Land Units, Planned Land Unit Acres, Tract Numbers, Land Unit Numbers, Land Use Information, NRCS Conservation Practice Codes, Planning and Application of Practice Dates, Planner Names, and Cost-Share Programs Used.

Linking the FSA CLU Database of Farmfields to the NRCS Customer Service Toolkit. It was determined at a meeting with Joseph McDonough, the Delaware NRCS Customer Service Toolkit Coordinator, that linking each individual Toolkit customer file to the FSA CLU database of farm fields would be far too cumbersome, time consuming, and impossible to complete. As a result, a Toolkit Rollup was performed on the Kent County data where all individual customer files over an approximate 10-year period were consolidated into four large Microsoft Access database files. The common administrative attributes of tract and CLU number found in both the NRCS and FSA databases were then used by MSD Associates to link the four Toolkit Rollup files to the FSA CLU database of farm fields. ArcView GIS shapefiles were subsequently created for those farm fields in the Murderkill River watershed possessing or receiving specific types of BMP or conservation practices. Respective shapefiles were created for those sets of farm fields receiving the practices listed in Table 2-1. The table contains the current list of National NRCS conservation practices. Those practices marked with an asterisk were applied to the Murderkill River watershed by agricultural agency personnel over the approximate 10-year period. Detailed descriptions and standards for the individual practices can be acquired at the following website: ***http://www.nrcs.usda.gov/technical/Standards/nhcp.html.***

Although MSD Associates successfully linked the CLU and Toolkit databases together, limitations to the approach should be noted. When the FSA divides CLUs for an assortment of reasons, including a land use change on a portion of a respective CLU, new farm tract and CLU numbers are created. The changes to these administrative numbers are not noted in the NRCS Customer Service Toolkit once the contracts with customers are finalized. Moreover, when District or NRCS field personnel create a new Planned Land Unit, they are not required to use the FSA CLU polygon. Field personnel may, instead, digitize a new Planned Land Unit that does not line up with CLU

boundaries. This new polygon receives a unique administrative number not captured in the FSA CLU database of farm fields. Both of these situations are uncommon and the vast majority of database records were successfully linked.

Figure 2-1
Murderkill River Farm Fields

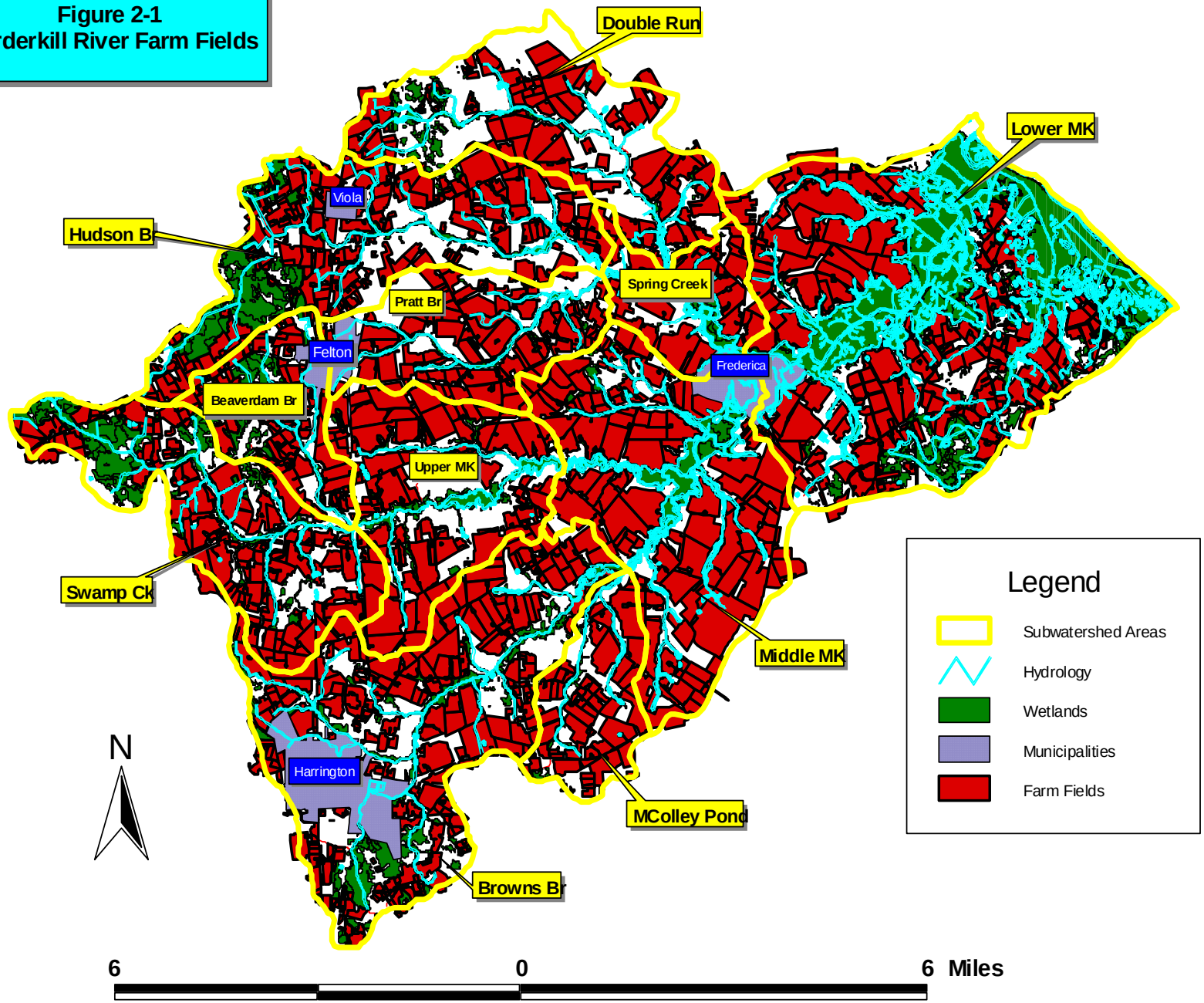


Table 2-1 Current List of National NRCS Conservation Practices			
Practice Code	***Practice Name***	***Practice Code***	***Practice Name***
*313	Waste Storage Facility	*468	Lined Waterway or Outlet
314	Brush Management	472	Use Exclusion
316	Animal Mortality Facility	500	Obstruction Removal
*317	Composting Facility	516	Pipeline
324	Deep Tillage	521A	Pond Sealing or Lining, Flexible Membrane
326	Clearing and Snagging	521B	Pond Sealing or Lining, Soil Dispersant
*327	Conservation Cover	521C	Pond Sealing or Lining, Bentonite Sealant
*329A	Residue Management, No-Till and Strip Till	521E	Pond Sealing or Lining, Sealed Fabric Liner
*329B	Residue Management, Mulch Till	533	Pumping Plant for Water Control
*329C	Residue Management, Ridge Till	543	Land Reconstruction, Abandoned Mined Land
*328	Conservation Crop Rotation	544	Land Reconstruction, Currently Mined Land
*340	Cover Crop	554	Drainage Water Management
*342	Critical Area Planting	558	Roof Runoff Structure
*344	Residue Management, Seasonal	560	Access Road
350	Sediment Basin	*561	Heavy Use Area Protection
351	Well Decommissioning	566	Recreation Land Grading and Shaping
353	Monitoring Well	568	Recreation Trail and Walkway
356	Dike	574	Spring Development
359	Waste Treatment Lagoon	575	Animal Trails and Walkways
360	Closure of Waste Impoundments	578	Stream Crossing
362	Diversion	580	Streambank and Shoreline Protection
365	Anaerobic Digester Ambient Temperature	584	Channel Stabilization
366	Anaerobic Digester Controlled Temperature	*587	Structure for Water Control
367	Waste Facility Cover	*590	Nutrient Management
*378	Pond	*595	Pest Management
*380	Windbreak/Shelterbelt Establishment	600	Terrace
382	Fence	*606	Subsurface Drain
386	Field Border	*607	Surface Drainage, Field Ditch
391	Riparian Forest Buffer	608	Surface Drainage, Main or Lateral
*393	Filter Strip	*612	Tree/Shrub Establishment
397	Aquaculture	614	Watering Facility
399	Fishpond Management	*620	Underground Outlet
*410	Grade Stabalization	634	Manure Transfer
*412	Grassed Waterway	635	Waste Water Treatment Strip
422	Hedgerow Planting	638	Water and Sediment Control Basin
432	Dry Hydrant	642	Water Well
436	Irrigation Storage Reservoir	*644	Wetland Wildlife Habitat Management
*441	Irrigation System, Microirrigation	*645	Upland Wildlife Habitat
*442	Irrigation System, Sprinkler	*646	Shallow Water Management for Wildlife
447	Irrigation System, Tailwater Recovery	657	Wetland Restoration
*449	Irrigation Water Management	658	Wetland Creation
466	Land Smoothing	769	Incinerator

***** Practices applied to the Murderkill River watershed by agricultural agency personnel over an approximate 10-year

period.

3 WATERSHED ASSESSMENT OF FARM FIELDS

The selected farm field assessment methodology provides a framework for the application of management tools that facilitate informed decision making about NPS pollution loading from agricultural land uses. Historically, a lack of information and management tools has forced the District and their state and federal partners to rely on a farmer/operator first-come, first-serve basis as the primary determinant for the allocation of cost-share money. Now, the farm field GIS database, coupled with an improved understanding of GIS, provides the District with an ability to administer a more proactive approach to evaluating agricultural watersheds and land uses; resulting in the strategic selection, siting, and implementation of effective pollutant control measure plans and BMPs in the Murderkill River watershed and other areas of Kent County. This will lead to a more effective means of implementing the agricultural nutrient loading reduction requirements called out in the Murderkill River TMDL. The following farm field prioritization approach applied to Murderkill River subwatershed areas provides the District with an example assessment methodology that can be used as an outline or process for future watershed planning in the County.

BMP Costs and Cost-Share Funding. The application of agricultural BMPs and conservation practices is not cost prohibitive if a targeted approach to siting is utilized. The targeted approach includes the use of GIS to identify potential farm field sites for BMP and conservation practice implementation followed by on-the-ground meetings with landowners to verify the desktop evaluation. The Delaware Department of Natural Resources and Environmental Control's Whole Basin Team has developed a Murderkill Fact Sheet at the request of the Murderkill Tributary Action Team that includes average costs for agricultural BMP and conservation practices applied to the Murderdill River watershed. The following costs were noted:

- Nutrient Management Planning – Must consider depth of plan and whether it includes design of structural components;
- Manure Storage Structures – For 40 X 80 foot structure, $22,000;
- Dead Bird Composters – Free Standing: $6,636; Lean-to: $5,895;
- Filter Strips – Cool Season Grasses: $200-250 per acre; Warm Season Grasses: $300-400 per acre;
- Stream Buffers - $500 per acre; and
- Cover Crops - $8-10 per acre.

Much of these costs are not borne by the landowner because they are available through the various state and federal cost-share programs including the USEPA Section 319 nonpoint source grant program; the USDA Farm Bill cost-share programs, such as the Conservation Reserve Enhancement Program (CREP) and the Environmental Quality Incentives Program (EQIP); the Delaware State Nutrient Management Plan Cost Assistance Program; and the Delaware State Revolving Loan Fund.

Nutrient Sources Addressed by Watershed Assessment. Three broadly defined farm field sites were targeted for agricultural BMPs and conservation practices in each of the specified

subwatershed areas, and prioritized for further review by agricultural field office personnel. Farm fields were prioritized to address nutrient (nitrogen) loading from pastureland manure or cropland poultry litter into surficial aquifers; nutrient (nitrogen and particulate phosphorous) runoff loading from pastureland manure and cropland litter into riparian areas lacking appropriate stream buffering; and nutrient (nitrogen and phosphorous) loading from farm animal waste sources through direct deposition of waste from animals having direct access to streams and from headquarter animal operations utilizing improper waste storage. The location of existing agricultural BMPs and conservation practices were noted during the application of procedures for BMP and conservation practice targeting.

Nutrient (Nitrogen) Loading from Farm Fields in High Groundwater Recharge Areas. Groundwater recharge has been identified as a major pathway for nitrogen loading. Two NRCS-defined conservation practices limiting nitrogen loading have been consolidated for this desktop evaluation: Nutrient Management Planning and Cover Crops (NRCS Practice Codes 590 and 340, respectively). Due to the immense quantities of poultry litter produced in the Murderkill River, Kent County and the Delaware Eastern Shore region, it is fair to assume that every FSA designated cropland and pasture in the Murderkill River watershed is receiving poultry litter for fertilizer. A total of 28 active poultry operations, for example, were identified in the Murderkill River watershed during the field survey of agricultural practices conducted by MSD Associates in July 2005. This does not include the poultry operations in neighboring watersheds. According to the NRCS, Nutrient Management Plans are developed to manage 'the amount, source, placement, form and timing of the application of plant nutrients and soil amendments. This practice applies to all lands where plant nutrients and soil amendments are applied.' Cover crops are affective at removing nitrogen prior to reaching groundwater sources because they provide a continuous source of nutrient uptake throughout the year. In fact, the NRCS personnel are directed to select cover crop species 'for their ability to absorb large amounts of nutrients from the rooting profile of the soil.' To reduce nitrogen loading from cropland into the localized unconfined aquifer, it is assumed that these practices would be most useful in high groundwater recharge areas. As a consequence, the following procedure to target cropland for potential nutrient management planning and/or cover crop enrollment in one of the various voluntary state or federal cost-share programs was adhered to:

1) Identification of all existing Murderkill River watershed farm fields that already possess nutrient management plans or have been enrolled in a cover crop conservation practice cost-share program over the approximate 10- year period as defined by the 'rolled-up' NRCS Toolkit data for Kent County;

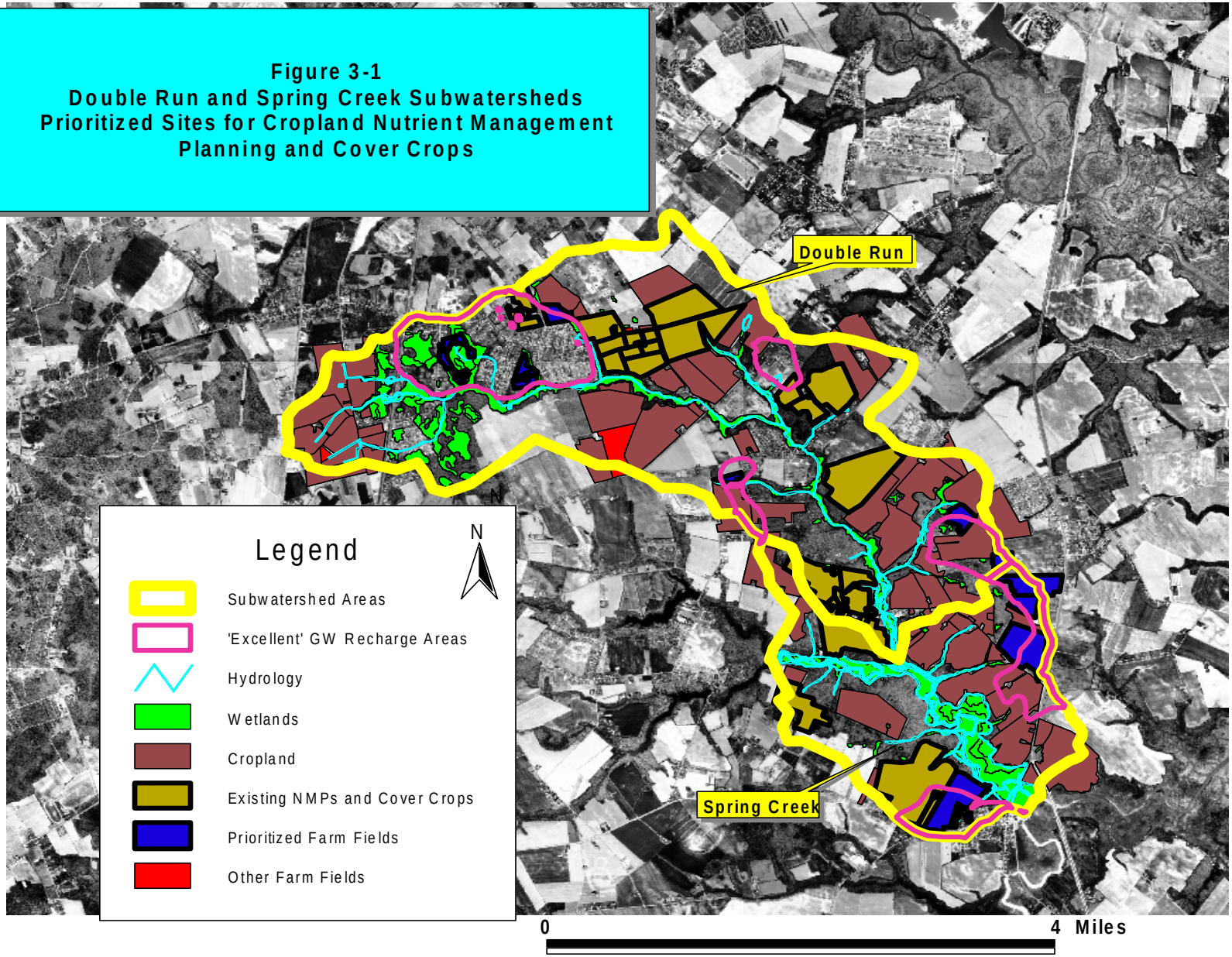
2) Selection of cropland and pastures for potential cost-share enrollment in the NRCS Nutrient Management Planning or Cover Crop practices where: (i.) cropland and pastures are not already enrolled in a nutrient management or cover crop cost-share program; and (ii.) cropland and pasture farm field polygons have their centers in areas where the Delaware Geological Society has mapped as 'excellent' for groundwater recharge.

The administrative numbers of prioritized cropland and pastures targeted for nutrient management

planning and/or cover crop cost-share programs are listed according to subwatershed groupings in Appendix A, and mapped at the subwatershed level in Figures 3-1 through 3-5.

MSD Associates, 103 46th Street, Virginia Beach, VA 23451, (757) 469-0546

Figure 3-1
Double Run and Spring Creek Subwatersheds
Prioritized Sites for Cropland Nutrient Management Planning and Cover Crops



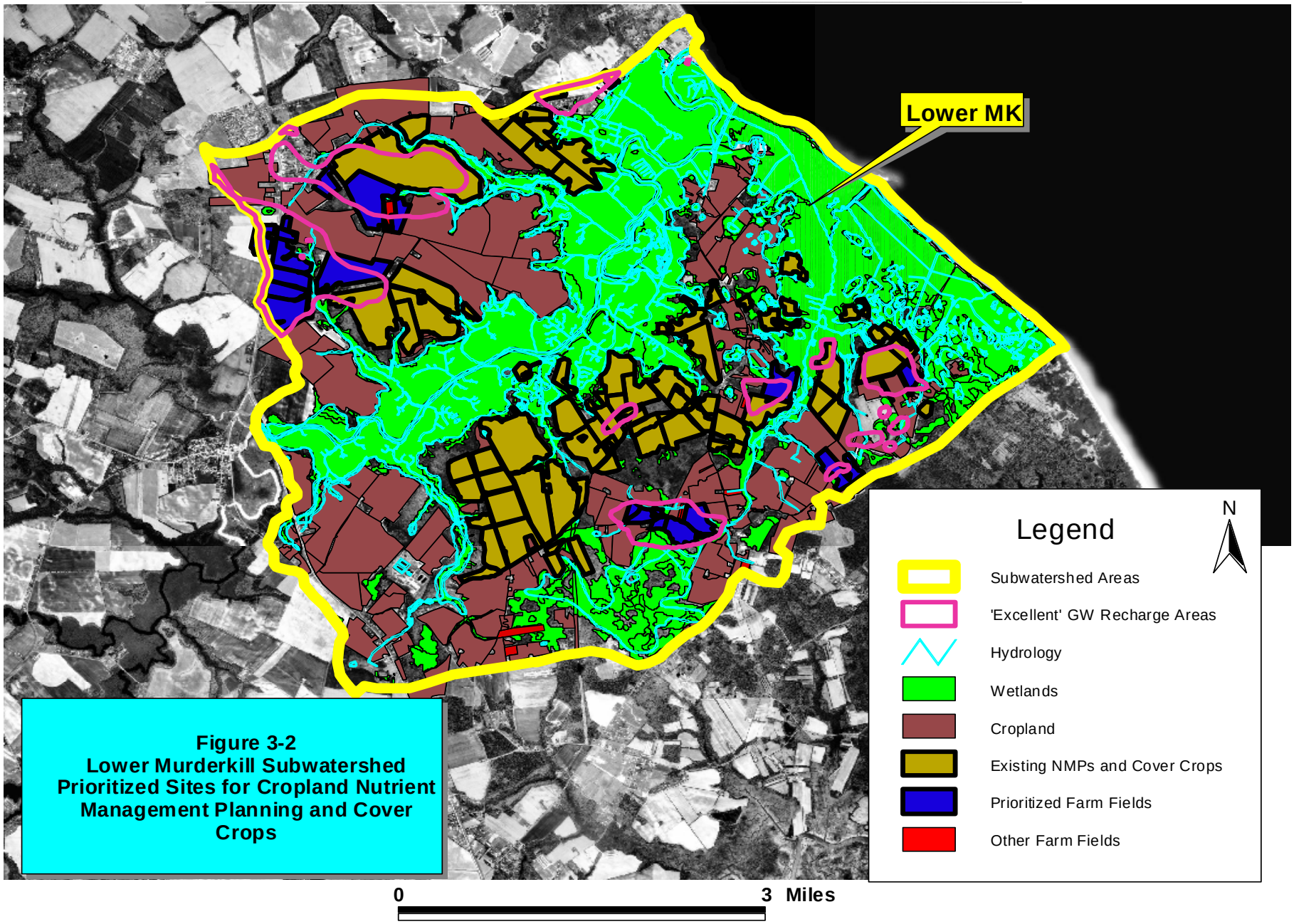
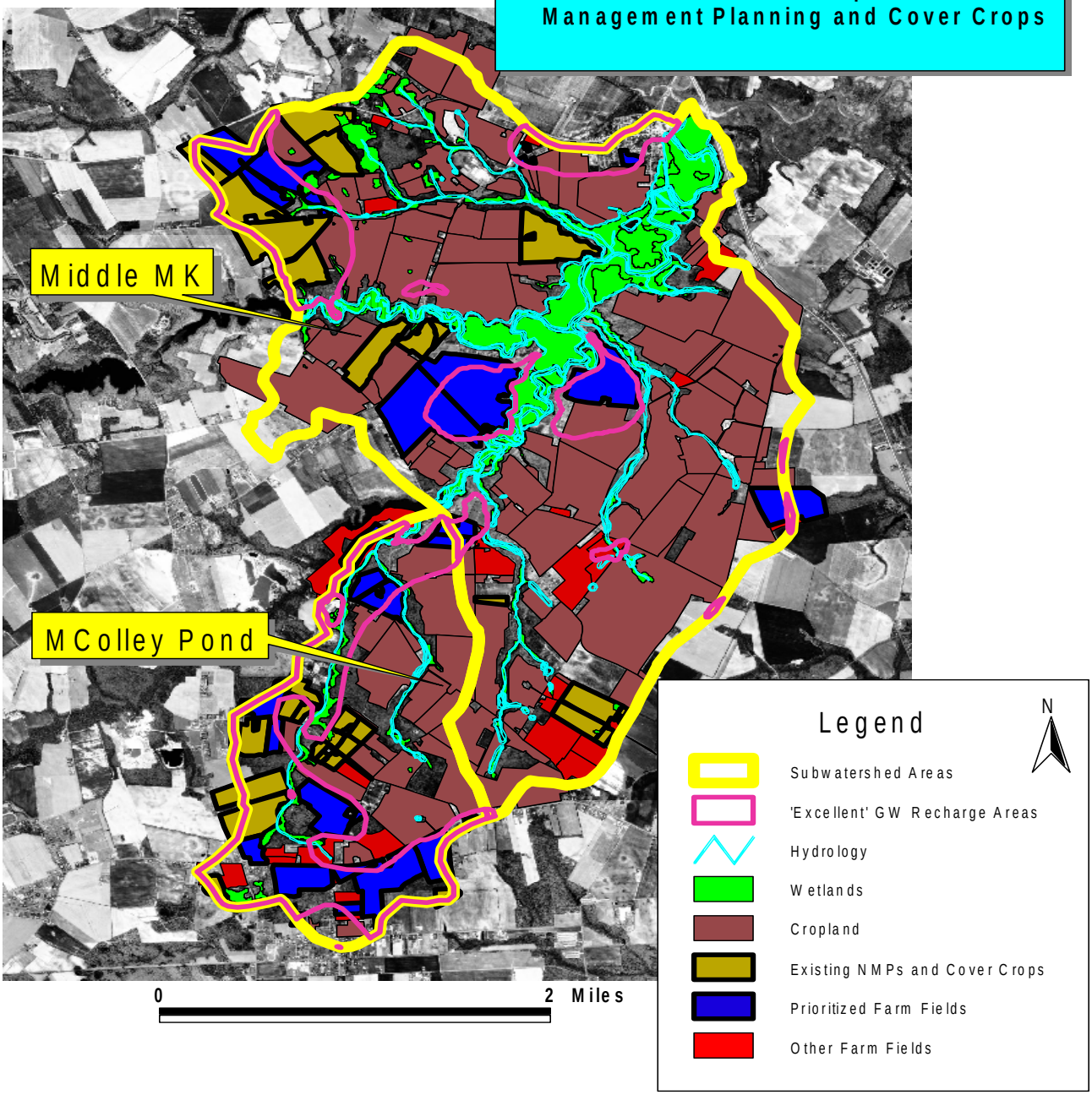


Figure 3-2
Lower Murderkill Subwatershed Prioritized Sites for Cropland Nutrient Management Planning and Cover Crops

Figure 3-3
Middle Murderkill and McColley Pond Subwatershed Areas
Prioritized Sites for Cropland Nutrient Management Planning and Cover Crops



MSD Associates, 103 46th Street, Virginia Beach, VA 23451, (757) 469-0546

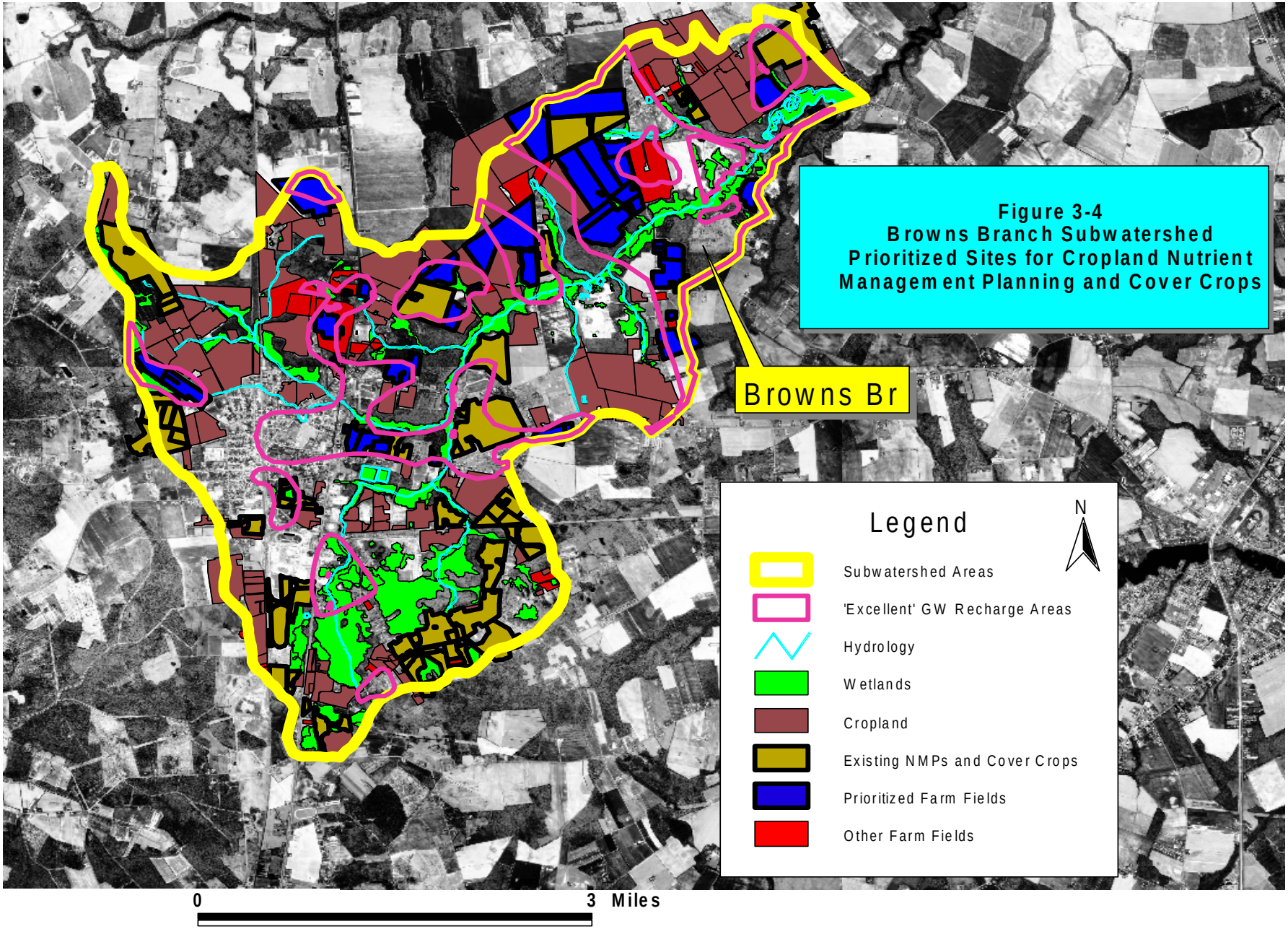
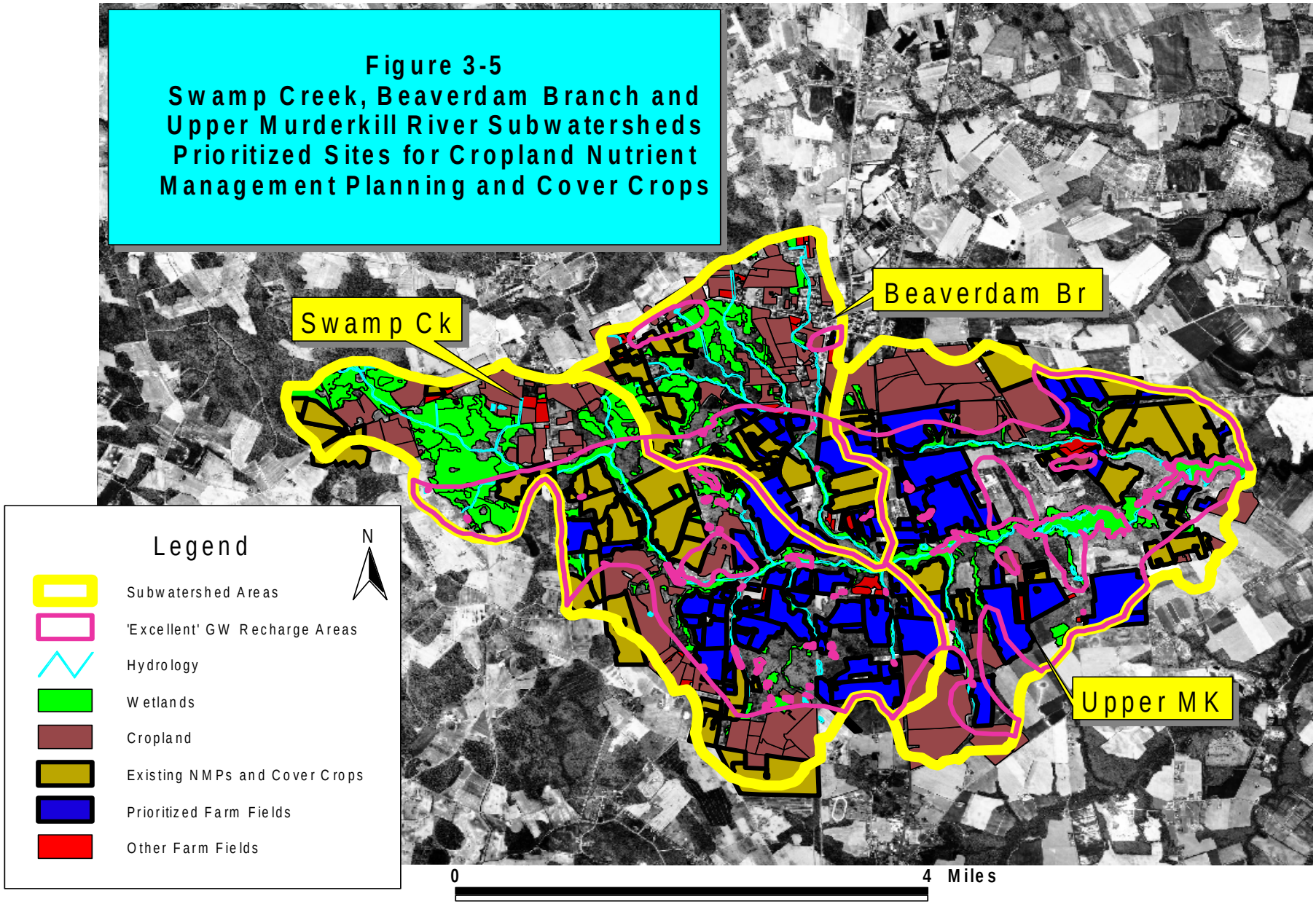


Figure 3-4
Browns Branch Subwatershed
Prioritized Sites for Cropland Nutrient
Management Planning and Cover Crops
Browns Br
Legend
N
Subwatershed Areas
'Excellent' GW Recharge Areas
Hydrology
Wetlands
Cropland
Existing NMPs and Cover Crops
Prioritized Farm Fields
Other Farm Fields
0
3 Miles



MSD Associates, 103 46th Street, Virginia Beach, VA 23451, (757) 469-0546

Nutrient Loading into Stream Areas Lacking Appropriate Riparian Buffering. A second nutrient loading pathway into the Murderkill River includes the runoff of pollution directly into the streams following precipitation events. Pollutant sources include pasture manure and cropland poultry litter. The NRCS employs several agricultural BMPs and conservation practices to address runoff; some of the most affective include the following buffer practices: Critical Area Planting (Code 342), Filter Strips (Code 393), Field Borders (Code 386), Riparian Forest Buffers (Code 391), and Riparian Herbaceous Cover (Code 390). Numerous studies have demonstrated the environmental benefits of establishing plantings inside and adjacent to stream corridors. Critical area plantings are used to address areas that are disturbed and possess the slopes that may cause extreme erosion. Filter strips are herbaceous cover sited between a disturbed land use (i.e., agriculture) and an environmentally sensitive area, including ditches and stream corridors. They are planted to absorb nutrients and to disperse concentrated flows. Riparian herbaceous cover provides many of the same functions as a filter strip, but is located in the wetter environments of perennial and intermittent watercourses. Field borders are applied typically to agricultural fields and are found on slightly higher grounds than filter strips. They are not only used to filter waterborne pollutants, but are applied along the perimeter of farm fields to address wind erosion. Riparian forest buffers are applied adjacent to stream corridors and consist of trees and bushes. Frequently, filter strips and riparian forest buffers are used in tandem to address NPS pollution.

As noted in the Center for Watershed Protection (CWP) technical memorandum ***Prioritization of Murderkill Subwaterheds (August 2005)***, DNREC completed a GIS analysis of riparian forested buffers in the Murderkill River (Kumerine 2004). It was found that considerable streamlengths remain inadequately buffered on one or both stream banks. This DNREC analysis was used to assist with the identification of farm fields for NRCS buffering practices in selected subwatershed groupings. The following steps were employed:

1) Identification of all existing Murderkill River watershed farm fields that have already been enrolled in an NRCS buffer practice cost-share program over the approximate 10- year period defined by the 'rolled-up' NRCS Toolkit database for Kent County. These farm fields were removed from the prioritization process.

2) Selection of all remaining cropland and pasture farm fields possessing sections of the inadequately buffered streamlengths on <u>both</u> banks.

These cropland and pasture farm fields are presented in Figures 3-6 through 3-10A, where maps provide a detailed view of potential buffer site locations. Farm field administration numbers denoted 'Tract Number – CLU Number' are included on the maps for all prioritized buffer sites. Appendix A contains the full list of prioritized farm fields.

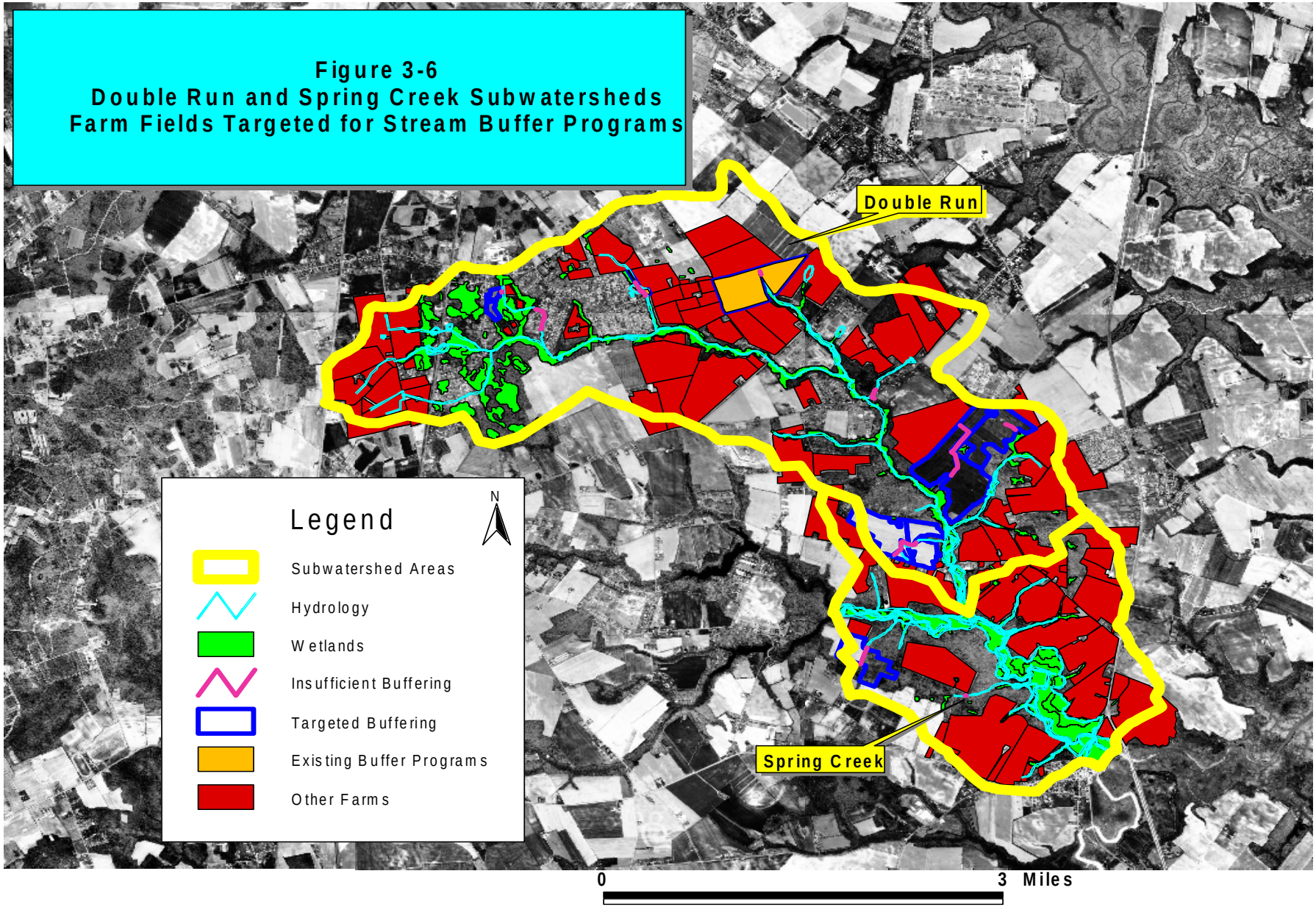
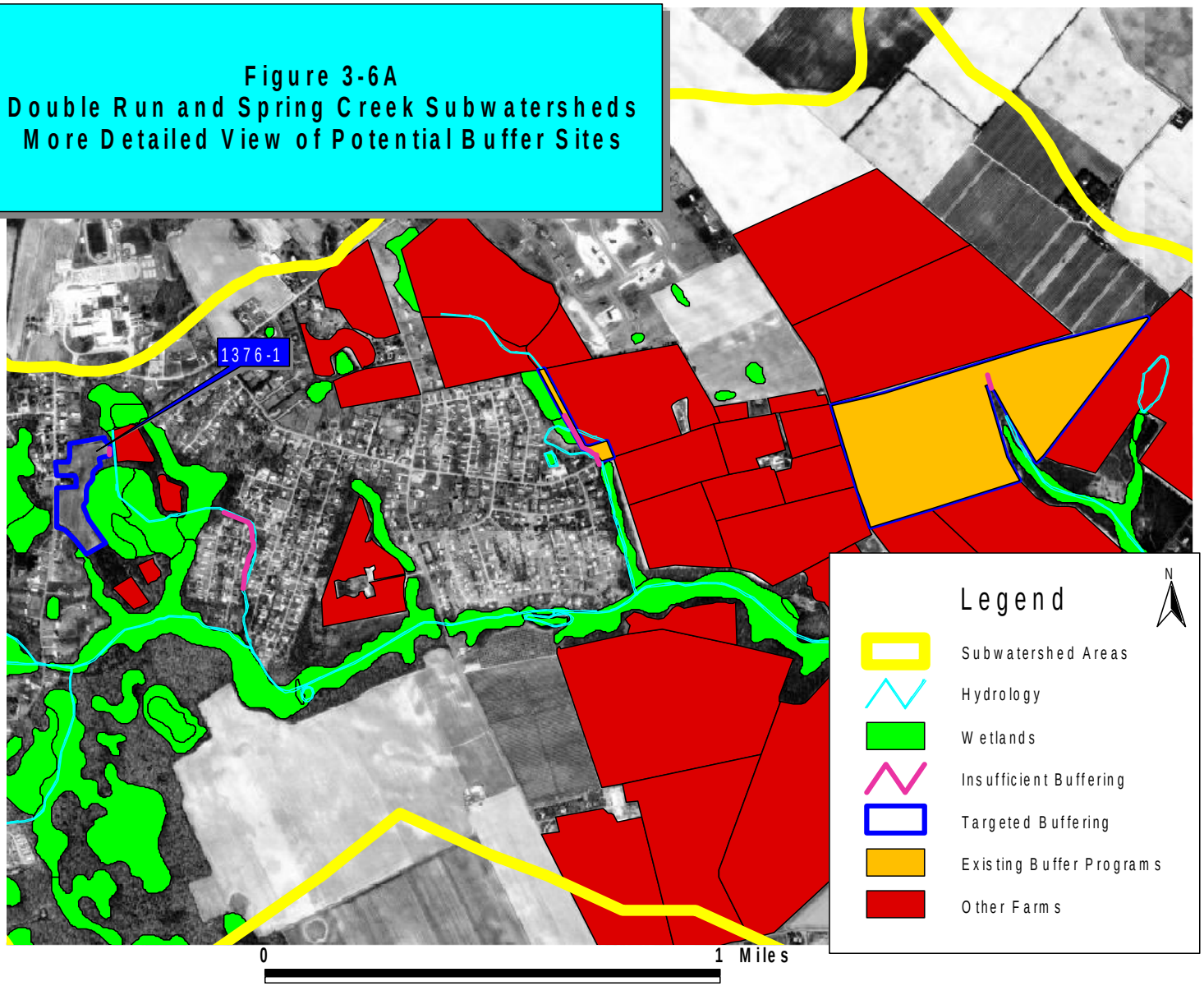


Figure 3-6
Double Run and Spring Creek Subwatersheds
Farm Fields Targeted for Stream Buffer Programs

MSD Associates, 103 46th Street, Virginia Beach, VA 23451, (757) 469-0546

Figure 3-6A
Double Run and Spring Creek Subwatersheds
More Detailed View of Potential Buffer Sites



MSD Associates, 103 46th Street, Virginia Beach, VA 23451, (757) 469-0546

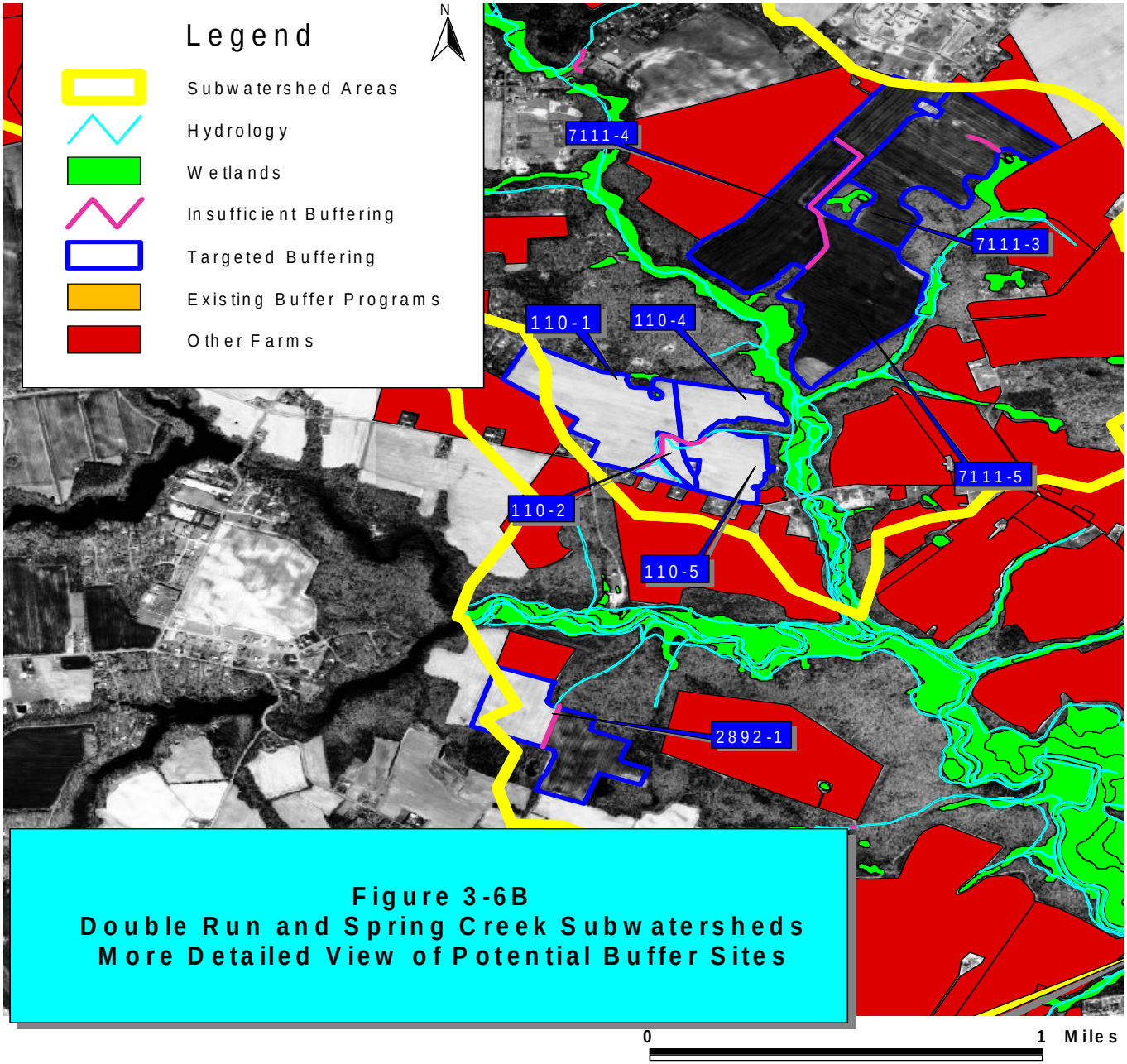


Figure 3-6B
Double Run and Spring Creek Subwatersheds
More Detailed View of Potential Buffer Sites

MSD Associates, 103 46th Street, Virginia Beach, VA 23451, (757) 469-0546

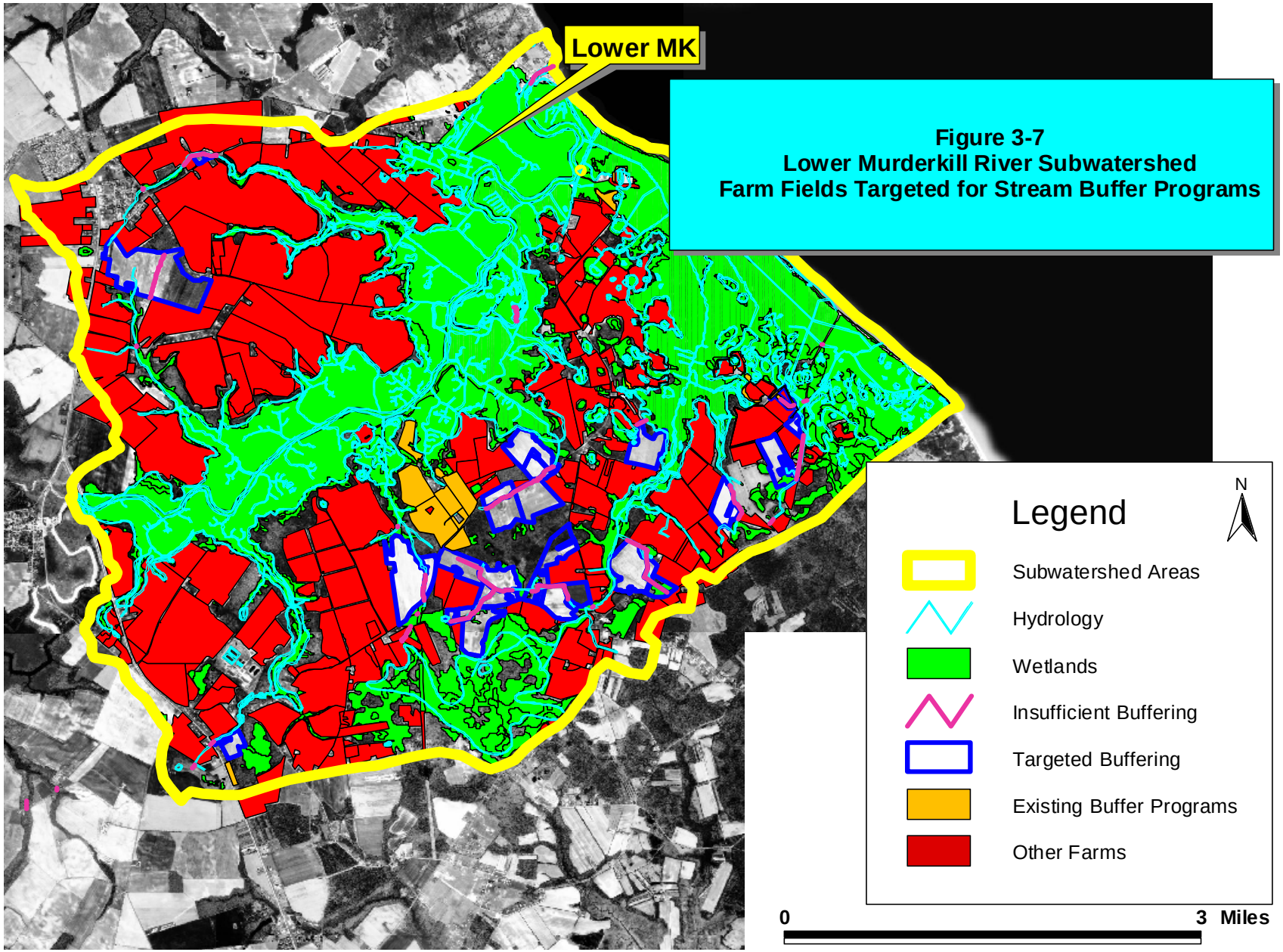
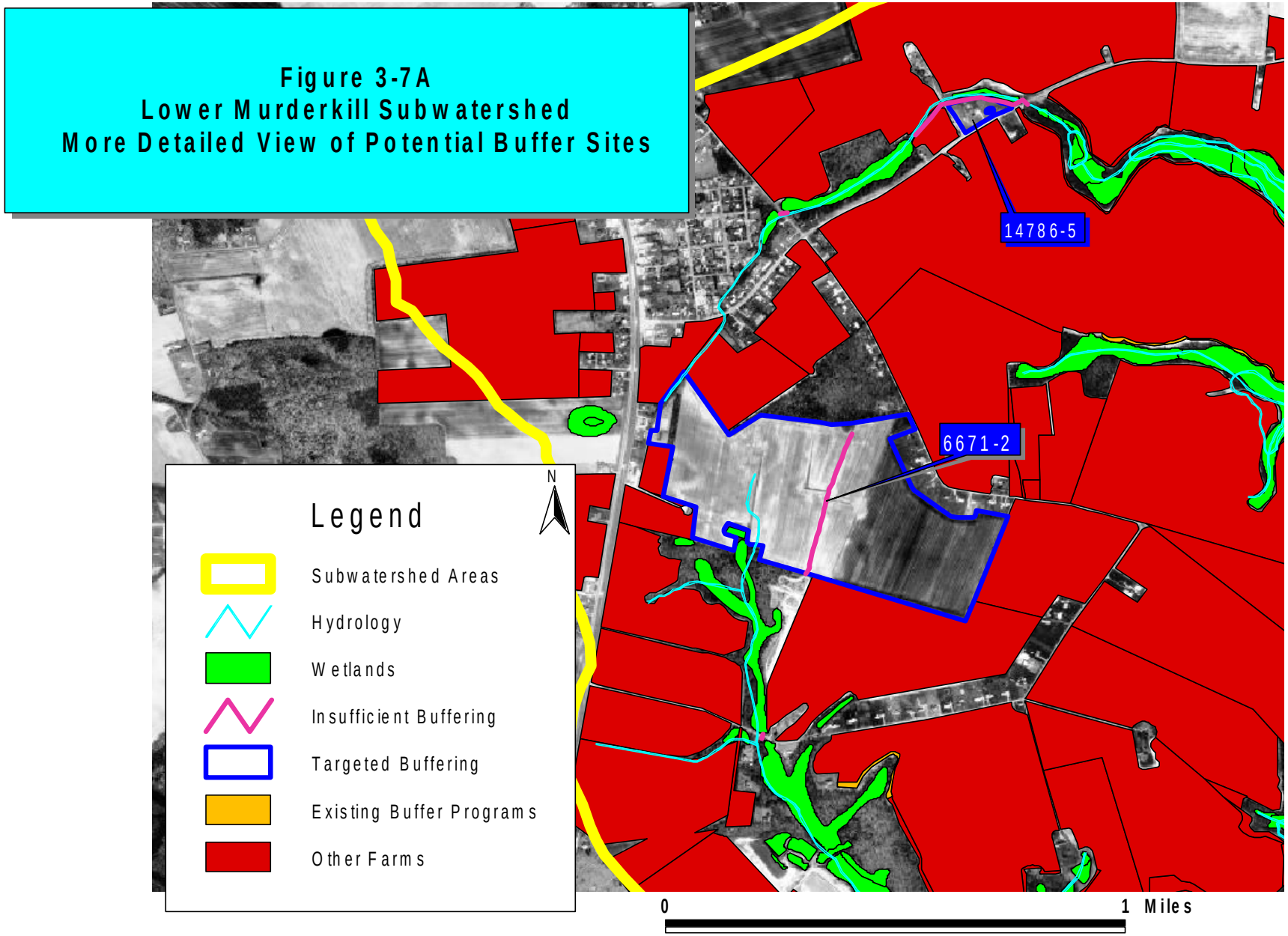
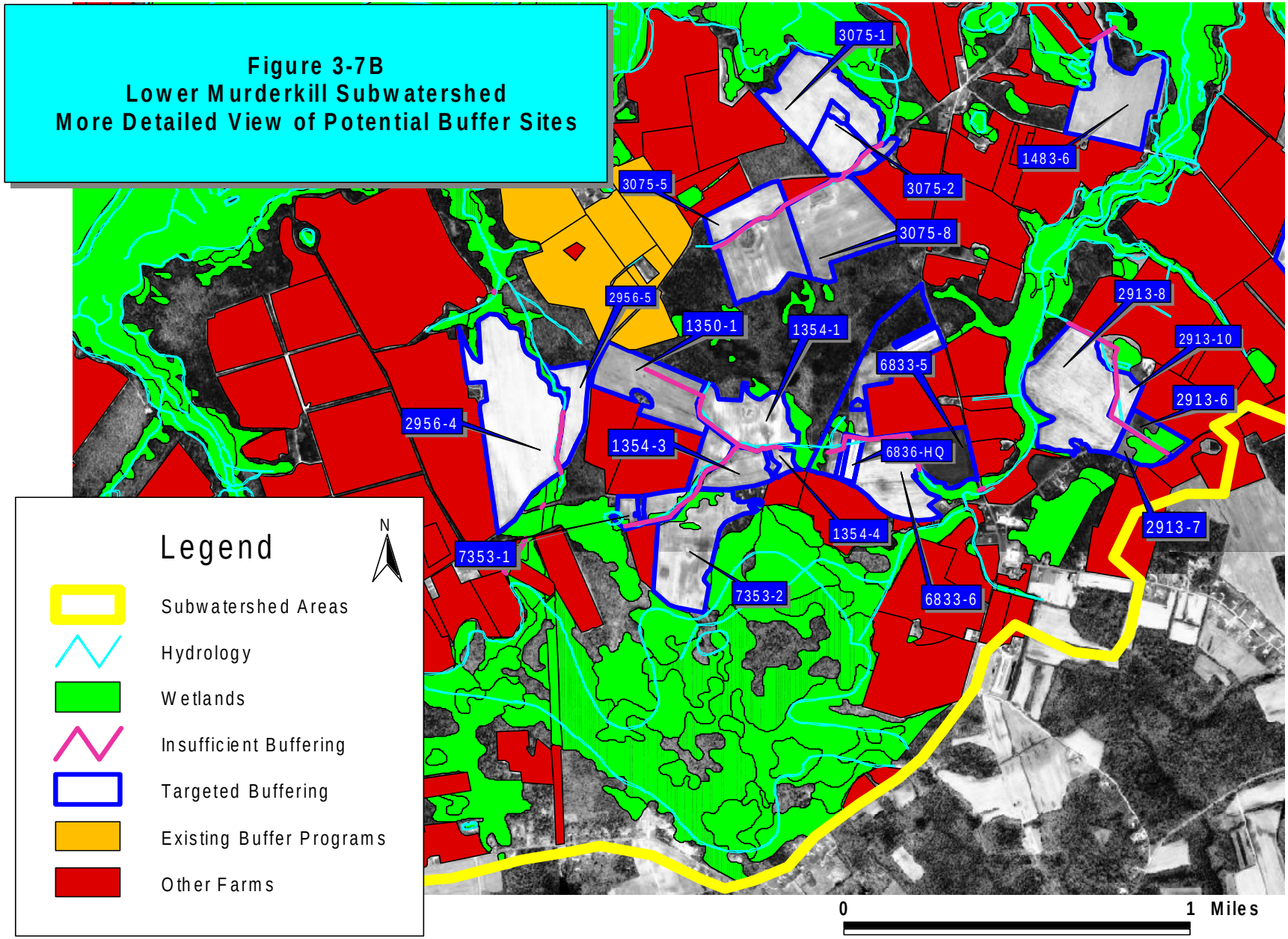


Figure 3-7
Lower Murderkill River Subwatershed
Farm Fields Targeted for Stream Buffer Programs

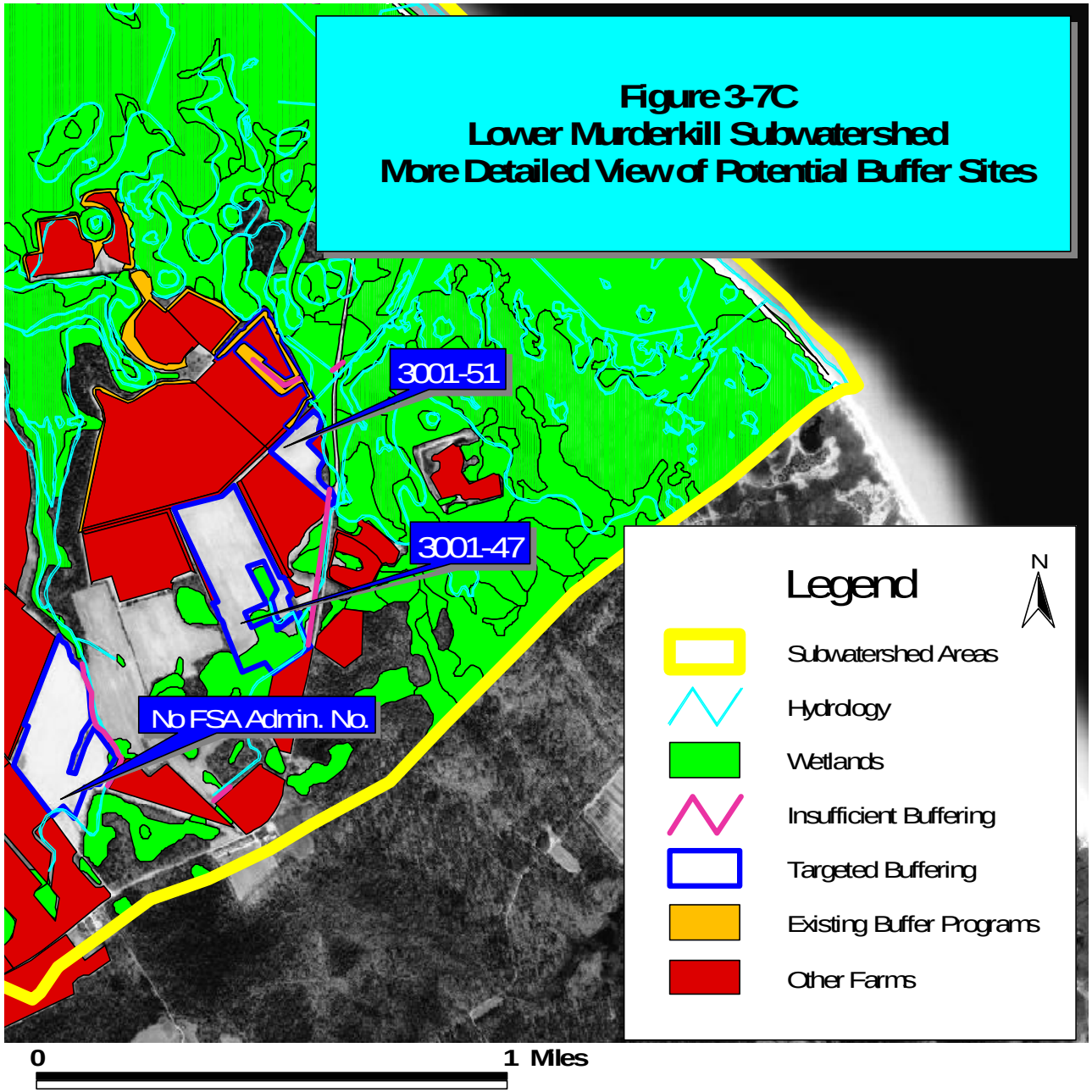
MSD Associates, 103 46th Street, Virginia Beach, VA 23451, (757) 469-0546



MSD Associates, 103 46th Street, Virginia Beach, VA 23451, (757) 469-0546

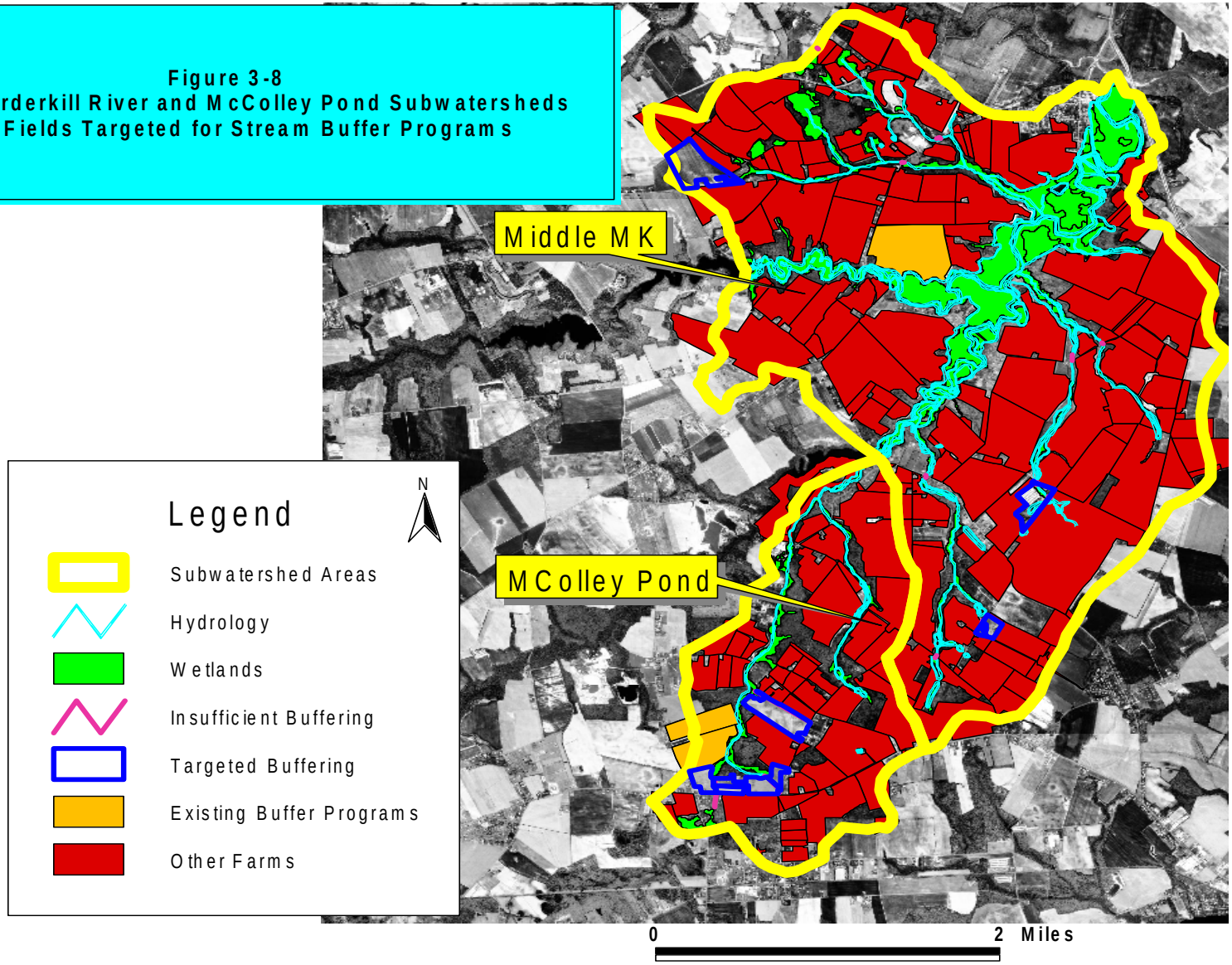


MSD Associates, 103 46th Street, Virginia Beach, VA 23451, (757) 469-0546



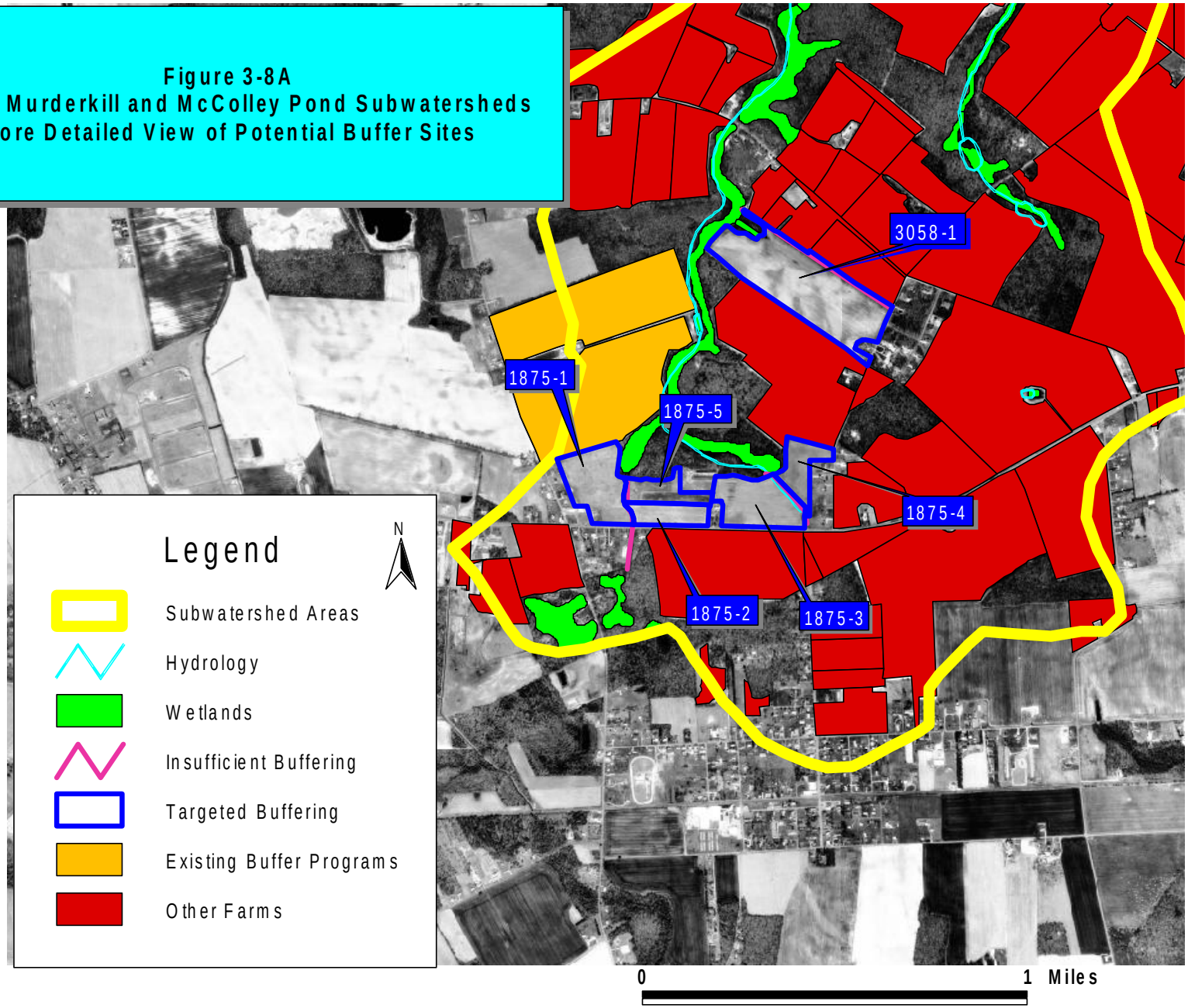
MSD Associates, 103 46th Street, Virginia Beach, VA 23451, (757) 469-0546

Figure 3-8
Middle Murderkill River and McColley Pond Subwatersheds
Farm Fields Targeted for Stream Buffer Programs

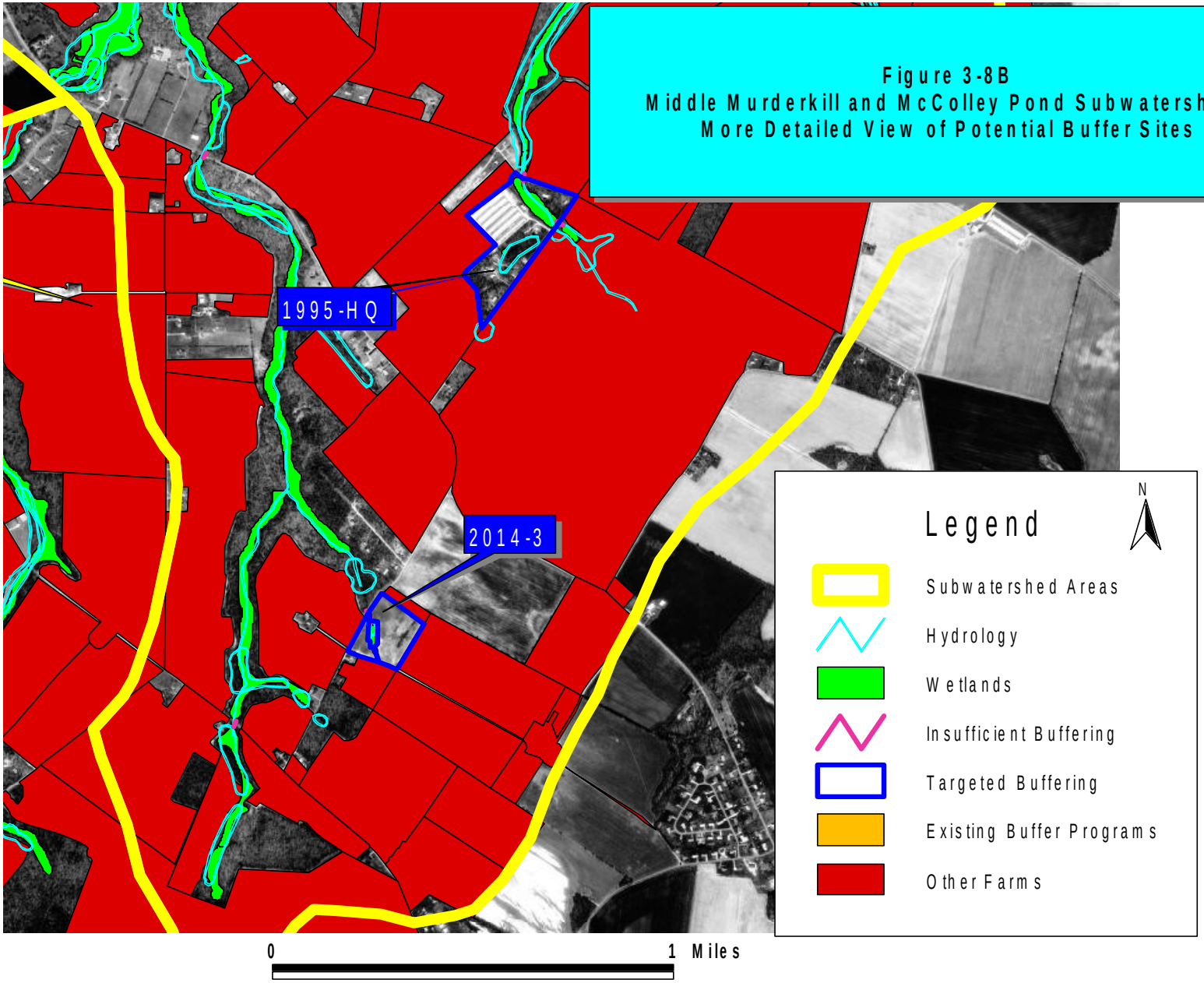


MSD Associates, 103 46th Street, Virginia Beach, VA 23451, (757) 469-0546

Figure 3-8A
Middle Murderkill and McColley Pond Subwatersheds
More Detailed View of Potential Buffer Sites



MSD Associates, 103 46th Street, Virginia Beach, VA 23451, (757) 469-0546



MSD Associates, 103 46th Street, Virginia Beach, VA 23451, (757) 469-0546

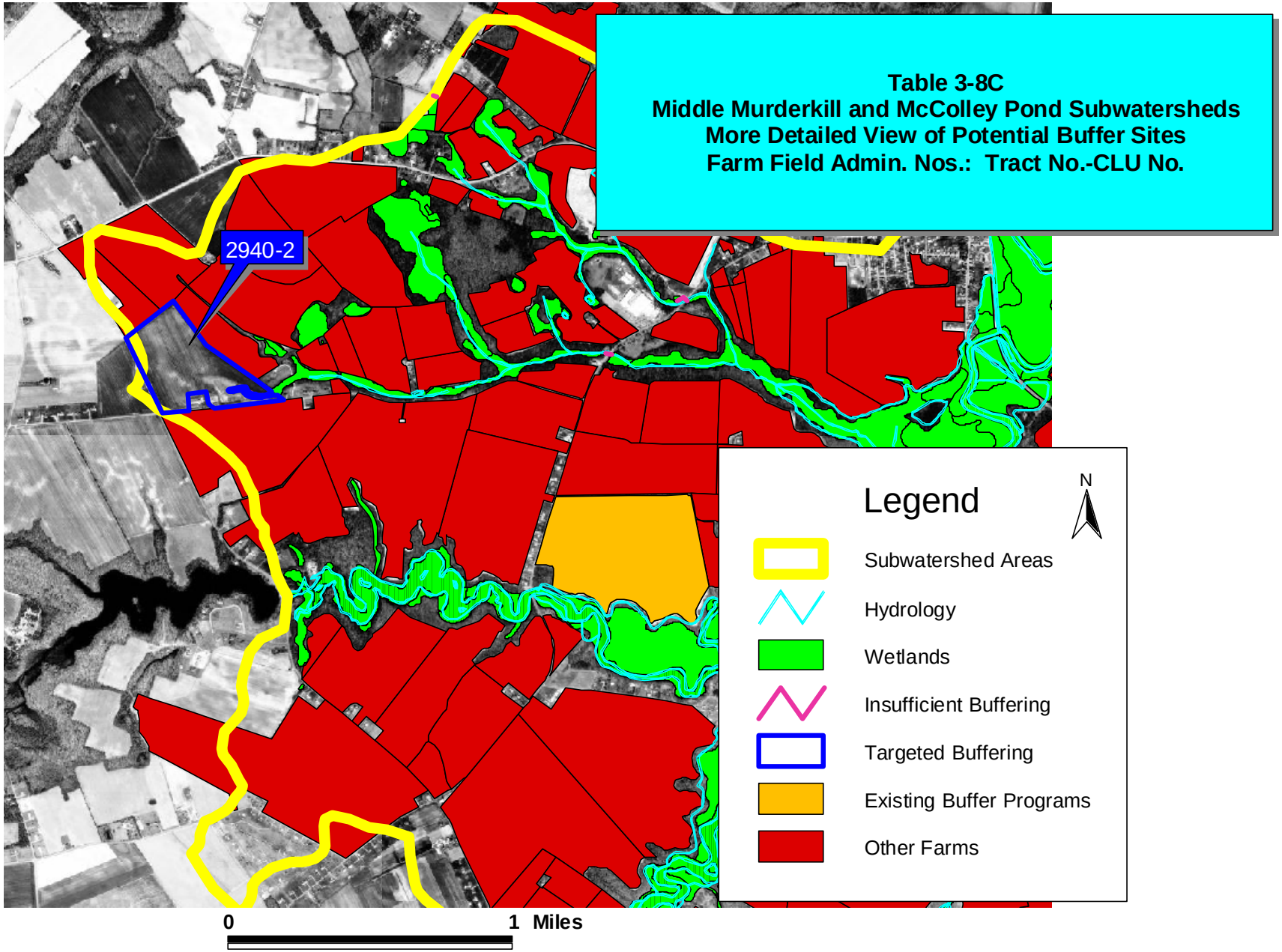


Table 3-8C
Middle Murderkill and McColley Pond Subwatersheds
More Detailed View of Potential Buffer Sites
Farm Field Admin. Nos.: Tract No.-CLU No.

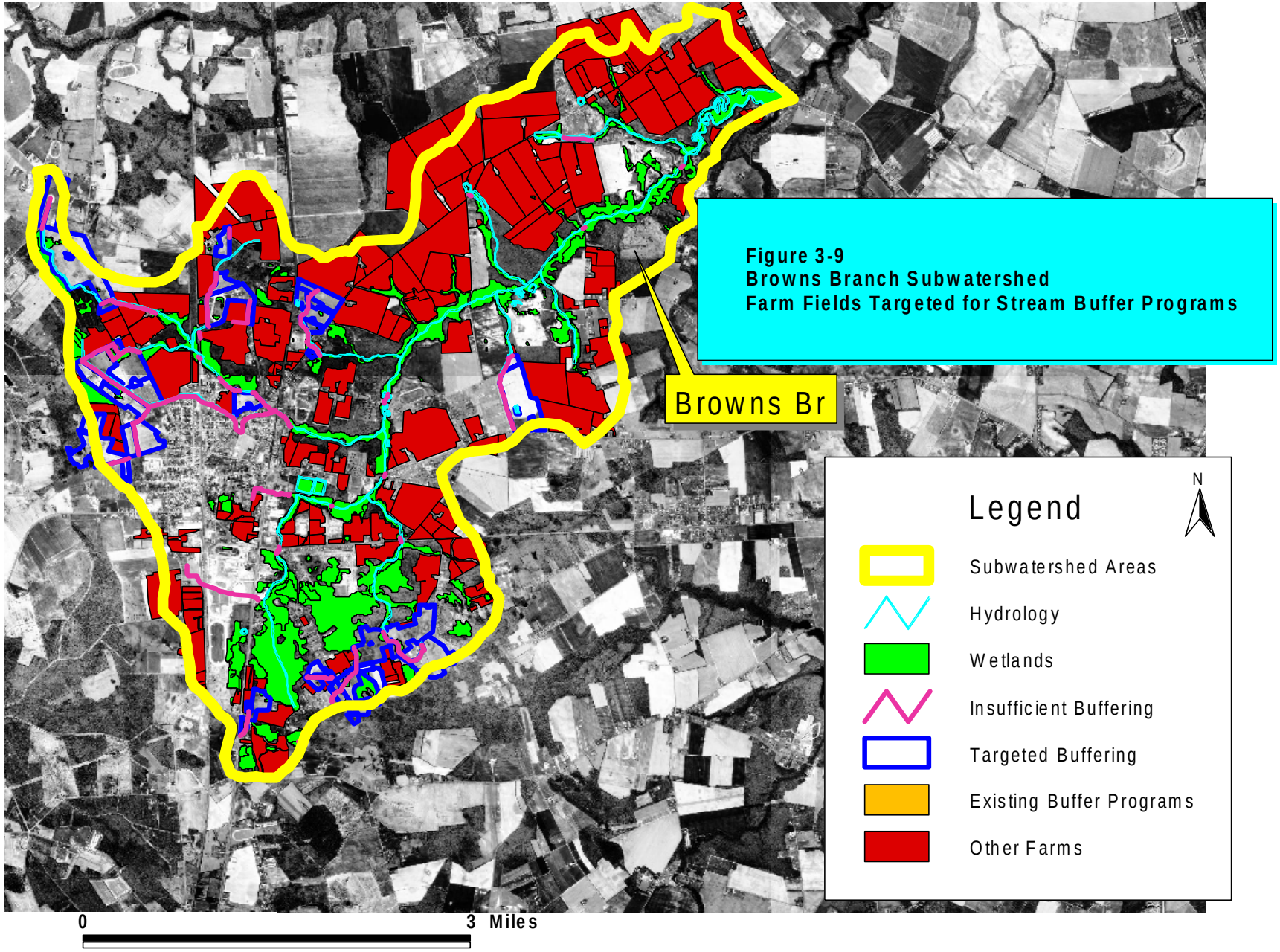


Figure 3-9
Browns Branch Subwatershed
Farm Fields Targeted for Stream Buffer Programs

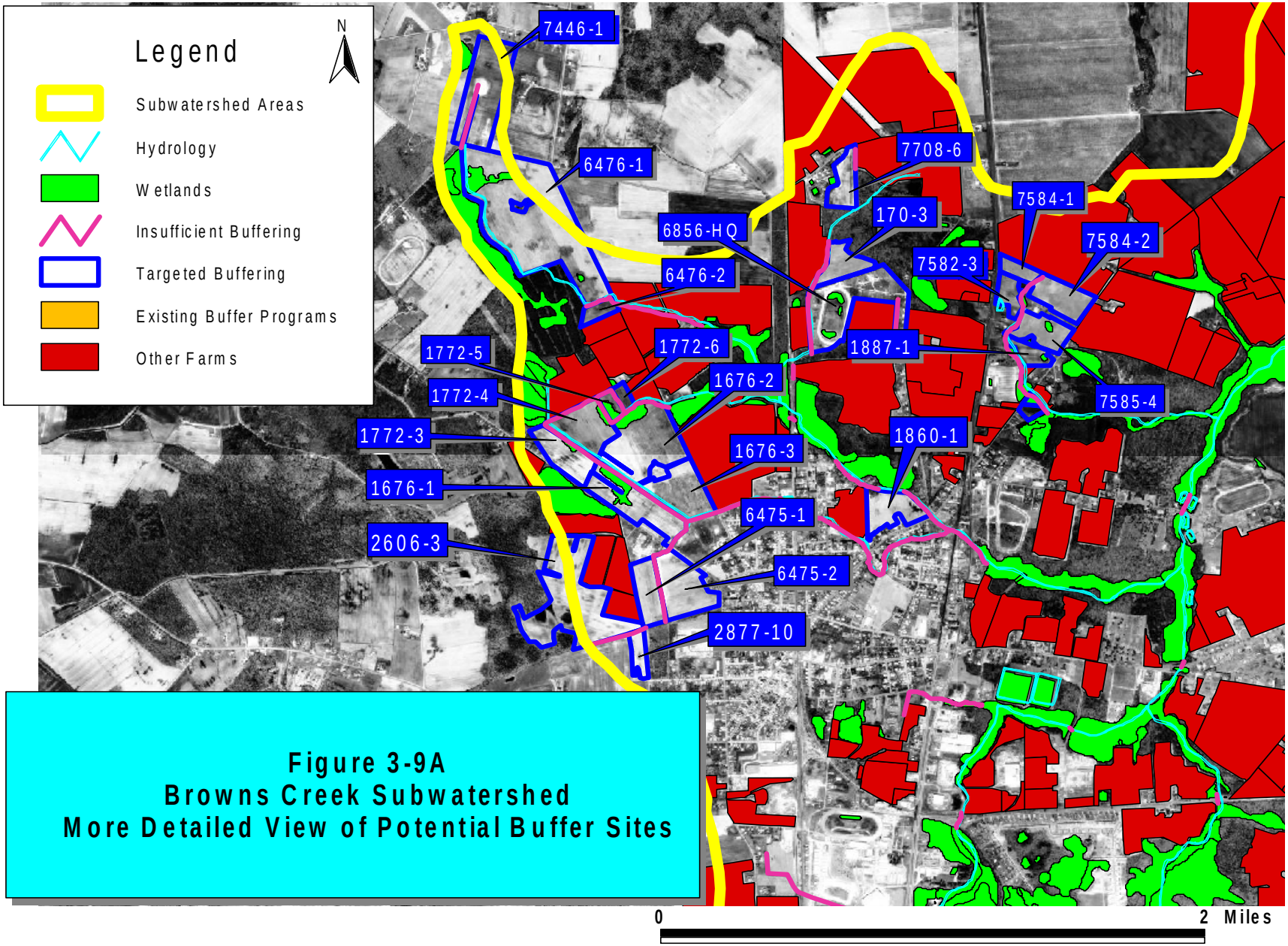


Figure 3-9A
Browns Creek Subwatershed
More Detailed View of Potential Buffer Sites

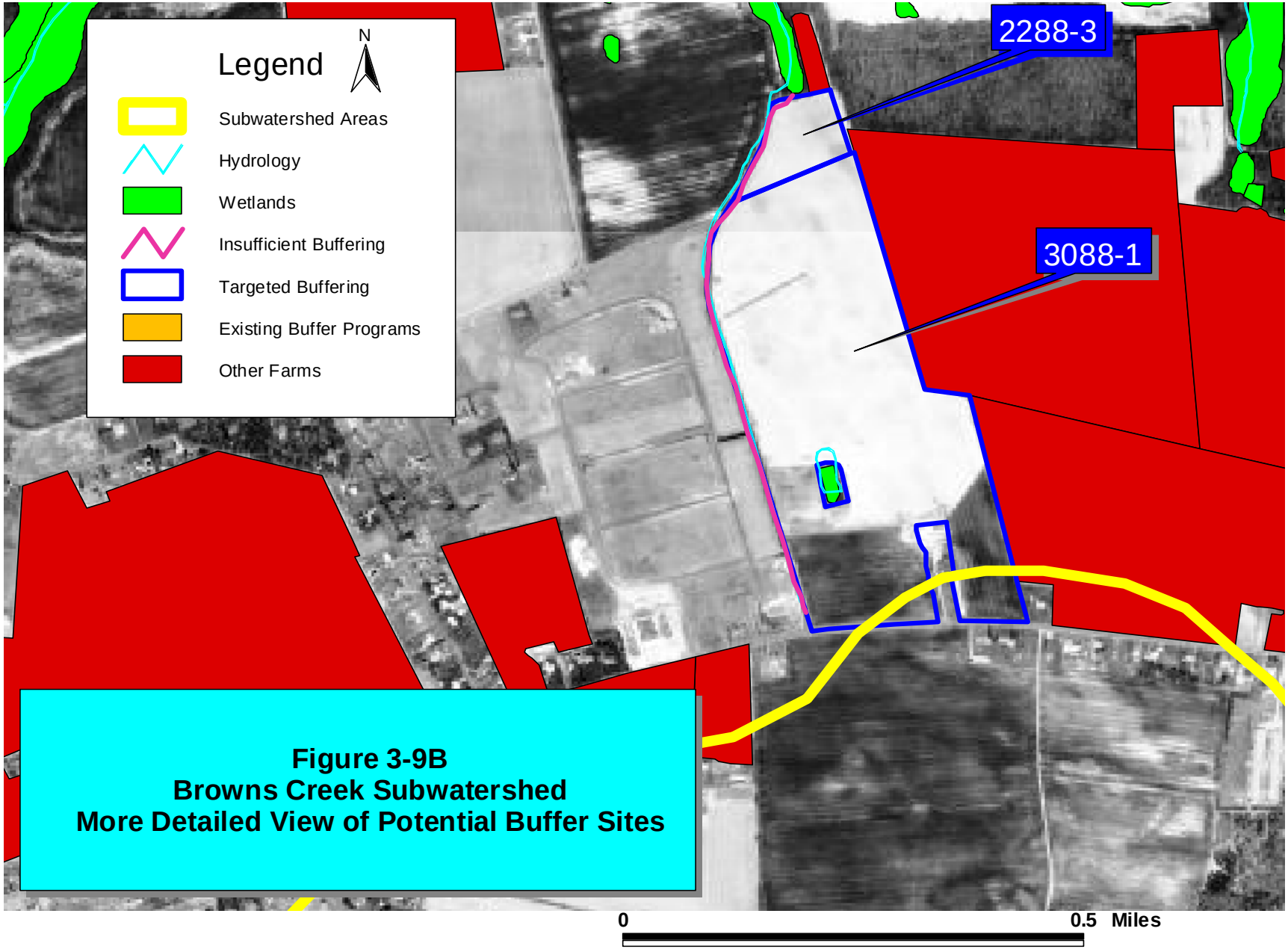
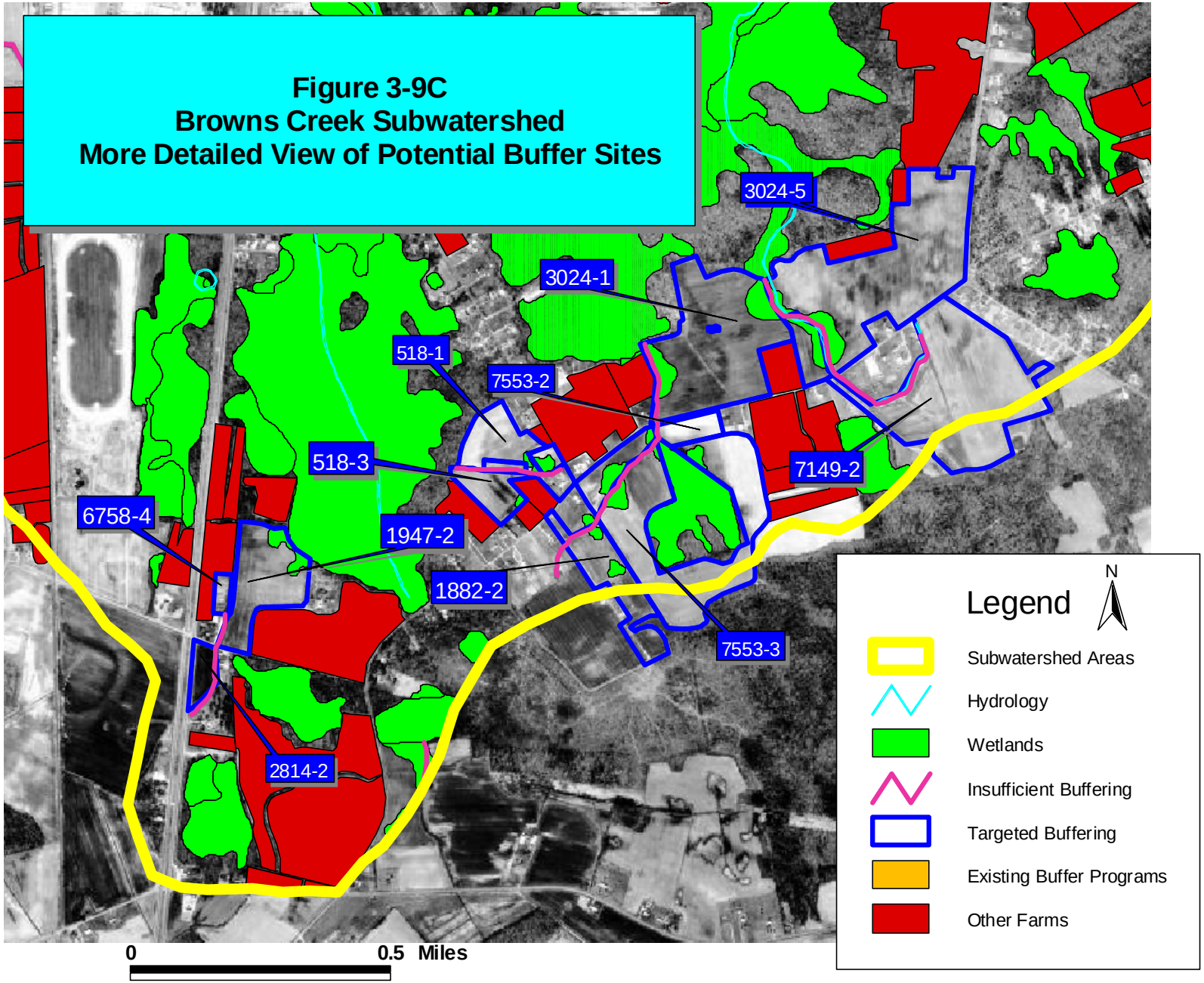


Figure 3-9B
Browns Creek Subwatershed
More Detailed View of Potential Buffer Sites

MSD Associates, 103 46th Street, Virginia Beach, VA 23451, (757) 469-0546



MSD Associates, 103 46th Street, Virginia Beach, VA 23451, (757) 469-0546

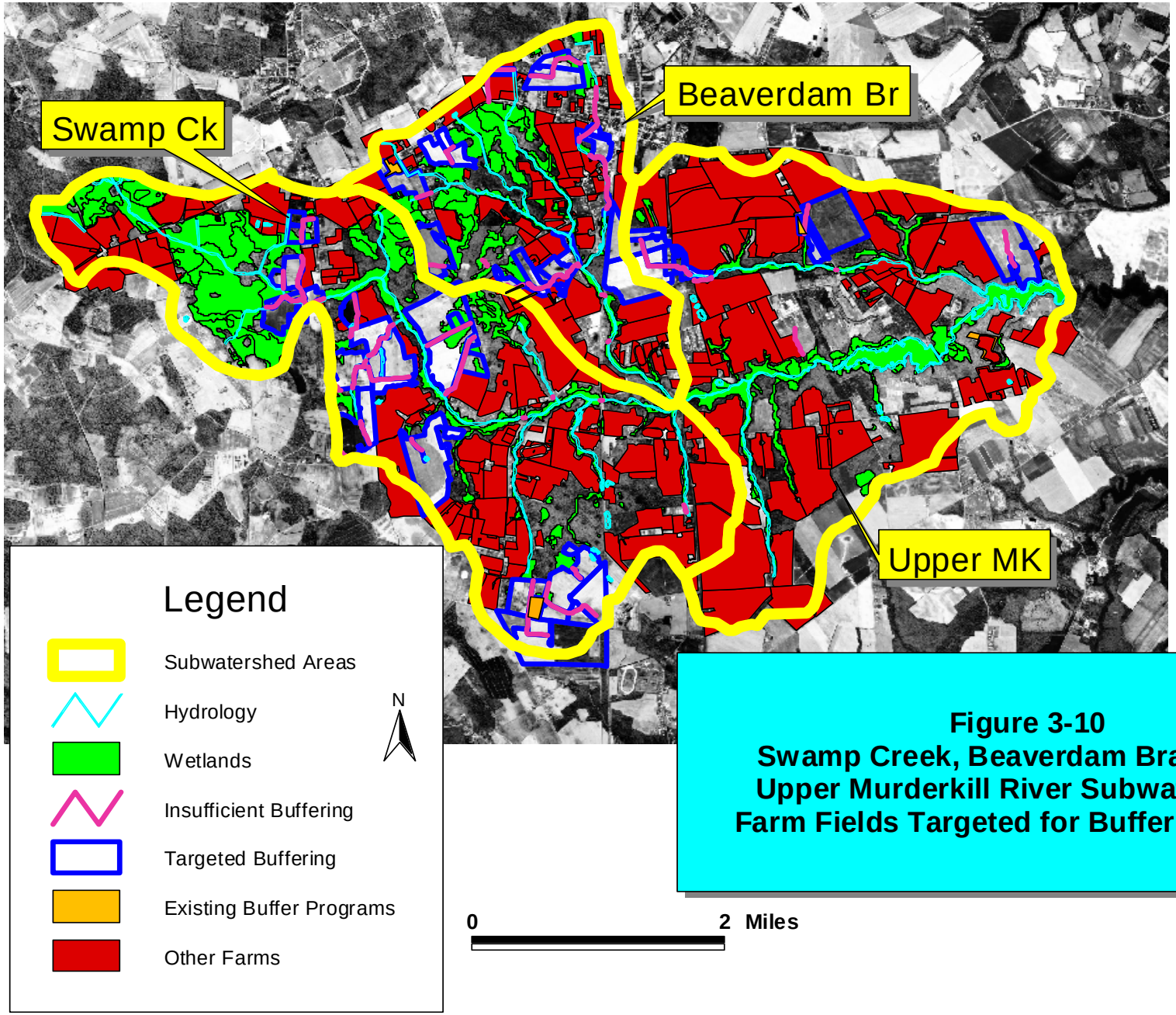


Figure 3-10
Swamp Creek, Beaverdam Branch and Upper Murderkill River Subwatersheds Farm Fields Targeted for Buffer Programs

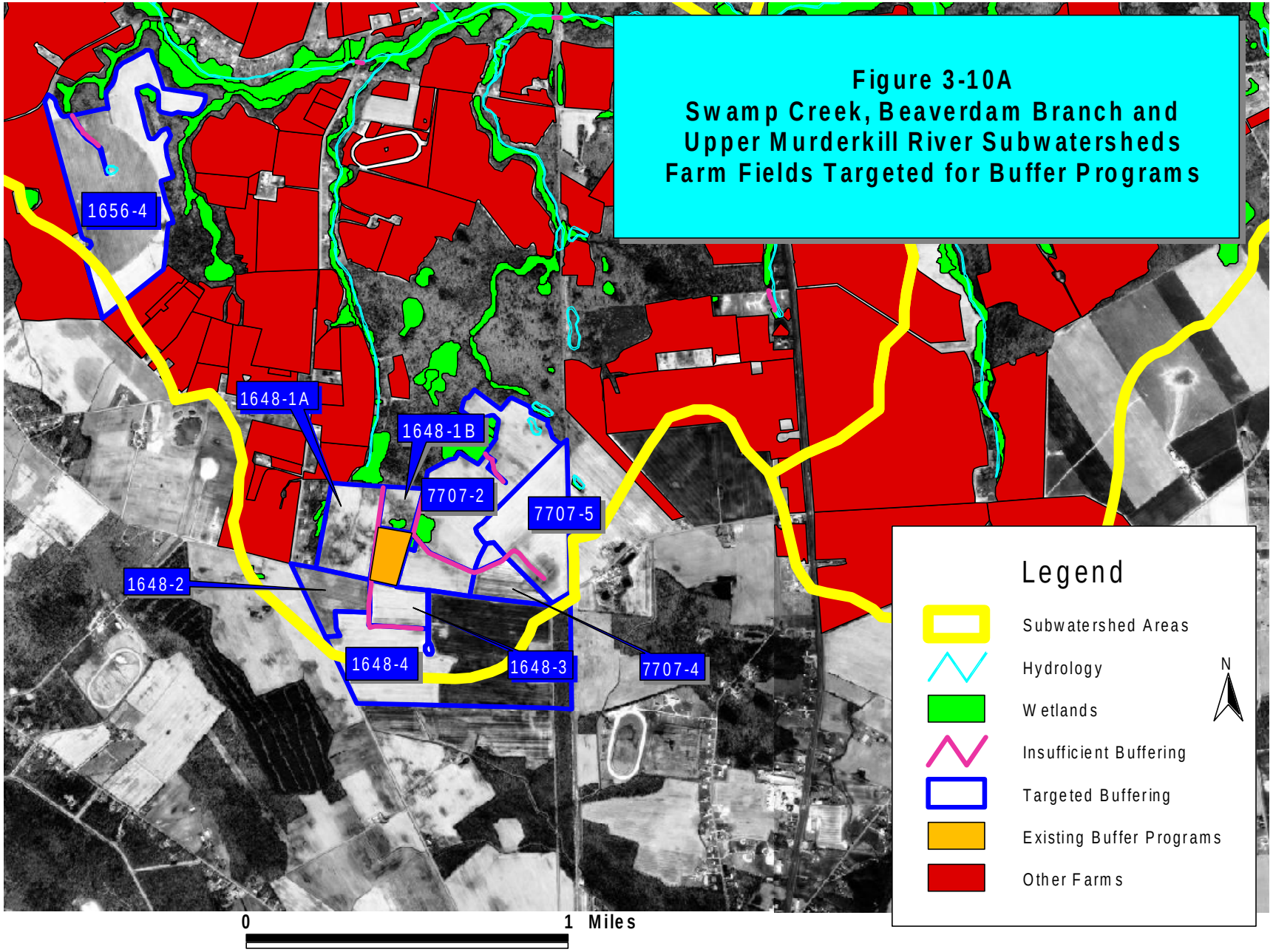


Figure 3-10A
Swamp Creek, Beaverdam Branch and
Upper Murderkill River Subwatersheds
Farm Fields Targeted for Buffer Programs
1656-4
1648-1A
1648-1B
7707-2
7707-5
1648-2
1648-4
1648-3
7707-4
Legend
Subwatershed Areas
Hydrology
Wetlands
Insufficient Buffering
Targeted Buffering
Existing Buffer Programs
Other Farms
N
0
1 Miles

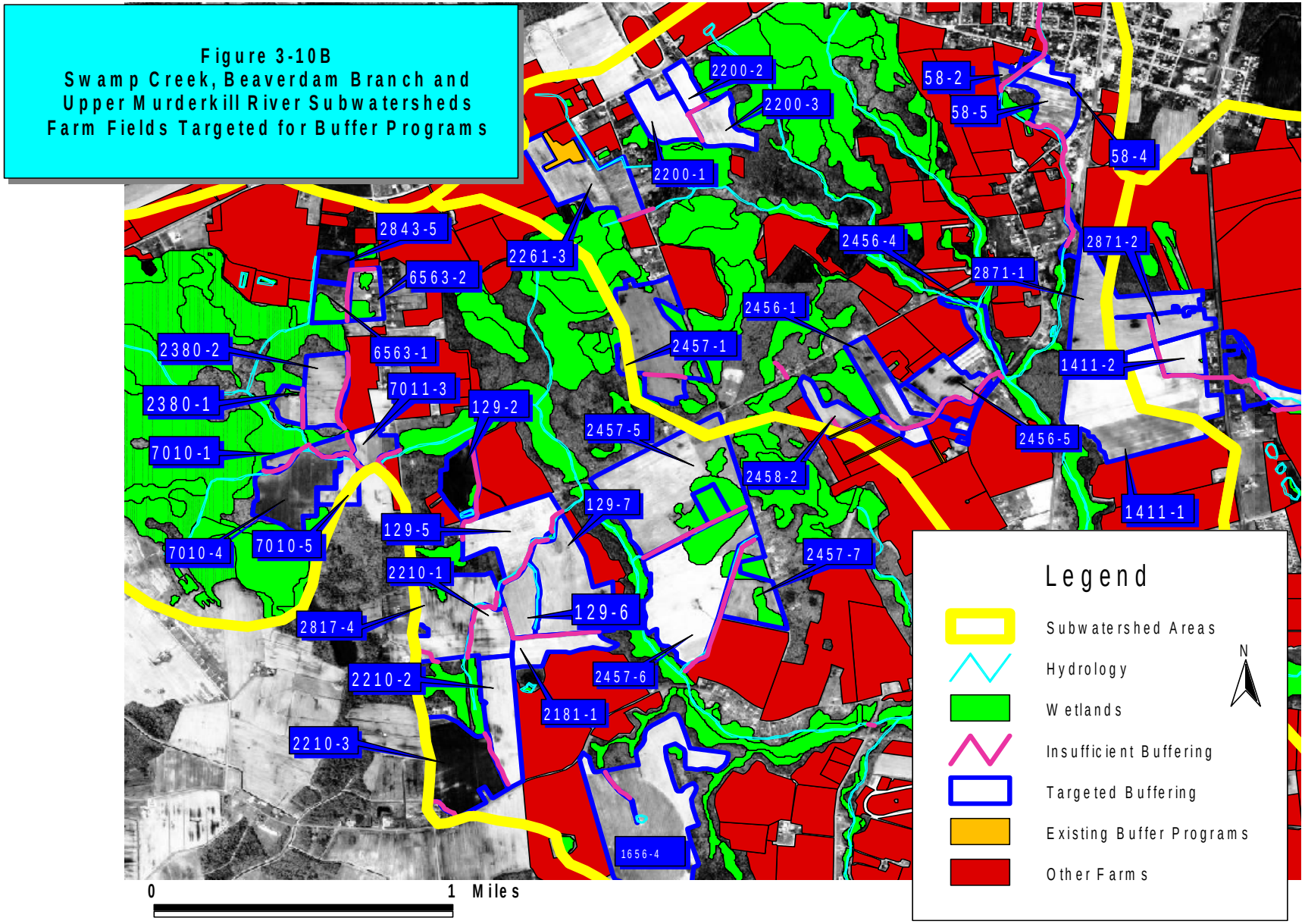


Figure 3-10B
Swamp Creek, Beaverdam Branch and
Upper Murderkill River Subwatersheds
Farm Fields Targeted for Buffer Programs
2200-2
2200-3
58-2
58-5
58-4
2200-1
2843-5
2261-3
2456-4
2871-2
6563-2
2871-1
2456-1
2380-2
6563-1
2457-1
1411-2
7011-3
2380-1
129-2
2457-5
2456-5
7010-1
2458-2
129-7
1411-1
129-5
7010-4
7010-5
2457-7
2210-1
129-6
2817-4
2457-6
2210-2
2181-1
2210-3
1656-4
0
1 Miles
Legend
Subwatershed Areas
Hydrology
Wetlands
Insufficient Buffering
Targeted Buffering
Existing Buffer Programs
Other Farms
N

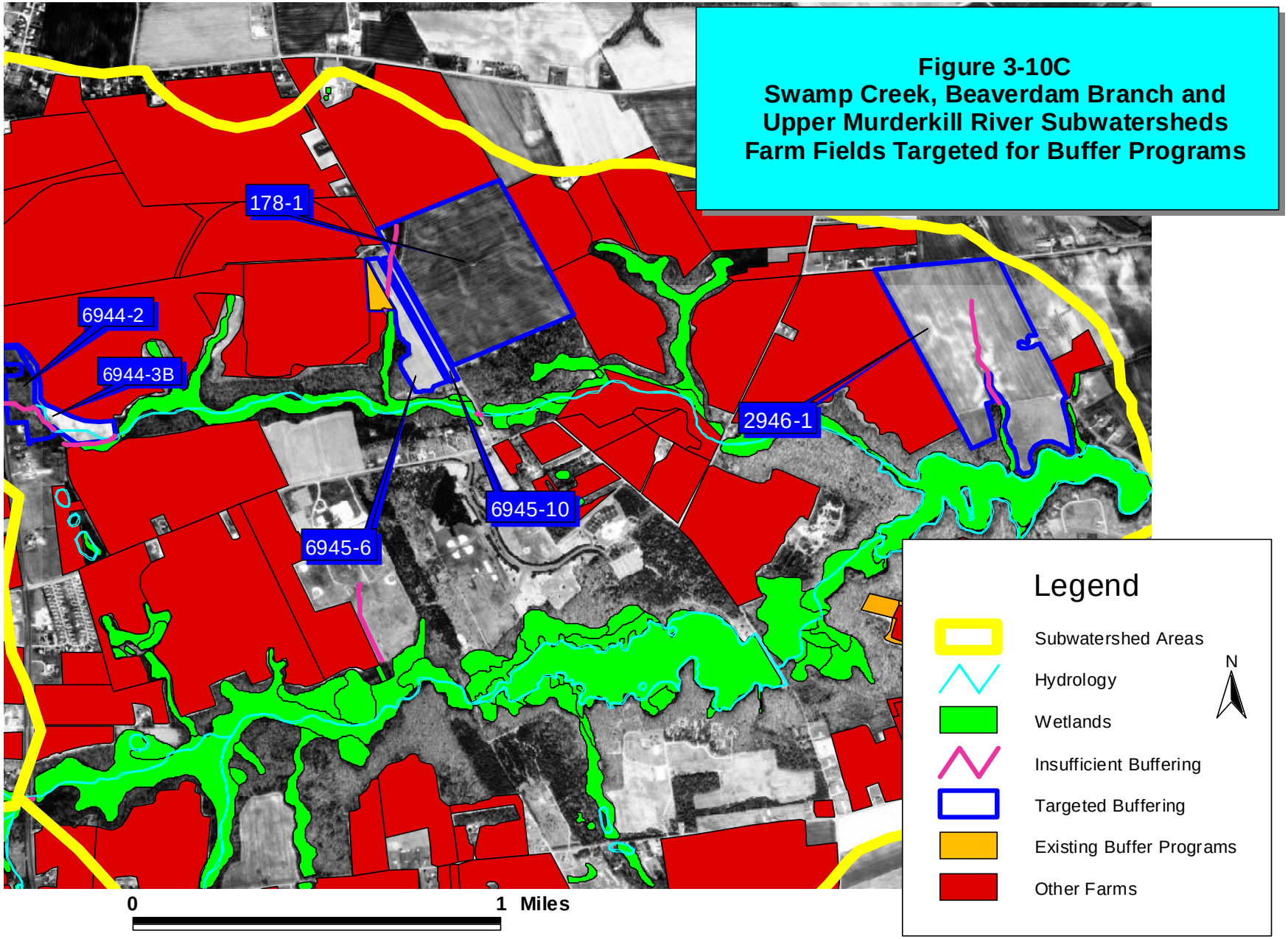


Figure 3-10C
Swamp Creek, Beaverdam Branch and Upper Murderkill River Subwatersheds Farm Fields Targeted for Buffer Programs

Nutrient Loading from Farm Animal Waste Sources. Unmitigated animal waste (i.e, the direct deposition of waste in streams, or runoff from animal headquarter operations) is the third pathway to nutrient loading addressed by this desktop study. The drive-bye field survey of farm fields in the Murderkill River watershed revealed the location of numerous animal operations of all sizes. Based on an evaluation of the current application of nutrient management plans and NRCS animal waste BMPs (i.e., composting facility, waste storage facility), it appears that a more determined application of BMPs and conservation practices on animal headquarter operation sites is warranted.

With the continued encroachment of residential land uses in the watershed, small horse lots containing one to two animals have increased in the Murderkill River watershed. These small operations are typically run by the non-farming watershed constituents and are frequently overlooked by local, state, and federal agricultural agencies. In fact, 33 pastures and animal operations in the Murderkill River watershed were identified during the drive-bye field survey to be located on CLUs not considered by the FSA as agricultural concerns. Farm animals were noted on 23 of these pastures and operations. Only three possessed a quantity of animals greater than five, and all but two were horse operations. It is recommended that the District develop an agricultural BMP and conservation practice program for small horse operations in residential communities. It should include education and the application of NRCS BMP specifications for nutrient and animal waste management.

Larger animal operations should also be reviewed with concern. It was noted during the drive-bye field survey that a total of eight pastures and/or animal operations of estimated stocking rates greater than 10 animals were not currently being addressed with nutrient or waste management plans / BMPs. If these pastures provide stream access, they are potentially large pollutant sources. The District should, therefore, attempt to meet with these landowners/operators on-site to determine the applicability and type of potential pollutant control measures (i.e. fencing).

Unaddressed concentrated waste flows and/or runoff from poultry houses can be large sources of NPS pollution. Waste management has been a concern in poultry operations for many years in Delaware. Problems with storing, handling, managing, and utilizing the byproducts of production have come to the forefront in planning, establishing, and operating poultry farms. Although considerable efforts have been expended by the District and its agricultural agency partners, thirteen of the twenty-nine poultry house operations are lacking nutrient management plans and/or waste storage or composting storage facilities. Developing poultry house NPS pollutant reduction solutions for these sites should, therefore, become a major priority of the District.

Figures 3-11 through 3-15 show the location of all pasture and animal operations, and poultry houses lacking nutrient management plans or either waste storage or composting storage facilities. These sites have been prioritized for District site visits and the confirmation of their potential for agricultural BMPs or conservation practices. Farm field administration numbers denoted ‘Tract Number – CLU Number’ are included on the maps for all prioritized animal waste BMP sites. Appendix A contains the list of prioritized farm fields.

Figure 3-11
Double Run and Spring Creek Subwatersheds
Farm Fields Targeted for Animal Waste BMPs

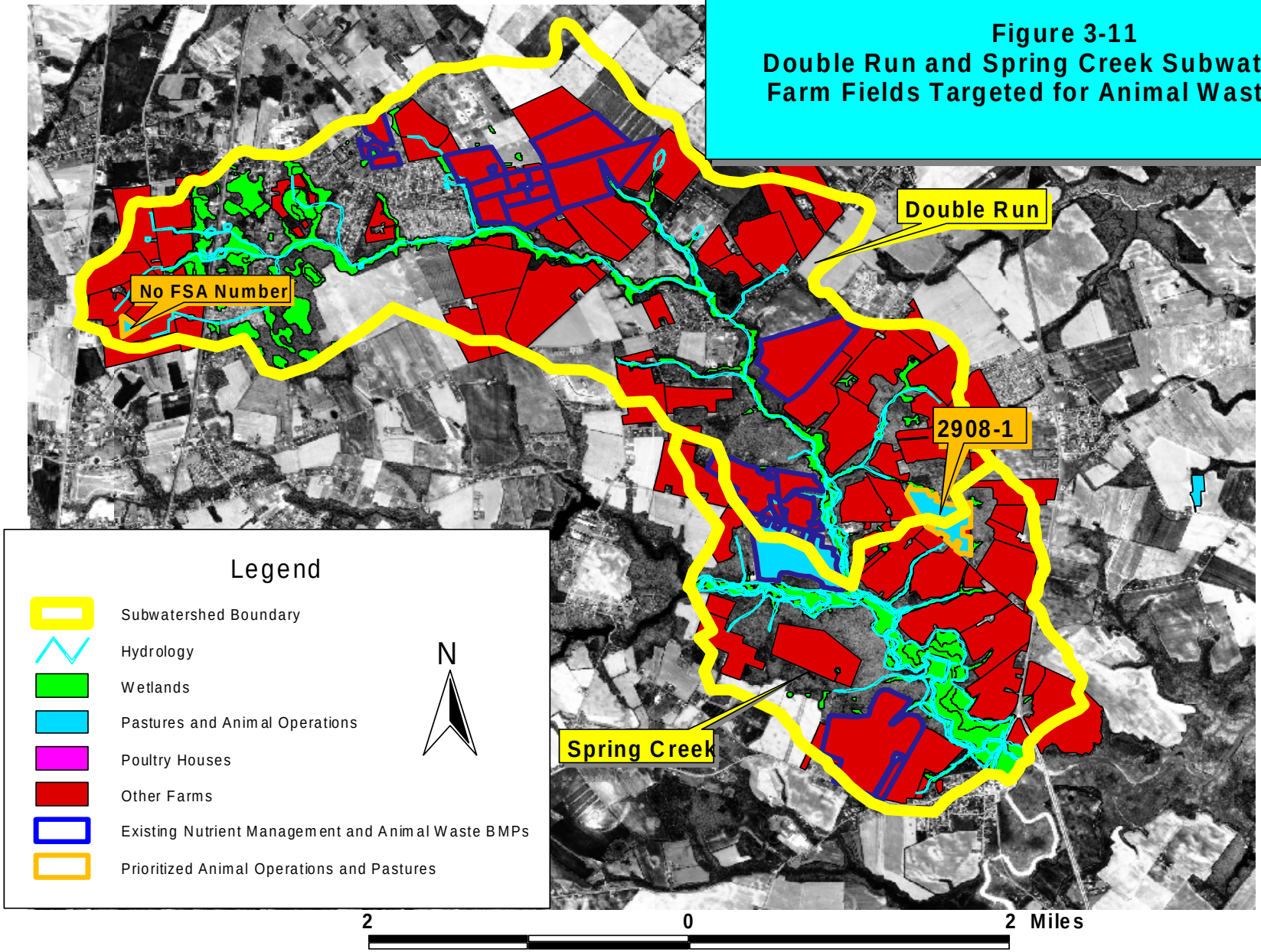
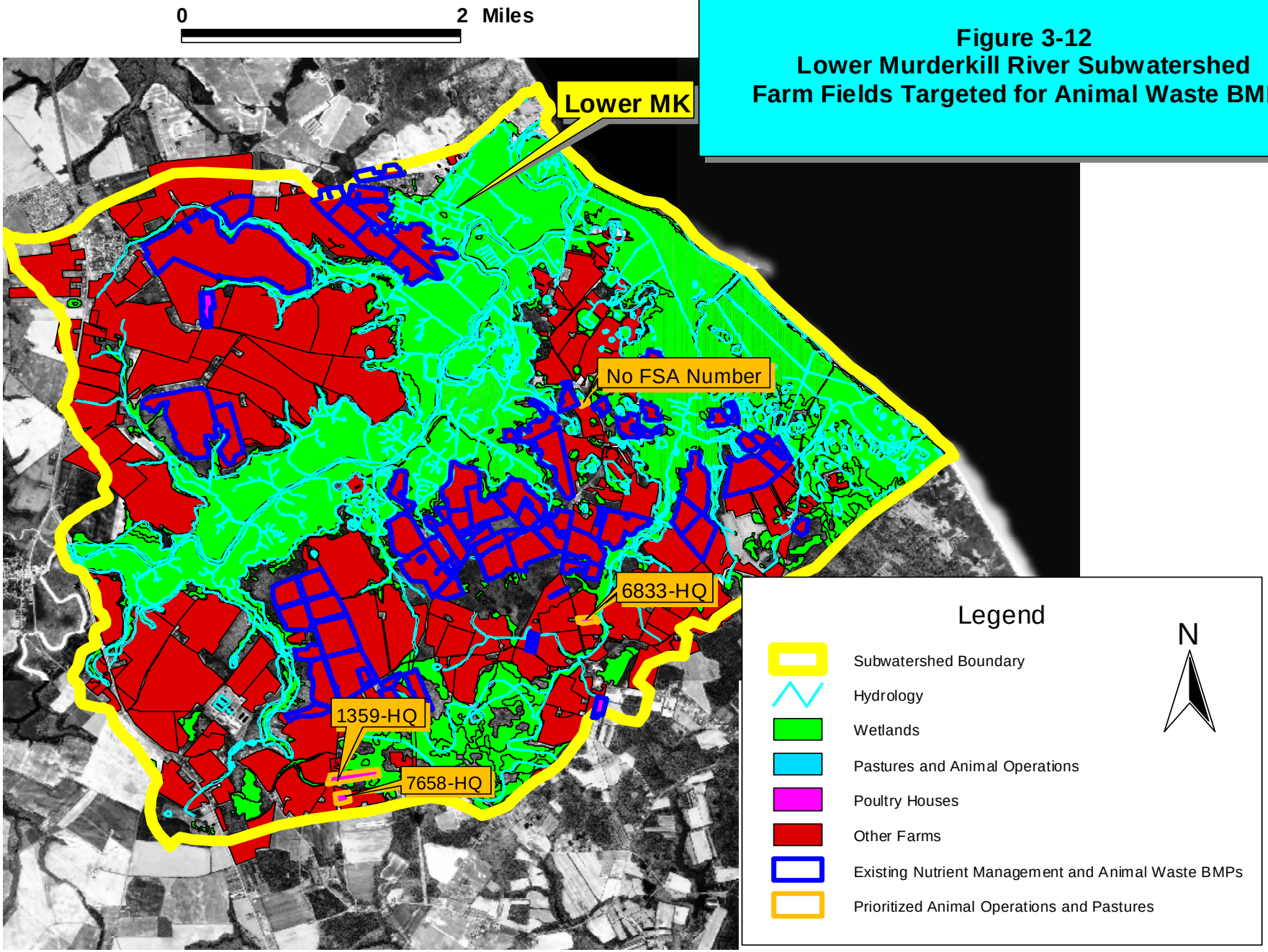


Figure 3-12
Lower Murderkill River Subwatershed
Farm Fields Targeted for Animal Waste BMPs



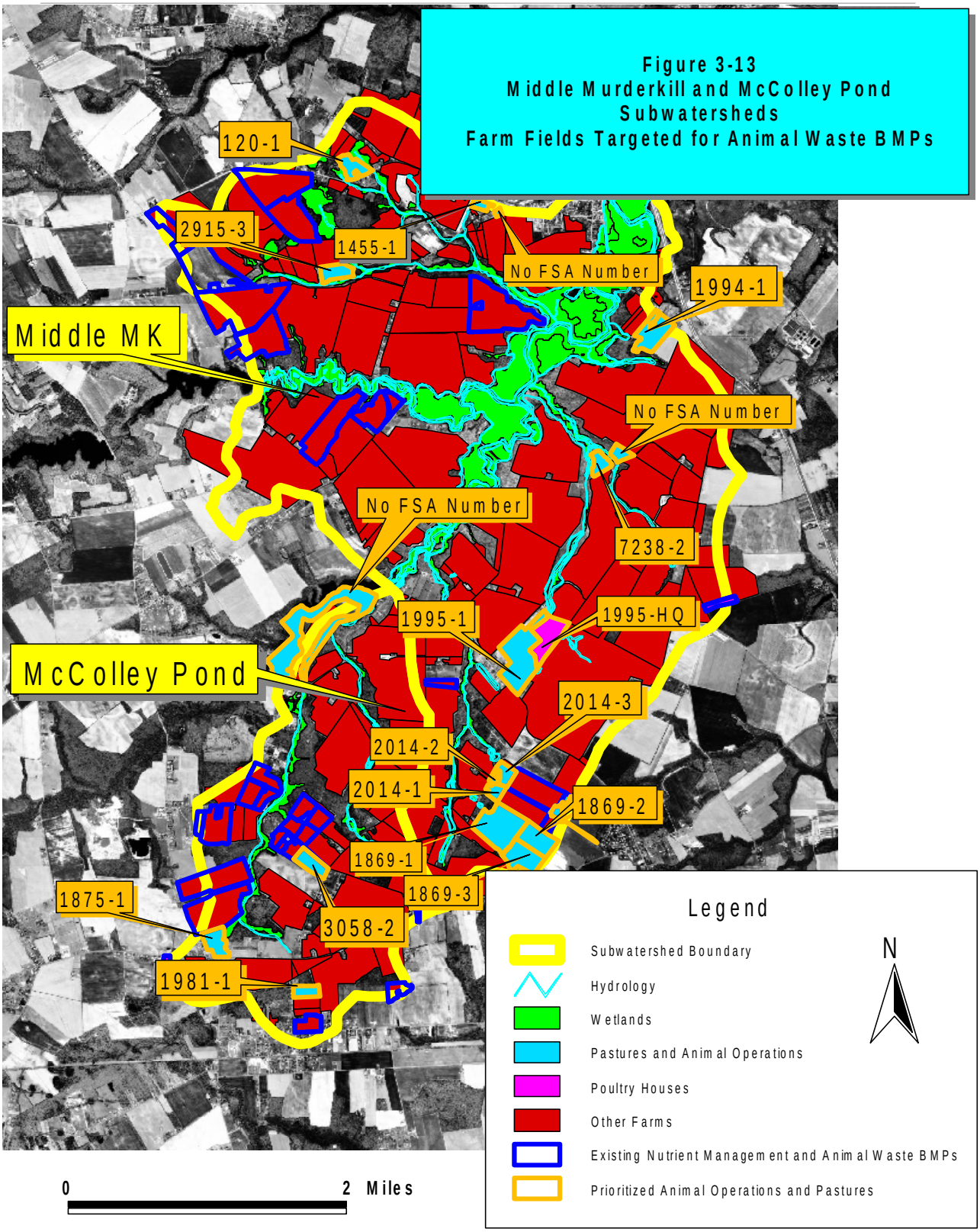


Figure 3-13
Middle Murderkill and McColley Pond
Subwatersheds
Farm Fields Targeted for Animal Waste BMPs
120-1
2915-3
1455-1
No FSA Number
1994-1
Middle MK
No FSA Number
No FSA Number
7238-2
1995-1
1995-HQ
McColley Pond
2014-3
2014-2
2014-1
1869-2
1869-1
1869-3
1875-1
3058-2
1981-1
Legend
Subwatershed Boundary
Hydrology
Wetlands
Pastures and Animal Operations
Poultry Houses
Other Farms
Existing Nutrient Management and Animal Waste BMPs
Prioritized Animal Operations and Pastures
N
0
2 Miles

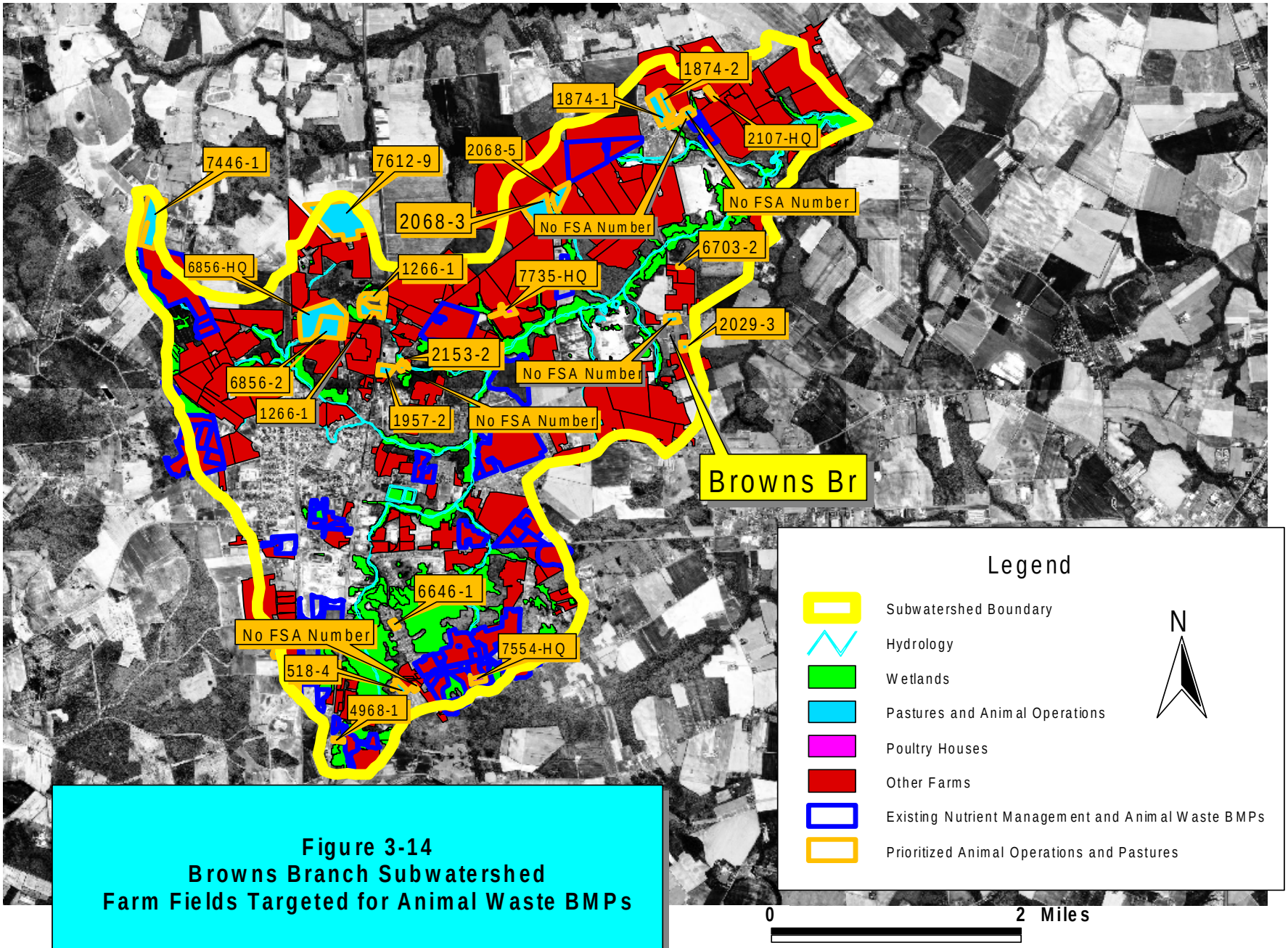


Figure 3-14
Browns Branch Subwatershed
Farm Fields Targeted for Animal Waste BMPs

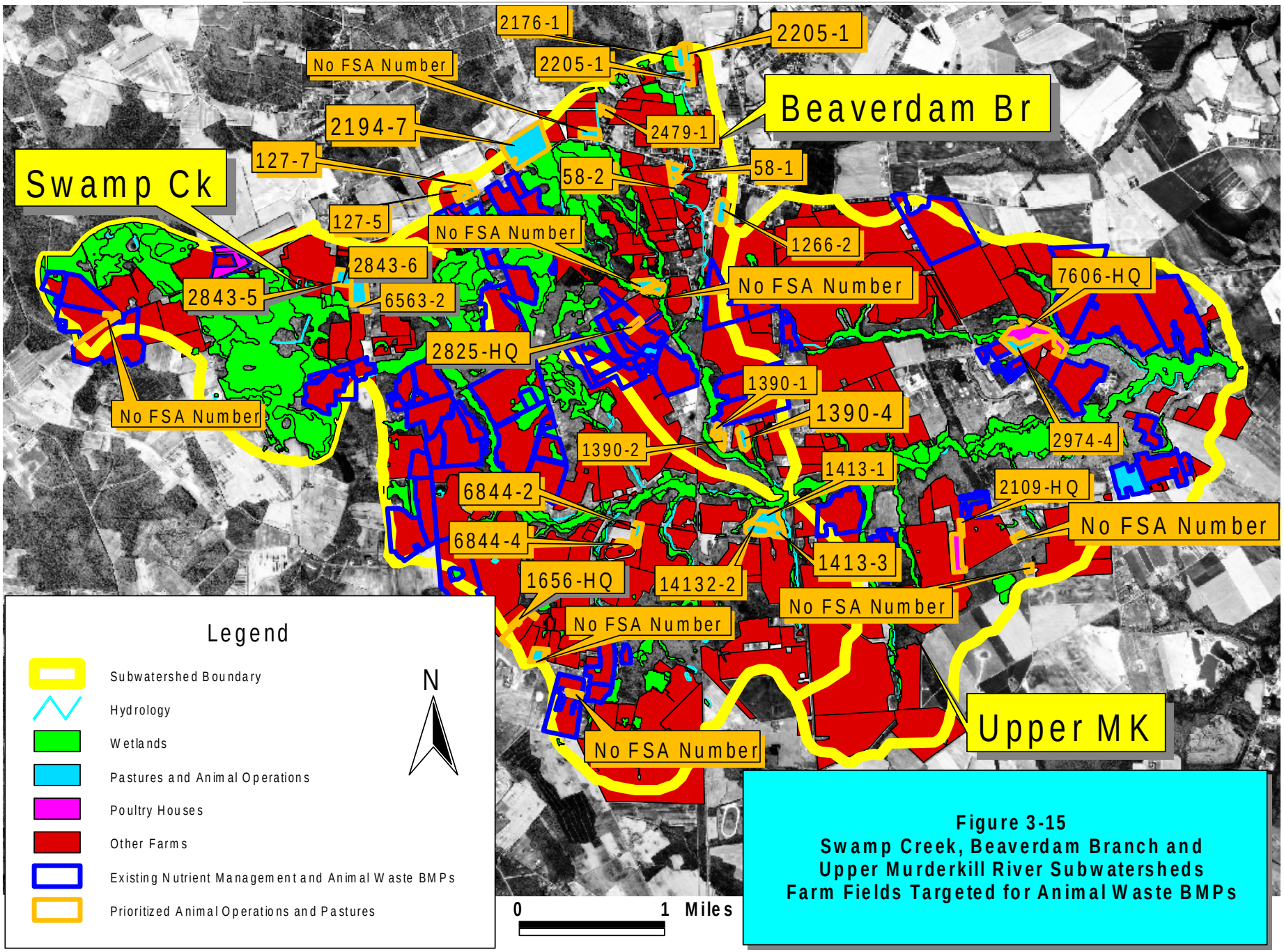


Figure 3-15
Swamp Creek, Beaverdam Branch and Upper Murderkill River Subwatersheds Farm Fields Targeted for Animal Waste BMPs

4 CONCLUSIONS

A desktop ArcView GIS database of farm fields was constructed by linking FSA CLU and other farm field polygons to an NRCS Toolkit database of existing agricultural BMP and conservation practice information. The FSA tract and CLU numbers were used to link the databases together. The integrated GIS database of farm fields was used to conduct an assessment of farm fields conducive to agricultural BMP and conservation practice enrollment. The desktop assessment advances a coordinated approach to acquiring landowner support for the implementation of corrective actions that address nutrient (nitrogen) loading from farms fields in groundwater recharge areas, nutrient loading from farm field runoff into non-buffered streams, and nutrient loading from animal waste sources. The targeting and ranking of farm fields for implementation measures is a necessary component to future implementation planning in the Murderkill River watershed and elsewhere. It not only ensures the optimum utilization of implementation revenues, but also facilitates a multi-phased implementation approach where stakeholders can identify and prioritize sets of farm fields for corrective action based on their probability of success and the availability of implementation funds. It maximizes water quality benefits from agricultural BMPs and conservation practices by utilizing a proactive methodology rather than the traditional first-come, first-serve basis for selection.

The GIS database of farm fields is also a live tool that maintains a record of where existing implementation activities have occurred and where they are planned to occur in the future. It therefore allows the planning process to be fined-tuned and adjusted to best meet the water quality goals of the stream in question.

Subwatershed Accounting. Considerable opportunities exist for nutrient loading reductions. Numerous farm fields were prioritized for various agricultural BMP and conservation practice types throughout the Murderkill River watershed. The GIS desktop evaluation findings should be used in conjunction with site verification procedures. Rather than fine-tuning the desktop evaluation to further reduce the number of prioritized farm fields, it is recommended that a more focused review of subwatershed areas be conducted through the application of an enhanced advocacy program resulting in one-on-one meetings with prioritized farm field landowners. Table 4-1 provides a subwatershed accounting of prioritized farm fields for implementation activities addressing the three nutrient loading pathways: groundwater recharge, runoff to non-buffered stream segments, and animal waste sources. The quantities of prioritized farm fields for BMP and conservation practice shown in Table 4-1 demonstrates a primary need to address potential nutrient loading from farming activities in the headwater areas of the Murderkill River watershed (i.e., Swamp Creek, Beaverdam Creek, Upper Murderkill River, and Browns Branch subwatersheds).

Table 4-1 Quantities of Prioritized Farm Fields Addressing Nutrient Loading			
Subwatershed(s)	**Nutrient Loading Pathway**		
	Groundwater Recharge Pathway	**Non-Buffered Streamlength Pathway**	**Animal Waste Pathway**
Double Run / Spring Creek	16	11	2
Lower Murderkill River	30	33	4
Middle Murderkill River / McColley Pond	32	10	20
Browns Branch	40	43	28
Swamp Creek / Beaverdam Branch / Upper Murderkill River	108	63	36
TOTAL	*226*	*160*	*90*

District Advocacy Campaign. It is important to emphasize that the prioritized farm fields listed in Appendix A are potential sites for agricultural BMP and conservation practices. In addition, the prioritized farm field sites will remain unaddressed without a well planned and implemented advocacy campaign. As a grassroot conservation organization, the District possesses an existing structure for advocacy and education that can be used to rapidly and effectively disseminate the value of agricultural BMP and conservation practices to landowners of prioritized farm fields for NPS nutrient loading abatement. The District should work with its state and federal partners to develop an effective advocacy campaign. The campaign may include the promotion of newsletters, workshops, field days, and sponsor education presentations. Leadership assistance could be acquired from the Murderkill Tributary Action team. The Delaware Division of Water Resources has initiated NPS pollution advocacy and education for the Murderkill River through this Tributary Action Team. Moreover, District personnel and their state and federal partners frequently meet with landowners on-site to determine the most applicable pollutant control measures for respective farm fields. The District could use these one-on-one meetings to determine the viability of the prioritized farm field for agricultural BMP and conservation practices, identify appropriate BMPs or suites of BMPs, and to promote the importance of improved water quality to appropriate landowners.

APPENDIX A
Prioritized Farm Fields for BMP and Conservation Practice Enrollment

Farm fields denoted with an asterisk (*) are not enrolled in an FSA program and were not provided FSA tract and CLU numbers. Instead, the CLU identification number was computer generated.

Farm fields with an FSA Tract No. = 0 were areas not possessing any CLU polygons and were, therefore, created by MSD Associates to denote a significant land-use activity observed during the drive-bye field survey (i.e., pasture, animal operation, etc.). A total of 8 polygons (with CLUs of A through H) were created by MSD Associates and were included as a component of the Farm Field datalayer that was provided to the District in September 2005.

Table A-1A
Double Run and Spring Creek Subwatersheds

Prioritized Sites for Cropland Nutrient Management Planning and Cover Crop Enrollment

FSA Tract No.	FSA CLU No.
2910	1
1334	1
2909	1
7750	4
1279	3
1279	2
1279	1
6803	5
7070	1
1376	3
1376	2
1376	1
1376	4
1376	5
1381	1
2949	1

Table A-1B Lower Murderkill River Subwatershed	
Prioritized Sites for Cropland Nutrient Management Planning and Cover Crop Enrollment	
FSA Tract No.	**FSA CLU No.**
3001	19
3001	17
3001	46
3001	48
3001	50
3001	49
3001	52
6833	6
6833	7
2911	1
1354	4
1354	2
1354	3
1334	2
1329	1
7311	3
7311	2
6672	1
6672	2
1328	1
1328	3
1328	4
7311	1
1328	2
1509	1
6834	1
6835	1
6833	8
2998	1
1483	6

Table A-1C Middle Murderkill River and McColley Pond Subwatersheds	
Prioritized Sites for Cropland Nutrient Management Planning and Cover Crop Enrollment	
FSA Tract No.	**FSA CLU No.**
6431	2
1897	4
1897	2
1897	1
2011	2
1983	1
1835	1
93	1
1991	1
7398	1
7104	2
2890	3
2890	6
2890	5
6708	2
6708	1
92	1
92	2
92	3
79	1
79	3
2022	1
2141	1
1999	1
1969	2
1875	1
134	1
2004	1
64	2
3079	1
2160	2
N/A	* dd979bf8-5f25-48d7-91a6-e19422e7ec47

Table A-1D Browns Branch Subwatershed	
Prioritized Sites for Cropland Nutrient Management Planning and Cover Crop Enrollment	
FSA Tract No.	**FSA CLU No.**
80	1
92	6
92	5
6445	2
6705	1
2025	2
2029	2
1969	1
6703	1
6578	1
2081	1
1880	3
1880	1
1880	2
6894	1
1894	1
1894	2
1894	3
2068	6
1902	1
7510	3
7509	1
7211	1
7735	4
7735	2
2134	1
2134	2
7612	9
1604	1
1266	2
7582	3
2114	1
1900	1
1676	1
1924	1
7	1
7	2
1772	3
1954	1

1785	1

Table A-1E
Swamp Creek, Beaverdam Branch, and Upper Murderkill River Subwatersheds

Prioritized Sites for Cropland Nutrient Management Planning and Cover Crop Enrollment

FSA Tract No.	FSA CLU No.
1520	6
1520	5
7145	2A
7145	4
1935	1
135	2
135	1A
135	1B
1399	7
1399	5
1399	4
1399	6
6944	9
6944	3A
6944	3B
1514	1
7605	2
2948	1
521	2
2109	4
2109	3
2109	2
1940	1
517	2
2084	2
7605	3
1266	1
2456	9
2456	4
2337	2
1411	2
1411	1
7250	1
2085	1
6472	2
6472	3
1390	6
1390	3

1390	7
1540	1

Table A-1E (Continued) Swamp Creek, Beaverdam Branch, and Upper Murderkill River Subwatersheds	
Prioritized Sites for Cropland Nutrient Management Planning and Cover Crop Enrollment	
FSA Tract No.	**FSA CLU No.**
1502	2
1502	1
1540	2
6422	1
1901	1
1901	2
6844	7
6844	6
6844	5
6844	3
6416	3
7307	2
7307	1
7308	4
1348	1
1616	1
1755	1
197	1
2137	1
2137	2
1956	2
1956	1
6939	2
176	2
176	1
176	3
2078	1
7612	7
7612	5
7612	6
7612	1
7612	3

7612	2
6421	1

Table A-1E (Continued)
Swamp Creek, Beaverdam Branch, and Upper Murderkill River Subwatersheds

Prioritized Sites for Cropland Nutrient Management Planning and Cover Crop Enrollment

FSA Tract No.	FSA CLU No.
1949	1
7011	9
2817	4
2191	2
2191	1
2825	3
2459	2
2458	2
2458	3
2458	4
2458	4
2458	5
2458	3
2300	1
2181	1
7717	2
7717	3
3026	2
3026	3
3026	4
6817	2
6817	1
1576	6
1576	7
1576	8
1576	9
1576	5
1576	4
1576	3
1576	2
1576	1
6472	1
N/A	*f95c65c5-8f82-49d1-9278-

	4fb5b9f61063
N/A	*f729fdd5-1e3e-40c9-a4d5-e65cbbfc4960

Table A-2A Double Run and Spring Creek Subwatersheds	
Prioritized Sites for Stream Buffering Cost-Share Enrollment	
FSA Tract No.	**FSA CLU No.**
7111	4
7111	5
110	1
110	2
110	3
110	5
110	4
2892	1
1376	1
7111	2
7111	3

MSD Associates, 103 46th Street, Virginia Beach, VA 23451, (757) 469-0546

Table A-2B Lower Murderkill River Subwatershed	
Prioritized Sites for Stream Buffering Cost-Share Enrollment	
FSA Tract No.	**FSA CLU No.**
3001	47
3001	51
3075	4
3075	1
3075	7
3075	5
6833	6
6833	5
6836	HQ
6836	HQ
2913	10
2913	8
6408	1
7353	2
7353	4
1354	4
1354	1
1354	2
1354	3
1350	1
2956	4
14786	5
6671	2
7353	1
3075	3
3075	8
3075	2
2956	5
2913	7
2913	6
1483	6
N/A	* 9fe9d173-5b0b-4788-942f-7d83ed2a5ee5
N/A	* a8e51e18-6bc5-4ea2-a0a4-69ded7392e92

Table A-2C Middle Murderkill River and McColley Pond Subwatersheds	
Prioritized Sites for Stream Buffering Cost-Share Enrollment	
FSA Tract No.	**FSA CLU No.**
2940	2
1995	HQ
2014	2
2014	3
3058	1
1875	4
1875	3
1875	2
1875	5
1875	1

Table A-2D Browns Branch Subwatershed	
Prioritized Sites for Stream Buffering Cost-Share Enrollment	
FSA Tract No.	**FSA CLU No.**
2288	3
3088	1
3024	1
3024	3
3024	5
1882	2
7553	1
7553	2
7553	3
7149	2
7708	6
170	3
7584	2
7584	1
7582	3
7585	4
6856	HQ
1887	1
2153	2
1676	1
1676	3
1676	2
1860	1
6475	1
6475	2
2814	2
6758	4
1947	2
518	2
518	3
518	1C
518	1
518	1A
7446	1
6476	1
6476	2
1772	3
1772	4
1772	5

1772	6

Table A-2D (Continued) Browns Branch Subwatershed	
Prioritized Sites for Stream Buffering Cost-Share Enrollment	
FSA Tract No.	**FSA CLU No.**
2606	3
2877	10
0	E

Table A-2E
Swamp Creek, Beaverdam Branch, and Upper Murderkill River Subwatersheds

Prioritized Sites for Stream Buffering Cost-Share Enrollment

FSA Tract No.	FSA CLU No.
58	4
58	2
58	3
58	5
129	2
129	6
129	5
129	7
178	1
1411	2
1411	1
1648	1A
1648	1B
1648	2
1648	3
1648	4
1656	4
2181	1
2200	1
2200	3
2200	2
2210	1
2210	2
2210	3
2261	3
2270	5
2378	1
2378	3
2378	2
2380	2
2380	1
2456	2
2456	3
2456	1
2456	4
2456	5
2457	5
2457	6
2457	7

MSD Associates, 103 46th Street, Virginia Beach, VA 23451, (757) 469-0546

Table A-2E (Continued) Swamp Creek, Beaverdam Branch, and Upper Murderkill River Subwatersheds	
Prioritized Sites for Stream Buffering Cost-Share Enrollment	
FSA Tract No.	**FSA CLU No.**
2457	1
2458	2
2817	4
2843	5
2871	1
2871	2
2946	1
6563	1
6563	2
6944	2
6944	3B
6945	6
6945	10
7010	1
7010	4
7010	5
7011	2
7011	3
7432	7
7707	3
7707	4
7707	2
7707	6
7707	5

Table A-3A Double Run and Spring Creek Subwatersheds	
Prioritized Sites for Animal Waste Management BMPs	
FSA Tract No.	**FSA CLU No.**
2908	1
2891	1
N/A	797ab28a-ce96-4f14-a78c-b7220ce853e9

Table A-3B Double Run and Spring Creek Subwatersheds	
Prioritized Sites for Animal Waste Management BMPs	
FSA Tract No.	**FSA CLU No.**
1359	HQ
7658	HQ
6833	HQ
N/A	d3a813b3-5324-40bf-b15e-1c2fda13cc83

Table A-3C Middle Murderkill River and McColley Pond Subwatersheds	
Prioritized Sites for Animal Waste Management BMPs	
FSA Tract No.	**FSA CLU No.**
1995	HQ
1994	1
1455	1
2915	3
1995	1
2014	1
2014	HQ
2014	2
2014	3
1869	1
1869	3
1869	2
120	1
N/A	* eb93adb3-27b7-472d-8ee0-cf70076a27db
1981	1
3058	2
1875	1
N/A	* fd3bb7f9-ac6f-4679-8deb-ad1d326c7612
7238	2
N/A	* 8c4f96c5-b265-4aeb-aa77-74da8d25b5d2

Table A-3D Browns Branch Subwatershed	
Prioritized Sites for Animal Waste Management BMPs	
FSA Tract No.	**FSA CLU No.**
N/A	* b7db2c00-81f2-447c-84be-13104430804e
N/A	* 314f9f39-dc8f-4ab0-a094-ab670167e3ed
1874	2
1874	1
2029	3
6703	2
2068	3
2068	5
6646	1
7612	9
1266	1
6856	2
6856	HQ
2153	2
1957	2
N/A	*6109f516-db53-4231-bddf-88f2662ce60c
4814	1
4814	2
N/A	*28067197-85a4-4314-9941-f139bdc62b7d
518	4
N/A	*bc6c16c7-e709-44ea-8d3b-ec34f7caf25a
4968	1
7446	1
0	A
0	E
2107	HQ
7735	HQ
7554	HQ

Table A-3E Swamp Creek, Beaverdam Branch, and Upper Murderkill River Subwatersheds	
Prioritized Sites for Animal Waste Management BMPs	
FSA Tract No.	**FSA CLU No.**
2019	1
2974	4
2974	5
N/A	*4e3cd828-478d-445c-a3de-60abad7a34e8
2176	1
2205	1
58	1
58	2
1266	2
2456	6
1390	1
1390	2
1390	4
6844	2
6844	4
14132	2
1413	1
1413	3
6563	2
2843	5
2843	6
N/A	*61024ca5-d61d-4772-b113-dbd1b4eb52f8
2479	1
127	5
127	7
2194	7
0	
2261	2
2261	3
2261	HQ
N/A	*5102df13-9338-424b-a978-f1bd87a4cc28
N/A	*126208a8-da86-4a50-bc2f-2db9c0b586d0
N/A	*3a063f4a-c055-408a-af53-61165e3dd2c0
0	B
0	C

Table A-3E (Continued) Swamp Creek, Beaverdam Branch, and Upper Murderkill River Subwatersheds	
Prioritized Sites for Animal Waste Management BMPs	
FSA Tract No.	**FSA CLU No.**
0	D
0	F

APPENDIX B
Drive-Bye Field Survey Information

Farm fields not included in the table were considered cropland or idle fields.

Farm fields denoted with an asterisk (*) are not enrolled in an FSA program and were not provided FSA tract and CLU numbers. Instead, the CLU identification number was computer generated.

Farm fields with an FSA Tract No. = 0 were areas not possessing any CLU polygons and were, therefore, created by MSD Associates to denote a significant land-use activity observed during the drive-bye field survey (i.e., pasture, animal operation, etc.). A total of 8 polygons (with CLUs of A through H) were created by MSD Associates and were included as a component of the Farm Field datalayer that was provided to the District in September 2005. Farm field with a CLU designation of 'G' was not included in Table B-1 because it was noted to be a cropland that was unrecognized by the FSA.

Table B-1
Drive-Bye Field Survey Information

Tract No.	CLU No.	Animal Sitings	Estimated Stocking Rate	Other Field Survey Information
1465	HQ	Poultry Houses		
7215	HQ	Poultry Houses		
6836	HQ	Poultry Houses		
6836	HQ	Poultry Houses		
1359	HQ	Poultry Houses		
7658	HQ	Poultry Houses		
1994	1	Cattle	10	Pasture
6431	HQ	Poultry Houses		
2908	1	No Current Animals		Cattle Operation/Pasture
1457	2			Grassed Lawn
2891	1	Horses	1	Horse Lot
1455	1	Horses	2	Pasture
2915	3			Pasture
7077	1			Residential
7078	1			Residential
1995	HQ	Poultry Houses		
1995	1	Horses	1	Horse Lot
7083	2			Residential
2014	1	Cattle	5	Pasture
2014	6			Cattle Operation/Pasture
2014	HQ			Cattle Operation
2014	2			Pasture
2014	3			Pasture

Table B-1
Drive-Bye Field Survey Information

Tract No.	CLU No.	Animal Sitings	Estimated Stocking Rate	Other Field Survey Information
1869	1			Pasture
1869	3			Pasture
1869	2	Cattle	15-20	Pasture
106	7			Grassed Lawn
2862	1			Residential
2862	2			Residential
2862	6			Orchard
7245	2			Residential
2760	1			Residential
1511	1			Residential
2864	1			Tree Farm
1563	2			Residential
1563	1			Residential
1487	1			Residential
2896	1	Goats	6	Pasture
1410	1			Residential
119	1			Residential
1534	1			Grassed Lawn
1562	2			Residential
120	1			Pasture
2019	1			Horse Farm/Pasture
2107	HQ	Poultry Houses		
1874	2	Horses	3	Pasture
1874	1	Horses	3	Pasture
7122	2			Mining Operation
7122	1			Forested
7123	1			Mining Operation
2002	1			Mining Operation
85	1			Mining Operation
1981	1			Pasture
3058	2	Horses	4	Residential/Horse Lot
2029	1			Residential
2029	3	Horses	3	Pasture
2029	4			Residential
1969	4			Residential
1969	6			Residential
1969	5			Residential
6703	2	Horses	1	Horse Lot
6704	1			Public Open Space
1950	1			Grassed Lawn
1950	2			Residential
1875	4			Residential
1875	3			Residential
1875	2			Residential

Table B-1
Drive-Bye Field Survey Information

Tract No.	CLU No.	Animal Sitings	Estimated Stocking Rate	Other Field Survey Information
1875	5			Residential
1875	1	Horses	3	Horse Lot
1852	HQ	Poultry Houses		
2003	1			Residential
2004	2			Residential
64	1			Residential
2022				Unknown Animal Farm
2927	2	Horses	1	Pasture
2927	1			Pasture
7552	1			Residential
1256	3			Grassed Lawn/Residential
1256	1			Grassed Lawn/Residential
1256	2			Grassed Lawn/Residential
7381	1			Residential
1430	HQ	Poultry Houses		
1309	1			Residential
1559	3			Pasture
1325	2			Residential
181	1			Residential
7706	HQ	Poultry Houses		
2701	HQ	No Animals Sited		Cattle Operation
180	2			Residential
180	1			Residential
2929	2	Cattle	30	Pasture
1480	2			Grassed Lawn
1514	2			Public School/Grassed Lawn
7606	HQ	Poultry Houses		
2974	4	Horses	2	Pasture
2974	5	Horses	2	Pasture
83	2			Grassed Lawn
83	1			Grassed Lawn
2109	HQ	Poultry Houses		
1938	1			Residential
2068	3			Cattle Operation/Pasture
2068	5	Cattle	10-20	Pasture
7484	1			Residential
1851	1			Residential
6744	1			Residential
6814	1			Residential
6893	3			Residential
7287	2			Residential
1921	1			Residential
2063	1			Residential
2063	2			Residential

Table B-1
Drive-Bye Field Survey Information

Tract No.	CLU No.	Animal Sitings	Estimated Stocking Rate	Other Field Survey Information
2063	10			Residential
7735	HQ	Poultry Houses		
6646	1			Pasture
6646	3			Grassed Lawn
6646	2			Grassed Lawn
7554	HQ	Poultry Houses		
2055	2			Residential
2483	4			Farm Buildings
2483	5			Farm Buildings
1366	1			Inactive Poultry House
2765	1			Grassed Lawn
2183	1			Pasture
2183	HQ	Poultry Houses		
1402	2			Grassed Lawn
1402	1			Grassed Lawn
1402	3	Goats/Ponys	10	Pasture
1542	1	Horses	2	Residential/Horse Lot
2365	1			Grassed Lawn
2365	2			Grassed Lawn
1488	1			Grassed Lawn
2332	1			Grassed Lawn
2426	1			Residential
2419	1			Residential
1317	1			Grassed Lawn
1552	1			Grassed Lawn
1379	1			Grassed Lawn
1485	1			Grassed Lawn
2490	1			Pasture
1773	1			Residential/Grassed Lawn
2176	1			Pasture
2205	1	Horses		Pasture
7130	6			Orchard
1533	1			Grassed Lawn
7130	5	Cattle	2	Pasture
1541	1			Residential/Grassed Lawn
1541	2	Horses	1	Horse Lot
1408	1			Electric Utility/Grassed Lawn
2336	1			Residential
1396	2			Residential
1396	1			Residential
2224	1			Grassed Lawn
58	1	Cattle	5	Pasture
58	2			Cattle Operation
1266	2	Horses	3	Horse Lot

Table B-1
Drive-Bye Field Survey Information

Tract No.	CLU No.	Animal Sitings	Estimated Stocking Rate	Other Field Survey Information
2469	2			Residential
7432	4			Grassed Lawn
7432	6			Grassed Lawn
2456	HQ	Poultry Houses		
2456	6	Horses	1	Pasture
7251	1			Commercial
7251	2			Commercial
1390	5			Grassed Lawn
1390	1			Pasture
1390	2			Pasture
1390	4			Pasture
6844	2			Horse Farm/Pasture
6844	4	Horses		Pasture
14132	2			Horse Farm/Pasture
1413	1	Horses		Pasture
1413	3	Horses		Pasture
1989	1			Public Open Space
7612	3	Horses	1	Residential/Horse Lot
7612	9	Goats/Pony	6	Residential/Pasture
1907	1			Residential
6471	2			Grassed Lawn
1266	1			Pasture
6856	2			Pasture
6856	HQ	Horses	20	Horse Farm/Pasture
1887	2			Grassed Lawn
2153	2	Horses	1	Pasture
1957	2			Pasture
1750	1			Residential
520	2			Residential
2065	1			Residential
2066	1			Residential
2154	1			Public School
2167	1			Public School
2155	1			Grassed Lawn
520	1			Grassed Lawn
6869	2			State Fair Grounds
2083	1			Grassed Lawn
2083	2			Grassed Lawn
2043	7			Commercial
2043	6			Grassed Lawn
2043	8			Grassed Lawn
1726	1			State Fair Grounds
1753	1			State Fair Grounds
4814	1			Pasture

Table B-1
Drive-Bye Field Survey Information

Tract No.	CLU No.	Animal Sitings	Estimated Stocking Rate	Other Field Survey Information
4814	2			Pasture
2150	1			State Fair Grounds
2150	2			State Fair Grounds
2150	5			State Fair Grounds
2150	4			State Fair Grounds
2150	3			State Fair Grounds
2150	6			State Fair Grounds
2150	8			State Fair Grounds
2150	7			State Fair Grounds
2150	9			State Fair Grounds
518	4			Pasture
2150	10			State Fair Grounds
4968	1	Horses	1	Horse Lot
7050	2	Horses	7-10	Pasture
6563	2			Residential/Pasture
2843	5			Pasture
2843	6			Pasture
2122	5			Residential
7046	2			Pasture
2391	1	Horses	5-10	Horse Farm/Pasture
2498	5			Horse Farm/Pasture
2498	1			Horse Farm/Pasture
2498	4			Horse Farm/Pasture
2498	6			Horse Farm/Pasture
6815	7			Residential
1801	3	Poultry Houses		
1801	HQ	Poultry Houses		
2223	5			Grassed Lawn
2479	1	Horses	1	Horse Lot
2370	1			Grassed Lawn
2370	2			Grassed Lawn
127	5	Goats/Horse	35	Pasture
127	7	Goats/Horse	35	Pasture
2194	7	Horses		Pasture
2825	HQ	Poultry Houses		
2458	6	Residential		
2261	2	Cattle	20	Pasture
2261	3	Cattle	20	Pasture
2261	HQ	Cattle/Poultry Houses	20	Cattle Operation
7446	1	Goats	10-15	Pasture
1656	HQ	Poultry Houses		
7312	HQ	Poultry Houses		
7238	2	Horses	2	Horse Lot
6832	HQ	Poultry Houses		

Table B-1
Drive-Bye Field Survey Information

Tract No.	CLU No.	Animal Sitings	Estimated Stocking Rate	Other Field Survey Information
6833	HQ	Poultry Houses		
2157	HQ	Poultry Houses		
N/A	da0d1c51-5262-44fa-87bd-4bcb312ca059	Poultry Houses		
N/A	f76a6389-fa19-4b11-88e8-80204e2fd0c3			Pasture
N/A	a2c1f336-065d-4cb8-b874-1f0d591eb703	Horses	2	Horse Lot
N/A	b7db2c00-81f2-447c-84be-13104430804e			Horse Lot
N/A	314f9f39-dc8f-4ab0-a094-ab670167e3ed			Horse Lot
N/A	eb93adb3-27b7-472d-8ee0-cf70076a27db	Horses	1	Horse Lot
N/A	bc4afdbc-0b57-4da2-b087-639ced9284b7	Horses	3	Pasture
N/A	3d4d9bdf-dd6b-440f-8985-cf0343dde5d2	Cattle	3	Pasture
N/A	4579b1af-7b45-4cba-8716-fbfa09b1d882			Peach Orchard
N/A	4e3cd828-478d-445c-a3de-60abad7a34e8	Horses	2	Horse Lot
N/A	797ab28a-ce96-4f14-a78c-b7220ce853e9		1	Pasture
N/A	26deb87a-9063-489d-ba4c-99acbb198ab1	Horses	1	Horse Lot
N/A	4f29ed44-70da-41c5-98d0-5d64112cd9ef	Horses	1	Horse Lot
N/A	20ee6407-5aa2-4c5a-b736-58d1c4e282bf	Horses	1	Horse Lot
N/A	a382394f-05be-46cf-8b8b-6948eaee201e	Horses	1	Horse Lot
N/A	8698c7c0-f751-491d-8eb0-b868e472eb90	No Animals Sited		CAFO
N/A	6109f516-db53-4231-bddf-88f2662ce60c	Horses	1	Horse Lot
N/A	28067197-85a4-4314-9941-f139bdc62b7d	Horses	1	Horse Lot
N/A	bc6c16c7-e709-44ea-8d3b-ec34f7caf25a	Horses	1	Horse Lot
N/A	68f7b3a6-66b7-4a7a-	Goats/Mules	10	Pasture

Table B-1
Drive-Bye Field Survey Information

Tract No.	CLU No.	Animal Sitings	Estimated Stocking Rate	Other Field Survey Information
	8245-6b6dd06ce1a3			
N/A	73f71788-5e61-475f-87cf-237026653c04			Horse Farm
N/A	9c174830-0f46-46b6-9d49-4ee571e529c2			Horse Farm
N/A	61024ca5-d61d-4772-b113-dbd1b4eb52f8			Pasture
N/A	24fa02f8-1e7d-48aa-b5aa-dd9093b6c00a	Horses	2	Horse Lot
N/A	126208a8-da86-4a50-bc2f-2db9c0b586d0	Horses	4	Horse Lot
N/A	3a063f4a-c055-408a-af53-61165e3dd2c0	Horses	2	Pasture
N/A	31af2750-c8be-4431-ac3e-d1b23368eaca	Poultry Houses		
N/A	fd3bb7f9-ac6f-4679-8deb-ad1d326c7612	Horses	3	Horse Lot
N/A	8c4f96c5-b265-4aeb-aa77-74da8d25b5d2	Cattle/Horses	5-10/5	Pasture
N/A	d3a813b3-5324-40bf-b15e-1c2fda13cc83	Horses	1	Horse Lot
0	A	Horses	1	Horse Lot
0	B	Horses	1	Horse Lot
0	C			Pasture
0	D			Pasture
0	E			Pasture
0	F	Horses	12	Pasture
0	H	Horses	3	Pasture