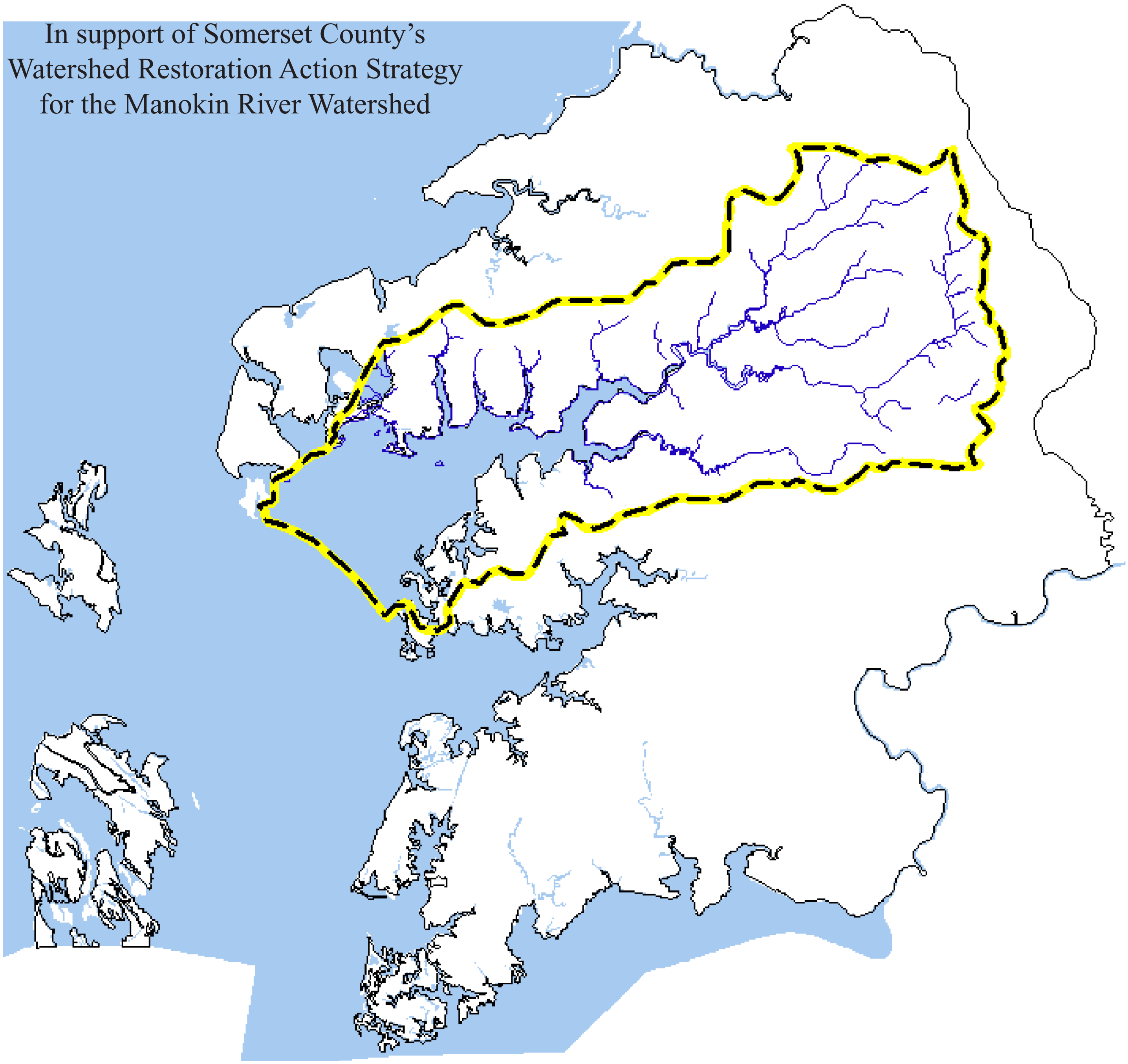
Manokin River
Watershed Characterization

May 2001

In support of Somerset County's
Watershed Restoration Action Strategy
for the Manokin River Watershed



Product of the
Maryland Department of Natural Resources
In partnership with Somerset County

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To inspire people to enjoy and live in harmony with their environment, and
to protect what makes Maryland unique – our treasured Chesapeake Bay,
our diverse landscapes, and our living and natural resources.

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TABLE OF CONTENTS

LIST OF MAPS
Manokin River Watershed Characterization

EXECUTIVE SUMMARY
For the Manokin River Watershed Characterization

The Manokin River is in the coastal plain on Maryland's Eastern Shore. The Manokin River watershed is entirely with Somerset County. The County is receiving Federal grant funding and State technical assistance to prepare a Watershed Restoration Action Strategy (WRAS) for the Manokin River watershed for several reasons:

– the 1998 *Maryland Clean Water Action Plan* identified the Manokin River watershed as a Priority Watershed "in need of restoration."
– Somerset County applied for grant funding and volunteered to develop a strategy in the watershed to improve water quality using protection and restoration projects.

The purpose of the Watershed Characterization is to assist Somerset County in collecting information and identifying issues that may be used as the County generates its Watershed Restoration Action Strategy.

Water Quality

The Manokin River watershed includes over 14,900 acres of open tidal water extending out to the Tangier Sound area of the Chesapeake Bay. It also includes at least 90 miles of streams within six subwatersheds. Tidal influence extends well up into many streams and many streams have been modified to improve drainage.

The Manokin River does not support its designated use (water contact recreation) due to problems associated with nutrients, fecal coliform, and suspended sediment:

- Water quality problems in the Manokin River watershed are linked to seasonal algae blooms and sporadic low dissolved oxygen below the State water quality standard.
- Nutrients (nitrogen and phosphorus) and Biological Oxygen Demand (BOD) are identified in the Total Maximum Daily Load (TMDL) as responsible for driving the algae and oxygen problems. Based on available water quality monitoring, several Manokin tributaries including Kings Creek are significant sources of high nutrient and BOD loads. Nonpoint sources appear to be greater contributors of nutrients and BOD than known point sources. Based on limited land use analyses, agriculture and/or animal feeding operations, are likely to be the greatest sources of nutrients and BOD reaching local waterways.
- An outbreak of toxic *Pfiesteria* occurred in Kings Creek, a tributary of the Manokin, in 1997. This problem appears to be consistent with findings of high nutrient loads. Toxic forms of the organism has not been identified in this area in the period 1998 through 2000.

Land Use

The Manokin River watershed encompasses nearly 59,400 acres of land in the Mid Atlantic coastal plain. There is very little topographic relief with few uplands having elevations of 30 feet or more. About one half of the watershed's land area is tidal or nontidal wetland. Most of the remaining land is hydric soil with few areas of relatively well drained soils. The Town of Princess Anne is located on the largest area of well drained soil. Drainage improvement via ditching in the watershed has not been quantified but it appears to be pervasive.

Land uses in the watershed can be categorized as nearly one half forested, over one quarter agricultural, one fifth tidal / emergent wetlands and most of the remainder being urban (nearly 6%). Over the next 20 years, urban lands are anticipated to expand to about 7% in the watershed at the expense of agriculture and forest lands.

Living Resources and Habitat

Little information is available on fish and most other aquatic life in the Manokin River watershed. An assessment of two stream sites indicate that poor conditions are impacting fish populations there.

Oyster harvest records indicate that oyster populations are small compared to historic levels. Numerous stresses are contributing to the depressed oyster population including loss of habitat, disease, sedimentation, water quality problems and other factors.

Submerged aquatic vegetation (SAV) in the Manokin River watershed is primarily Widgeon grass. The extent of SAV in the watershed varied from 20 and 300 acres between 1978 and 1999. This acreage is well below the Chesapeake Bay restoration goal of 683 acres for the Manokin.

Rare species are found in several areas of the watershed. Two of these areas are designated Wetlands of Special State Concern: Dublin Swamp and the Princess Anne Wetlands.

Restoration Targeting Tools

The stream corridor assessment scheduled during 2001 will use several teams to walk the streams. Products will include a catalog of inadequate buffers, stream bank erosion, and other problems that can be visually identified.

Computerized mapping was used to demonstrate restoration targeting techniques and to help identify areas for restoration of stream buffers and wetlands. For example, numerous areas of inadequate stream buffers associated with hydric soils and crop were identified with GIS. More than twenty potential opportunities for wetland restoration on DNR land that was formerly owned by Chesapeake Forest Products are identified for potential site investigations.

The potential for oyster restoration may be explored if Somerset County elects to incorporate this interest into the Manokin River WRAS.

The WRAS can employ information generated by these tools and other sources to establish priorities for types of restoration projects that meet local interests. It will also provide priorities for the detailed site investigations necessary to identify viable restoration project candidates based on information collected by the stream corridor assessment and identified using GIS.

INTRODUCTION

Watershed Selection

Maryland's Clean Water Action Plan, completed in 1998, identified water bodies that failed to meet water quality requirements. As part of the State's response, the Maryland Department of Natural Resources (DNR) is offering funding and technical assistance to Counties willing to work cooperatively to devise and implement a Watershed Restoration Action Strategy (WRAS) for the impaired water bodies.

Somerset County is one of five Counties participating in the first round of the WRAS program. The Manokin River Watershed is the area selected for restoration. This watershed has several key physical characteristics: coastal plain location, low elevation, very limited topographic variation, water table is commonly near the surface and generally rural land uses.

Location

The entire Manokin River watershed is in Somerset County, Maryland. This area is the focus of the Watershed Restoration Action Strategy and this Watershed Characterization. Map 1 WRAS Project Area shows the geographic location of the WRAS watershed in Maryland. The acreage summary table points out that one fifth of the watershed is open tidal water. As shown in Map 2 Streams and Sub-Watersheds, there are six subwatersheds identified by DNR within the Manokin River watershed.

Manokin River Watershed Acreage Summary	
Land	59,384
Water	14,927
Watershed Total	74,311

Purpose of the Characterization

One of the earliest steps toward devising a Watershed Restoration Action Strategy is to characterize the watershed using immediately available information. This Watershed Characterization is intended to meet several objectives for this purpose:

– briefly summarize the most important or relevant information and issues
– provide preliminary findings based on this information
– identify sources for more information or analysis
– suggest opportunities for additional characterization and restoration work.

Additional Characterization Recommended

The Watershed Characterization is intended to be a starting point. It is part of a framework for a more thorough assessment involving an array of addition inputs:

– self-investigation by the local entity
– targeted technical assistance by partner agencies or contractors
– input from local stakeholders
– Stream Corridor Assessment, i.e. physically walking the streams and cataloguing issues, which is part of the technical assistance offered by DNR
– Synoptic water quality survey, i.e. a program of water sample analysis, can be used to focus on local issues like nutrient hot spots or point source discharges or other selected issues. This is also part of the technical assistance offered by DNR.

Identifying Gaps In Information

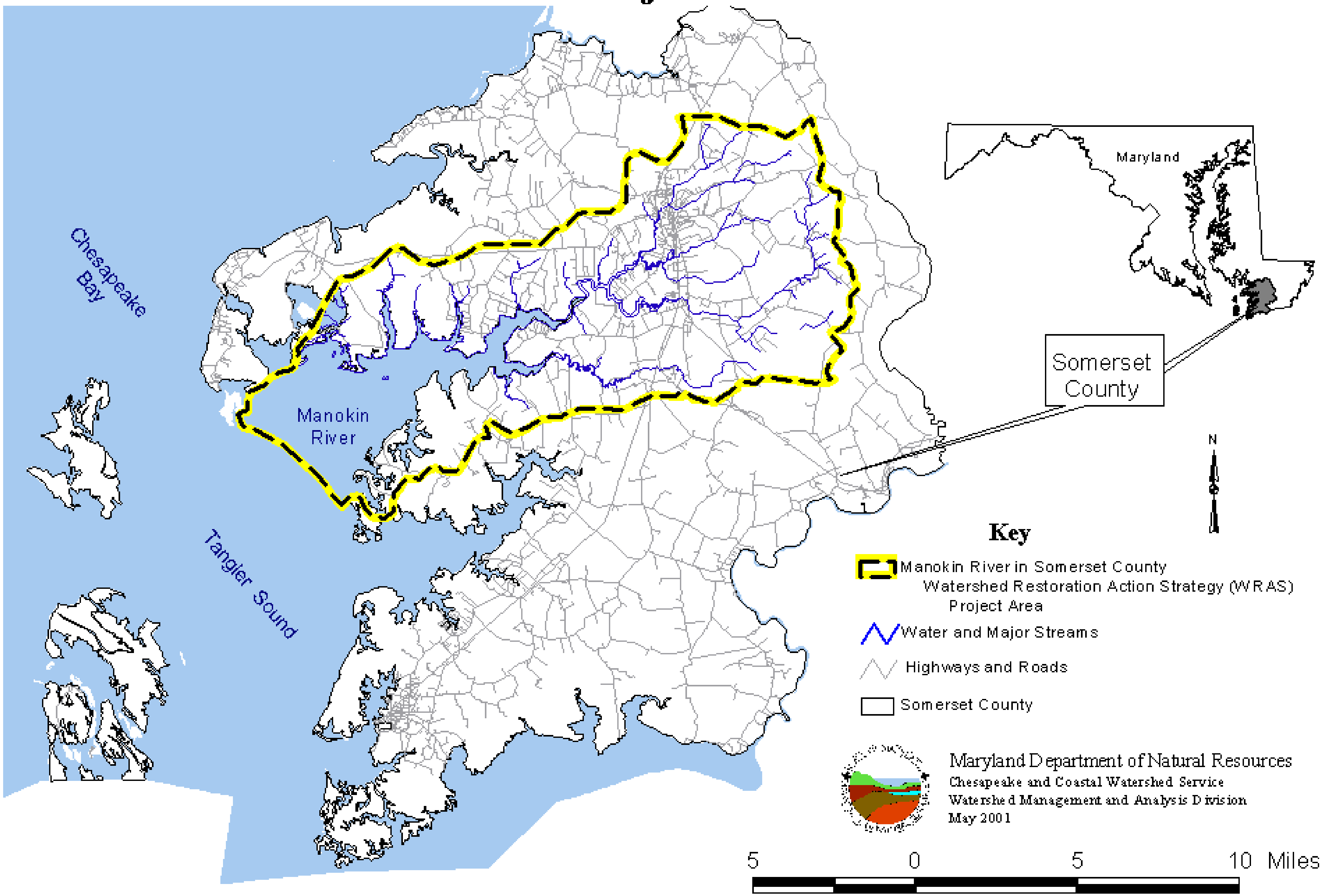
It is important to identify gaps in available watershed knowledge and gauge the importance of these gaps. One method is to review available information in the context of four physical / biological assessment categories that have been successfully applied in other watershed restoration efforts. These are the main categories that impact aquatic biota:

– Habitat: physical structure for stream stability and biotic community (including riparian zone)
– Water Quantity: high water - storm flow & flooding; low water - baseflow problems from dams, water withdrawals, reduced infiltration
– Water Quality: water chemistry; toxics, nutrients, sediment, nuisance odors/scums, etc.
– Cumulative effects associated with habitat, water quantity and water quality.

Adaptive Management

In addition, the Watershed Characterization and the Watershed Restoration Action Strategy should be maintained as living documents within an active evolving restoration process. These documents will have to be updated periodically as new, more relevant information becomes available and as the watershed response is monitored and reassessed. This type of approach to watershed restoration and protection is often referred to as “adaptive management.”

Map 1 Manokin River Watershed
Watershed Restoration Action Strategy (WRAS)
Project Area



Map 2 Streams and Subwatersheds
Manokin River Watershed
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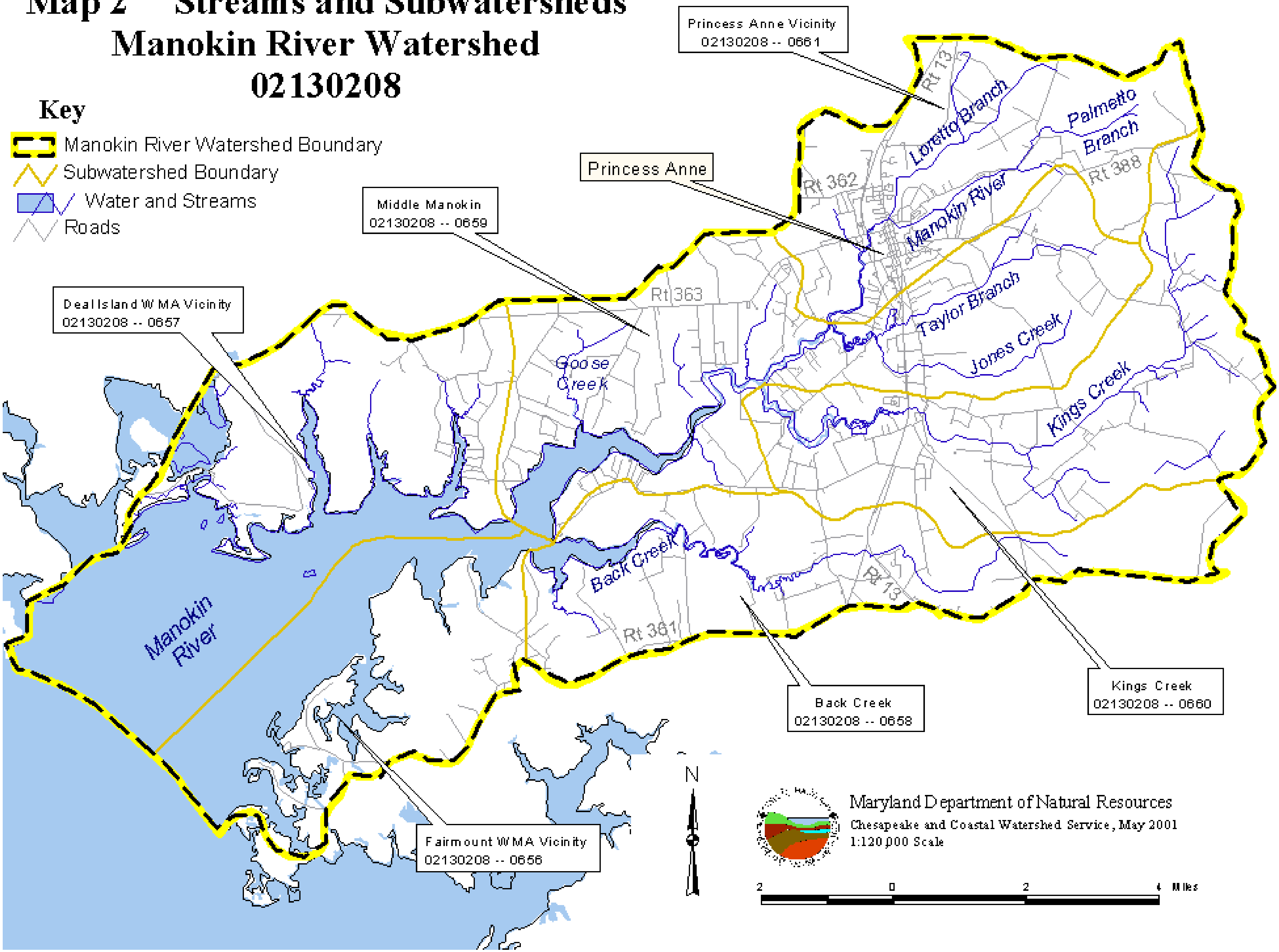


WATER QUALITY

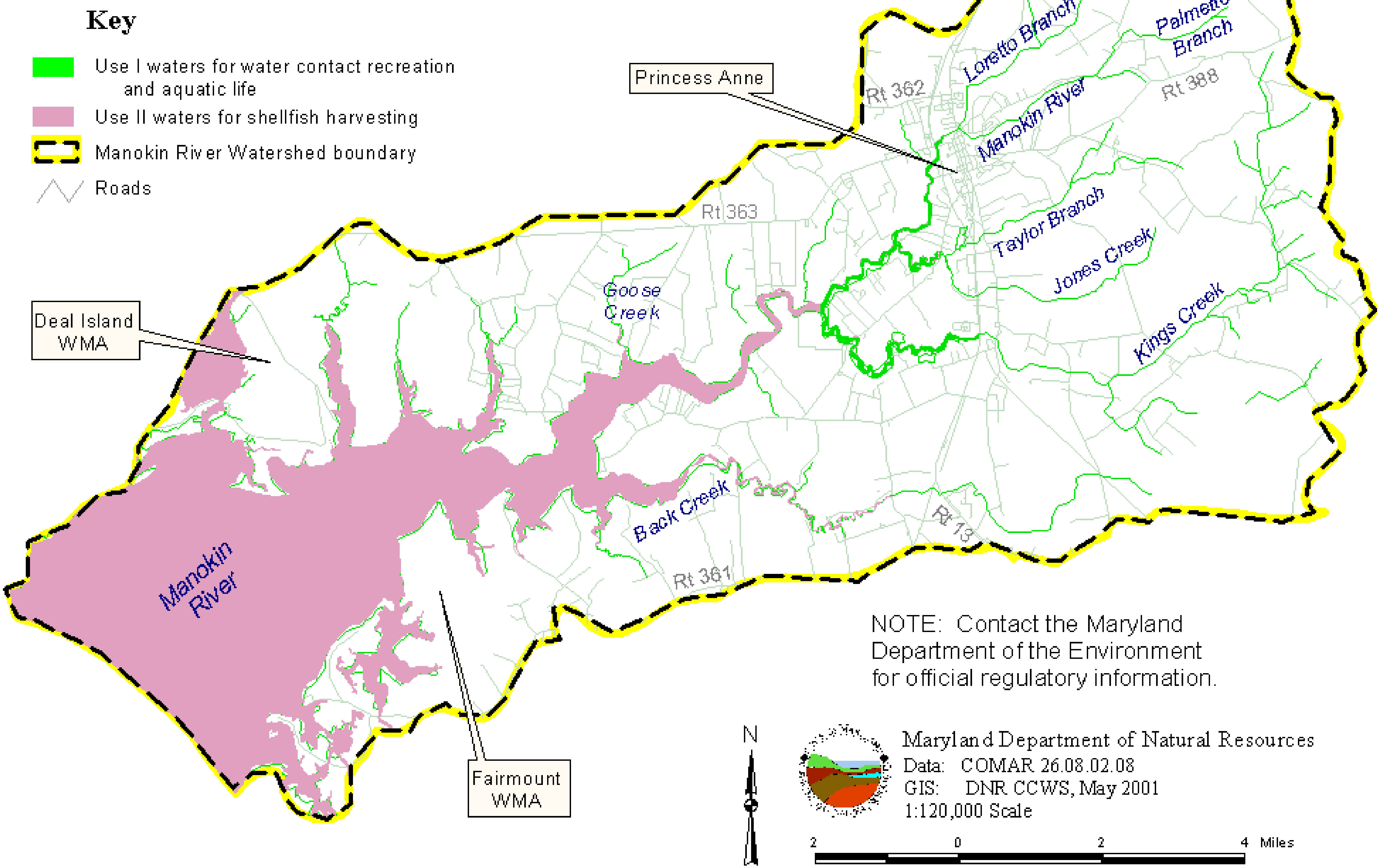
In meetings that addressed characterization of the Manokin River, Somerset County representatives expressed concern that the current understanding of the river and its water quality is insufficient. General concerns included the extensive tidal nature of the Manokin (no flow conditions) and natural conditions (black water chemistry, tannins). The following discussion is presented as an overview of the current level of knowledge for the river system. Intensive effort to improve understanding of the river system in reaction to the *Pfiesteria* outbreak has added significantly to our understanding of local water quality. As additional knowledge becomes available, it should be considered as the Watershed Restoration Action Strategy (WRAS) is developed.

Designated Uses

All waters of the State are assigned a "designated use" in regulation, COMAR 26.08.02.08, which is associated with a set of water quality criteria necessary to support that use. Map 3 Designated Uses shows major water bodies in the Manokin River watershed categorized by designated use. A simplified summary of the Designated Uses in the Manokin River watershed is listed below. (The Department of the Environment should be contacted for official regulatory information.) [9]

- Use I: for water contact recreation and aquatic life: All waters not designated as Use II
- Use II: for shellfish harvesting: Tidal waters downstream of the confluence of the Manokin River and Kings Creek.

Map 3 Designated Uses
Manokin River Watershed



NOTE: Contact the Maryland Department of the Environment for official regulatory information.

Maryland Department of Natural Resources
Data: COMAR 26.08.02.08
GIS: DNR CCWS, May 2001
1:120,000 Scale

Not Supporting Designated Use – 303(d) Listings

Significant portions of the Manokin either do not fully or partially support their designated use.[2] As required under Section 303(d) of the Federal Clean Water Act, Maryland tracks waterways that do not support their designated use in a prioritized list of "Water Quality Limited Basin Segments" sometimes simply called the 303(d) list. The Manokin River is referenced in the list in two places:

- Nutrients. In the 1996 303(d) list, the Pocomoke River (02-13-02, which includes the Manokin River) is listed as Priority #2. Nutrients from point, nonpoint and natural sources are identified as the problem.
- Nutrients, Fecal Coliform, Suspended Sediment. In the 1996 303(d) list, the Manokin River is also listed independently of the Pocomoke for nutrients, fecal coliform and suspended sediment from nonpoint and natural sources.

The 303(d) priority referenced above is established by the Maryland Department of the Environment. Information considered in setting these priorities include, but is not limited to, severity of the problem and the extent of understanding of problem causes and remedies. These priorities are used to help set State work schedules various programs including total maximum daily loads (TMDLs).

The consequences of nutrient high concentrations are generally described in the text box What Are Effects of Nutrient Over-Enrichment? There are no standards for nutrient concentration that define the threshold for high nutrient concentrations. However, qualitatively any nutrient concentration that promotes algae blooms, undesirable changes in aquatic populations, low dissolved oxygen or other problems can be considered too high.

Other related factors contributing to the degraded use capability in the Manokin are associated with seasonal low dissolved oxygen (below the 5 mg/l water quality criteria) and seasonal algae blooms. Water quality modeling indicates that these water quality problems are caused by excessive nutrients and biological oxygen demand (BOD) entering the Manokin from nonpoint sources and point sources.[4]

What Are the Effects of Nutrient Over-Enrichment
National Academy Press, Clean Coastal Waters (2000) [22]

The productivity of many coastal marine [and estuary] systems is limited by nutrient availability, and the input of additional nutrients to these systems increased primary productivity [microscopic organisms including algae]. In moderation in some systems, nutrient enrichment can have beneficial impacts such as increasing fish production; however, more generally the consequences of nutrient enrichment for coastal marine ecosystems are detrimental. Many of these detrimental consequences are associated with **eutrophication**.

The **increased productivity** from eutrophication increases oxygen consumption in the system and can lead to low-oxygen (hypoxia) or oxygen-free (anoxic) water bodies. This can lead to fish kills as well as more subtle changes in ecological structure and functioning, such as lowered biotic diversity and lowered recruitment of fish populations.

Eutrophication can also have deleterious consequences on estuaries even when low-oxygen events do not occur. These changes include **loss of biotic diversity**, and changes in the ecological structure of both planktonic and benthic communities, some of which may be deleterious to fisheries. Seagrass beds and coral reefs are particularly vulnerable to damage from eutrophication and nutrient over-enrichment.

Harmful algal blooms (HABs) harm fish, shellfish, and marine mammals and pose a direct public health threat to humans. The factors that cause HABs remain poorly known, and some events are entirely natural. However, nutrient over-enrichment of coastal waters leads to blooms of some organisms that are both longer in duration and of more frequent occurrence.

Although difficult to quantify, the **social and economic consequences** of nutrient over-enrichment include aesthetic, health, and livelihood impacts.

Water Quality Indicators

The *Maryland Clean Water Action Plan* published in 1998 listed the Manokin River water quality indicators shown in the table below.[3] The Manokin River is also identified in the Plan as a Category 1 Priority Watershed "in need of restoration during the next two years." For more details on the *Clean Water Action Plan* see www.dnr.state.md.us/cwap/

Water Quality Indicator Click on name for more information	**Finding**	**Rank**	**Bench Mark** (percent based on 138 watersheds)
State 303(d) Impairment Number	1 and 3	Fail	1= restoration needed. 3 = additional protection needed. This watershed is included in the 303d list.
Tidal Habitat Index	7.0	Pass	In a scale of 1 (worst) to 10 (best) ranking of all138 watersheds in Maryland, this watershed is among the 75% with the higher index.
Tidal Eutrophication Index	4.3	Fail	In a scale of 1 (worst) to 10 (best) ranking of all 138 watersheds in Maryland, this watershed is among the 25% with the lowest index.
Modeled TN Load	7.27 lbs/acre	Pass	In comparison to 138 watersheds in Maryland, this watershed is among the 75% with the lower loads.
Modeled TP Load	0.44 lbs/acre	Pass	In comparison to 138 watersheds in Maryland, this watershed is among the 75% with the lower loads.

Interpreting Water Quality Indicators

State 303(d) Impairment Number. This number is used to characterize watersheds relative to regulatory requirements of the Federal Clean Water Act. It is based on numerous water quality-related factors that are tracked by the State of Maryland under these federal requirements.

Tidal Habitat Index. This index uses selected water quality parameters to gauge habitat quality for aquatic life like fish. Using data from 1994-1996, measurements of surface chlorophyll *a*, secchi depth and summer (July-September) bottom dissolved oxygen were each ranked on a scale of 1 (most degraded) to 10 (best condition). These individual ranks were combined to create the single index shown in the table.

Tidal Eutrophication Index. Eutrophication refers to relative levels of nutrients in an aquatic system. Using data from 1994-1996, measurements of surface mixed layer total nitrogen, total phosphorus and total suspended solids were each ranked on a scale of 1 (most degraded) to 10 (best condition). These individual ranks were combined to create the single index shown in the table.

Modeled TN Load. TN refers to Total Nitrogen. Nitrogen Load is a measure of how much of this important nutrient is reaching streams and other surface waters. For each type of land use in the watershed, on average, stormwater tends to carry or transport a characteristic amount of nitrogen from the land to nearby streams. Based on these averages, computers can be used to estimate (model) how much nitrogen is likely to be reaching local streams. This method was applied Statewide to all the 138 watersheds in Maryland to allow comparison of "modeled total nitrogen load" among them. A rank of "fail" means that this watershed was among the 34 watersheds (25%) that had the highest estimated total nitrogen load. High nitrogen levels in tidal waters and lakes are often associated with poor water quality.

Modeled TP Load. TP refers to Total Phosphorus. It is a measure of how much of this important nutrient is reaching streams and other surface waters. The ranking for modeled TP Load was performed in parallel to the ranking for modeled TN Load above. (Note: details of the models differ.)

Modeled Loads and Actual Loads. The modeled nutrient loads used for the indicators are based on average nutrient loads generated by land uses in the watershed. The indicator does not address nutrient loads from point sources, concentrated animal manure use, etc. Therefore, it is possible for a watershed to "pass" on the modeled TN and TP indicators and simultaneously not support its Designated Use due, in part, to nutrient loads.

Tributary Team Characterization

As part of the work of the Lower Eastern Shore Tributary Team, Manokin River water quality is characterized overall as summarized below. [1, 12] Also see additional explanation below the table.

Manokin River - Tributary Team Characterization		
Parameter	**Status 1997-99 Data**	**Trend 1985 Through 1999**
Nitrogen: total	fair	no trend
Phosphorus: total	fair	no trend
Algae: Abundance	good	no trend
Dissolved Oxygen: summer, bottom	good	no trend
Water Clarity: secchi depth	poor	degrading (39%)
Suspended Solids: total	poor	no trend

The Status column in the table includes assessments of good/fair/poor that are generalized from data gathered from across the river system. For example, the "good" status for dissolved oxygen indicates that overall oxygen levels are satisfactory. However, low dissolved oxygen concentrations are known in localized areas (see Water Quality Assessment). Therefore, these generalizations may be best used as indicators of improvement needs that would be beneficial for the entire river. For example, it is believed that overall the Manokin River could benefit from improved water clarity.

In the Trend column, "no trend" means that during the time period assessed no significant change toward improvement or degradation could be discerned. In the case of water clarity, significant change toward reduced water clarity across the river system was identified between 1985 and 1999..

The assessments in the table are based on data analysis by the DNR Resource Assessment Service where a technical consensus was developed to define appropriate thresholds between categories (between poor and fair; and fair and good). Additional information can be obtained by contacting DNR.

Water Quality Assessment

In recent years, several different groups have collected water quality data in the Manokin River watershed. Map 4 Monitoring Stations shows some of these sites including monitoring station ET8.1 where water quality data is regularly collected at the mouth of the Manokin River. Water quality data covering the recent months is presented in graphs and tables www.dnr.state.md.us/bay/conditions/index.html . Click on "Manokin" on the Internet map to view dissolved oxygen, salinity, water temperature, pH and secchi depth. The following discussion is based on mostly on 1998 and 1999 data. Also see:

– MDE stations: Maryland's Lower Delmarva Peninsula 1998 Data Report [7]
– University of Maryland Eastern Shore stations: UMES 1999 Water Quality Report [25]

1. Discussion of Recent Data

Depressed dissolved oxygen (DO) concentrations tended to occur during summer months upstream of the confluence of the Manokin River and Back Creek. Several stations in the Manokin mainstem and at least one station in each tributary exhibited summer DO below the 5.0 mg/L water quality standard.

Biological Oxygen Demand (BOD) appears to be contributing to low dissolved oxygen levels. BOD concentrations greater than 10 mg/L during summer months were identified in five MDE monitoring stations: the two Manokin mainstem stations immediately downstream of Princess Anne, two downstream Kings Creek stations and the Back Creek station downstream of Route 13. (For comparison, some wastewater treatment plants in the Chesapeake Bay area discharge sewage effluent with lower levels of BOD.)

Chlorophyll *a* concentrations in many areas of the Manokin River watershed during summer months are commonly higher than the 15 *u*g/L maximum recommended for growth of submerged aquatic vegetation (SAV). In 1998 beginning in late March, concentrations above 15 *u*g/L were observed in the three stations closed to Tangier Sound. Summer 1998 Chlorophyll *a* concentrations higher that 50 mg/L (an indicator of eutrophic conditions) were found in several areas:

– Manokin River mainstem from Taylor Branch to Princess Anne
– Back Creek below Route 13
– Kings Creek between the Manokin River and Route 13

Chloropyll *a* concentrations observed during May 1999 and May 2000 are shown in Map 5 Algae Concentrations. The map indicates the kind of variability that tends to occur over time. The concentrations shown in the map also suggest that Manokin River chloropyll *a* regularly reaches levels that inhibit SAV growth.

In the Manokin River mainstem, the highest 1998 nutrient concentrations (about 4.0 mg/L for total phosphorus and for total nitrogen) were found immediately downstream of Princess Anne. Similarly high total phosphorus concentrations were found in Kings Creek at Route 13 and in Back Creek downstream of Route 13. (There is no water quality standard for nutrient concentration. For comparison, however, there are a few wastewater treatment plants discharging sewage effluent to the Chesapeake Bay with lower concentrations for both nutrients.)

Kings Creek water quality was compared to other Chesapeake Bay tributary areas that have similar salinity. Based on median concentrations from 1995-1997 monitoring data, Kings Creek can be characterized relative to these similar water bodies: [5]

– Organic Carbon (median total and dissolved). Kings Creek ranked highest. While natural causes are likely to contribute, human sources are also believed to be contributors.
– Total Nitrogen. Kings Creek was in the top 10%
– Total Phosphorus. Kings Creek was in the top 10%
– Dissolved Organic Phosphorus. Kings Creek was in the top 5%

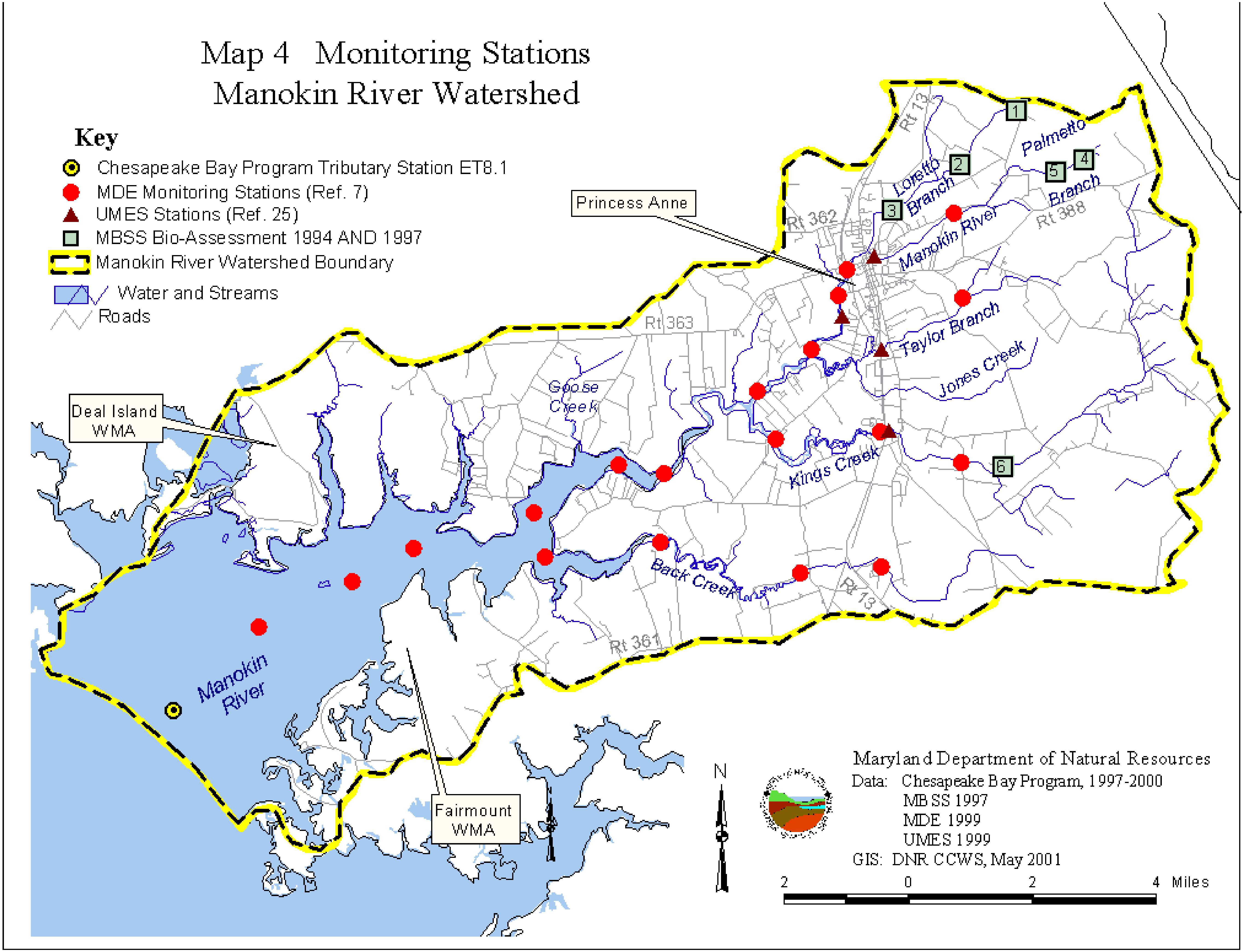
2. Relevance to Watershed Restoration

To prevent the low dissolved oxygen concentrations observed in the Manokin River, at least two general courses of action are probably necessary: reduction of biological oxygen demand (BOD) and prevention of harmful algal blooms by reducing the nutrient sources that are feeding their summer growth.

Total Maximum Daily Load (TMDL) calculations by MDE indicate the following relative sources for nutrients in the Manokin River.[4] Questions were raised by the Somerset County Sanitary District on nonpoint source estimates in the draft TMDL.[20] Revised information presented in the final TMDL is summarized in the table below that shows relative contributions. The WRAS may include elements and/or projects intended to help reduce nutrient loads.

Nutrient Source Estimates from the 2001 Final TMDL				
Source	**Total Phosphorus**		**Total Nitrogen**	
	Percent	**Pounds Per Year**	**Percent**	**Pounds Per Year**
Nonpoint Source	98	26,620	95	384,520
Point Source	2	432	5	19,270
Total	100	27,052	100	403,790

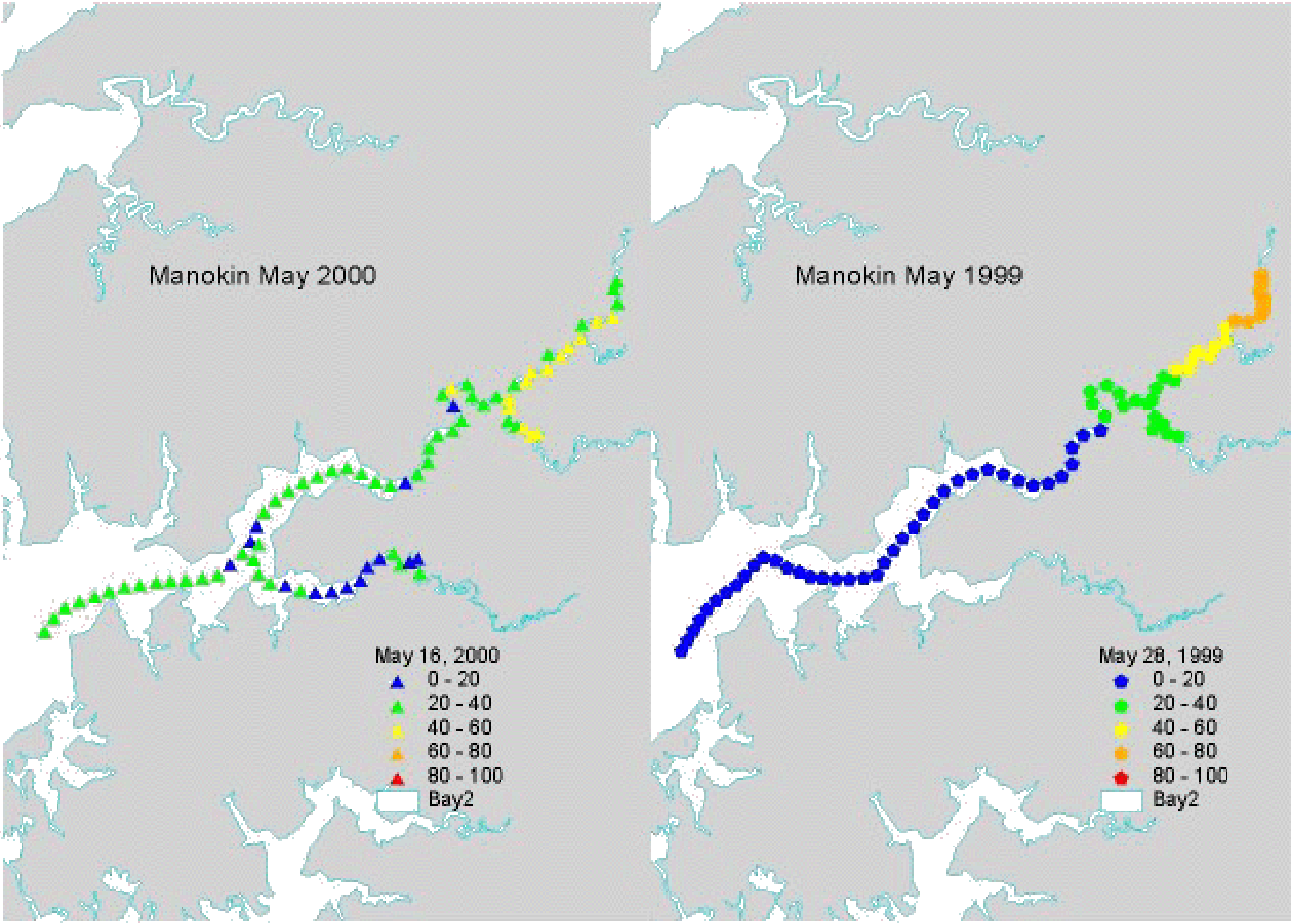
In the table, the nonpoint source estimate is an average annual load including atmospheric deposition. The point source loads used 1998 as a baseline year water quality monitoring data from this year was used by MDE for model calibration.


Map 4 Monitoring Stations
Manokin River Watershed
Key
Chesapeake Bay Program Tributary Station ET8.1
MDE Monitoring Stations (Ref. 7)
UMES Stations (Ref. 25)
MBSS Bio-Assessment 1994 AND 1997
Manokin River Watershed Boundary
Water and Streams
Roads
Princess Anne
Deal Island WMA
Fairmount WMA
Manokin River
Loretto Branch
Palmetto Branch
Taylor Branch
Jones Creek
Kings Creek
Back Creek
Goose Creek
Rt 13
Rt 362
Rt 363
Rt 388
Rt 361
1
2
3
4
5
6
N
Maryland Department of Natural Resources
Data: Chesapeake Bay Program, 1997-2000
MBSS 1997
MDE 1999
UMES 1999
GIS: DNR CCWS, May 2001
2 0 2 4 Miles

Map 5 Algae Concentration (Chloropyll *a*)

(micrograms per liter)

Note: 15 micrograms per liter Chlorophyll *a* is recommended for growth of Submerged Aquatic Vegetation (SAV)



Point Sources

Discharges from discrete conveyances like pipes are called "point sources." Because point sources may contribute various forms of pollution to surface water or to groundwater, it is useful to have some understanding of the point sources discharges in a watershed targeted for restoration.

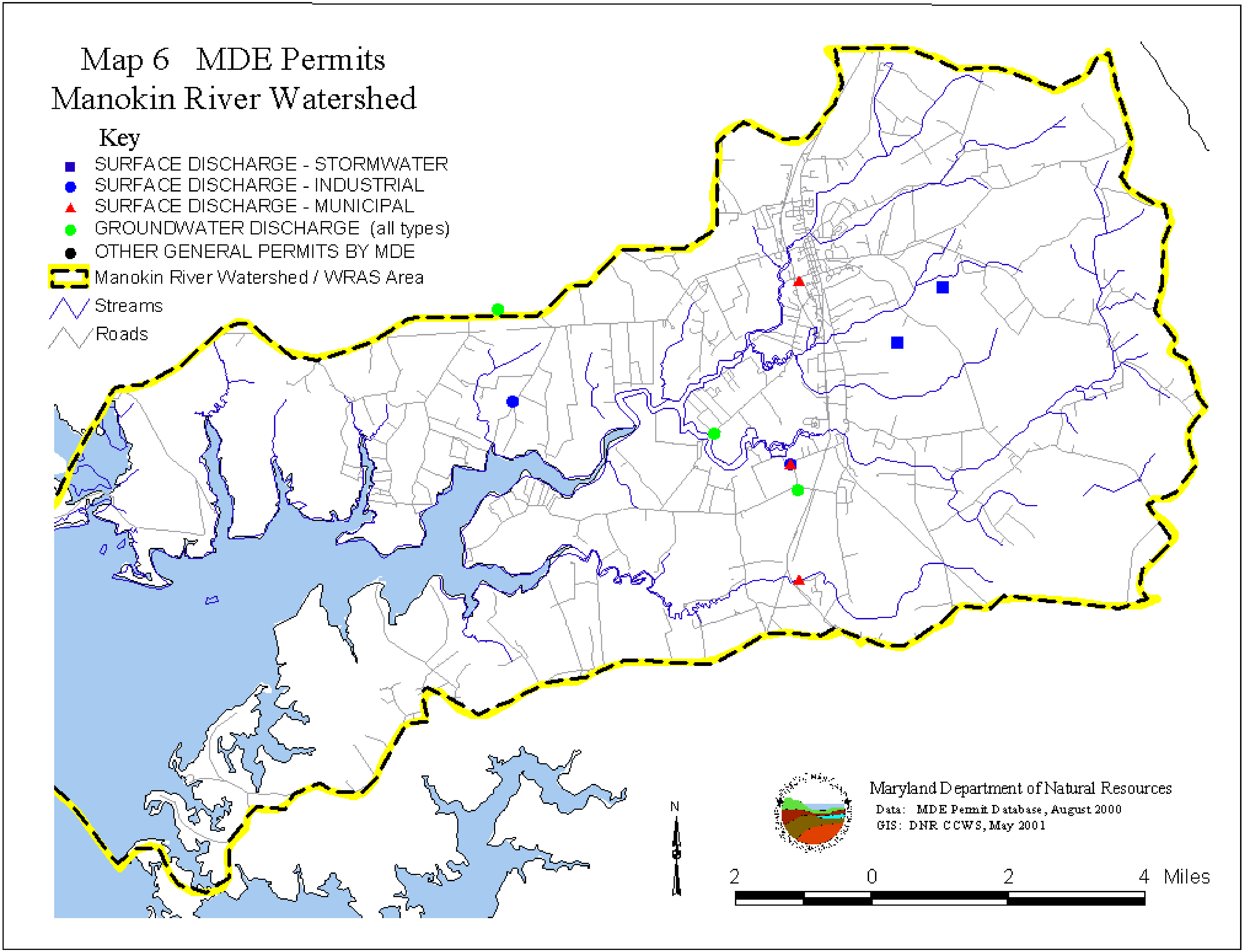
According to the Maryland Department of the Environment (MDE) permit data base summarized in the Table Permits for Surface and Groundwater Discharge, there are five permitted surface water discharges and three permitted groundwater discharges in the Manokin River watershed. Not included in the table are six general industrial stormwater permits listed in MDE's permit data base. The approximate location of all permits issued by MDE are shown in Map 6 MDE Permits. Characteristics of the these permitted discharges (volume, temperature, pollutants, etc.) are tracked by MDE through the permit system and can be obtained from MDE.

Overall, point sources are a small percentage of the total nutrient loads entering the Manokin River system as shown in the Nonpoint Source section. The three point source discharges from Waste Water Treatment Plants (WWTPs) in the Manokin River watershed have been incorporated into MDE's Total Maximum Daily Load (TMDL). Nutrient loads where estimated for these and are summarized in the following table. [4]

Reductions in point source nutrient contributions are already in place or anticipated according to the Somerset County Sanitary District. The new Biological Nutrient Removal technology installed at the Eastern Correctional Institute is intended to achieve 3.0 mg/L total nitrogen concentrations in its effluent during warm months. Additionally, the Princess Anne WWTP will be upgrading its facility to meet the same seasonal total nitrogen concentration. [26]

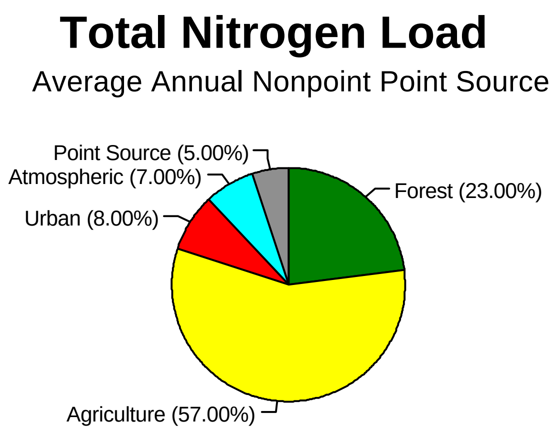
Point Source Nutrient Loads from the Draft TMDL						
Facility Name	NPDES Permit Number	Flow mgd	Total Nitrogen		Total Phosphorus	
			Load lbs/yr	Concentration mg/l	Load lbs/yr	Concentration mg/l
Princess Anne WWTP	MD0020656	1.1	26,788	8.0	1043	0.3
Eastern Correctional Institute	MD0066613	0.48	11,689	8.0	481	0.3
Goose Creek Store	MD0053104	0.0065	110	18.0	18	3.0

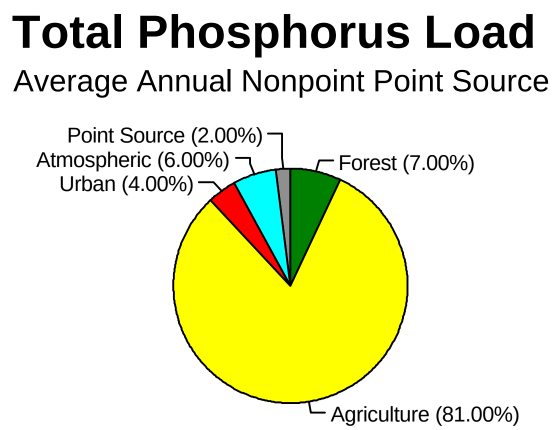
Permits for Surface and Groundwater Discharge Manokin River Watershed			
Facility Name	**NPDES Permit / MD Code**	**Discharge Type / MDE Permit Category**	**Location**
Eastern Correctional Institute	MD0065595 97DP2861	Surface Water / Industrial State operated	30420 Revells Neck Road
Eastern Correctional Institute	MD0066613 92DP3027	Surface Water / Municipal State operated	30420 Revells Neck Road
Hyrock Aquaculture Farm	MD0068098 98DP3031	Surface Water / Industrial	10874 Anderson Road
Princess Anne WWTP	MD0020656 90DP0486	Surface Water / Municipal County operated	Linden Ave. Ext.
Westover Goose Neck Food Store	MD0053104 93DP1233	Surface Water / Municipal	Route 13
Perdue Farms, Inc. Princess Anne Hatchery	99DP3306	Groundwater / Industrial	10789 Stewart Neck Road
Perdue Farms, Inc. Westover Egg Facility	93DP1430	Groundwater / Industrial	9891 Old Princess Anne Road
Tyson Foods Princess Anne Feed Operation	94DP1460	Groundwater / Industrial	Revels Neck Road and Route 13


Map 6 MDE Permits
Manokin River Watershed
Key
SURFACE DISCHARGE - STORMWATER
SURFACE DISCHARGE - INDUSTRIAL
SURFACE DISCHARGE - MUNICIPAL
GROUNDWATER DISCHARGE (all types)
OTHER GENERAL PERMITS BY MDE
Manokin River Watershed / WRAS Area
Streams
Roads
N
Maryland Department of Natural Resources
Data: MDE Permit Database, August 2000
GIS: DNR CCWS, May 2001
2 0 2 4 Miles

NonPoint Sources

The nonpoint sources of nutrients in the Manokin River watershed tend to be dominated by agriculture according to modeling conducted for the TMDL as summarized in the following pie charts.[4] Questions were raised by the Somerset County Sanitary District on the confidence that can be ascribed to these nonpoint source estimates in the draft TMDL.[20] However, these estimates are useful because they generally indicate relative levels contributed by different nutrient sources in the Manokin River watershed based on the best available information. The pie charts shown below were adapted from February 2001 final TMDL for the Manokin River watershed.





Nonpoint source pollution control programs (CREP, Environmental Quality Incentive Program, Wildlife Quality Incentive Program, etc.) are available to land owners in the watershed. Somerset County representatives have expressed interest in tracking these programs as part of the WRAS. Creation of a digital database with GIS mapping has been suggested as an approach.

1. Shorelines and Stream Banks

Wherever land and open water meet, natural processes cause inevitable change in the form of erosion or accretion of land. Human activity in these areas either tends to inadvertently accentuate these natural processes or purposefully attempt to control movement of water and/or loss of land. Erosion of stream banks and shorelines can contribute significant amounts of nutrients (mostly phosphorus) and sediment (water column turbidity, habitat loss.)

In preliminary discussions between County and DNR, County representatives expressed interest in several areas of concern related to shorelines and stream banks:

– Identifying erosion prone areas
– Tracking new information on projected sea level rise.

The January 2000 Final Report of the Shore Erosion Task Force provides a foundation for addressing this issue. This report summarized Countywide shoreline erosion as listed in the following table. [14]

Somerset County Shore Erosion Rate Summary				
Total (miles)	Total Eroding (miles)	Erosion Rate		
		0 - 2 feet / year	2 - 4 feet / year	> 4 feet / year
619	155	117	24	14

Maps of historic shoreline change were produced in 1999 by the Maryland Geological Survey (MGS) in a cooperative effort between DNR and the National Oceanic and Atmospheric Administration (NOAA). These maps included digitized shorelines in the Manokin River watershed for several historic time frames. The maps show that extensive changes have occurred adjacent to all large bodies of open water with relatively much less change adjacent to smaller water bodies. Copies of these 1:24000 scale maps are available from MGS.

The maps and documentation listed above consider *area* of changes, rather than volume or sediment type. Therefore, additional work would be necessary to relate this erosion to pollutants in the water column.

Future shoreline change may accelerate due to change in sea level. Projections suggest that land adjacent to large bodies of water will erode significantly in coming decades.

Total Maximum Daily Loads [4]

The Clean Water Act requires development and implementation of Total Maximum Daily Loads (TMDLs) as the approach to restore water quality for water bodies that fail to meet water quality standards including their designated use. In simple terms, the TMDL is intended to set water pollution reduction goals for the water body. Waste Load Allocations in the TMDL assign responsibilities for reduction of pollutant loads to pollutant generators or sources.

The final TMDL for the Manokin River was developed by the Maryland Dept. of the Environment (MDE) in 1999/2000 and approved by the US Environmental Protection Agency (EPA) in February 2001. Both the final and draft TMDL for the Manokin River were used extensively as a source of information for the Manokin River Watershed Characterization. The intent of the TMDL, summarized in the table below, is to improve Manokin River water quality by preventing low dissolved oxygen concentrations below the 5.0 mg/l standard and to reduce summer algae populations as measured by chlorophyl *a*.

Water Quality Improvement Needs From TMDL [4]		
Parameter	**Average Summer Concentration**	**Goal**
Algae - Chlorophyl *a*	100 to 350 *ug/l*	50 *ug/l*
Dissolved Oxygen	4.5 to 15 *mg/l*	5.0 *mg/l*

To achieve these goals, several loading caps or TMDLs have been adopted. TMDLs for biological oxygen demand (BOD) and total nitrogen (TN) apply to summer months when algae blooms tend to occur and droughty conditions also tend to decrease water flows and flushing of tidal waters. In additional, a TMDL for TN is also established for annual loads because significant nitrogen loads tend to enter waterways during wet weather periods.

TMDLs Adopted February 2001 for the Manokin River [4]		
Applicable Time Period	**Parameter**	**Load**
May 1 through October 31	Total Nitrogen	1,610 pounds per month
May 1 through October 31	BOD	4,420 pounds per month
Annual	Total Nitrogen	353,680 pounds per year

LAND USE
Manokin River Watershed

Landscape Indicators

Water quality, particularly in streams and rivers, is affected by the land in the riparian area and throughout the watershed. In an effort to gauge the affects of land use on water quality, and to allow comparison between watersheds, DNR has developed a series of Landscape Indicators. These indicators can be used to portray landscape conditions at a watershed scale that tend to support good water quality or that tend to degrade water quality.

The *Maryland Clean Water Action Plan* published in 1998 listed landscape indicators for the Manokin River watershed as summarized in the table below.[3] Most indicator ranking (pass / fail) is a relative measure that compares the Manokin River watershed with the other 137 watersheds of similar size that cover the entire State of Maryland.

Landscape Indicator Click indicator for more information	**Finding**	**Rank**	**Bench Mark**
Impervious Surface	1.7 % of watershed is impervious	Pass	Of 138 watersheds in Maryland, this watershed is among the 104 (75%) with the lower imperviousness.
Population Density	0.12 people per acre	Pass	Of 138 watersheds in Maryland, this watershed is among the 104 (75%) with the lower population density.
Historic Wetland Loss Density	43,036 acres	Fail	Of 138 watersheds in Maryland, this watershed is among the 34 (25%) with the greatest historic loss.
Unforested Stream Buffer	39 percent	Pass	Of 138 watersheds in Maryland, this watershed is among the 104 (75%) with fewer unbuffered streams.
Soil Erodibility	0.27 value per acre	Pass	Of 138 watersheds in Maryland, this watershed is among the 104 (75%) with lesser soil erodibility.

Interpreting Landscape Indicators Page 1 of 2

Impervious Surface. Reduction of impervious area can be a valuable component of a successful Watershed Restoration Action Strategy (WRAS). Roads, parking areas, roofs and other human constructions are collectively called impervious surface. Impervious surface blocks the natural movement of rain into the ground. Unlike many natural surfaces, impervious surface typically concentrates stormwater runoff, accelerates flow rates and directs stormwater to the nearest stream. Side-effects of impervious surfaces become increasingly significant as the percentage of impervious area increases. Examples include reduction of groundwater infiltration, soil and stream bank erosion, sedimentation, destabilization or loss of aquatic habitat, and "flashy" stream flows (reduced flow between storms and excessive flows associated with storms.)

Population Density. While population density may be beyond the scope of a WRAS, directing growth is a potential WRAS component. Humans are usually very successful in competing for use of land and water. As human population increases, effects of human activity tend to degrade, displace or eliminate natural habitat. Watersheds with higher populations, assuming other factors are equal, tend to exhibit greater impacts on waterways and habitat. However, growth can be directed in ways to reduce negative impacts.

Historic Wetland Loss Density. About 72% of the Manokin River watershed is hydric soil (about 43000 out of 59000 acres). The historic wetland loss estimate is based on the assumption that the hydric soils were all, at one time, wetlands. Thoughtful selective restoration of historic wetland areas can be an effective WRAS component. In most of Maryland's watersheds, extensive wetland areas have been converted to other uses by draining and filling. This conversion unavoidably reduces or eliminates the natural functions that wetlands provide. These functions include habitat and nursery areas for many aquatic organisms, buffering floods, and uptake and redistribution of nutrients, etc. In general, watersheds exhibiting greater wetland loss tend to also exhibit greater loss of the beneficial functions that wetlands provide. Strategic replacement of wetlands can significantly improve natural function in local watershed areas.

Interpreting Landscape Indicators Page 2 of 2

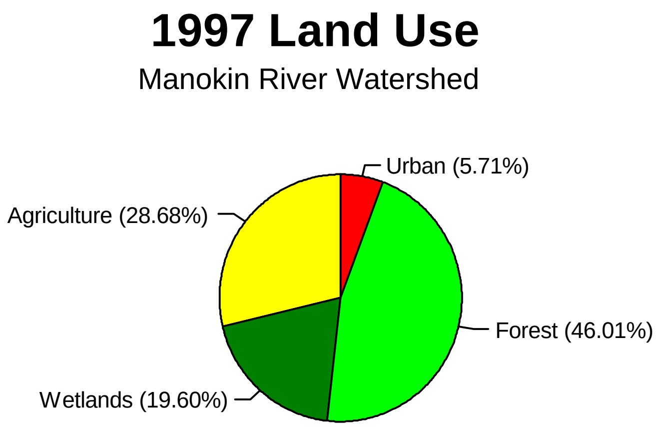
Unforested Stream Buffers. The finding listed in the table means that 39% of the "blue line" streams (excluding shoreline) in the watershed do not have sufficient stream buffers to promote high quality stream habitat. DNR recommends that forested buffer 100 feet wide , i.e. natural vegetation 50 feet wide on either side of the stream, is typically necessary to promote high quality aquatic habitat and diverse aquatic populations. Restoration of of natural vegetation adjacent to streams can be a valuable and relatively inexpensive WRAS element. In most of Maryland, trees are key to healthy natural streams. They provide numerous essential habitat functions: shade to keep water temperatures down in warm months, leaf litter "food" for aquatic organisms, roots to stabilize stream banks, vegetative cover for wildlife, etc. In general, reduction or loss of riparian trees / stream buffers degrades stream habitat while replacement of trees / natural buffers enhance stream habitat.

Soil Erodibility. The soil erodibility indicator accounts for natural soil conditions but not for management of the land. The naturally erodible soils of the Manokin River watershed are addressed by techniques called Best Management Practices (BMPs) to prevent soil loss that are typically in use on local farms. BMPs like no-till, reduced till, cover crops, field strips, and others significantly reduce erosion and sediment movement. These BMPs can be seen in use in many places in the watershed.

A finding of 0.27 means that the Manokin River watershed has "moderate" soil erodibility considering soils types, steep slopes and extent of cropland within 1000 feet of waterways. Watersheds with more easily erodible soils are naturally more susceptible to surface erosion, sedimentation, streambank erosion and other problems related to soil movement. These negative effects of soil erosion on water quality can be minimized through careful management. A WRAS can reasonably promote a reduction in disturbance of erodible soils and/or effective soil conservation practices like planting stream buffers.

1997 Land Use / Land Cover

The Land Use Summary table and pie chart show that the Manokin River Watershed is nearly one half forest. Agriculture covers over one quarter of the watershed and wetlands cover about one fifth of the land area as categorized by the Maryland Department of Planning. Map 7 1997 Generalized Land Use shows the distribution of additional perspective on potential nonpoint source nutrient generation. The Land Use Technical Report provides additional land use details.

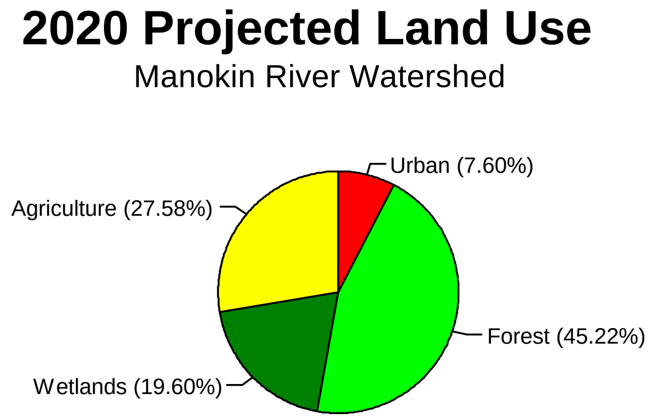


Viewing these land uses as potential nonpoint sources of nutrients, agriculture primarily and urban land secondarily are likely to be the dominant contributors of nutrients based on extensive acreage and/or nutrient management associated with that land use.

1997 Land Use / Land Cover Summary for the Manokin River Watershed		
Category	**Description**	**Acres**
Agriculture	Field, Pasture, Ag buildings	17,029
Forest	All woodlands and brush	27,319
Urban	All developed areas	3,389
Wetlands	Tidal marsh, Emergent wetland	11,634
Other	Extractive and bare ground (only 0.02% , not graphed)	13
Watershed Total (excluding open water)		**59,384**

Land Use Projected to 2020

The Maryland Department of Planning has projected planning estimates for land use / land cover to the year 2020 as summarized on the pie chart and the Table 2020 Land Use Projection Summary.[23] Several 2020 projections are potentially important for WRAS planning in the Manokin River watershed. (The Land Use Technical Report has additional details):



– Urban land use is projected to increase 33% while agriculture and forest lands are projected to decrease about 4% and 2% respectively. The projection predicts some limited shifts in urban land patterns in the Manokin River watershed. The subwatershed containing Princess Anne will contain 36% of the Manokin watershed's urban land by 2020 -- down from 40% in 1997.

– In 1997, there were approximately 1,319 households in the Manokin watershed with 67% on septic systems. Of the 600 new households projected to be located in the Manokin watershed by 2020, about 51% are projected to be on septic systems.

– Impervious cover for the Manokin River watershed is low overall -- less than 2%. In the subwatershed containing Princess Anne, impervious cover on about 6% of its land area in 1997 is a projected to increase to 7% by 2020. Increasing imperviousness is known to increase stress on organisms living in streams.

These projections suggest an overall tend toward increasing stress on natural systems in the watershed and particularly on aquatic life. In light of these projections, Manokin River watershed planning could consider potential WRAS elements to help counterbalance the anticipated trends. Potential WRAS initiatives could relate to smart growth, agricultural land preservation, stream / natural area enhancement or protection, etc.

2020 Land Use Projection Summary for the Manokin River Watershed		
Category	**Description**	**Projected Change in Acres 1997 to 2020**
Agriculture	field, Pasture, Ag buildings	- 652
Forest	All woodlands, brush	- 470
Urban	All developed areas	1,122
Wetlands	Tidal marsh, Emergent wetlands	no change
Other	Extractive and bare ground	no change

Land Use Management

There are numerous programs that have existing or potential ability to address issues of water quality improvement and living resource protection. While a thorough assessment of these programs is beyond the scope of this Watershed Characterization, the relationship of several programs to the WRAS process is included here.

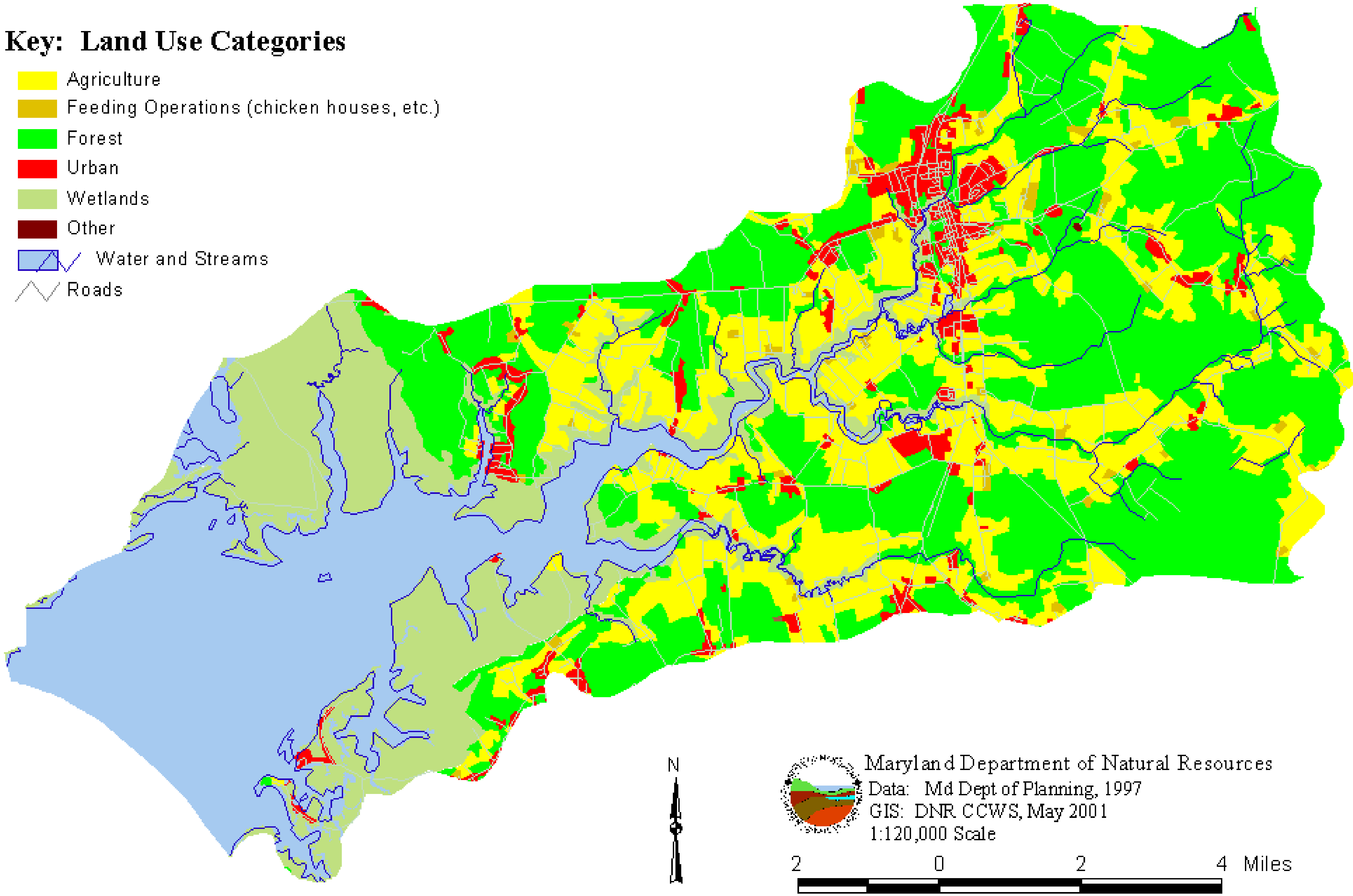
1. County Comprehensive Planning

The primary governmental means to address change in land use is the local comprehensive planning process. In general, watershed restoration projects that may be developed through the WRAS process must be consistent with Comprehensive Plan requirements. In addition, comprehensive planning and watershed restoration do have similar environmental management objectives. As Somerset County explores opportunities for watershed restoration, the County may consider the potential for watershed protection and/or restoration through its comprehensive planning process.

2. Chesapeake Bay Critical Area Program

Somerset County has delegation of authority to carry out requirements under the State Chesapeake Bay Critical Area law. In general, watershed restoration projects that may be developed through the WRAS process must comply with Critical Area requirements.

Map 7   1997 Generalized Land Use / Land Cover
Manokin River Watershed



Green Infrastructure

An additional way to interpret land use / land cover information is to identify "Green Infrastructure." In the GIS application developed by Maryland DNR and its partners, Green Infrastructure refers to areas of natural vegetation and habitat that have statewide or regional importance as defined by criteria developed by DNR. The criteria for identifying of lands as Green Infrastructure is limited to considering natural resource attributes currently found on those lands. One example of the criteria is that interior forest and wetlands complexes at least 250 acres in size are considered as part of Green Infrastructure. As a second example, sensitive species habitat that is located within areas of natural vegetation at least 100 acres in size is also counted as Green Infrastructure. Other potential attributes of Green Infrastructure lands, such as ownership or if the current natural conditions are protected in some way, are not criteria for Green Infrastructure but they may be considered independently.

Within the Green Infrastructure network, large blocks of natural areas are called hubs, and the existing or potential connections between them, called links or corridors. Together the hubs and corridors form the Green Infrastructure network which can be considered the backbone of the region's natural environment.[8]

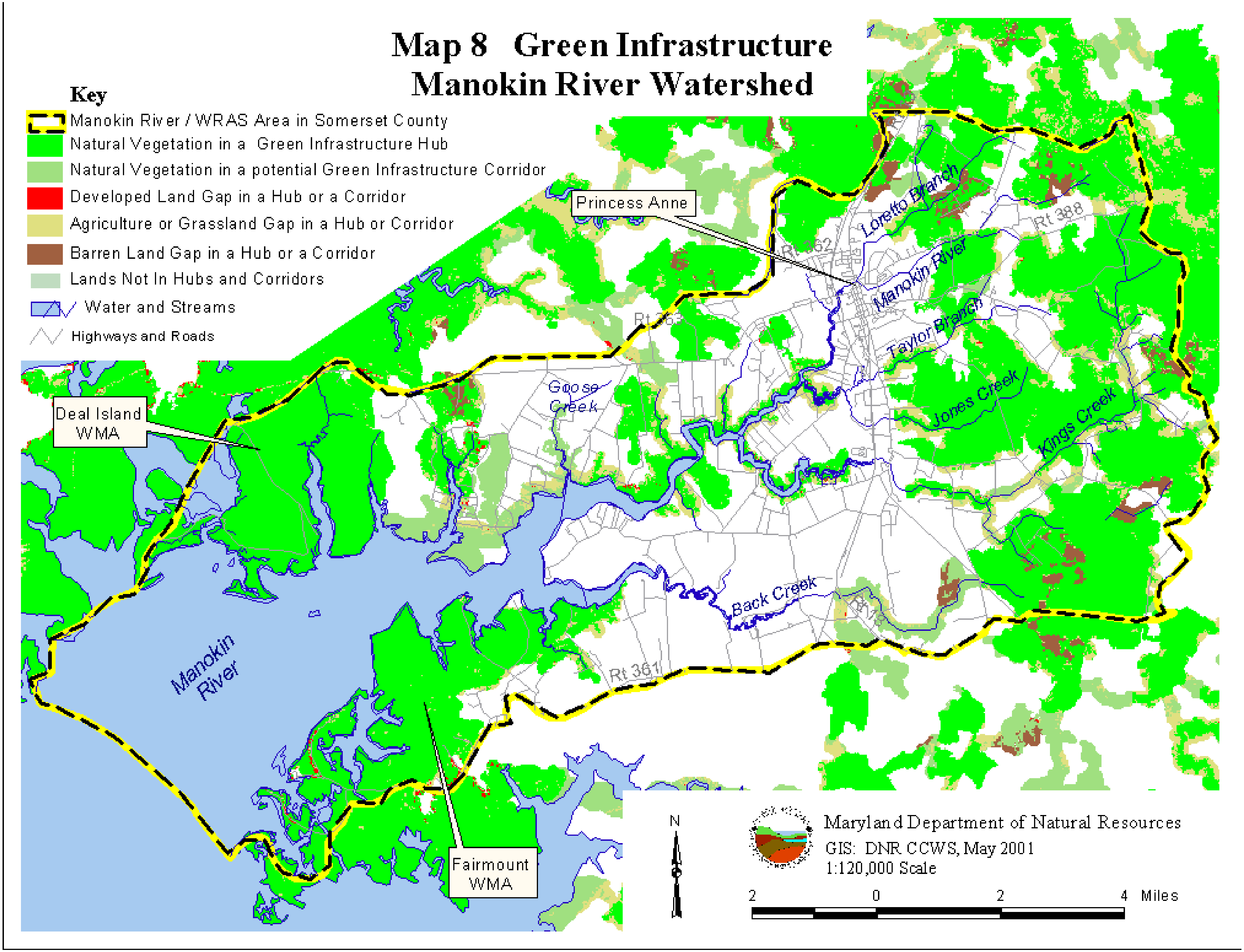
Protection of Green Infrastructure lands may be addressed through various existing programs including Rural Legacy, Program Open Space, conservation easements and others. The 2001 Maryland General Assembly approved $35 million for the Green Print program which is targeted primarily to protecting Green Infrastructure areas. This new funding category will be administered by Program Open Space.

In preliminary discussions between County and DNR representatives, several interests or issues have been identified that are potentially useful for Green Infrastructure enhancement:

– Forest conservation - modification of current banking system to include prioritization
– Nontidal wetlands - creation of a tracking system, identification of funding sources and potential future sites.

In the Manokin River watershed, as shown in Map 8 Green Infrastructure, several significant characteristics can be identified:

– Wetland Hubs are concentrated at the mouth of the Manokin River. Much of the acreage is within the Deale Island WMA and the Fairmont WMA. (Wetlands considered here are about **a** of acre or larger in size, i.e. large enough to be identified by interpretation of aerial / satellite images.)
– Forest Hubs are concentrated in the headwaters areas of the Manokin's tributaries. Much of this acreage is in private ownership.
– Smaller Hubs of wetland and forest, as well as potential connectors, are associated with the middle reaches of the Manokin River and lower portions of its tributaries. Natural vegetation in these connectors appears to have numerous gaps composed of lands in agricultural or urban land uses.

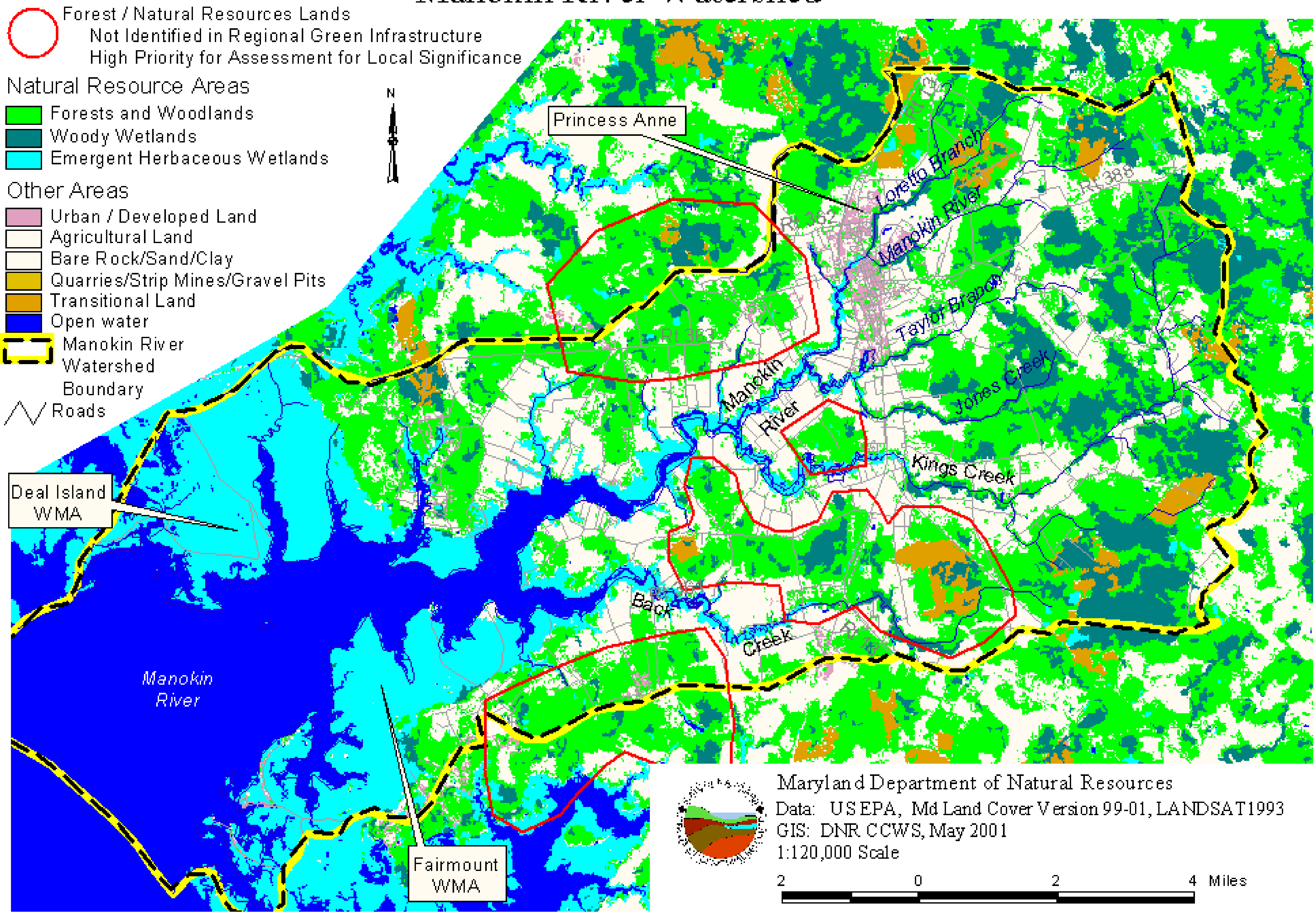


Map 8 Green Infrastructure
Manokin River Watershed
Key
Manokin River / WRAS Area in Somerset County
Natural Vegetation in a Green Infrastructure Hub
Natural Vegetation in a potential Green Infrastructure Corridor
Developed Land Gap in a Hub or a Corridor
Agriculture or Grassland Gap in a Hub or Corridor
Barren Land Gap in a Hub or a Corridor
Lands Not In Hubs and Corridors
Water and Streams
Highways and Roads
Princess Anne
Loretto Branch
Rt 388
Rt 362
Manokin River
Taylor Branch
Rt 363
Goose Creek
Jones Creek
Kings Creek
Deal Island WMA
Back Creek
Rt 13
Rt 361
Manokin River
Fairmount WMA
N
Maryland Department of Natural Resources
GIS: DNR CCWS, May 2001
1:120,000 Scale
2
0
2
4
Miles

Natural Resource Lands at the Watershed Scale

The Green Infrastructure scenario described here, due to its Statewide or regional focus, may not identify natural resource areas that are locally significant. It is reasonable to employ GIS information at the watershed scale to help identify natural areas of potential local significance. Map 9 Natural Resource Lands at the Watershed Scale identifies several areas that may have local natural resource importance even though they were not selected as hubs or corridors in the Green Infrastructure. This GIS map (and similar scenarios) can be used to assist in prioritizing areas for further assessment and to help clarify local interests and needs for locally important natural resource areas.

Map 9 Natural Resource Lands At The Watershed Scale
Manokin River Watershed



Protected Lands

As used in the context of watershed restoration, “protected land” includes any land with some form of long term limitation on conversion to urban / developed land use. This protection may be in various forms: public ownership for natural resource or recreational intent, private ownership were a third party acquired development rights or otherwise acquired the right to limit use through the purchase of an easement, etc.   The extent of “protection” varies greatly from one circumstance to the next and it may be necessary to explore the details of land protection parcel by parcel through the local land records office.

For purposes of watershed restoration, a knowledge of existing protected lands can provide a starting point in prioritizing potential restoration activities. In some cases, protected lands may provide opportunities for restoration projects because owners of these lands may value natural resource protection or enhancement goals.

In drafting the WRAS for the Manokin River watershed, existing protected lands could be assessed as potential contributors to WRAS implementation. Various types of opportunities could be explored:

– Potential sites for implementation projects and/or demonstration projects
– Opportunities for management enhancement or additional protection
– Opportunities for protecting adjacent areas.

The following listing and Map 10 Protected Land and Smart Growth summarize the status of protected lands in the Manokin River watershed.

– Most land in the watershed has no protection from conversion to urban use. Therefore, promoting available opportunities for private land owners to protect rural, agricultural and similar land values may be valuable in the Watershed Restoration Action Strategy. In preliminary discussions between County and DNR representatives, communicating opportunities for agricultural easements was raised as an interest.
– Local / County parks are concentrated in two areas: one at the confluence of Back Creek and the Manokin River and second is south of Back Creek at the edge of the watershed.
– DNR has been a significant land holder in the watershed for many years. Prior to 1999, DNR land was mostly at the mouth of the Manokin River in two Wildlife Management Areas encompassing large tidal marshes. Following the effort to acquire the former Chesapeake Forest properties, DNR lands have expanded to incorporate significant scattered blocks of forest land in the eastern half of the watershed.
– Land protected with the intent of continued agricultural uses is primarily in several farms in the eastern half of the watershed. In preliminary discussions between County and DNR representatives, it was noted that current agricultural easement opportunities can not compete with complimentary programs such as CREP. The Watershed Restoration Action Strategy could promote conservation of agricultural lands.
– Conservation-related easements are not depicted in Map 10 Protected Land and Smart Growth. These protected areas can be incorporated as the more detailed information becomes available. A partial list of protected areas that are not shown follows below:
  1) Former Chesapeake Forest properties currently owned by the Conservation Fund, a

national private nonprofit organization, are shown as DNR land because the intent is to transfer ownership to the State in the near future.

2) Maryland Environmental Trust (MET) easements. There is a MET easement near Raccoon Point and also one on Stewart Neck Road (Jones Creek--Rose Hill Subdivision) worked out with The Nature Conservancy (TNC) and the State to protect an endangered plant species. Another is under consideration by TNC in the vicinity. [21]

3) Easements for Forest Conservation and Wetland Reserve Program. For example, Forest Conservation requirements include Long Term Protection Agreements that run with the land for forested areas and that Critical Area limits most of the area within tidal reaches to one per twenty. When developed, 15% must be forested and only 15% can be impervious surface, plus the 100 ft. buffer requirements. [21]

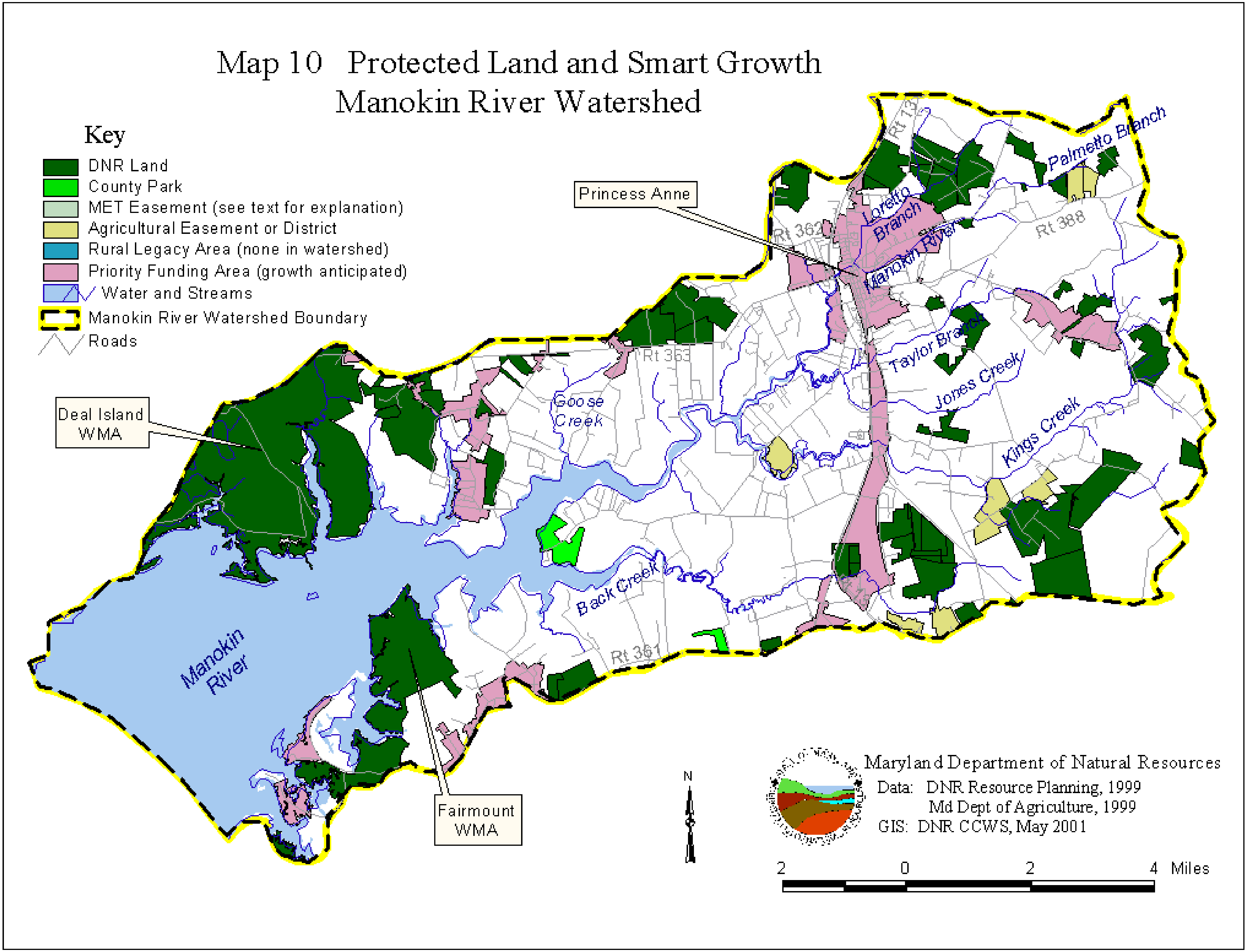
4) Conservation Reserve Programs (CRP and CREP) provide opportunities to conserve selected areas of agricultural land. These programs could be tracked and/or promoted as part of the WRAS.

Smart Growth

Within Maryland's Smart Growth program, there are two targeting programs that should be considered as potential watershed restoration projects are prioritized. In Rural Legacy Areas, protection of land from future development through purchase of easements (or fee simple purchase) is promoted. In Primary Funding Areas, State funding for infrastructure may be available to support development and redevelopment. Both areas are shown on Map 10 Protected Land and Smart Growth:

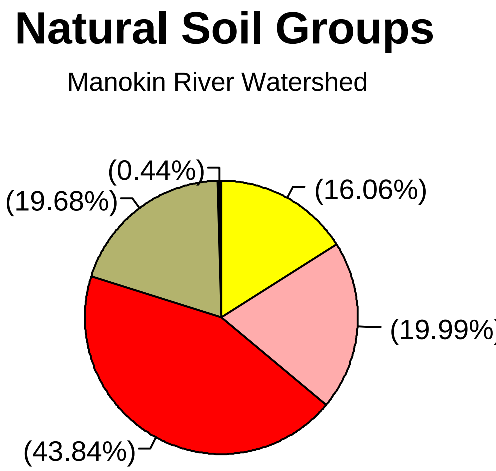
- Rural Legacy Areas. The Manokin River watershed does not include a Rural Legacy Area. Somerset County's Rural Legacy Area is located in the Pocomoke River watershed. Expansion of protected land through this program may be considered in drafting the Watershed Restoration Action Strategy for the Manokin River watershed.

- Priority Funding Areas. In the Manokin River watershed, Primary Funding Areas are mostly concentrated in and around five areas: Princess Anne, the Route 413 Corridor, Oakville, Oriole and Champ, and near the Fairmount WMA. In Priority Funding Areas, new development and/or redevelopment may be anticipated. Planning for watershed restoration projects in Priority Funding Areas, or downstream of them, needs to account for potential changing conditions during the life of the project. For example, increasing impervious area may alter stormwater conditions that a watershed restoration project will have to adequately address.



Map 10 Protected Land and Smart Growth
Manokin River Watershed
Key
DNR Land
County Park
MET Easement (see text for explanation)
Agricultural Easement or District
Rural Legacy Area (none in watershed)
Priority Funding Area (growth anticipated)
Water and Streams
Manokin River Watershed Boundary
Roads
Princess Anne
Deal Island WMA
Fairmount WMA
Rt 13
Palmetto Branch
Loretto Branch
Rt 362
Manokin River
Rt 388
Rt 363
Taylor Branch
Jones Creek
Goose Creek
Kings Creek
Back Creek
Rt 361
Manokin River
N
Maryland Department of Natural Resources
Data: DNR Resource Planning, 1999
Md Dept of Agriculture, 1999
GIS: DNR CCWS, May 2001
2 0 2 4 Miles

Soils of the Manokin River Watershed



1. Interpreting Local Conditions with Natural Soil Groups

Soil conditions, like soil type and moisture conditions, greatly affect how land may be used and potential for vegetation and habitat on the land. Soil conditions are also one determining factor for water quality in streams and rivers. Local soil conditions vary greatly from site to site as the published information in the Soil Survey for Somerset County shows. This complicated information can be effectively summarized using Natural Soil Groups to help identify useful generalizations about groups of soils.

In Map 11 Soils and the pie chart, prime farmland is depicted in yellow or yellow with crosshatching. Not counting open water, about 16% of the Manokin River watershed is prime farmland. The various shades of reds and greens depict soil areas with wetness conditions that affect their agricultural or development potential. The pie chart indicates that soils with wetness-related limitations cover about 64% of the watershed: mostly F3 (43.84%) and F2 (19.99%). Marsh and swamp covers 19.68% of the watershed. All other soil types together cover only 0.44% of the watershed.

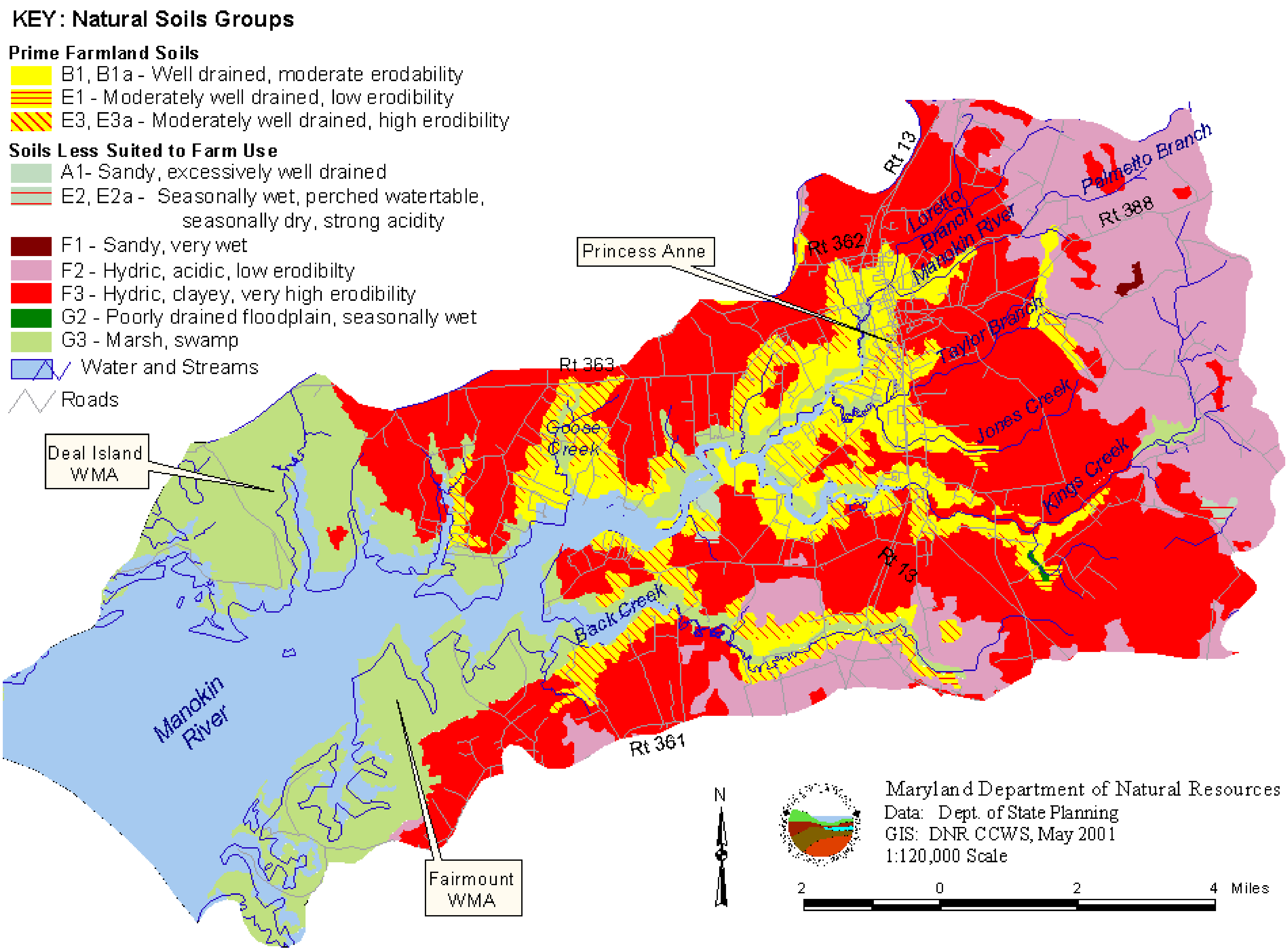
2. Soils and Watershed Planning

Local soil conditions can be a useful element in watershed planning and for targeting restoration projects. For example, wet soils are so extensive in the watershed that land owners have invested substantial effort in ditching to improve drainage and utility of the land. However, land owners have also tended leave some of the wetter areas in natural vegetation or other low intensity use. By comparing the soils map to other information including the maps listed below, it is possible to see that existing natural habitat areas in the watershed frequently are associated with areas of wet soils:

– Map 7 1997 General Land Use,
– Map 8 Green Infrastructure,
– Map 9 Natural Resource Areas of Potential Local Significance.

Based on soils and other information like land cover and land owner interest, it is possible to develop WRAS objectives that meet local interests. For example, candidate areas for protection, like preserving prime agricultural soils for agricultural use, could be identified. Similarly, this information can also help identify potential sites for restoration projects like stream buffers and wetland restoration.

Map 11 Soils in the Manokin River Watershed



Wetlands

The Chesapeake 2000 Agreement has several objectives regarding wetlands including no net loss, restoring/creating 25,000 acres of wetlands and providing information and assistance to local governments and community groups.[1] In this context, development of the Manokin River WRAS is an opportunity to express local watershed priorities that can be integrated into the larger Chesapeake Bay effort.

1. Introduction to Wetland Categories [24]

The Eastern Coastal Plain Province likely has the highest diversity of emergent estuarine and palustrine wetland communities relative to other Maryland physiographic regions because both tidal and nontidal freshwater marshes occur here. Wetlands are most abundant in the Coastal Plain due to the low topographic relief and high groundwater table characteristic of the region.

Estuarine Wetlands. Estuarine wetlands are abundant throughout the Coastal Plain. These systems consist of salt and brackish tidal waters and contiguous wetlands where ocean water is at least occasionally diluted by freshwater runoff from the land. These wetlands may extend far upstream in tidal rivers to freshwater areas. Differences in salinity and tidal flooding within estuaries have a significant effect on the distribution of these wetland systems. Salt marshes occur on the intertidal shores of tidal waters in areas of high salinity. Brackish marshes are the predominant estuarine wetland type in Maryland. They are found along the shores of Chesapeake Bay, mostly on the Eastern Shore, and for considerable distance upstream in coastal rivers. Estuarine shrub swamps are common along the Maryland coastal zone. Aquatic beds, comprised mostly of submerged aquatic vegetation, are abundant in shallow water zones of Maryland's estuaries, especially Chesapeake Bay and its tributaries.

Palustrine wetlands. Forested wetlands are the most abundant and widely distributed palustrine wetland type on the Coastal Plain. These wetlands are found on floodplains along the freshwater tidal and nontidal portions of rivers and streams, in upland depressions, and in broad flat areas between otherwise distinct watersheds. Tidal freshwater swamps occur along coastal rivers in areas subject to tidal influence. Scrub-shrub swamps are not abundant on the Eastern Shore but are represented in the Manokin River watershed. Emergent wetlands on the Coastal Plain are characterized by a wide range of vegetation, depending on water regime. (Adapted from *Wetlands of Maryland*, Tiner and Burke, 1995.)

2. Tracking Wetlands [24]

Oversight of activities affecting wetlands involves several regulatory jurisdictions. The Maryland Dept. of the Environment (MDE) is the lead agency for the State and cooperates with DNR, the Army Corps of Engineers and other Federal and local agencies. As part of its responsibility, MDE tracks State permitting and the net gain or loss of wetlands over time. As the Wetlands Regulatory Status table shows, changes tracked in the State regulatory program have been minor in the Manokin River watershed.

Wetlands Regulatory Status
Manokin River Watershed
Permits Authorized = 0
Letters of Authorization Issued = 13

Wetland Class	Acres
Permanent Impacts	-0.77
Mitigation by Permittee	0.00
Other Gains (Regulatory)	0.38
Programmatic Gains	0.00
Net Gain/Loss	**-0.39**

Note: Regulatory tracking for authorized nontidal wetland losses began in 1991. Comprehensive tracking of voluntary wetland gains began in 1998. Tidal wetland changes are not shown.

3. Interpreting Wetland Distribution

Map 12 Wetlands shows that wetlands are extensive throughout the Manokin River watershed. The adjacent table indicates that together tidal and nontidal wetlands cover about 30,000 acres or about half of the watershed.

Wetland Acreage Summary Manokin River Watershed [24]			
Wetland Class			Acres
Estuarine, Intertidal (E2)		aquatic bed	0
		beach bar	0
		emergent	13,383
		forested	310
		scrub shrub	168
Palustrine (P)		aquatic bed	0
		emergent	2,231
		flat	0
		forested	11,470
		scrub shrub	1,804
Riverine, Lower Perennial (R2)		beach bar	0
Riverine, Upper Perrenial (R3)		beach bar	0
Total Wetlands	Total from above		29,366
	DOQQ (DNR estimate)		29,580
	National Wetlands Inventory		30,329

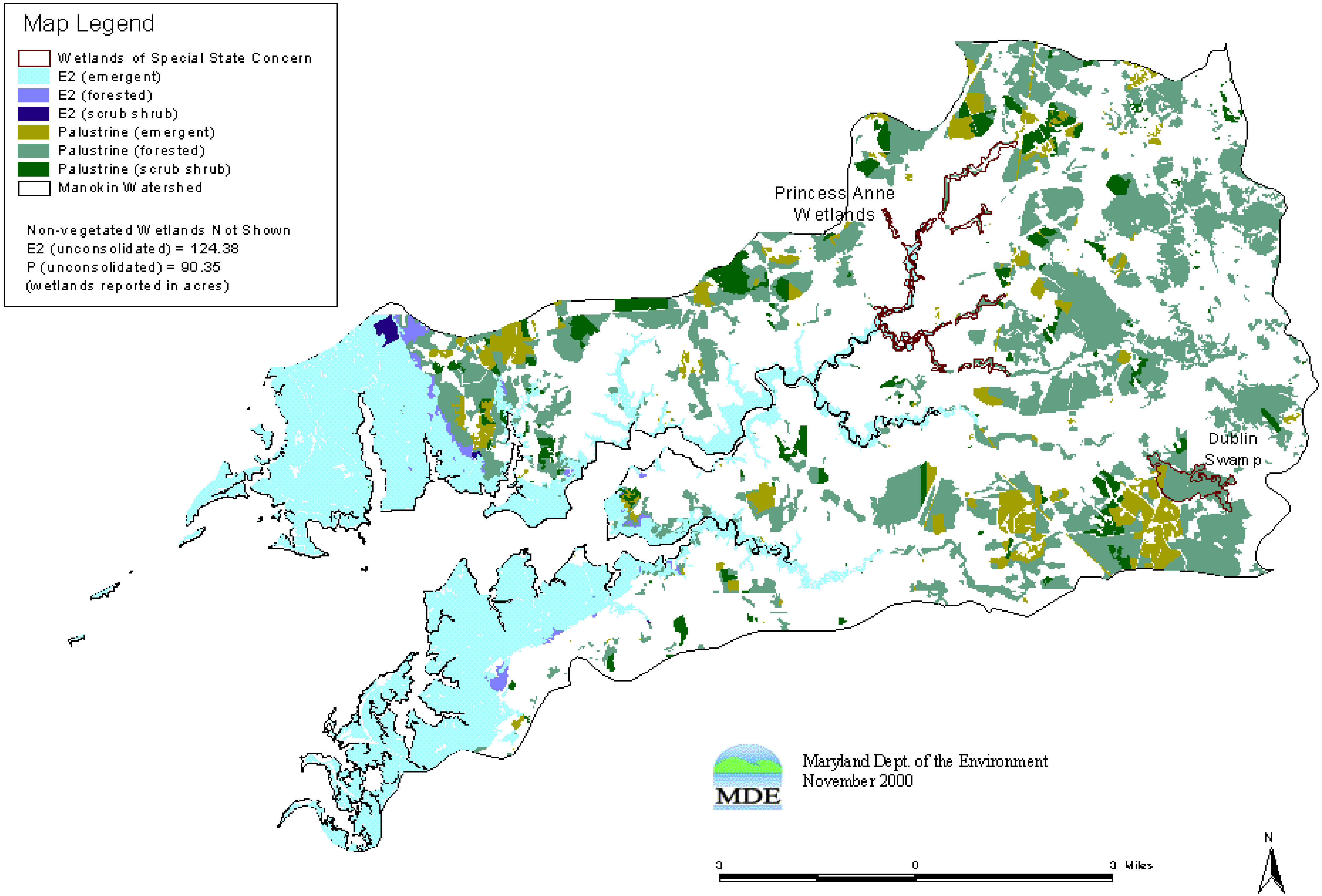
In comparing the wetlands map to Map 7 1997 Generalized Land Use, it can be seen that much of the forested land in the watershed is found in association with Palustrine wetlands or adjacent to them. Also, the comparison shows that many of the nontidal wetland areas shown on the wetlands map are depicted as forest on the land use map. This difference is simply the result of two differing views of the landscape. For example, wooded nontidal wetlands can be viewed as "wetlands" from a habitat / regulatory perspective and they can be viewed as "forest" from a land use perspective.

In the Manokin River watershed, differing perspectives on counting wetlands are significant for watershed management. From a land use perspective, 11,634 acres of wetlands are identified by the Maryland Department of Planning. From a habitat / regulatory perspective, there are approximately 30,000 acres of wetlands in the watershed. However, as the table shows there are differing estimates from different sources/interpretations. [24]

In the context of the Watershed Restoration Action Strategy (WRAS), wetlands serve valuable water quality and habitat functions that may not be provided by other land uses. Therefore, protection and enhancement of existing wetlands, and restoration of past wetland areas, can be a valuable element in the WRAS. (Also see Wetland Restoration.)

Map 12

Wetlands of the Manokin River Watershed (02130208)



LIVING RESOURCES AND HABITAT

Overview

Living resources, including all the animals, plants and other organisms that call the land and waters of the Manokin River watershed home, are being affected by human activity. The information summarized in this characterization suggest some of the significant stresses in the watershed are manipulation of habitat, excessive movement of sediment and excessive availability of nutrients.

In meetings that addressed the characterization of the Manokin River, Somerset County representatives expressed concern that the current understanding of the river's living resources is insufficient. The living resource information summarized here should be considered as a starting point for additional exploration. It is recommended that stakeholders in the watershed identify important living resource issues or priorities so that additional effort can be focus where it is most needed. New information should be added or referenced as it becomes available.

Living Resource Indicators

Aquatic organisms are sensitive, in varying degrees, to changes in water quality and the habitat associated with water. This association offers at least two perspectives that are important for watershed restoration. First, improvements for living resources offer potential goals, objectives and opportunities to gauge progress in watershed restoration. Second, selected living resources can be used as to gauge local conditions for water quality, habitat, etc. This second perspective is the basis for using living resources as an "indicator."

The *Maryland Clean Water Action Plan* published in 1998 listed the following living resource indicators for the Manokin River Watershed.[3] Compared to other watersheds in Maryland, indicators for the Manokin watershed raised relatively severe concern for submerged aquatic vegetation and for bottom-dwelling organisms in nontidal streams.

Living Resource Indicator Click name for more information	**Score**	**Rank**	**Bench Mark** (percent based on 138 watersheds)
SAV Abundance Index	1.00	Fail	Scale of 1 (worst) to 10 (best) Score of 1 yields a rank of "fail"
SAV Habitat Index	5.00	Fail	Scale of 1 (worst) to 10 (best) Score less than 7 yields a rank of "fail"
Non-Tidal Benthic Index of Biotic Integrity	4.45	Fail	Scale of 1 (worst) to 10 (best) Score less than 6 yields a rank of "fail"
Non-Tidal Fish Index of Biotic Integrity	5.25	Pass	Score less than 6 for Category 1 streams Score greater than or equal to 8 for Category 3 streams
Non-Tidal In-stream Habitat Index	4.57	Pass	Scale of 1 (worst) to 10 (best) Of 138 watersheds in Maryland, the 34 (25%) with the lowest nontidal in-stream habitat index received a rank of "fail" and were designated as Category 1 watersheds in need of restoration. The top 34 (25%) were designated as Category 3 watersheds in need of protection.

Interpreting Living Resource Indicators Page 1 of 2

General. Several of these indices rely on index rankings generated from a limited number of sampling sites which were then generalized to represent entire watersheds. Considering this limitation on field data, it may be beneficial to conduct additional assessments to provide a more complete understanding of local conditions as part of the WRAS

SAV Abundance Index. The Finding of "1.0" means that Submerged Aquatic Vegetation (SAV) in 1996 covered 10% or less of the potential SAV habitat. This index allows comparison of watersheds based on the SAV actual/potential SAV area. To generate the number under Finding, the watershed area covered by SAV in a single year is measured using an aerial survey. The year used here was 1996. The potential SAV area is determined by water depth, physical characteristics and historic occurrence of SAV, includes water area up to two feet deep. (This is the Tier III SAV restoration goal.)

SAV Habitat Index. An index less than 7 means that, based on available data from 1994 through 1996 for these parameters, habitat conditions for SAV are less than favorable. This index allows comparison of watersheds based on how well SAV habitat requirements are attained. To create this index, five measurements of habitat conditions are considered (secchi depth, dissolved inorganic nitrogen where applicable, dissolved inorganic phosphorus, Chlorophyll *a* and total suspended solids.

Interpreting Living Resource Indicators Page 2 of 2

Non-Tidal Benthic Index of Biotic Integrity. This index allows comparison of streams based on the populations of bottom-dwelling "bugs" (benthic macroinvertebrate organisms) found in the stream. For coastal plain streams, this index employs seven measurements of these populations which is translated into a rank for each sampling site. An index less than 6 indicates that benthic organisms are significantly stressed by local conditions.

Non-Tidal Fish Index of Biotic Integrity. In index less than 6 indicates that improvements would be beneficial to fish populations. This index allows comparison of selected streams (first through third order nontidal streams) based fish community health. In each sampling site where fish are surveyed, the makeup of the overall fish population is measured in nine distinct ways such as the number of native species, number of benthic fish species, percent of individuals that are "tolerant" species, etc. These nine scores are then integrated to generate an index ranking for the survey site.

Non-Tidal In-Stream Habitat Index. This index allows comparison of streams based on fish and benthic habitat as measured by in-stream and riparian conditions. For each stream site that was assessed, visual field observations are used to score the site for substrate type, habitat features, bank conditions, riparian vegetation width, remoteness, aesthetic value, etc. These scores are then integrated to generate a single rank for each stream site.

Fish and Crabs in Tidal Waters

On the Lower Eastern Shore, monitoring and assessment of fish and crab populations has focused mostly on the Pocomoke River and the Nanticoke River. Relatively little information is available specifically for the Manokin River for either fish or crabs. While there may be some similarities between the Manokin River and other Lower Eastern Shore Rivers, the Manokin River is physically different because it is a relatively small, mostly tidal, river system. [17]

Somerset County may elect to request assistance from DNR in assessing aquatic living resources like fish populations to support development of Manokin River WRAS. Based on current information fisheries could be enhanced by reducing erosion and sedimentation, controlling nutrients, etc.

In addition, the Chesapeake 2000 Agreement calls for Bay-wide strategies to be developed over the next several years on management of fish and other aquatic resources.[1] This activity presents an opportunity for enhancing management in the local watershed if Manokin River needs are addressed in the larger effort.

Fish and Benthos in Nontidal Streams

In 1997, fish, benthos living in streams (benthic macroinvertebrates or stream bugs) and their physical habitat were assessed at two sites in the Manokin River watershed in Somerset County as shown in Map 4 Monitoring Stations. This data was gathered by the Maryland Biological Stream Survey (MBSS) which is a program in DNR. This Manokin River watershed sampling by MBSS was part of a statewide program during 1995 through 1997.

The 1997 MBSS Index Findings Table below lists two sites that were assessed for fish, benthos and physical habitat. Both sites had similar fish populations but Loretto Branch exhibited significantly better benthic populations and physical habitat. The Fish in Nontidal Streams Table provides additional details from 1997 and 1994. One tendency suggested in the table is that fewer fish species were found in smaller headwater areas of a stream than in nearby downstream areas on the same stream where the stream tends to be larger.

Little additional information on non-tidal organisms in the Manokin watershed has been found for use in this characterization. However, it is known that some areas, like the Dublin Swamp, have aquatic communities that include rare fish and/or mussel species. (See the section on Sensitive Species.) In addition, the Maryland Biological Stream Survey (MBSS) is scheduled to assess ten sites in the Manokin watershed beginning in the year 2003.

1997 MBSS Index Findings for the Manokin River Watershed *

Station # SO-...-97	Stream Location	Fish		Benthos		Physical Habitat	
		Score	Condition	Score	Condition	Score	Condition
S-003-111	Kings Creek	3.25	Fair	1.86	Very Poor	18.38	Poor
S-021-102	Loretto Branch	3.25	Fair	3.0	Fair	56.49	Fair

Index Used In 1997 MBSS	Description
Fish Index of Biotic Integrity	Ranges from 1.0 (worst) to 5.0 (best)
Benthic Index Biotic Integrity	Ranges from 1.0 (worst) to 5.0 (best)
Physical Habitat Index	Range from 0 (worst) to 100 (best)

* Additional details are available at www.dnr.state.md.us. At the DNR home page:
– Click on "Bays and Streams"
– Click on "Streams" (upper left corner of page)
– Click on "Small Streams (MBSS)" (upper left corner of page)
– Click on "Results" (near top center of page)
– Scroll toward bottom of page and click on "Searchable data from first round MBSS"

Fish in Nontidal Streams of the Manokin River Watershed by Maryland Biological Stream Survey in 1994 and 1997															
Location			Common Name of Fish Species												
Stream	Map Key	Station (Last two digits are) (year of sampling)	American Eel	Banded Sunfish	Bluegill	Bluespotted Sunfish	Brown Bullhead	Creek Chubsucker	Eastern Mudminnow	Golden Shiner	Pirate Perch	Pumpkinseed	Redfin Pickerel	Swamp Darter	Yellow Perch
Loretto Branch	1	SO-S-021-2-94							X						
	2	SO-S-021-102-97	X	X				X	X	X	X	X	X		
	3	S0-S-021-3-94	X	X	X	X		X	X	X	X	X	X	X	
Manokin Branch	4	SO-S-018-1-94		X		X		X	X	X					
	5	SO-S-018-2-94		X		X	X	X	X	X	X	X	X		
Kings Cr.	6	SO-S-003-111-97	X	X	X			X	X	X	X	X	X	X	X

Oysters

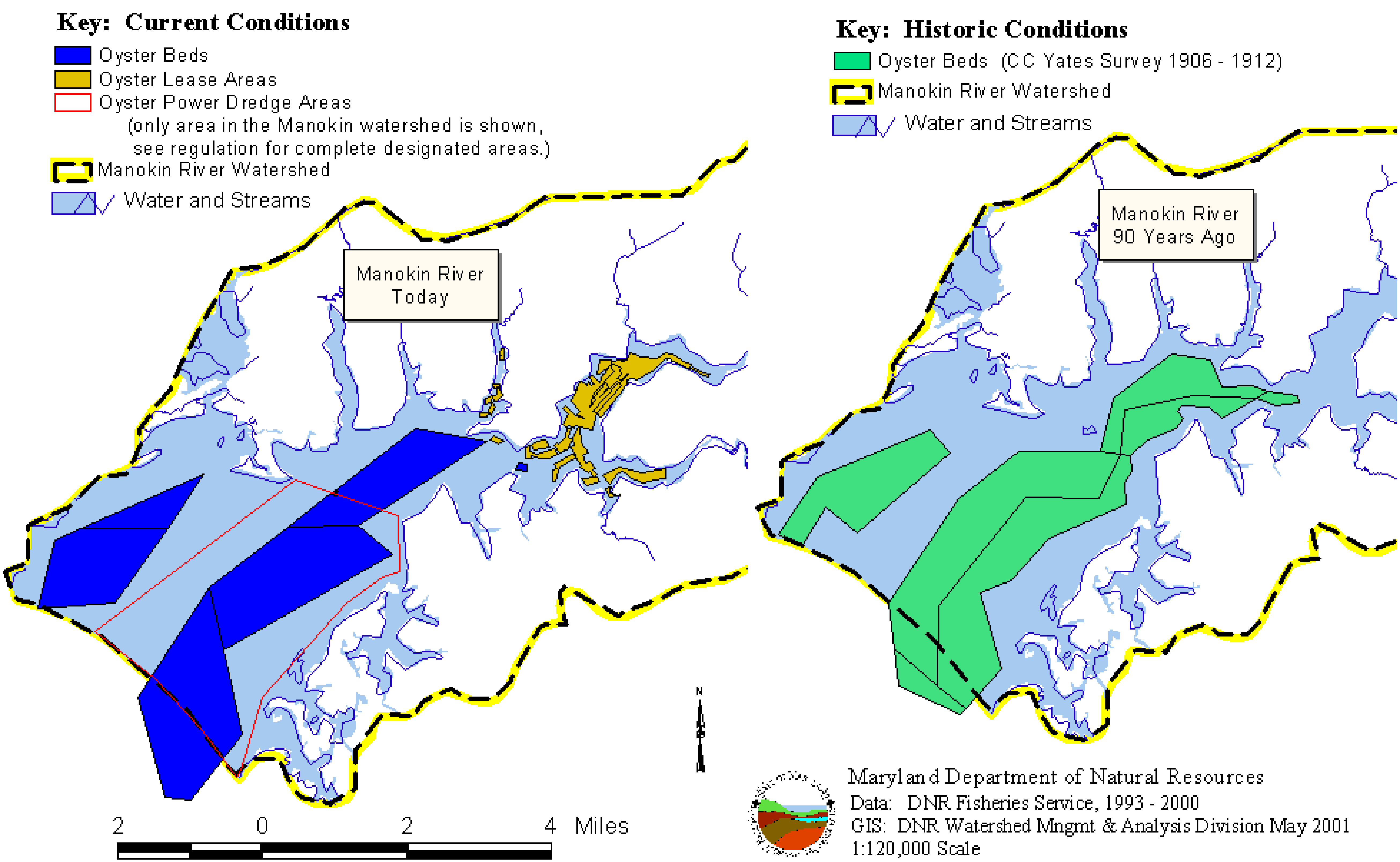
In recent decades, oyster populations in the Manokin River and the Lower Chesapeake Bay in general have declined due to a variety of stresses. These stresses include loss of habitat, disease, sedimentation, water quality problems and other factors. Manokin River oyster harvest, an indicator of oyster population status, declined from over 40,000 bushels in 1986 to just a few hundred bushels recently. The primary stress responsible is oyster disease, which in the lower Chesapeake area can yield over 50% mortality rates per year, at times as high as 80%. For comparison, the same trend is seen in nearby Tangier Sound where harvest has declined from 148,000 bushels in 1986 to about 10,000 bushels recently, also due to oyster disease. [16]

Oyster beds exist in the Manokin River as far upstream as the Fishing Point area. [16] Map 13 Oyster Beds, Leases, and Power Dredge Areas shows both current and historic oyster information for the Manokin River watershed. The historic information was provided by the Sarbanes Cooperative Oxford Lab.[19]

One objective in the new Chesapeake 2000 Agreement is to develop an oyster management strategy (by 2002) that would yield a tenfold population increase over the 1994 population by 2010.[1] In Maryland's portion of the Chesapeake Bay, focused oyster restoration efforts like oyster bar creation and placement of oyster spat are being targeted to areas with suitable bottom, salinity and disease conditions that will encourage oyster growth and survival. Such areas are generally in low salinity zones below 12 ppt, but this is not an exclusive criteria. As part of developing the Manokin River WRAS, Somerset County may elect to incorporate a goal to improving conditions for oysters locally and to request information and guidance from DNR to evaluate the Manokin River for a possible oyster restoration effort and report its findings for use in finalizing the WRAS. The Manokin River WRAS could then be updated to incorporate projects on land or water intended to enhance oyster habitat and populations. [16]

General Habitat Requirements for the American Oyster [18]	
Dissolved Oxygen Level – Minimum	1 parts per million (ppm)
pH – Optimum Range	6.75 - 8.75 for eggs and larvae
Salinity – Optimum Range	12 to 27 parts per thousand (ppt) Note: disease incidence tends to increase with higher salinity. Therefore, oyster restoration efforts focus on the low end of the oyster's salinity range.
Temperature – Optimum Range	Eggs: 19^0 C to 31^0 C Larvae: 19^0 C to 31^0 C Adults: 7^0 C to 32^0 C

Map 13
Oyster Beds, Leases and Power Dredge Areas
Manokin River Watershed



Plankton

Plankton, microscopic plants and animals that are important contributors to natural aquatic systems. Among other valuable functions, they are important food sources for fish and shellfish. In general, these organisms become a concern only with the occurance of excess population levels (blooms) or problems that they cause for resources important to people (fish kills, etc.) Fish kills can be caused by either low dissolved oxygen (as algae die and decompose) or toxic substances produced by these organisms. Other concerns linked to population imbalances (harmful algae blooms) include limiting water clarity and light penetration. Additional general information on algae species composition, macroalgae distribution , etc. is available from DNR.

1. Algae

In the Manokin River, algae populations frequently reach levels that limit or harm populations of other organisms. Algae concentrations in the Manokin River tend to be highest in the upper river around the mouth of Kings Creek. Levels vary seasonally with peaks tending to occur on July / August. (Based on chlorophyll *a* concentration 1998 through 2000.) Compared to samples collected across the Lower Eastern Shore and the Coastal Bays in 1999, the Manokin River / Kings Creek areas were among the highest algae concentrations (chlorophyll *a*) measured.[6]

As measured by chlorophyll *a* concentration, during warm months algae populations commonly exceed the 15 *u*g/L maximum that are conducive to growth of submerged aquatic vegetation (SAV). As shown in Map 5 Algae Concentrations, significant areas have experienced chlorophyll *a* concentrations above 20 mg/L during the month of May in 1999 and 2000.

Also see the Algae and *Pfiesteria* Technical Report for the Manokin River.

2. *Pfiesteria* [10]

In 1997, the Kings Creek area of the Manokin River was one of several areas of the Maryland's Lower Eastern Shore Chesapeake Bay that had reports of numerous fish with lesions. That year, presence of *Pfiesteria* was confirmed in the Manokin River water column including apparently toxic forms of the organism.

In response, the Maryland Department of Natural Resources began a monitoring program in 1998 which continued through calendar Year 2000. One of the targets for monitoring was *Pfiesteria*, a microscopic organism believed to be associated with the fish health problem. In Manokin River sediment samples collected in 1998, potentially toxic *Pfiesteria* populations were not identified.[15] In 2000, no *Pfiesteria* has been recorded in biweekly monitoring of the Manokin River between April and August 28, 2000.

Research indicates that the *Pfiesteria* organism has various life forms including both toxic and nontoxic forms. In general, areas where *Pfiesteria* has been found consistently in the water column have had relatively high nutrient and chlorophyll levels; dissolved organic nutrients are also particularly high.

Additional detail is available in the Algae and *Pfiesteria* Technical Report for the Manokin River.

Sensitive Species

Sensitive species are most widely known in the form of Federally listed Endangered or Threatened animals such as the bald eagle. In addition to these charismatic rare animals, both US Environmental Protection Agency and Maryland DNR work through their respective Federal and State programs to protect numerous endangered, threatened, or rare species of plants, animals and ecological communities of those species. Locally, sensitive species tend to become known when review of projects proposals indicates their presence. For example, Sensitive Joint Vetch within the Manokin watershed has been a factor in several development proposals, including a canoe launch in the Town of Princess Anne. [21]

For the purposes of targeting watershed restoration activities, it is valuable to account for known locations of habitat for these sensitive species. These places are often indicators, and sometimes important constituents, of the network of natural areas or "green infrastructure" that are the foundation for many essential natural watershed processes. Protecting these species and/or promoting expansion of their habitats can be an effective foundation for a watershed restoration program.

Two wetlands areas in the Manokin River watershed are designated as Wetlands of Special State Concern and have specific State regulatory protection: [24]

– Dublin Swamp includes a densely forested swamp within the Wellington Wildlife Management Area and a naturally regenerating swamp forest on private land last harvested in 1985. The removal of canopy cover (harvestable trees) created a vegetated wetland populated by a State threatened plant species. Its very limited distribution indicates that its rarity may be due to highly specific soil or hydrologic requirements (from *Ecological Significance of Nontidal Wetlands of Special State Concern*, DNR, 1991).

– The Princess Anne Wetlands are located along the Manokin River and its headwater tributaries including Loretta Branch, Taylor Branch and Jones Creek.

1. Habitat Protection Categories

One way to characterize a watershed for sensitive species is to identify known habitat locations using several broad categories employed by DNR's Wildlife and Heritage Division. The following table and map summarize this information. Based on this general information, more detailed information and guidance can be requested from Division staff.

The two of the three categories used to help protect sensitive species during review of applications for a State permit or approval or involve State funds are found in the Manokin River Watershed. For projects potentially affecting these areas, the State permit or approval will include recommendations and/or requirements to protect sensitive species and their habitat. In addition, many counties have incorporated safeguards for these areas into their permit review process. Map 14 Sensitive Species shows the relative locations of these areas.

These categories do not place requirements on any activities that do not require a permit or approval or involve State funds. However, there are State and Federal restrictions that address "takings" of protected species that apply more broadly. In addition, property owners are encouraged to seek advice on protecting the sensitive species / habitat within their ownership.

2. Rare Fish and Mussels

In the Manokin River watershed, the Kings Creek subwatershed received a "moderately high" ranking in comparison to the more than 1000 small (12-digit) watersheds identified by DNR in the Maryland. The other "12-digit" subwatersheds within the Manokin watershed were ranked "neutral" in the same assessment. These findings are part of DNR's recent project to rank watersheds across Maryland to aid in targeting conservation and restoration efforts to benefit known populations of rare fish and mussels. Map 14 Sensitive Species shows the distribution of the ranking.

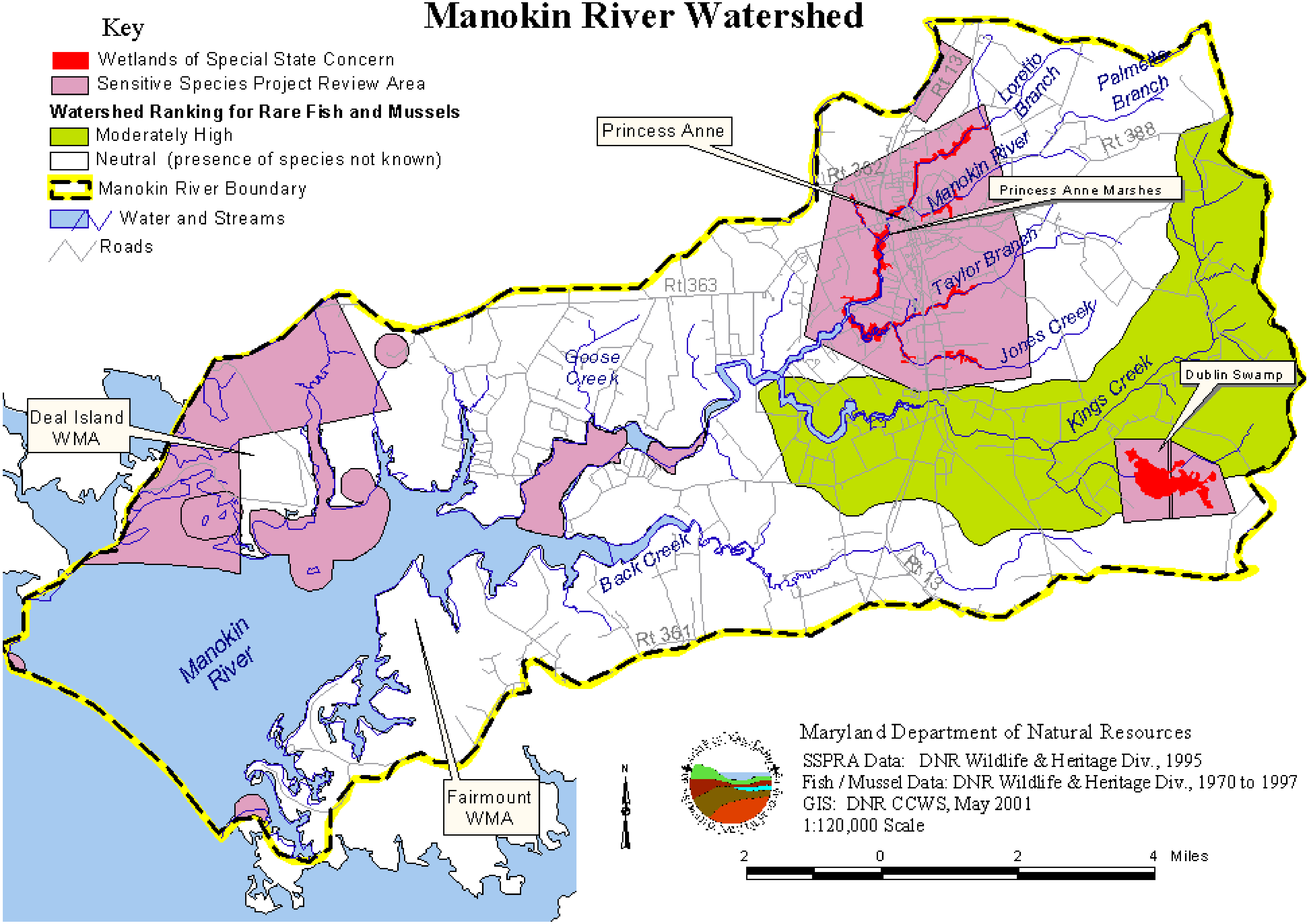
In general, higher ranking suggests that restoration or conservation projects in these areas may have greater potential to protect aquatic species diversity. Projects could be used to protect, enhance or expand existing aquatic habitat. A ranking of neutral indicates that information is insufficient. (It does not mean absence of these species or low priority.) In neutral ranked areas, it is reasonable to rely on other available criteria for targeting watershed conservation and restoration projects.

This ranking considers information from 1970 to 1997 only for rare species of fish or mussels being tracked in Maryland. Four possible ranks were used for this project: Very High, High, Moderately High and Neutral. Each rare species being tracked contributed to this ranking based on two types of criteria: 1) presence or absence, and 2) if present, weighting relative rarity on worldwide and Statewide scales.

Maryland's Sensitive Species Protection Categories

Sensitive Species Project Review Area (SSPRA)	Natural Heritage Area (NHA)	Wetlands of Special State Concern (WSSC)
At least eight SSPRAs are identified in the Manokin River watershed. Each SSPRA contains one or more sensitive species habitats. However, the entire SSPRA is not considered sensitive habitat. The SSPRA is an envelop identified for review purposes to help ensure that applications for permit or approval in or near sensitive areas receive adequate attention and safeguards for the sensitive species / habitat they contain. At least one SSPRA compasses each NHA and WSSC. Also see Map 14 Sensitive Species.	No NHAs are located in the Manokin River watershed. NHAs are rare ecological communities that encompass sensitive species habitat. They are designated in State regulation COMAR 08.03.08.10. For any proposed project that requires a State permit or approval that may affect an NHA, recommendations and/or requirements are placed in the permit or approval that are specifically aimed at protecting the NHA.	There are two WSSCs designated in the Manokin River watershed: 1) Princess Anne Wetlands 2) Dublin Swamp. These wetlands are associated with one or more sensitive species habitats that are in or near the wetland. For any proposed project that requires a wetland permit, these selected wetlands have additional regulatory requirements beyond the permitting requirements that apply to wetlands generally. For a listing of designated sites see COMAR 26.23.06.01

Map 14 Sensitive Species
Manokin River Watershed



Submerged Aquatic Vegetation

The well-defined link between water quality and submerged aquatic vegetation (SAV) distribution/abundance make SAV communities good barometers of the health of estuarine ecosystems. SAV is important not only as an indicator of water quality, but it is also a critical nursery habitat for many estuarine species. For example, blue crab "post-larvae" are up to 30 times more abundant in SAV beds than adjacent unvegetated areas. Additionally, several species of waterfowl depend on SAV for food when they over-winter in the Chesapeake region.

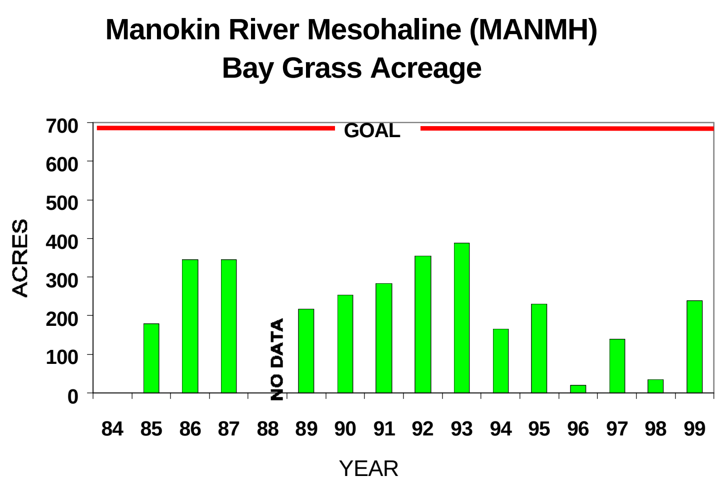
The Chesapeake 2000 Agreement calls for protecting and restoring 114,000 acres of SAV. It also calls for implementing a strategy (by 2002) to accelerate protection and restoration of SAV beds and for revising SAV restoration goals by 2002, including specific levels of water clarity and strategies to achieve the goals by addressing water clarity, water quality and bottom disturbance.

1. Criteria for Tracking SAV

The Chesapeake Bay Program has developed new criteria for determining SAV habitat suitability of an area based on water quality. The measurement called "Percent Light at Leaf" assesses the amount of available light reaching the leaf surface of SAV after being reduced in the water column and by epiphytic growth on the leaves themselves. The document describing this new model measuring SAV habitat suitability is found on the Chesapeake Bay Program [27] (www.chesapeakebay.net under publications search for SAV). The older "Habitat Requirements" of five water quality parameters are still used for diagnostic purposes. Re-establishment of SAV is measured against the "Tier 1 Goal", an effort to restore SAV to any areas known to contain SAV from 1971 to 1990.

2. Manokin River Assessment [11]

Abundance of SAV around the Chesapeake Bay has been slowly increasing since the middle 1980's. However, this trend is not readily apparent in the Manokin River area. Based on data collected by the Virginia Institute of Marine Science, SAV acreage in the Manokin River has been fluctuating since 1984 with peak acreage occurring in 1993 as the adjacent graph shows.

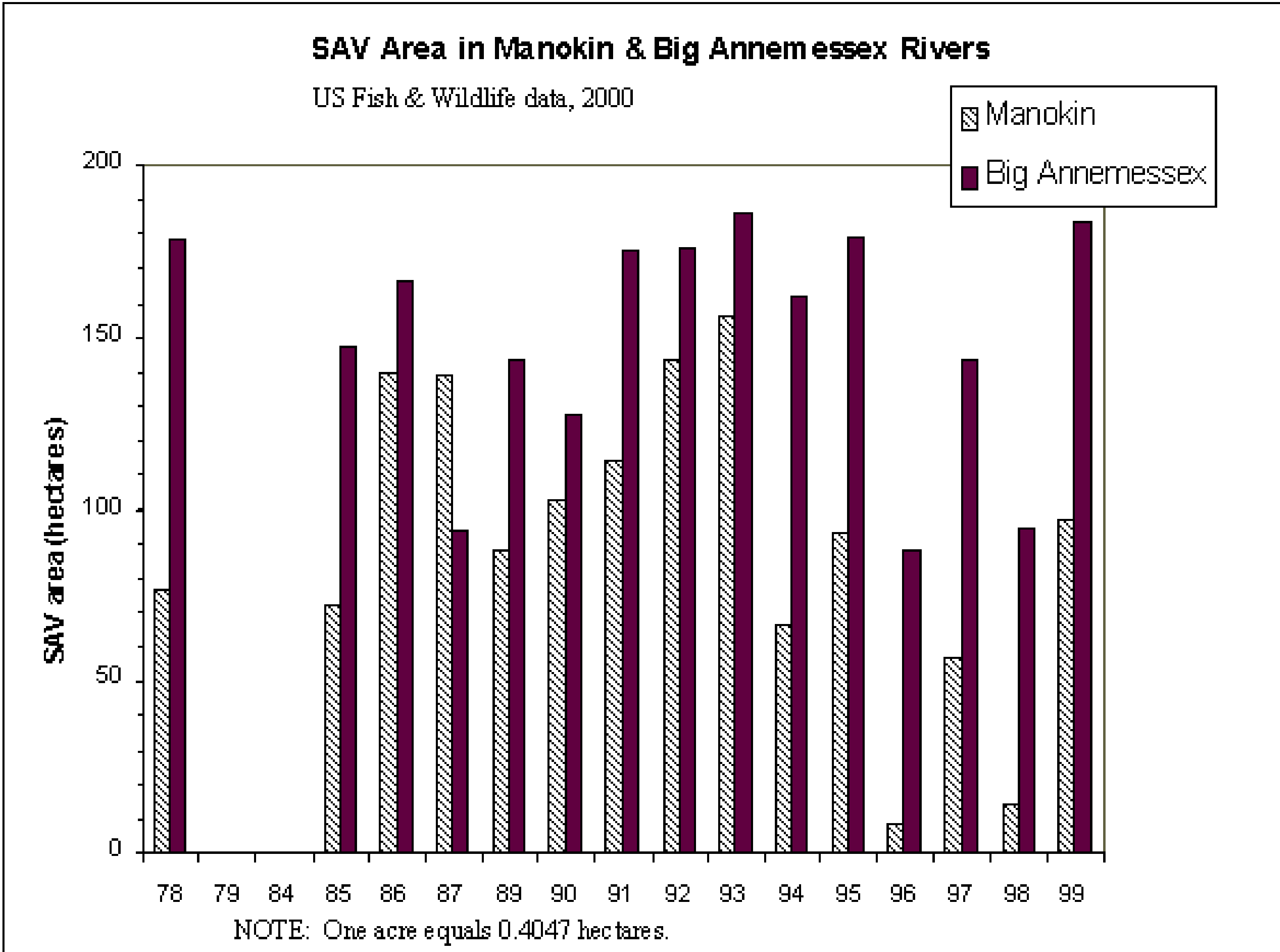


A comparison of SAV coverage by the US Fish and Wildlife Service for the Manokin River and Annemessex River adjacent to it on the south offers some additional insight. The Chart - SAV Area in Manokin & Big Annemessex Rivers shows that between 1978 and 1999, both rivers exhibited great fluctuations in SAV area. However, with the exception of 1987, the Manokin has fostered significantly less SAV than the Annemessex. In August 2000 a Chesapeake Bay Program report considering data from 1992 through 1997 identified the Manokin River as failing SAV-related requirements while the Big Annemessex passed the same requirements for the same time period. [28]

SAV coverage in 1999 for the Manokin River watershed was approximately 35% of the 2005 interim goal of 683 acres set by the Chesapeake Bay Program. This interim goal is based on restoration of SAV to areas currently or previously inhabited by SAV as mapped through regional and baywide surveys from 1971 to 1990.

The SAV species found in the Manokin River area is *Ruppia maritima* - Widgeon grass. SAV beds are concentrated along the Manokin northern shore in Lower Thorofare, Laws Thorofare, and Big Sound, Little Sound, Broad, and Geanquakin creeks. On the southern shore, SAV beds were mapped in Drum Point Cove and Teague, Goose, and Mine Creeks.

The most current SAV information is available at the Virginia Institute of Marine Science website www.vims.edu/bio/sav . DNR's MERLIN Internet site www.mdmerlin.net has maps of SAV beds by County for each year 1984 through 1996.


SAV Area in Manokin & Big Annemessex Rivers
US Fish & Wildlife data, 2000
Manokin
Big Annemessex
SAV area (hectares)
200
150
100
50
0
78
79
84
85
86
87
89
90
91
92
93
94
95
96
97
98
99
NOTE: One acre equals 0.4047 hectares.

RESTORATION TARGETING TOOLS

2000/2001 Stream Corridor Assessment

Using the Stream Corridor Assessment Methodology (SCAM) developed and applied by the DNR Watershed Restoration Division, additional valuable information can be compiled to assist in targeting restoration activities. In partnership with Somerset County, DNR is conducting a Stream Corridor Assessment in the Manokin River watershed during winter 2000/2001. Trained teams from the Maryland Conservation Corps will walk along streams to identify and document potential problems and restoration opportunities such as inadequate stream buffers, erosion, etc.

A report will be generated, including maps and photographs, to support targeting decisions for restoration projects. Draft data summaries are expected to be available in Summer 2001 with a final report by December 2001. The data from this assessment will provide an important companion report for this watershed characterization and will be used in development of the Watershed Restoration Action Strategy.

Clean Marinas

Overboard discharges of sewage from boats are a concern for water quality because they contribute nutrients, biological oxygen demand, pathogens, etc. These discharges are preventable if a sufficient number of pumpout facilities are locally available and boat operators take advantage of these services.

Records in DNR indicate that one marina is located in the Manokin River watershed. There are no boat pumpout facilities available in the watershed and there are no participants in Maryland's Clean Marina Program. The Clean Marinas Program is voluntary way for marina owners to demonstrate that their pumpout service and other high quality boating services provided in accordance with Program guidelines are helping keep local waters cleaner.

One potential element of a Watershed Restoration Action Strategy (WRAS) is to encourage and/or support adding marina pumpout facilities serving the local area and increasing participation in the Clean Marina Program.

Fish Blockages

Many fish species need to move from one stream segment to the next in order to maintain healthy resilient populations. This is particularly true for anadromous fish species because they spawn and hatch from eggs in free flowing streams but live most of their lives in estuarine or ocean waters. Blockages in streams can inhibit or prevent many fish species from moving up stream to otherwise viable habitat.

To help prioritize stream blockages for mitigation or removal, the DNR Fish Passage Program maintains a database of significant blockages to fish movement. The database has no listings for fish blockages in the Manokin River watershed. However, blockages to fish movement will likely be identified during the stream corridor assessment and new information will be added to the database. With this information, Somerset County can determine if fish blockage is an issue to be addressed in the Manokin River WRAS.

Stream Buffer Restoration

1. Benefits and General Recommendations

Natural vegetation in stream riparian zones act as stream buffers that can provide numerous valuable environmental benefits:

- Reducing surface runoff
- Preventing erosion and sediment movement
- Using nutrients for vegetative growth and moderating nutrient entry into the stream
- Moderating temperature, particularly reducing warm season water temperature
- Providing organic material (decomposing leaves) that are the foundation of natural food webs in stream systems
- Providing overhead and in-stream cover and habitat
- Promoting high quality aquatic habitat and diverse populations of aquatic species.

To realize these environmental benefits, DNR generally recommends that forested stream buffers be at least 100 feet wide , i.e. natural vegetation 50 feet wide on either side of the stream. Therefore, DNR is promoting this type of stream buffer for local jurisdictions and land owners who are willing to go beyond the minimum buffers standards. The DNR Watershed Restoration Division and other programs like CREP are available to assist land owners who volunteer to explore these opportunities.

Additionally, Somerset County Representatives have expressed interest in exploring the potential for mitigation banking. The stream buffer restoration targeting tools described in this section could also be used help explore potential mitigation banking sites in order to maximize multiple benefits like nutrient retention or wetland enhancement.

2. Using GIS

Identifying the areas in a watershed that could benefit from stream buffer restoration and prioritizing them for projects is often a time-consuming expensive effort. Fortunately, use of a computerized Geographic Information System (GIS) to manipulate remote sensing data can help save limited time and funds. To assist in this technical endeavor, DNR Watershed Management and Analysis Division has developed GIS-based tools to assist in the buffer restoration targeting process. With these tools, GIS maps and other information can be generated to help select stream segments for additional Stream Corridor Assessment, to identify geographic areas for community and land owner contact and for similar uses. Then, with an appropriate level of on-the-ground verification or "ground truthing," these GIS tools can provide an efficient first step toward stream buffer restoration.

Several scenarios are presented here to help consider potential areas for stream buffer restoration. These scenarios can be used alone or in combination as models for targeting potential restoration sites for field verification. These maps are intended to demonstrate a methodology that can be used to locate sites having a high probability of optimizing certain ecological benefits. The resolution of the data used to generate these maps is not sufficient for an accurate site assessment, but can be used to identify potential candidate sites for detailed investigation. The streams presented in the maps are "blue line streams" as generally shown on US Geological Survey Quadrangle Maps. Intermittent streams were not considered in the stream buffer scenario maps.

3. Headwater Stream Buffers

Headwater streams are also called First Order Streams. These streams, unlike other streams (Second Order, etc.), intercept all of the surface runoff within the watersheds that they drain. In addition, for many watersheds, first order streams drain the majority of the land within the entire watershed. Therefore, stream buffers restored along headwater streams (First Order) tend to have greater potential to intercept nutrients and sediments than stream buffers placed elsewhere. In targeting stream buffer restoration projects, giving higher priority to headwater streams is one approach to optimizing nutrient and sediment retention.

Restoring headwater stream buffers can also provide habitat benefits that can extend downstream of the project area. Forested headwater streams provide important organic material, like decomposing leaves, that "feed" the stream's food web. They also introduce woody debris which enhances in-stream physical habitat. The potential for riparian forest buffers to significantly influence stream temperature is greatest in headwater regions. These factors, in addition to positive water quality effects, are key to improving habitat for aquatic resources.

4. Land Use and Stream Buffers

One factor that affects the ability of stream buffers to intercept nonpoint source pollutants is adjacent land use. Nutrient and sediment loads from different land uses can vary significantly. As the following table indicates, crop land typically contributes the greats nutrient and sediment loads. However, under some conditions urban land can contribute higher phosphorus loads.

By identifying land uses in riparian areas with inadequate stream buffers, like crop land adjacent to streams, potential to reduce nutrient and sediment loads can be improved. To assist in finding areas with crop land adjacent to streams, the same land use data shown in Map 7 1997 Generalized Land Use can be filtered using GIS. The new scenario shown in the Map 15 Land Use Scenario for Stream Buffer Restoration focuses on the land use within 150 feet of a stream. This view, supplemented with the land use pollution loading rates, suggests potential buffer restoration opportunities that could maximize nutrient and sediment loads.

Nonpoint Source Pollution Load Rates By Land Use
Chesapeake Bay Watershed Model, in kg/ha-yr

Land Use		Nitrogen	Phosphorus	Sediment
Crop land		17.11	1.21	0.74
Urban	Impervious	8.43	0.58	0.00
	Pervious	10.79	1.56	0.20
Pasture		8.40	1.15	0.30
Forest		1.42	0.00	0.03

5. Nutrient Uptake from Hydric Soils in Stream Buffers

In general, the nutrient nitrogen moves from the land into streams in surface water runoff and in groundwater. In watersheds like the Manokin River, a significant percentage of nitrogen enters streams in groundwater. Stream buffer restoration can be used to capture nitrogen moving in groundwater if buffer restoration projects have several attributes:

– Plants with roots deep enough to intercept groundwater as it moves toward the stream
– Plants with high nitrogen uptake capability, and
– Targeting buffer restoration projects to maximize groundwater inception by buffer plants.

Hydric soils in stream riparian areas can be used as one factor to help select stream buffer restoration sites. Siting buffer restoration on hydric soils would offer several benefits:

– Plant roots are more likely to be in contact with groundwater for longer periods of time
– Hydric soils tend to be marginal for many agricultural and urban land uses
– Natural vegetation in wet areas often offer greater potential for habitat.

Map 16 Nutrient Retention Using Hydric Soils Scenario identifies lands adjacent to streams that are on hydric soil in the Manokin River watershed. An important next step in using this information is verification of field conditions. Care must be taken during field validation to evaluate any hydrologic modification of these soils, such as ditching or draining activities, which would serve to decrease potential benefits.

A refinement of this approach appears in Map 17 Nutrient Retention Using Hydric Soils Associated With Cropland Scenario. This map suggests shows only hydric soils adjacent to streams on open land which is generally fields in the Manokin River watershed. In cooperation with interested land owners, stream buffer restoration in the areas highlighted on the map are likely to offer the greater reduction of nutrients and sediment entering streams than restoration of buffers elsewhere.

6. Wetland Associations

Wetlands and adjacent natural uplands form complex habitats that offer a range of habitat opportunities for many species. These "habitat complexes" tend to offer greater species diversity and other ecological values that are greater than the values that the wetland or uplands could offer independently. Therefore, restoring stream buffers adjacent to or near to existing wetlands tends to offer greater habitat benefits than the restoration project could otherwise produce. Map 18 Wetland Proximity Scenario for Stream Buffer Restoration identifies unforested buffers zones that are in close proximity (within 300 feet) to wetlands (National Wetlands Inventory). Restoration projects in these areas may offer opportunities to enhance and expand wetland habitat in addition to the other desirable buffer functions.

7. Optimizing Benefits by Combining Priorities

Strategic targeting of stream buffer restoration projects can take into account many different potential benefits. Several of these scenarios are presented independently in this section. However, site selection and project design generally incorporates numerous factors to optimize benefits from the project. For example, finding a site with a mix of attributes like those in the following list could result in the greatest control of nonpoint source pollution and enhancement for living resources:

– land owner willingness / incentives
– marginal land use in the riparian zone
– headwater stream
– hydric soils
– selecting appropriate woody/grass species
– adjacent to existing wetlands / habitat

Two of the many ways to integrate targeting criteria to help identify candidate sites for additional investigation are shown here. One example is shown on Map 17 Nutrient Retention Using Hydric Soils Associated With Cropland Scenario. This map suggests potential stream buffer restoration areas that are likely to offer the greatest opportunity to reduce both nutrients and sediment entering the stream. Another example shown in Map 19 Prioritizing Streams Scenario prioritizes stream segments based on lack of adequate naturally vegetated buffers, land use adjacent to the stream and headwater stream status.

Wetland Restoration

Wetlands serve important environmental functions such as providing habitat and nursery areas for many organisms, nutrient uptake and recycling, erosion control, etc. However, most watersheds in Maryland have significantly fewer wetland acres today than in the past. This loss due to draining, filling, etc. has led to habitat loss and water quality impacts in streams and in the Chesapeake Bay. Reversing this historic trend is an important goal of wetland restoration. One approach to identifying candidate wetland restoration sites involves identifying "historic" wetland areas based on the presence of hydric soils. This process can be accelerated by using GIS to manipulate soils information with other data like land use. The GIS products can then assist in initiating the candidate site search process, targeting site investigations and helping to identify land owners. To promote wetland restoration, DNR Watershed Management and Analysis Division has developed GIS capability for these purposes.

In discussions between Somerset County and DNR representatives, several concerns that need to be considered in targeting of potential wetland restoration projects:

– Conversion of productive farmland is not appropriate.
– Prioritization focused on "wetter" hydric soils is desirable.
– Consistency with the County Comprehensive Plan, etc. is essential.

For the Manokin River watershed, an initial step toward targeting used GIS to map and prioritize areas of hydric soil to support a more thorough review of potential wetland restoration areas. The steps and priorities used to generate the map are listed below:

– Data used: Hydric soils (identified using Natural Soil Groups), existing wetlands (based on the National Wetlands Inventory), land use (Maryland Department of Planning 1997 data), DNR land ownership (using DNR 2000 data).
– Identify candidate hydric soil areas based on land use. Hydric soils on open land (agricultural fields, bare ground, etc.) are retained while those underlying natural vegetation and developed lands are excluded.
– Explore hydric soils based on proximity to existing wetlands or streams. In the Manokin watershed, hydric soils are so pervasive, that extensive hydric soil areas are adjacent to wetlands.
– Identify hydric soils areas on public lands. DNR is the only significant owner of public land in the Manokin watershed.

Map 20 Wetland Restoration Opportunities highlights at least twenty hydric soil areas on open DNR land. This number is small enough that on-site investigation can reasonably assess the viability of each area as a wetland restoration candidate. In addition, a few of the DNR land opportunities appear to be adjacent to streams which suggests that they may offer multiple habitat benefits if wetlands were to be restored there.

The map also shows that extensive areas of hydric soils on open land in the Manokin watershed are privately owned. If assessments of private land for wetland restoration are desirable, identifying land owners (via GIS) and willing cooperators (via direct contact), may be appropriate.

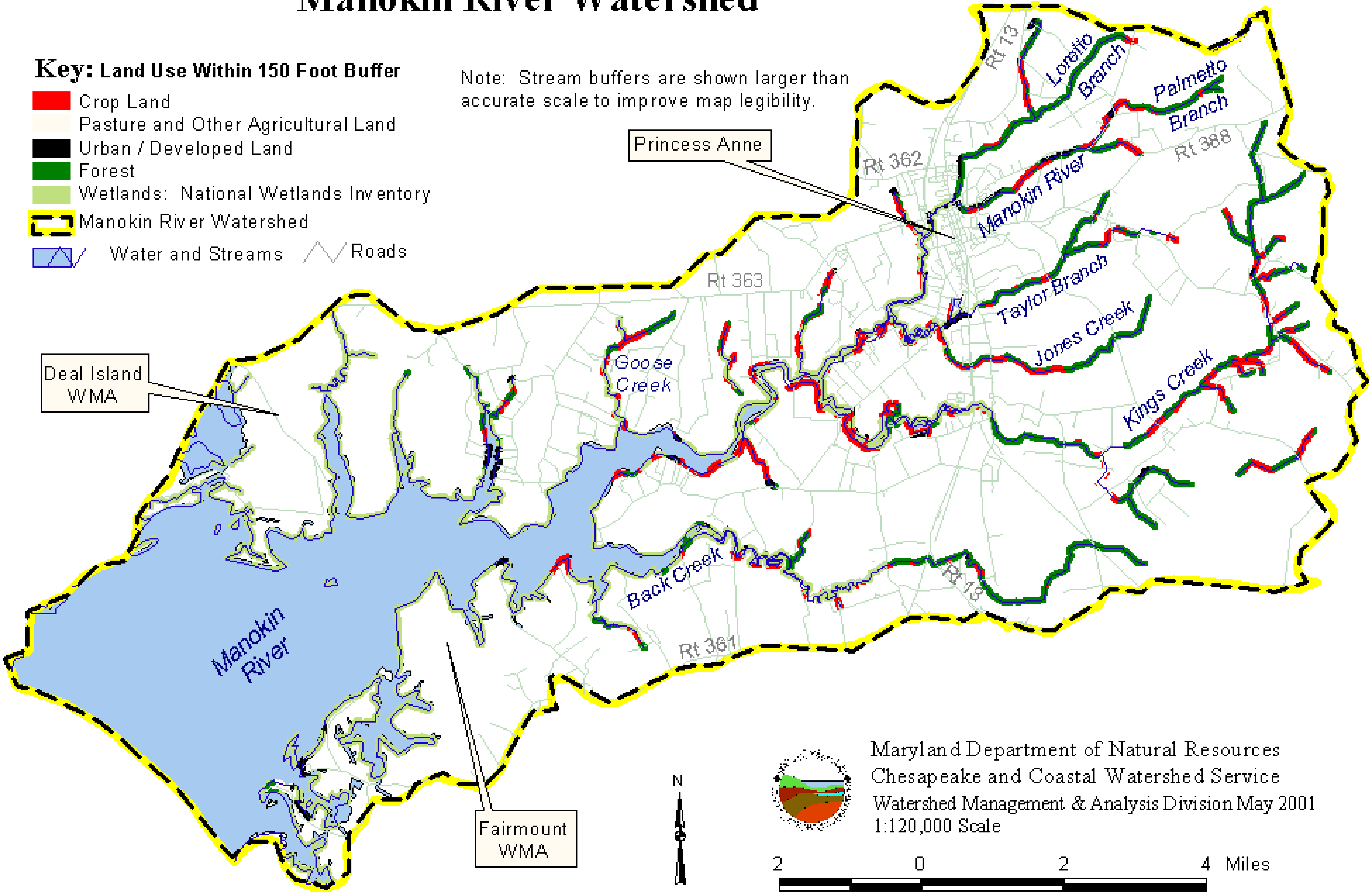
Based on the analysis above, the following priorities for further assessment are offered:

-- Highest Priority: Hydric soils on open DNR land adjacent to streams

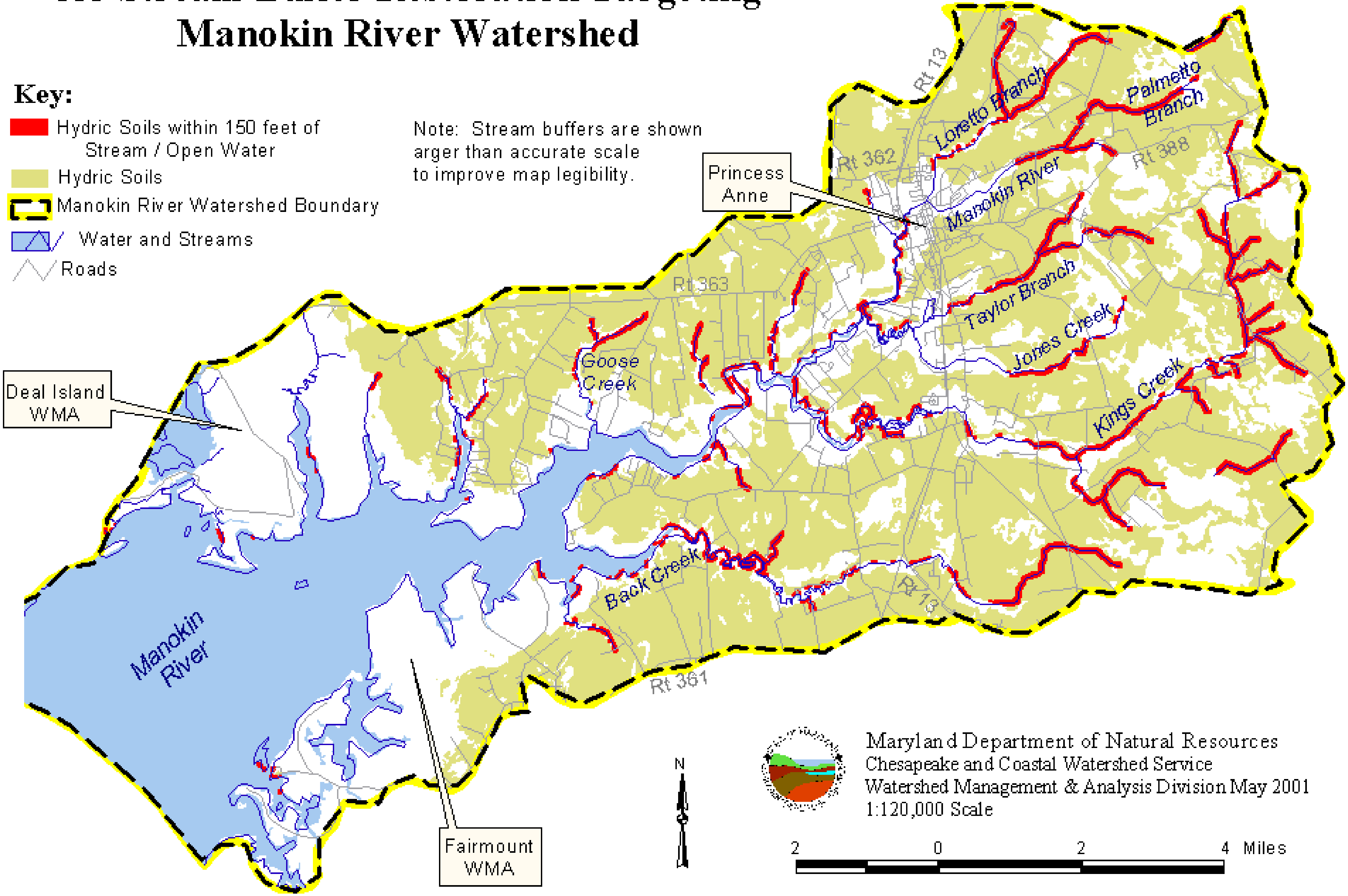
-- High Priority: All other hydric soils on open DNR land

-- Mid Priority: In addition to considering proximity to wetlands and streams, identify private land owners who are interested in cooperating.

Map 15 Land Use Scenario for Stream Buffer Restoration
Manokin River Watershed

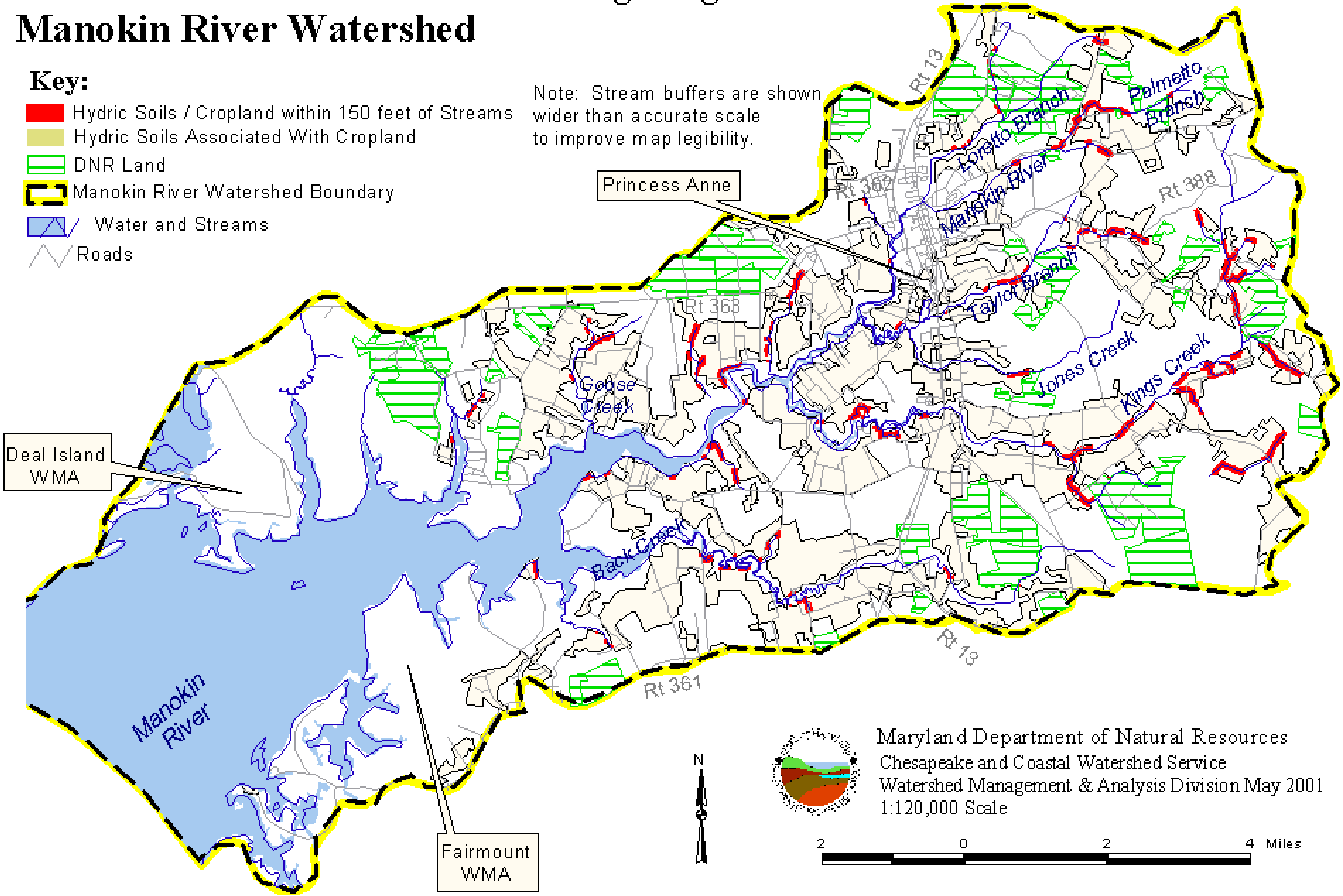


Map 16
Nutrient Retention Using Hydric Soils Scenario for Stream Buffer Restoration Targeting Manokin River Watershed

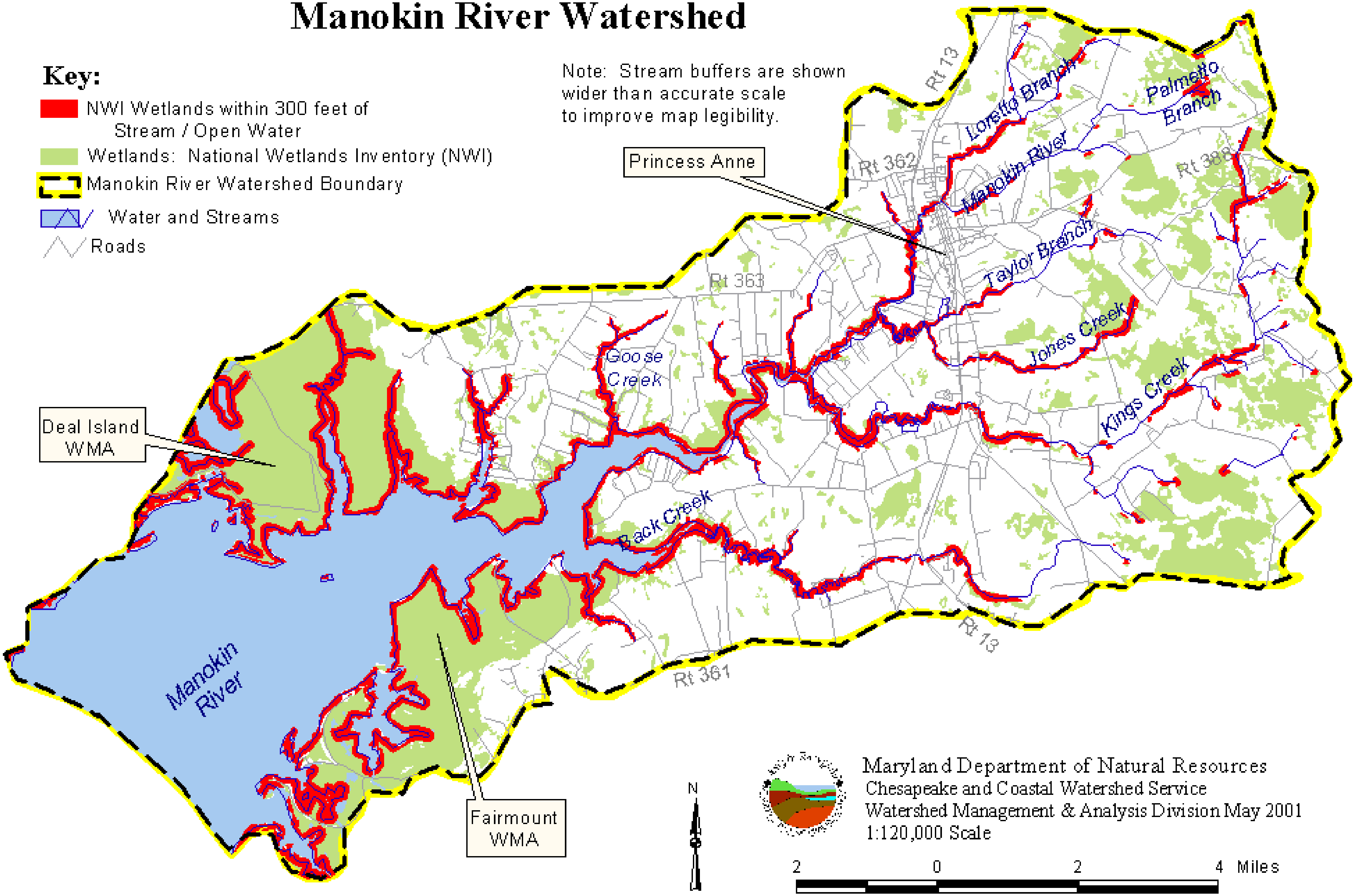


Maryland Department of Natural Resources
Chesapeake and Coastal Watershed Service
Watershed Management & Analysis Division May 2001
1:120,000 Scale

Map 17
Nutrient Retention Using Hydric Soils Associated With Cropland Scenario for Stream Buffer Restoration Targeting Manokin River Watershed

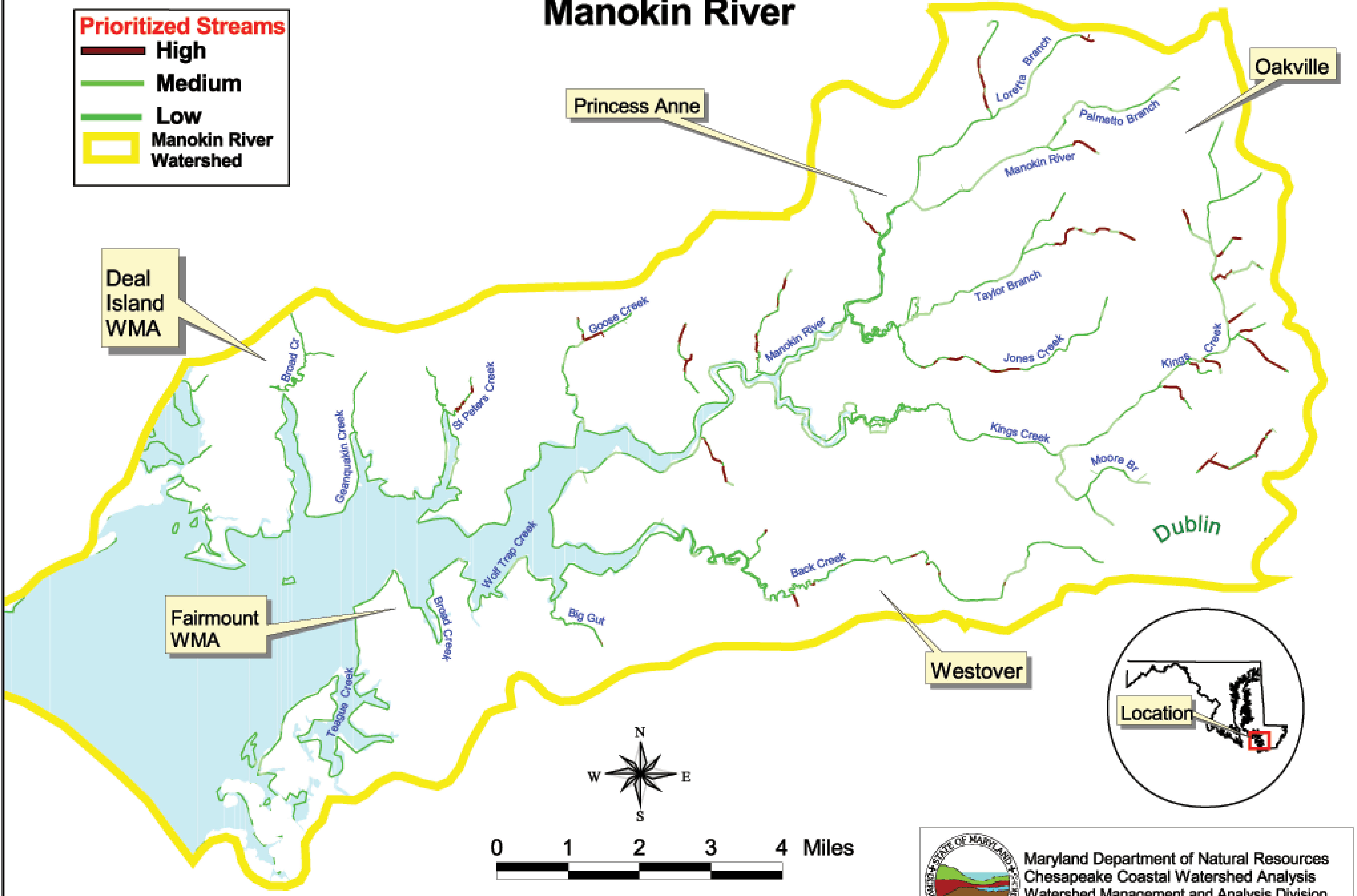


Map 18
Wetland Proximity Scenario for Stream Buffer Restoration
Manokin River Watershed



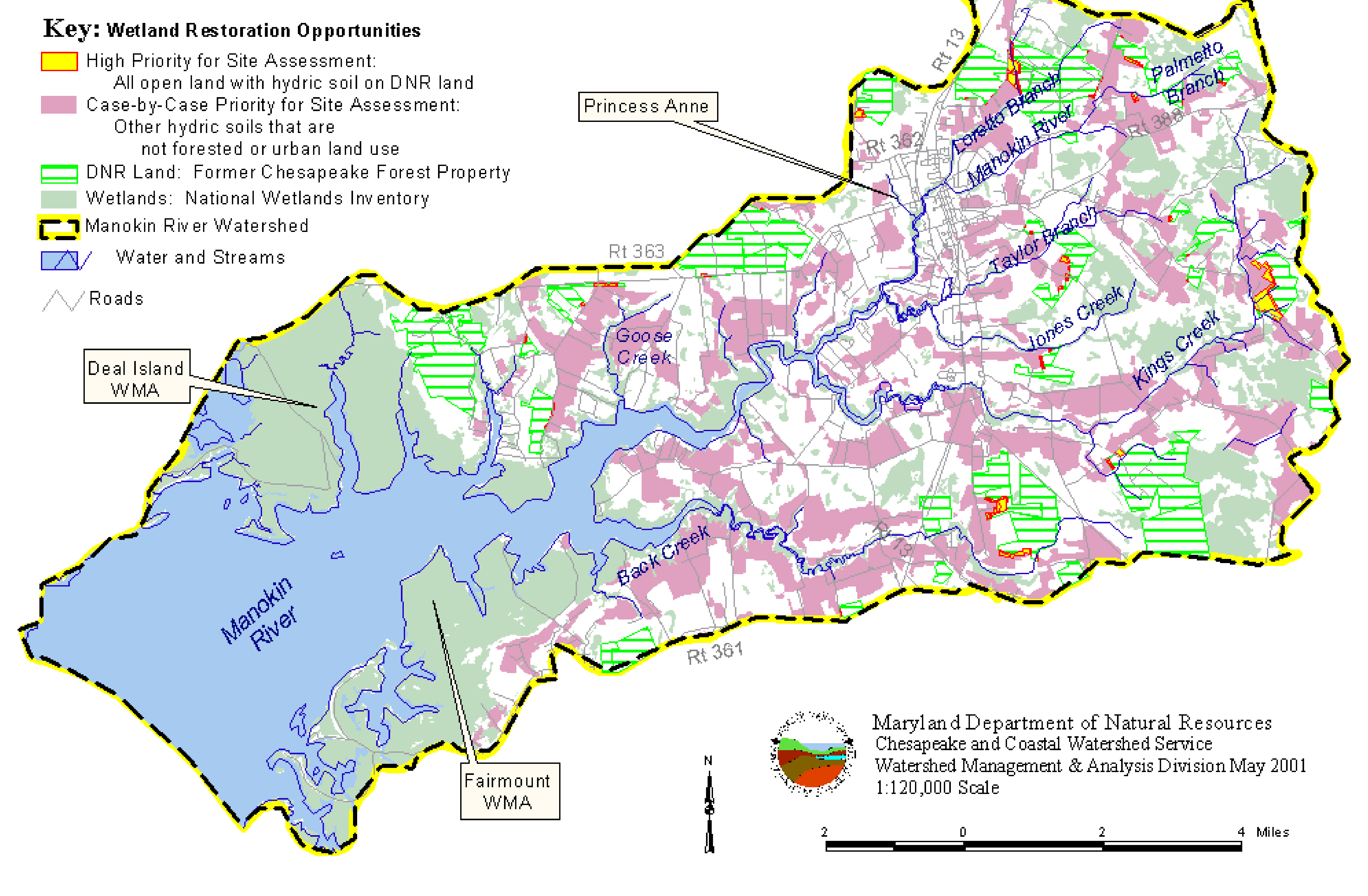
Map 19

Stream Prioritization Scenario Manokin River



Maryland Department of Natural Resources
Chesapeake Coastal Watershed Analysis
Watershed Management and Analysis Division

Map 20
Manokin River Watershed in Somerset County
Wetland Restoration Opportunities



RELATED PROJECTS TO THE WRAS PROCESS

Overview

There are numerous projects and programs that have the potential to contribute to successful development and implementation of a Watershed Restoration Action Strategy (WRAS). Some of these projects and programs are listed here to suggest opportunities for cooperation and coordination that can improve the likelihood of success for the WRAS. While this listing is not all-inclusive, additions should be made to include important related projects and follow-up should continue to be undertaken to promote the WRAS process with these and other projects and programs.

319(h)-Funded Projects

No 319(h)-funded projected are currently located in the Manokin River watershed.

Other Projects

This section summarizes projects that have the potential to contribute to development and implementation of the Watershed Restoration Action Strategy that have not been addressed elsewhere in the watershed characterization.

Conservation Reserve Program (CRP). The CRP program pays farmers on a per acre basis to remove fields from production. One of numerous benefits from the program is reduction of sediment and nutrient movement into streams.

Conservation and Restoration Enhancement Program (CREP). The CREP program reimburses farmers who restore stream riparian areas to natural vegetation. Under the program, this land creates new or enhanced stream buffer which is placed under a conservation easement.

The Year 2000 edition of the **Maryland Greenways Atlas** identifies Greenway and Green Infrastructure projects and issues important to Somerset County and the Manokin River watershed. A conceptual framework is already in place to develop a Greenway between the University of Maryland Eeastern Shore campus and Raccoon Point Park.

POTENTIAL BENCHMARKS FOR WRAS GOAL SETTING

Several programs designed to manage water quality and/or living resources have existing or proposed goals that are relevant to setting goals for the Manokin River Watershed Restoration Action Strategy (WRAS). The goals from these other programs tend to overlap and run parallel to potential interests for developing WRAS goals. Therefore, to assist in WRAS development, selected goals from other programs are included here as points of reference.

Chesapeake Bay 2000 Agreement

Numerous goals and objectives applicable to the Manokin River watershed are presented in a Baywide context. References to the 2000 Agreement appear in numerous sections of the Manokin River Watershed Characterization. (The Agreement is available via the Internet. See Additional Information reference #1 for internet viewing directions.)

Clean Water Action Plan [3]:

– Clean Water Goals - Maryland watersheds should meet water quality standards, including numerical criteria as well as narrative standards and designated uses.

– Other Natural Resource Goals - Watersheds should achieve healthy conditions as indicated by natural resource indicators related to the condition of the water itself (e.g. water chemistry), aquatic living resources and physical habitat, as well as landscape factors (e.g. buffered streams and wetland restoration).

Total Maximum Daily Loads for the Manokin River [4]:

– Assure that a minimum dissolved oxygen level of 5 mg/l is maintained throughout the Manokin River system.

– Reduce peak chlorophyll *a* levels (a surrogate for the biomass of algal blooms) to below 50 *u*g/l.

Chesapeake Bay Program (will likely be revised in 2002)

– By the Year 2005,reach SAV coverage of 683 acres in the Manokin River watershed. (This interim goal is based on restoration of SAV to areas currently or previously inhabited by SAV as mapped through regional and bay-wide surveys form 1971 to 1990.)

Water Quality Improvement Act of 1998

– The most significant feature is requiring nutrient management plans for virtually all Maryland farms. The requirement is being phased in over a several year period:
  - Nitrogen-based plan implementation will be required in 2002
  - Phosphorus-based plan implementation will be required in 2005

– Assistance with costs of manure transportation has the potential to move nutrients to sites where they are needed.

ADDITION INFORMATION

Sources of Information for Manokin River Watershed Characterization

1. DNR. *Internet Site: www.dnr.state.md.us* May 2001. Some source areas from the site:
   - -- Manokin River Watershed documents online:
     click Bays and Streams, then Watersheds, then Surf Your Watershed;
   - – Chesapeake Bay 2000 Agreement www.dnr.state.md.us/bay/tribstrat/index.html , then
     click on The New Bay Agreement, then in the feature article, click on "Chesapeake Bay Agreement."
   - -- Tributary Strategy:
     click on Bays and Streams / Chesapeake Bay / Tributary Strategies;
   - -- Stream Survey info., click on Bays and Streams, then on Streams, then on Md Biological Stream Survey;
   - -- Data and Publications:
     click on IRC *the library,* then on either Publications or then on Data;

2. DNR. *Maryland Water Quality Inventory, 1993-1995.* December 1996.

3. Clean Water Action Plan Technical Workgroup. *Maryland Clean Water Action Plan.* December 1998. (Available in electronic form, see 1.)

4. MDE. *Draft Total Maximum Daily Loads of Nitrogen, Phosporus, and Biological Oxygen Demand for the Manokin River, Somerset County, Maryland.* Maryland Department of the Environment. March 2000.
   And
   Total Maximum Daily Loads of Nitrogen and Biological Oxygen Demand for the Manokin River, Somerset County, Maryland. Maryland Department of the Environment. February 13, 2001.
   See www.mde.state.md.us/tmdl/ for electronic copies of the final TMDL and related documents. On this web page, scroll down to "Current Status of Maryland's TMDL Program." Then click on "Final, Approved TMDLs."

5. DNR. *Water Quality, Habitat and Biological Conditions of River Systems Affected by Pfiesteria or Pfiestria-like Organisms on the Lower Eastern Shore of Maryland: 1997 Summary.* July 1998.

6. Magnien, R.E., D Goshorn, B. Michael, P Tango and R. Karrh. *Associations between pfiesteria, Fish Health and Environmental Conditions in Maryland.* DNR. April 2000.

7. MDE. *Maryland's Lower Delmarva Peninsula 1998 Data Report.* Pages 47 through 56. Also see the Internet site www.mde.state.md.us/tmdl/

8. Maryland Greenways Commission. *The Maryland Atlas of Greenways, Water Trails and Green Infrastructure 2000 Edition.* August 2000.

9. Department of State Documents Internet Site

10. Tango, Peter. DNR Living Resource Assessment Program. Dr. Tango's technical summary is included in its entirety in Appendix B. September 2000.

11. Parham, Thomas. Summary text generated specifically for this report. DNR Submerged Aquatic Vegetation Restoration Program. August 2000.

12. Karrh, Renee. Personal communication on 1999 data for status/trends. DNR RAS Biomonitoring Analysis Section. Sept. 2000.

13. Klauda, Ron. Personal communication with Katharine Dowell. Monitoring and Non-Tidal Assessment Program, DNR RAS. July 2000 through November 2000.

14. DNR. *State of Maryland Shore Erosion Task Force Final Report.* January 2000.

15. DNR Internet site www.dnr.state.md.us. Navigation directions within the web site:
- Click on Bays and Streams
- Click on Chesapeake Bay
- Click on Pfiesteria

16. Judy, Chris. Personal communication with Chris Judy, Director, DNR Shellfish Restoration Program. October 2000.

17. Casey, James and Rick Schaefer. Personal communications with James Casey, DNR Marine and Crab Survey and with Rick Schaefer, DNR Fisheries Service Eastern Region Office. September and October 2000.

18. Funderburke, S.L. et al. *Habitat Requirements for Chesapeake Bay Living Resources.* June 1991, pp. 3-1 - 3-6.

19. Greenhawk, Kelly. Personal communication with Kelly Greenhawk, Sarbanes Cooperative Oxford Lab, DNR Fisheries Service. October 2000.

20. Ludy, Earl. Letter from the Somerset County Sanitary District to US EPA Region III. August 16, 2000.

21. Kean, Joan. Personal communication the Director of Somerset County Dept. of Technical and Community Services regarding US Consensus figures. October 2000.

22. National Academy of Sciences. *Clean Coastal Waters: Understanding and Reducing The Effects of Nutrient Pollution.* National Academy Press. 2000.

23. Weller, Deborah M.G., Watershed Modeling and Reosurce Planning Section, Maryland Dept. of Planning. December 2000.

24. LaBranche, Julie. Maryland Department of the Environment. November 2000.

25. Jesian, Roman. *Final Report, 1999 Water Quality Survey of Somerset County Streams.* October 1999.

26. Ludy, Earl C. Letter dated December 6, 2000.

27. Chesapeake Bay Program. *Chesapeake Bay Submerged Aquatic Vegetation Water Quality and Habitat-Based Requirements and Restoration Targets: A Second Technical Synthesis.* August 2000. Executive Summary. (www.chesapeakebay.net under publications search for SAV).

28. Chesapeake Bay Program. *Chesapeake Bay Submerged Aquatic Vegetation Water Quality and Habitat-Based Requirements and Restoration Targets: A Second Technical Synthesis.* August 2000. Page 112. (www.chesapeakebay.net under publications search for SAV).

Abbreviation Key

CCWS - Chesapeake and Coastal Watershed Service (Part of DNR)
COMAR - Code Of Maryland Regulations (Maryland State regulations)
CREP - Conservation and Restoration Enhancement Program (program of MDA)
CRP - Conservation Reserve Program (program of MDA)
CWAP - Clean Water Action Plan (Adopted by Maryland December 1998
DNR - Department of Natural Resources (Maryland State)
EPA - Environmental Protection Agency (United States)
MBSS - Maryland Biological Stream Survey (program in DNR RAS)
MDA - Maryland Department of Agriculture
MDE - Maryland Department of the Environment
MDP - Department Department of Planning
MET - Maryland Environmental Trust
MGS - Maryland Geological Survey
mg/l - milligram per liter (one one-thousandth of a liter
ug/l - microgram per liter (one one-thousandth of a milligram)
NHA - Natural Heritage Area (designation by DNR in COMAR)
NOAA - National Oceanagraphic and Atmospheric Agency
NRCS - Natural Resource Conservation Service
PDA - Public Drainage Association
RAS - Resource Assessment Service (part of DNR)
SAV - Submerged Aquatic Vegetation
SSPRA - Sensitive Species Protection Review Area (designation by DNR)
TMDL - Total Maximum Daily Loads
USFWS - United States Fish and Wildlife Service
USGS - United State Geological Survey
WRAS - Watershed Restoration Action Strategy (funding/assistance project by DNR)
WSSC - Wetland of Special State Concern (designation by MDE in COMAR)

Contacts for More Information
Manokin River Watershed
Watershed Restoration Action Strategy (WRAS)

Somerset County

Department of Technical and Community Services
Director: Joan Kean 410-651-1424

Maryland Department of Natural Resources

Tributary Team: Lower Eastern Shore
Sean McGuire, 410-260-8727
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Manokin River: Mary Conley 410-260-8984
Statewide: Katharine Dowell, 410-260-8741
Watershed Management and Analysis Division
Ken Shanks, 410-260-8786
Watershed Restoration Division
John McCoy, 410-260-8795

Techincal Issues Contacts

TMDL, County Contact - Earl Ludy, Somerset County Sanitary District 410-651-3831
State Contact - Jim George, MDE 410-631-3579

TECHNICAL REPORTS

Maryland's Lower Delmarva Peninsula 1998 Data Report. (Link to document)

Algae and *Pfiesteria* Technical Report for the Manokin River

Peter Tango, PhD. DNR Living Resource Assessment Program. July 2000.

Samples were collected in the Manokin River watershed as a result of the fish lesion event in 1997, then as part of the Maryland Department of Natural Resources *Pfiesteria* monitoring program between 1998 and the present 2000 season. Chlorophyll *a* concentrations are one of the parameters typically measured and the measure is used to estimate algal biomass. In addition to direct measurements of chlorophyll from water samples taken back to the lab, *in vivo* flourescence is another technique used for estimating algal biomass concentration and its distribution in a system. In general, the flourscence measurements allow for finer scale resolution of the vertical or horizontal distribution of algal concentrations over a broad area than does point sampling but the two techniques are complimentary in monitoring programs.

In 1998, the *Pfiesteria* monitoring program (*in vivo* flourescence segment) recorded low to mid-range chlorophyll concentrations in the lower Manokin River (10-90 ug/L). The upper Manokin River was typified by mid to high range chlorophyll levels (20-1110 ug/L) while King's Creek had chlorophyll concentrations between 20 and 320 ug/L. The chlorophyll maxima in the system was consistently located upriver in the Manokin branch in the vicinity of the wastewater treatment plant. During July and August, chlorophyll levels peaked there at 450 ug/L and 1080 ug/L respectively.

Also in 1998, sediment samples collected in the Manokin River and numerous other Lower Eastern Shore Rivers were tested for the presence of *Pfiesteria*. In the Manokin, potentially toxic *Pfiesteria* populations were not identified.[15]

In 1999, summer median chlorophyll *a* concentrations greater than 50 ug/L only occurred at about 20% of the *Pfiesteria* monitoring program's water quality stations throughout the Eastern Shore. In the Manokin/King's Creek system, however, half of the concentrations were greater >50 ug/L. Based on results from the *in vivo* flourescence segment of the program, concentrations of chlorophyll *a* were low (less than 20 *u*g/l) in the lower river in May and June, but concentrations upstream (in and above King's Creek) were between 20 and 80 *u*g/l. Chlorophyll concentrations continued to increase in the entire system through September, with the high concentration area extending further and further downstream. In mid August, concentrations were greater than 80 *u*g/l in the entire sampled area in and above King's Creek. In August and September, high chlorophyll concentrations (greater than 60 *u*g/l) extended downstream as far as Top Point. Compared to samples collected across the Lower Eastern Shore and the Coastal Bays in 1999, the Manokin River / Kings Creek areas were among the highest chlorophyll *a* concentrations measured.[6]

In 1997, a fish lesion event in Kings Creek on the Manokin River was associated with an outbreak of toxic *Pfiesteria*. In 1998, *Pfiesteria* was not detected (using a genetic probe developed by Dr. David Oldach at the University of Maryland) in samples collected from the mainstem of the Manokin, however, it was detected in Back Creek in August 1999 near a report of a human health problem. In 2000, no *Pfiesteria* has been recorded in biweekly monitoring of the Manokin River between April and August 28, 2000. In general, areas where *Pfiesteria* has been found consistently in the water column have relatively high nutrient and chlorophyll levels; dissolved organic nutrients are also particularly high. Nutrient enrichment continues to be a common denominator in river systems with the history of toxic *Pfiesteria* events or exhibiting the greatest nontoxic *Pfiesteria* activity.[1]

1. Magnien, R.E., D Goshorn, B. Michael, P Tango and R. Karrh. *Associations between pfiesteria, Fish Health and Environmental Conditions in Maryland.* DNR. April 2000.

1997 Land Use Summary Table

1997 Land Use Summary for the Manokin River Watershed Maryland Department of State Planning Estimates							
Category	**Acres**	Percent of Watershed	**Land Use**	**Code #**	**Acres**	Percent of Category	Percent of
Agriculture	17029	28.7	Row Crop	21	16067	94	27
			Pasture	22	295	2	-
			Feeding Operations	241	612	4	1
			Ag Building	242	55	-	-
Forest	27319	46.0	Deciduous	41	11600	43	20
			Evergreen	42	3622	13	6
			Mixed Deciduous & Evergreen	43	6370	23	11
			Brush	44	5727	21	10
Urban	3389	5.7	Residential Low Density	11	1778	53	3
			Residential Medium Density	12	445	13	½
			Residential High Density	13	121	3	-
			Commercial	14	427	13	½
			Industrial	15	37	1	-
			Institutional	16	577	17	1
			Transportation	80	4	-	-
Wetlands*	11634	19.6		60	11634	-	20
Other	13	--	Extractive	17	7	-	-
			Bare Ground	73	6	-	-
TOTAL	59384	100			59384	-	100

* Wetlands counted here are those large tidal marshes and emergent wetlands identified using remote sensing. Nontidal wetlands with woody vegetation are typically considered forest here.

2020 Land Use Projections for the Manokin River Watershed, Somerset County *

In 1997, approximately 6% of the watershed was developed with the highest percent (40%) of development in the subwatershed 021302080661. This subwatershed contains the Town of Princess Anne. Overall the level of impervious cover is low - less than 2%. With the exception of subwatershed 021302080661 which has a estimated impervious cover of 6%.

It is estimated that in 2020, forest and wetlands will remain the dominant land use in the watershed. Urban land is projected to increase by 1,122 acres between 1997 and 2020 representing a 33% increase. In absolute acreage, this increase is low compared the total land area. Segment 02130208661 continues to have the highest level of urban land. It is estimated that by 2020 only 36% of the urban land will be located in this segment. Development in Segment 021302080656, is projected to increase from 234 acres to 449 acres representing a 48% increase in development. Impervious cover will remain low at the watershed scale but will increase from 6% to 7% in 021302080661.

In 1997, there were approximately 1,319 households in the Manokin watershed with 67% on septic systems. It is projected that the number of households will increase by approximately 600 households. It is projected that 51% of the new households will be on septic systems.

* Weller, Deborah M.G., Watershed Modeling and Reosurce Planning Section, Maryland Dept. of Planning. December 2000.

Final Report

October 1999

1999 Water Quality Survey

of

Somerset County Streams

by

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Acknowledgements

I wish to thank the students from Environmental Science 221 and Ecology 402 at the University of Maryland Eastern Shore who collected water samples and contributed in the analytical processes. I especially want to thank Peter Sakaris and Marijo Gormely who conducted many of the analytical procedures.

Summary

A total of nine locations on seven streams and one spring within Somerset County were monitored for water quality approximately monthly from October 1998 through September 1999. Streams from all the major drainages in the county, i.e., Wicomico River (Somerset Creek), Manokin River (Manokin Creek, Manokin River, Kings Creek, Taylor Branch, Westover Spring) and Pocomoke River (Marumsco Creek, Rehobeth Creek) watersheds, were sampled. Water quality parameters included temperature, dissolved oxygen, conductivity, pH and nutrients. Results during the 1999 survey were compared to data obtained during the 1997 and 1998 surveys. Based on the results locations were generally in the transition zone between fresh and brackish water. During spring, surface water at the seven streams was generally fresh but as surface flow decreased during summer, brackish water moved into the creeks. Typically, waters were about neutral in pH except the Westover spring which was generally low in pH (1999

mean = 5.78). Dissolved oxygen was low in most streams during the summer, concentrations less than 5 mg/L were detected at all streams. Dissolved oxygen was generally higher during the summer 1999 than in 1998 1997.

Of the surface waters, nutrient levels were highest in spring and summer and typically highest at Taylor Branch and Marumsco Creek. Ammonia concentration exceeded 0.7 mg/L at Kings Creek, Taylor Branch and Marumsco Creek. Nitrate concentrations in surface waters ranged from not detected to 3.0 mg/L. Nitrate exceeding 2.0 mg/L was observed in all creeks except Manokin, Rehobeth and Kings creeks. Nitrate was consistently high at the Westover well where up to 15.0 mg/L was detected which exceeded the upper limit for drinking water. High phosphate concentrations (> 1.0 mg/L) were detected in all creeks except Somerset, Manokin and Rehobeth Creeks.

Scope of Work

This report contains results obtained during the 1999 water quality survey in Somerset County along with an summary of the results obtained during the 1997 and 1998 surveys and reported in Jesien (1997, 1998). Nine locations were visited approximately monthly from October 1998 through September 1999 and monitored for physical and chemical water quality parameters, including temperature, dissolved oxygen, conductivity, pH and nutrients. Nutrients included ammonia, nitrate and phosphate. Station locations were selected to provide wide coverage of freshwater areas within the county.

Monitoring Site Descriptions

Creeks from all the major drainages in the county, i.e., Wicomico River, Manokin River and Pocomoke River watersheds, were sampled (Table 1, Figure 1). One station was located within the Wicomico River watershed, Somerset Creek in the northern part of the county. Four stations were located within the Manokin River watershed, Manokin Creek, Manokin River, Kings Creek and Taylor Branch which are in the mid portion of the county. Three stations were located within the Pocomoke River watershed, two on Marumsco Creek and one on Rehobeth Creek. A spring located near the mid portion of the county was sampled because it is commonly used for drinking water.

Station 1 on Somerset Creek is located upstream of the bridge at Rt 529 (Table 1). The watershed above the sampling station is generally wooded. A large stand of bamboo occurs downstream of the bridge and a gravel mine is operating upstream of the sampling site.

Four stations were established within the Manokin River watershed, Manokin Creek, Station 2, Kings Creek, Station 3, Taylor Branch, Station 4 and Manokin River, Station 7. The creeks have been channelized and drain areas that are intensively used for agriculture. For the 1999 survey, a new station was established further up river than the station at Raccoon Point. The new station was established along the Manokin River in the Hayman's Purchase Community off Stewart Neck Road. The station is located at Mr. A.

Murray's dock, which is about 0.5 miles downstream of the Princess Anne Sewage Treatment Plant.

Two stations were established on Marumsco Creek, a tributary of the Pocomoke River. Station 5 was located at the Rt 667 bridge. Station 5A was located at Marumsco Road which is downstream from Station 5 and was designated as 5(lower). The creek above the Rt 667 bridge drains agricultural fields. There is a poultry house about 100 m upstream of the bridge. Below the bridge the flow expands considerably into brackish marsh.

Station 8 is located at the Rt 667 bridge at Rehobeth Creek. The watershed is largely agriculture and was included to expand coverage of the Pocomoke River drainage.

Station 6 was established at the spring near Westover, Maryland. The spring is located on the east side of Rt 13 near the old prisoner-of-war barracks. The water from the spring is very unusual for the area. The water is very clear and has been used for drinking water since, at least, the 1930's, according to some long-time residents. The spring ultimately flows into Back Creek, a tributary of the Manokin River.

Sampling Protocol and Analytical Procedures

At each location temperature, dissolved oxygen, conductivity/salinity, and pH were measured onsite. Two 125 ml bottles were filled with water and returned to the water quality laboratory at UMES for nutrient analysis. Analytical parameters and procedures are listed in Table 2.

Analytical Parameters

Temperature

Temperature was measured to investigate relative amount of stream cover. Areas of streams exposed to sunlight or reduced flow would tend to have higher temperatures than areas that are shaded.

Dissolved Oxygen

Dissolved oxygen was measured because it is important to the respiration of aquatic biota and its concentration is a major determinant of their species composition in the water and underlying sediments (Smith et al., 1991). Dissolved oxygen in streams is a major determinant of the biochemical reactions that occur in the water and sediments. These reaction, in turn, affect numerous aspects of water quality, including the solubility of many toxic elements and the esthetic qualities of odor and taste. Typically, 5 mg/l is considered adequate for aquatic life. For this survey, dissolved oxygen was measured as concentration and as percent saturation. Percent saturation is a measure of the proportion of oxygen in water relative to the solubility of oxygen, or the capacity of oxygen to dissolve in water. The solubility is dependent on physical factors including temperature, altitude and amount of material dissolved in water. For example, 5 mg/l dissolved oxygen in 30°C freshwater at sea level is 70% saturated, but at 10°C is 40% saturated. Oxygen concentration in streams should tend toward saturation if there is aeration from turbulent flow, which is unlikely in the slow sluggish streams in the flat terrain of the Eastern Shore. Dissolved oxygen can also be added to stream water by the process of photosyntheis of aquatic plants and algae, which can be common in Somerset County streams. Depletion of oxygen, from respiration of organisms, including microbes, or oxidation of inorganic materials, would be more prevalent than aeration and oxygen levels would be low.

Conductivity

Conductivity is a measure of the amount of material dissolved in water. Distilled water has a conductivity of less than 10 uSiemans/cm (uS/cm), surface freshwaters range from about 25 uS/cm to 1,000 uS/cm and brackish water > 1,000 uS/cm. Generally, 1,000uS/cm is equivalent to 1 part per thousand salinity. Conductivity is expresses as ambient conductivity and specific conductance. Ambient conductivity is the conductivity at the temperature present in the stream. Specific conductance is conductivity corrected to 25°C.

pH

pH is a measure of the hydrogen ion content in water. Water that is neutral has a pH of 7.0. Acidic surface waters may range from 3.5 to 6.9. Alkaline surface waters may range from 8.0 to 12. High photosynthetic activity consumes carbon dioxide which causes a shift in the carbonate equilibrium of the water which results in high pH. On the other hand, high decomposition produces carbon dioxide which cause the opposite shift in carbonate which results in low pH.

Nutrients

Ammonia and nitrate nitrogen is present in many surface and ground waters, both species of nitrogen are products of microbiological activity. Ammonia nitrogen is sometime accepted as chemical evidence of sanitary pollution when encountered in raw surface supplies. Its occurrence in ground water samples is generally a result of natural reduction processes. Ammonia concentrations encountered in water vary from < 0.10 mg/L in natural waters to more than 30 mg/l in some wastewaters. Batiuk et al. (1992) reported that in tidal fresh water in the upper Potomac, ammonia concentration >0.6 mg/L was associated with failure of submerged aquatic vegetation (SAV) revegetation efforts and successful revegetation was observed when ammonia concentrations were < 0.4 mg/L In areas of slight salt content (oligohaline) submerged aquatic grasses survived at ammonia concentrations of 0.4 – 0.7 mg/L.

Major sources of nitrate in streams are municipal and industrial wastewater discharge and agricultural and urban runoff. Deposition from the atmosphere of the nitrogenous material in automobile exhaust and industrial emissions also is a source. Nitrate generally occurs in trace quantities in surface water supplies but may attain high levels in some ground waters. In excessive amount, it contributes to the illness known as infant methemoglobinemia. A limit of 10 mg nitrate as nitrogen/L has accordingly been imposed on drinking waters as a means of averting this condition (American Public Health Association, 1989). Microbial activity breaks down ammonia to nitrite then nitrate. In this study, the analytical procedure converts nitrite to nitrate before determining the nitrate concentration. The nitrate concentration of most surface waters usually falls below 10 mg/l, but concentrations frequently do exceed that limit in shallow ground water in agricultural areas where animals wastes and nitrogen fertilizers are concentrated (Smith et al. 1991). Nitrate plus nitrite concentrations <1.7 – 2 mg/l were found to be compatible with SAV propagation and survival in both tidal fresh and oligohaline waters (Batiuk et al. 1992).

In streams, phosphorus occurs primarily as phosphate and can be either dissolved, incorporated in organisms, or attached to particles in the water or in bottom sediments. In this study, phosphorus was measured as dissolved phosphorus or ortho-phosphate. Phosphorus is a particularly important nutrient in freshwater ecosystems because phosphorus usually is the nutrient in shortest supply and its availability often controls the rate of eutrophication. When human activities make phosphorus available in larger quantities, the accelerated growth of algae and other aquatic plants in streams can cause eutrophication, which depletes dissolved oxygen, imparts undesirable tastes and odors in the water, and clogs water-supply intakes. Sources of phosphorus are the decomposition of organic matter and inorganic phosphate minerals that are mined and incorporated in fertilizers, detergents, and other commodities. Thus, major point sources of phosphorus to streams are waste discharges from sewage-treatment and food-processing plants and other industrial facilities. Nonpoint sources of phosphorus include agricultural and urban runoff (Smith et al. 1991).

Results

Wicomico River Drainage

<u>Somerset Creek (Station 1)</u>

Temperature exhibited typical seasonal variability in all of the streams. In Somerset Creek temperature ranged from 6.9°C in January to 25.9°C in October (Table 3, Fig. 2). A wide fluctuation in conductivity was observed and was dependant on rain events and tide. Lowest conductivity was in July (55.6 uS/cm) and September (56.6 uS/cm) following heavy rains. The September sample was obtained the day after Hurricane Floyd passed through the area. The highest conductivity, in fact the highest recorded at this station over the three-year study was observed in June when 3,000 uS/cm was measured following a very dry period. A lack of rainfall and a high tide contributed to the high conductivity.

Dissolved oxygen was generally low at this station. Average % saturation was 67% and saturation greater than 80% was observed on only four occasions in 1999, whereas saturation greater than 80% occurred on most sampling occasions in 1998 (Table 3, Fig.3). In 1999 the lowest dissolved oxygen saturation (30.4%, 2.4 mg/L) was observed in June when very high conductivity was also observed. Saturation less than 80% only occurred during July (63.7%) and August (15.8%). Apparently the heavy rains and resultant high water during Hurricane Floyd reduced dissolved oxygen to 50.6% (4.69 mg/L). The lowest reading between the two years was observed during August 1998 when 1.28 mg/L (15.8%) was measured.

pH in Somerset Creek was acidic to slightly acidic, the average pH was 6.43 (Table 2, Fig. 4). In 1999 pH ranged from 5.09 during September to 7.28 during August. The lowest value observed during the three-year study occurred during January 1998 when 5.08 was observed.

Ammonia was typically low in Somerset Creek, the average concentration was 0.23 (Table 3, Fig. 5). In 1999 ammonia ranged from 0.05 mg/L in November and September to 0.66 mg/L in May. All levels were less than 0.5 mg/l except for the May sample. Nitrate levels were typically low (<0.40 mg/L) throughout the period of observation, except for July when an exceptionally high level of 2.5 mg/l was measured which was the highest measured at that station. At the time of sampling, construction activity was observed to be associated with what appeared to be sewer lines, which may account for the high nitrate concentration. Phosphate levels averaged 0.28 mg/L and ranged from 0.05 mg/L in December to 0.6 mg/L in May, which was the highest level recorded at this station.

Manokin Creek (Station 2)

Temperature in Manokin Creek exhibited the same seasonal variability as the other small headwater streams (Table 3, Fig. 2). In 1999 temperature ranged from 6.3^{o} C during December to 24.5^{o}C in July. Conductivity varied little throughout the year and ranged from 63. uS/cm during September to 203.9 uS/cm during May. Conductivity at Manokin Creek at this particular location was generally less than 200 uS/cm throughout the study which indicates that there is virtually no tidal influence at this station.

Dissolved oxygen ranged from 52% to 77% saturation in 1999 (Table 3, Fig. 2). Manokin Creek water was lightly acidic throughout the survey, pH ranged from 5.86 during September to 7.12 during May (Table 3, Fig.4

Ammonia was typically low (<0.20 mg/L), except for one value (0.80 mg/L) in April. Ammonia ranged from "not detected" in November and May to 0.19 mg/L in October and January. (Table 3, Fig.5). Except for one sample in January in which 2.70 mg/L was measured, nitrate was generally low, concentrations ranged 0.1 mg/L in April to 0.28 mg/L in December. Phosphate ranged from 0.13 mg/L in January to 0.86 mg/L in August.

Manokin River, Station 7

Temperature at Manokin River tracked general seasonal trends. Temperature ranged from 7.7^{o}C in January to 28.0^{o}C in July (Table 3, Fig 2). Conductivity was less than 500 uS/cm in January and April and increased up to 5,060 uS/cm in August. Dissolved oxygen saturation was greater than 60% on all sampling occasions except in September when 35.6% was measured. pH was generally greater than 7.0, and high pH, 8.85, in April was associated with high primary production as evidenced by the supersaturated (132.9%) dissolved oxygen observed at the station.

Ammonia averaged 0.25 mg/L and was less than 0.3 mg/L except for April when 0.7 mg/L was measured. Nitrate concentrations greater than 1.0 mg/L was observed on three occasions, January (2.8 mg/L), April (2.10 mg/L), and September (3.00 mg/L). Phosphate concentrations were 0.5 mg/L or less except in September when 1.28 mg/L was measured.

Taylor Branch, Station 3.

Temperature at Taylor Branch fluctuated from 5.4^{o}C in December to 22.8^{o}C in July and August (Table 3, Fig. 2). Conductivity was lowest in September after the hurricane (95 uS/cm) and other times ranged from 154.6 uS/cm in April to 3,181 uS/cm in January.

Average dissolved oxygen was near 54% saturation and ranged from 33% in November to 93% in April. pH averaged 6.74 and ranged from 5.94 in September to 7.69 in April. (Table 3, Fig. 4).

Average ammonia concentration was 0.3 mg/L and ranged from 0.07 mg/L in April to 0.78mg/L in June. During 1998 ammonia concentrations ranged from 0.03 mg/L during February to 0.37 mg/L during October (Table 3, Fig. 5). Except for the high concentration observed in April 1997, ammonia did not exceed 0.4 mg/L throughout the study. Nitrate concentrations exceeded 0.5 mg/L on three occasions, December (1.2 mg/L), May (2.0 mg/L) and July (1.2 mg/L). High phosphate concentrations were observed during 1999. Concentrations > 0.5 mg/L were observed on all sampling occasions except three, October (0.37 mg/L), December (0.33 mg/L) and April (0.17 mg/L).

Kings Creek, Station 4

The temperature regime at Kings Creek followed the typical seasonal pattern observed in the other creeks (Table 3, Fig. 2). Low temperature was observed during December (3.0^{o}C) , and the maximum temperature was observed during July (26.4^{o}C). Conductivity was low during winter and spring and increased during fall. Conductivity ranged from 154 uS/cm in January to 269 uS/cm in May. Conductivity rose significantly during June and August when 1,608 uS/cm and 3, 248 uS/cm, respectively, was recorded. Conductivity fell to 90.9 uS/cm during September following hurricane Floyd.

Dissolved oxygen at >70% saturation was observed only during December, January and April, other times % saturation ranged from 36 – 67%. pH ranged from 6.06 din January to 7.55 in April (Table 3. Fig. 4). The rise in pH coincided with the increase in conductivity. The higher salt content provided better buffer and consequently a higher pH.

Ammonia averaged 0.15 mg/L and, except for one high value in May (0.88 mg/L) was less than 0.52 mg/L throughout the year (Table 3, Fig. 5). Highest ammonia concentrations were observed during 1997 when 0.48 mg/L and 1.38 mg/L were observed during May and April, respectively. Nitrate was typically low, most values were less that 0.40 mg/L. Phosphate was <0.5 mg/L except during the summer when 0.76 – 4.08 mg/L was measured. .

<u>Westover Spring, Station 6</u>

All parameters measured at the well exhibited very little fluctuation over the year. Temperature generally followed seasonal trends but variability was considerably muted relative to the surface waters (Table 3, Fig. 2). Conductivity fluctuated very little throughout the survey but exhibited a slight increase over the course of the year. Conductivity ranged from 198 uS/cm during January 1998 to 259.5 uS/cm in October.

Dissolved oxygen was > 70% saturation throughout the study and a slight seasonal trend of increasing saturation during the summer was observed (Table 3, Fig. 3). pH was generally acidic, values ranged from 5.37 in October to 6.17 in April (Table 3, Fig. 4). Ammonia was very low during the survey; values ranged from none detected on three occasions to 0.11 mg/L during October. Nitrate was typically high at all times; concentration average was 10.62 and values ranged from 3.00mg/L in June to 19.2 mg/L during October (Table 3, Fig. 5).

Pocomoke River Drainage

<u>Marumsco Creek, Stations 5 and 5A</u>

Two stations were established on Marumsco Creek, Station 5 was located near Hudson Corner and Station 5A was downstream at Marumsco Road (Fig. 1). Temperature continued the trend observed in 1998 in that the down river station was consistently higher than the upriver station which is consistent with its proximity to the larger Pocomoke River. Conductivity was lowest at both stations in September following Hurricane Floyd. Conductivity in the upper station was below 500 uS/cm in January and April and ranged from 1,221 uS/cm to 14, 710 uS/cm during other times. At the lower station conductivity ranged from 1,789 in January to 21,440 uS/cm in August.

Dissolved oxygen was typically higher at the down river station, average dissolved oxygen concentration was 51.7% at the upper station and 67.5% the upper station. Saturation was less than 50% on six occasions at the upper station but only on three occasions at the lower station. At the lower stations low oxygen levels were observed in June (33%), July (40.2%) and September (40.1%). In 1998 dissolved oxygen saturation never was below 48%. Of particular interest was the super-saturation (104%) observed in October 1998 at the down river station. Apparently high photosynthetic activity caused that high concentration.

pH at the two locations tracked each other fairly well and the down river station was generally higher than the upriver station (Table 3, Fig. 4). The higher pH was consistent with the higher conductivity, and therefore, better buffering capacity at that location.

Ammonia concentrations were less than 1.0 mg/L throughout the study at both stations (Table 3, Fig. 5). Mean concentration was higher at the upper station, 0.43 mg/L, than the lower station, 0.23 mg/L. Nitrate was considerably higher at the upper station (mean 0.84 mg/L) than the lower station (mean 0.35 mg/L). Concentrations greater than 2.00 mg/L were observed in January (2.3 mg/L) and September (2.4 mg/L). Phosphate was > 1.0 mg/L on three occasions at both the upper and lower stations. At the upper station concentrations exceeded 1.0 mg/L in May (1.3 mg/L), July (2.32 mg/L), and September (2.24 mg/L). At the lower station, concentration exceeded 1.0 mg/L in January (1.34 mg/L), June (1.36 mg/L) and September (2.24 mg/L).

<u>Rehobeth Creek, Station 8</u>

Temperature during the study ranged from 5.5 ^{o}C during march to 27.6^{o}C in August. Conductivity was similar to other surface waters, levels were low (<600 uS/cm) in winter/spring and after Floyd and highest in August (10,870 uS/cm). Dissolved oxygen was greater than 45% saturation and saturation greater than 100 % was observed during October (139%), April (104%) and July (105%) probably from high photosynthetic activity (Table 3, Fig. 3). Average pH was slightly acidic, 6.83, and ranged from 5.87 in September to 7.25 in December (Table3, Fig. 4). Ammonia levels were constantly less than 0.80 mg/L (Table 3, Fig. 5). Nitrate concentrations exceeded 1.0 mg/L on one occasion, May, when 2.0 mg/L was measured. Phosphate concentrations were less than 0.35 mg/L on all occasions except in September, when 0.88 mg/L was recorded.

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Table 1. Locations sampled for water quality analysis

Site/Location	Description	Watershed	Lat/Long coordinates
1. Somerset Creek	Bridge at Rt 529	Wicomico River	38 15.844 75 40.890
2. Manokin River	UMES campus	Manokin River	38 12.388 75 40.943
3. Taylor Branch	Bridge at Rt 13	Manokin River	38 11.104 75 41.440
4. Kings Creek	Bridge at Rt 13	Manokin River	38 09.882 74 41.351
5. Marumsco Creek	Bridge at Rt 667 near Hudson Corner	Pocomoke River	38 03.210 74 41.391
5a. Marumsco Creek	Bridge at Marumsco Rd	Pocomoke River	38 01.947 75 42.844
6. Westover Well	Well near old prisoner-of-war barracks, Westover	Manokin River	38 08.020 75 41.879
7. Rehobeth Creek	Bridge at Rt 126	Pocomoke River	
8. Manokin River	Daphne Road, at Hayman's Purchase Community, off Stewart Neck Road replaced Raccoon	Manokin River	

	Point		

Table 2. Analytical procedures used for the analysis of water quality parameters.

Parameter	Analytical Procedure
Temperature	Thermister Probe, YSI Model 33 SCT meter as ^{o}C
Dissolved Oxygen	YSI Model 55 Dissolved Oxygen Meter as mg/l
pH	Acument pH Meter, in standard units
Conductivity/Salinity	Thermister Probe, YSI Model 33 SCT meter, as uS/cm or ppt, respectively
Ammonia[1]	Hach Spectrophotometer, Salicylate Method as NH_3-N
Nitrate[1,]	Hach Spectrophotometer, Cadmium Reduction Method as NO_3 –N (Method 8192 for conc< 0.4 mg/L, Method 8039 for conc > 0.04 mg/L)
Phosphorus[1], Reactive, also called Orthophosphate	Hach Spectrophotometer, Ascorbic Acid Method as PO_4 – P (Method 8048)

Hach Spectrophotometer = DR/2010, hm/dp 12-16-96,

[1] nitrite is converted to nitrate

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