USING GEOGRAPHIC INFORMATION SYSTEMS (GIS) AS A TOOL FOR CHARACTERIZING THE CHARLESTON-NORTH CHARLESTON URBANIZED AREA TO GUIDE STORMWATER EDUCATION AND OUTREACH PROGRAMMING

An internship report submitted in partial satisfaction of the requirements for the degree of

MASTER OF SCIENCE

in

ENVIRONMENTAL STUDIES

by

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Abstract

Using Geographic Information Systems (GIS) as a tool for characterizing the Charleston-North Charleston urbanized area to guide stormwater education and outreach programming

Julia B. Carter

Public education and involvement are key components in the larger effort to improve water quality associated with non-point source (NPS) "stormwater" runoff. The Ashley Cooper Stormwater Education Consortium (ACSEC) is a partnership between communities and education providers in the Charleston-North Charleston urbanized area, which was organized in 2008 to coordinate and implement a watershed-scale education strategy to help address and improve stormwater runoff pollution. The ACSEC identified a need to define the physical and social characteristics of the region to help guide a targeted education strategy, which recognizes the significance of identifying pollutants, audiences, and land use and their spatial relationships. This internship was developed to support the regional characterization, and utilized a Geographic Information Systems (GIS) approach to define the region at two scales: 1) Tricounty and 2) Watershed (hydrologic unit code [HUC] 12). Over 150 maps were created that define physical attributes, such as land use, protected land, impervious cover, impaired watersheds as well as social characteristics, such as demographics. The resultant GIS database provides a platform for the ACSEC to make more informed decisions about targeting areas, audiences, and pollutants relevant to the characteristics of the region and at the individual

watershed level. The maps also serve as a resource for future education efforts and a baseline for future studies.

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1.0 Introduction

The primary goal of this internship is to develop a physical and social characterization of the Charleston-North Charleston urbanized area (Figure 1) for watershed outreach programming guidance in support of the Ashley Cooper Stormwater Education Consortium. The objectives for this goal are:

(1) Create a Geographic Information Systems (GIS) database platform for organizing, recording, and analyzing physical and social data;

(2) Acquire, rectify, and project GIS layers that represent physical and/or landscape features of the region (i.e. impervious surfaces, septic tank distribution, land use, watershed boundaries, etc.);

(3) Compile demographic data from census bureau and display within the GIS.

The National Pollutant Discharge Elimination System (NPDES) targets point source pollution under the Clean Water Act (CWA) by regulating discharges. The NPDES is a provisional program within the Clean Water Act. Under NPDES, the Phase I and Phase II programs were developed. Both the Phase I and Phase II programs target nonpoint source pollution in urban centers and require these areas to gain an NPDES permit for their stormwater discharges. The Phase II program targets small municipal stormwater sewer systems associated with defined urbanized areas. Each designated SMS4 community must develop a stormwater management plan, which addresses six minimum control measures. Two of the six minimum control measures include public education, and public involvement.

The Ashley Cooper Stormwater Education Consortium (ACSEC) is a partnership between eleven designated small municipal separate stormwater sewer system (SMS4) communities in the Tricounty (Charleston, Berkeley and Dorchester Counties) region and education providers, which include universities, state and government agencies, and local non-profits. Clemson University's Carolina Clear program organized the effort and coordinates the program in this region. Carolina Clear was developed by Clemson University to inform and educate communities about water quality, water quantity and the cumulative effects of stormwater. The Carolina Clear Program looks at the role that South Carolina's water resources play in the state's economy, environmental health, and overall quality of life. There are a total of seven consortiums or groups in the State of South Carolina that are working with Carolina Clear to help address the Phase II minimum control measures of the National Pollutant Discharge Elimination System (NPDES).

There are two primary groups of partners that form the ACSEC: (1) community partners and (2) education partners. The ACSEC's participating SMS4 communities include Berkeley, Charleston and Dorchester Counties, and the municipalities of Charleston, Folly Beach, Hanahan, Isle of Palms, Lincolnville, North Charleston, Sullivan's Island and Summerville. The education partners include: The Clemson Extension – Carolina Clear Program, the South Carolina Sea Grant Extension Program, the College of Charleston – Master's of Environmental Studies Program, the South Carolina Department of Natural Resources (SC DNR) – Soil and Water Conservation Districts, the SC DNR and National Estuarine Research Reserve (NERRS) ACE Basin

Coastal Training Program, the SC DNR – SC Oyster Restoration and Enhancement Program (SCORE), Lowcountry Earth Force, the Michaux Conservancy, the Spirit of South Carolina, and Charleston Water Keeper.

The official beginning of the ACSEC was marked with a joint resolution that showed a public commitment by the community partners to "address stormwater runoff pollution as partners working with regional education providers" (ACSEC Education Plan 2008) and was signed on July 29, 2008 by local elected officials representing the SMS4 communities. The first ACSEC education plan began in the fall of 2008 and included a target audience-target pollutant focus for an education strategy and both short-term and long-term overall goals. The primary short-term goals of the first year were: (1) to characterize the social and physical geography of the region, and (2) support, implement, and expand existing water resource education programs of the partner organizations (ACSEC Annual Report of Activities 2009).

The first goal will be met with the completion of this internship; the product of which will be a document for the ACSEC to hand out to its education and community partners in an effort to further education program guidance. The second goal was met through the successes of the partners' programs and the consortium model and is outlined in the 2009 ACSEC Annual Report of Activities.

In the same time frame as this internship, ACSEC and Carolina Clear conducted two surveys in the Tricounty region – a phone-based and a field-based survey. The phone survey was done by Clemson University in July of 2009. The survey included

over 400 randomly selected respondents in the Tricounty area and asked them a variety of issues related to their behaviors, perceptions, and attitudes about water quality and stormwater runoff. The field-based survey focused on home landscape practices and was conducted at public events, such as the Coastal Carolina Fair, Earth Day Festival, and Harbor Fest and included over 300 respondents. The survey data will not be used in this report, but instead may assist future social studies that will incorporate the physical data from this internship report. The content of the field-based survey can be viewed in Appendix B.

This internship used Geographic Information Systems (GIS) as a platform for characterizing the region. GIS is a tool that analyzes data and displays data spatially; it is technology for displaying and analyzing geographic locations and their associated data. Within GIS, data takes many different forms, one of which is data layers, which are geographic features in the form of points, lines and polygons; each of these features has a corresponding data table or attribute table (Gorr & Kurland 2005). Points are features that display single point data such as cities, schools, water treatment facilities, etc. Lines are features that display linear data such as roads, highways, rivers, and streams, while polygons are area features that display data such as individual watersheds, school districts, counties and states. GIS data can be purchased or acquired from existing sources, e.g. county governments, federal agencies, internet (TIGER line census data), school databases (College of Charleston), or independent firms or non-profits.

The goal of this project was in part, to create a GIS database platform for organizing, recording, and analyzing physical and social data. In GIS, such a database is referred to as a 'geodatabase.' Korr and Kurland (2005) define a geodatabase as a, "collection of maps and database tables stored in a relational database management system." A geodatabase is the common data storage and management framework for GIS (ArcUser 2009). A geodatabase is a tool within GIS to organize the data into a manageable system. Feature datasets can be created within geodatabases, which are essentially file folders to organize and contain different sets of information. Organizing the data for this project within a geodatabase will allow future users to log in quickly and easily update data and information.

2.0 Literature Review

The southeastern United States is undergoing a population influx, especially along the coast (Holland et al. 2004; Kleppel et al. 2005), including cities such as Charleston. The growth through in-migration to the coastal counties of South Carolina is expected to exceed 520,000 people by 2025; the estimated predicted trend for coastal South Carolina is that more than 450,000 people will live in small coastal watersheds by 2025 (Kleppel et al. 2005). Community growth is coupled with the increase in infrastructure to support a larger population (Stanfield et al. 2002). Increased infrastructure could mean the increase of impervious surfaces through construction of roads, industrial sites, parking lots, driveways, and low and high density suburban developments, which in turn leads to an increase in stormwater runoff. As population increases, the amount of natural area

that is converted to urban and suburban land increases, which has a major effect on water quality (Holland et al. 2004; Mallin et al. 2001).

Stormwater runoff is rain, snowmelt, or applied water that does not infiltrate into the ground and flows through the storm drain and ditch system into surface waters. Runoff from urban and suburban areas can contain bacteria, sediment, oil and grease, fertilizer and pesticides, and other pollutants. The majority (90-100%) of the rainfall onto impervious surfaces is quickly exported through stormwater runoff into all surrounding water bodies (Holland et al. 2004). Holland et. al. (2004) goes on to report that due to a larger percentage of impervious cover in developed watersheds versus forested watersheds, the data shows that runoff from rainfall was 3-25 times greater in developed watersheds than forested watersheds. A main concern with stormwater runoff is the amount of pollutants from urban and suburban centers that is collected in rainfall events and transported through runoff to rivers, streams, estuaries, and all other water bodies. This untreated water negatively affects recreational areas (swimming and boating) and harvesting areas for local seafood, sometimes impairing a watershed to the extent that recreation and harvesting areas are closed to the public due to toxicity levels. Increased urbanization has affected coastal water quality and has led to a decrease in harvesting domestic seafood and an increase in importing seafood (Nelson et al. 2005). Mallin et al. (2001) report in their study of coastal North Carolina that, "regressing human population on shellfish closures indicated that approximately 70% of the variability in annual shellfish areas closed by fecal bacterial pollution could be explained by human population increases alone." Kelsey et al. (2004) discuss how bacterial

contamination is negatively affecting recreational and commercial uses of bays, inlets, estuaries and rivers throughout the United States.

A watershed in South Carolina is deemed impaired by the SC Department of Health and Environmental Control (SC DHEC) if it,

> "does not currently meet State water quality standards after application of required controls for point and nonpoint source pollutants… pollution severity and the classified uses of water bodies were considered in establishing priorities and targets… the list will be used to target water bodies for further investigation, additional monitoring, and water quality improvement measures, including Total Maximum Daily Loads (TMDLS)"
>
> (SC DHEC 303(d) List 2008).

The TMDL is the maximum amount of a contaminant that a waterway or water body can receive and still meet water quality standards (SC DHEC 303(d) List 2008). Point source pollution is targeted and handled through the Clean Water Act. Nonpoint source (NPS) pollution is harder to target because it is so widespread and comes from many different sources. Mallin et al. (2001) states, "nonpoint source microbial pollution of coastal waters is intimately related to human population increases." It is hard to regulate NPS pollution due to the inability to observe the origin of the pollutant. In addition, air and water point source pollution are regulated more efficiently because there is a penalty associated with the violation of standards, whereas it is difficult to identify and therefore punish NPS polluters (Helfand 1995). Rain washes heavy metals, motor oils, tire wear, and compounds from automobile exhaust off roads, parking lots, driveways and suburban developments in the form of stormwater runoff, which is a nonpoint source pollutant. The runoff then washes into and pollutes local waterways (Lee & Maruya 2006). There

needs to be an increase in the discussion of NPS pollution and its regulation (Helfand 1995), due to the fact that (1) coastal urbanization is gradually increasing and (2) this increase has led to increased stormwater runoff and therefore NPS pollution.

In 1990, South Carolina implemented a SC Nonpoint Source Management Program that focuses on, "reducing NPS impacts in priority watersheds, and implementing activities statewide in order to prevent NPS pollution… this program includes both regulatory and voluntary approaches" (SC NPS Management Program Update 1999). The Management Program has identified nine categories of NPS pollutants that affect South Carolina's water bodies: agriculture, forestry, urban areas, marinas and recreational boating, mining, hydrologic modification, wetlands disturbance, land disposal/groundwater impacts, and atmospheric deposition (SC NPS Management Program Update 1999). The Program has set up management measures as well as a schedule of implementation for each of these categories (SC NPS Management Program Update 1999). The 2008 Annual Report for the NPS Management Program outlines South Carolina's current TMDL programs, South Carolina's priority watersheds, and the successful projects that have taken place between 1999 and 2008 along with highlighting partner's contributions (conferences, outreach updates, etc.) and including a section on future directions.

Common impairments to coastal watersheds include bacteria (fecal coliform and enterococci), turbidity, heavy metals (mercury, copper, zinc, nickel, lead, chromium and cadmium), and nutrient overloads (phosphorous, nitrogen, ammonia nitrogen, hydrogen,

and dissolved oxygen) (SCDHEC 303(d) list 2008). Holland et al. (2004) researched land-use adjacent to watersheds in the Lowcountry and found metal sediments that are correlated with industrial sources (copper, mercury and zinc among others) were 2-10 times higher in creeks within urban and industrial watersheds; they also found that Chlorophyll A increased with higher levels of development.

The common thread among these contaminants is the increase in urbanization leading to a large rise in impaired waterways. Young and Thackston's (1999) study showed that fecal bacteria densities were related to housing density, development, population, percent impervious area, and animal density; results implied that surface runoff from a highly urbanized area may be contributing to an increase in fecal coliform in adjacent waterways. Many studies have been done studying the relationship between increased urbanization, population, human activities and stormwater runoff, and increased bacteria content in coastal waterways. Mallin et al. (2001) found increases in fecal bacteria concentrations in coastal North Carolina after 'alterations of the natural landscape,' i.e. development; Kelsey et al. (2004) found that "the major source of fecal pollution in Murrell's Inlet appears to be stormwater runoff, particularly from areas with urban land-use characteristics." Other studies show results of elevated levels of fecal bacteria associated with urbanization and a strong relationship between fecal bacteria and impervious surfaces (Nelson et al. 2005; Holland et al. 2004). Fecal coliform contamination can come from various sources, including septic tanks, boats, sewage collection system devices, wild and domestic animal populations, and stormwater runoff (Kelsey et al. 2004).

This study investigates the many watersheds in the region that are impaired with bacteria, nutrient overloads, heavy metals, and turbidity, and characterizes the region and the watersheds as a basis for education programming. Data from the internship can help address the situations that have arisen in the Lowcountry in response to increased urbanization, population and human activities.

3.0 Data & Methodology

3.1 Data Acquisition

Various sources supplied data for this internship. The GIS Database Administrator for Berkeley County (e.g. water cover layers for Berkeley) , the Stormwater Engineer for the City of Charleston (e.g. stormwater layers for the City of Charleston) , the College of Charleston Data Resources (e.g. all ESRI data and structural data (buildings and parcels)), HAZUS (state data), The Nature Conservancy (e.g. impervious surface and protected land data) and Jason McMasters (National Oceanic and Atmospheric Association (NOAA) 2008 M.E.S. septic tank project) all provided information in digital format. Data from the following sources were available for download on the World Wide Web: the South Carolina Department of Natural Resources GIS Data Clearinghouse (NWI), the South Carolina Department of Health and Environmental Control GIS Data Clearinghouse (approved TMDL sites and watersheds), and the U.S. Census Bureau Topologically Integrated Geographic Encoding and Reference system (TIGER/Line) (urbanized area and demographic information). A full list of all data acquired, the source, and a description can be found in Appendix A.

3.2 Data Manipulation

The data manipulation and analysis for this project was completed using the GIS program ArcGIS 9.3, created by ESRI (ESRI 2009). For every layer used in this project, the following parameters were necessary: projection in Transverse Mercator, geographic coordinate system in GCS North American 1983, and datum of D North American 1983. Data that was not originally in the necessary form was re-projected into the correct coordinate systems. Approximately 50% of the data layers acquired were clipped first to the Tricounty level, and secondly to the individual watershed levels (Figure 2). All layers were imported into a geodatabase that acts as the database for the internship project.

The water, land use, forest cover, and agricultural land maps were all made using the National Wetlands Inventory (NWI). The impaired watersheds were determined after using the SC DHEC 303(d) list to identify impaired watersheds at the Hydrologic Unit Code (HUC) 12. HUC codes are a way of identifying waterbasins; a larger HUC code, i.e. 12-digit versus 8-digit indicates a smaller stream or watershed. This project used HUC 12 to identify smaller watersheds to aid in better comparisons.

Using the HUC 12 layer, impaired watersheds were selected and exported to form individual impaired watershed layers. These layers were exported and saved under the name of the drainage basin in which the watershed is contained, i.e. Santee water basin or Edisto water basin. The rest of the maps described above were created using layers listed in Appendix A.

The second set of maps constructed show the individual contaminants causing watersheds impairment for the Tricounty level. The impaired watersheds were determined after using the SC DHEC 303 (d) list to identify both impaired watersheds at the HUC 12 and the specific pollutants for which they are impaired. Using the same impaired watershed layers that were exported individually (see description above), individual maps were made to show individual contaminated watersheds. If a watershed was impaired for more than one pollutant, each impaired watershed was represented in the corresponding pollutant map, e.g. pollutant A in watershed 1 was depicted in pollutant A's map, and pollutant B in watershed 1 was depicted in pollutant B's map.

The third set of maps consists of individual watersheds both impaired and unimpaired that fall within the urbanized regions for the Tricounty area. These maps of each watershed provide an individual characterization for each of the following criteria: forest cover, water cover, protected areas, impairment, land-use, impervious surfaces, agricultural land, schools, and stormwater runoff. To determine which watersheds fell within the urbanized area, the urbanized layer was overlaid with the watershed layer at 35% transparency to correctly depict the identification of the watersheds to include in the characterization. The NWI land cover layers for each of the watersheds were set at 35% transparency in order to see the land forms underneath the layer. For the water coverage maps, the 'low marsh' layer was omitted due to the fact that this layer and the 'non-forested wetland' layer show the exact same region.

3.3 Tabular Calculations

In order to determine the total area (m^2) of the land-use for comparison among land covers, the NWI layers for the Tricounty quadrangles were first merged. The desirable data within the attribute table for the merged layer was then selected and exported into an individual shapefile, e.g. 'cropland/pasture.' Within the new layer's attribute table, the 'Area' column was selected, and upon right clicking and selecting 'Statistics,' a sum is given for the 'Area' column. These sums for each land cover or land-use layer were then input into a Microsoft Excel spreadsheet along with the corresponding title of the layer. The equation function within Excel allowed for the conversion of m^2 to the desired units of hectares and acres, thus allowing for easier assessment of total area.

Figure 1. Study Area

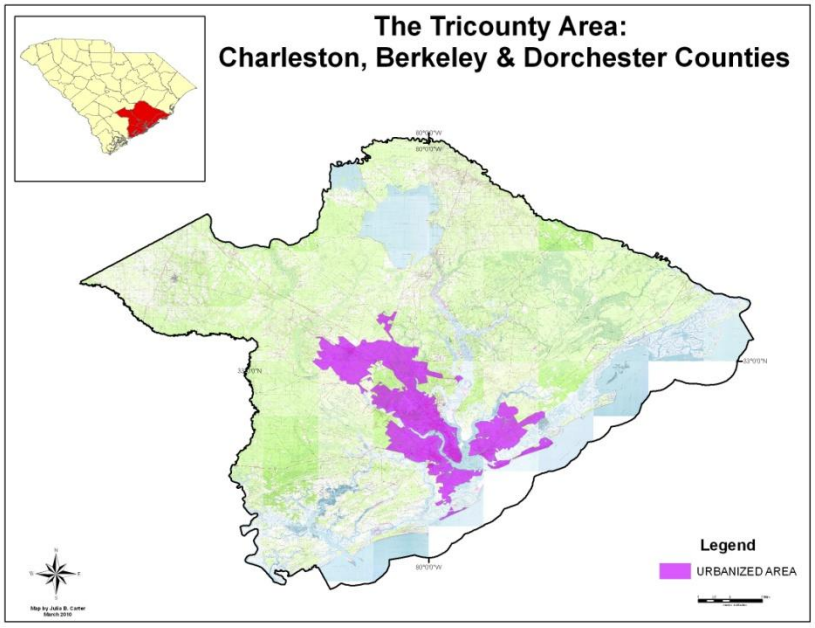
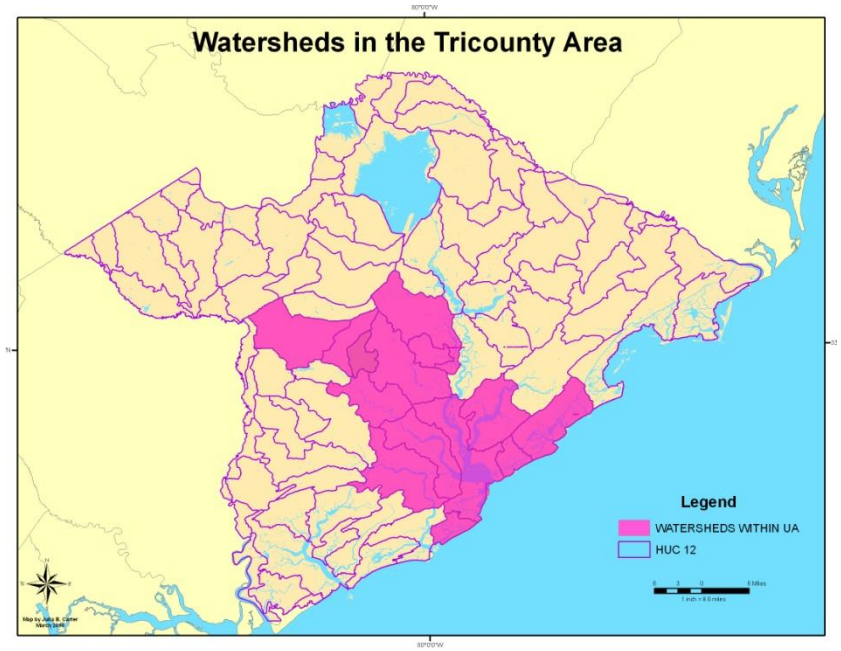


Figure 2. Study Area



4.0 Results

4.1 Tricounty

4.1.1

The Tricounty is comprised of three coastal counties: Charleston, Berkely and Dorchester (Figure 1). The total area for these three counties is 826,684.7697 hectares or 2,042,782.245 acres. Charleston County lies directly on the coast, and consists mainly of estuaries, marshland and urbanized or developed land. The outskirts of Charleston contain part of the Francis Marion National Forest, Cape Romain National Wildlife Refuge, and rural farm land. The southeast corner of Dorchester County is developed, while the rest of the county is mainly agricultural land. Berkeley County is bisected by the West Branch of the Cooper River that meanders North to South from Lake Moultrie to the coast. The southeastern portion of Berkeley County contains part of Francis Marion National Forest, while southwestern Berkeley County is developed and much of the rest of the county is rural to agricultural.

Three sets of maps were constructed to depict the physical landscape of the region; the first two sets of maps incorporated a background made from the National Wetlands Inventory (NWI) that depicts all land as beige and all water as blue. The third set of maps used the digital orthophotographic quarter quadrangles (DOQQ) from the SC DNR for a background that represents the landscape of the Tricounty area. The first set of maps constructed were made at the Tricounty level and are: (1) water, wetlands, and estuary, (2) protected areas (federal, state & private), (3) impaired watersheds, (4) land

use, (5) impervious surfaces, (6) forest cover, (7) agricultural land, and (8) water supply and drainage infrastructure (sewer systems and water systems).

4.1.2 Land-use

Using the NWI, 14 categories were chosen to represent land-use in the Tricounty; these categories and the areas that they represent can be found in Table 1 and Chart 1. The four main categories are: water (Figure 3), forest (Figure 4), agricultural land (Figure 5) and urbanization (Figure 6). Figure 3 represents wetlands and estuaries by displaying the high marsh, low marsh, forested wetland, non-forested wetland, and estuary layers. Forested wetlands, non-forested wetlands and bay/estuaries total 701646.13 acres or 34.34% of the total area in the Tricounty region (Table 2 and Chart 2**).** Figure 4 shows forest cover with the deciduous upland, evergreen upland, and mixed upland forest and upland planted pine layers, which make up 727300.61 acres or 35.63 of the total area (Table 3and Chart 3). Figure 5 represents cropland and pasture, orchards and vineyards, and a confined feeding operation, which make up 165310.74 acres or 8.11 % of the total area (Table 4 and Chart 4). Lastly, Figure 6 depicts commercial, industrial, industrial and commercial complexes, and residential land-uses, that represent some of the urbanization processes in the Tricounty and total 142369.54 acres or 6.97% of the total area (Table 5 and Chart 5).

4.1.3 Impervious Coverage

Figure 7 depicts the extent of impervious coverage at the Tricounty level. The highways, I-26 and I-526 have a total length of 877.826 miles. Due to no length data for

the major roads layer, this calculation was unable to be completed. The impervious surface layer was given by The Nature Conservancy and due to the fact that it is in converted raster grid format, no measurements can be calculated to determine the percent area.

4.1.4 Water and Sewer Systems

Figure 8 represents the sewer systems by using three layers: sewage treatment facilities, sewer lines and septic tanks. The septic tank data comes from another student's thesis project (Jason McMaster 2009) and identifies a portion of Charleston County. The sewer lines have a total length of 1,968.583 miles. Figure 9 represents the water system through such layers as water treatment facilities and water lines. The water lines have a total length of 17,512.751 miles.

4.1.5 Protected Land

Figure 10 depicts the protected land through three levels: federally protected, state protected, and private protected. The federally protected land accounts for an area of 303,103.19 acres or 14.84% of the Tricounty. The total area for the state protected land is 46,608.56 acres or 2.28% of the Tricounty. The private protected land has a total area of 135,093.04 acres or 6.61% of the Tricounty.

4.1.6 Schools

Figure 11 depicts the four school districts within the Tricounty region and the individual schools within each district.

4.1.7 Demographics

Figure 12 depicts the population by census block at the Tricounty level.

4.1.8 Impaired Watersheds

Figure 13 shows impaired watersheds at the HUC 12 level defined by the SC DHEC 303(d) List. Impaired watersheds or waterways are defined as waters that are too polluted or degraded to meet water quality standards set by states (SC DHEC 303(d) List 2008). The solid green color indicates a single impairment, the green stripe indicates two impairments, and the green hatch indicates three or more impairments. The contaminants (or impairments) found in the Tricounty include: fecal coliform bacteria, mercury, dissolved oxygen, chlorophyll A, copper, turbidity, total phosphorous, ammonia nitrogen, and concentrated hydrogen.

Table 1. Land-use within the Tricounty region

Land-use	Area/Hectares	Area/Acres	Percent of Total Area
Upland Planted Pine	220282.15	544329.04	26.65
Forested Wetland	156185.16	385941.94	18.89
Other	123753.03	305800.39	14.99
Non-forested Wetland	93826.39	231850.05	11.35
Cropland/Pasture	66252.15	163712.62	8.01
Mixed Upland Forest	44341.05	109569.11	5.36
Residential	41631.86	102874.57	5.04
Bay/Estuary	33934.56	83854.14	4.1
Evergreen Upland Forest	22868.96	56510.44	2.77
Commercial	14451.6	35710.67	1.75
Deciduous Upland Forest	6835.96	16892.02	0.82
Industrial/Commercial Complex	785.3	1940.52	0.09
Industrial	746.15	1843.78	0.09
Orchard/Vineyard	643	1588.89	0.07
Confined Feeding Operation	2.12	5.23	0.03

Chart 1. Land-use within the Tricounty region

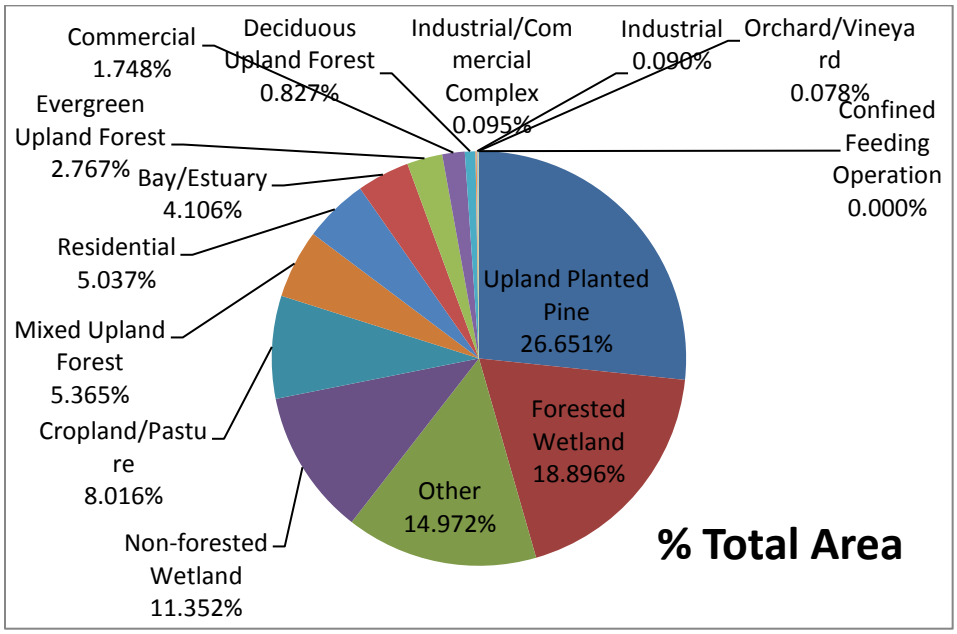


Figure 3. Water cover in the Tricounty

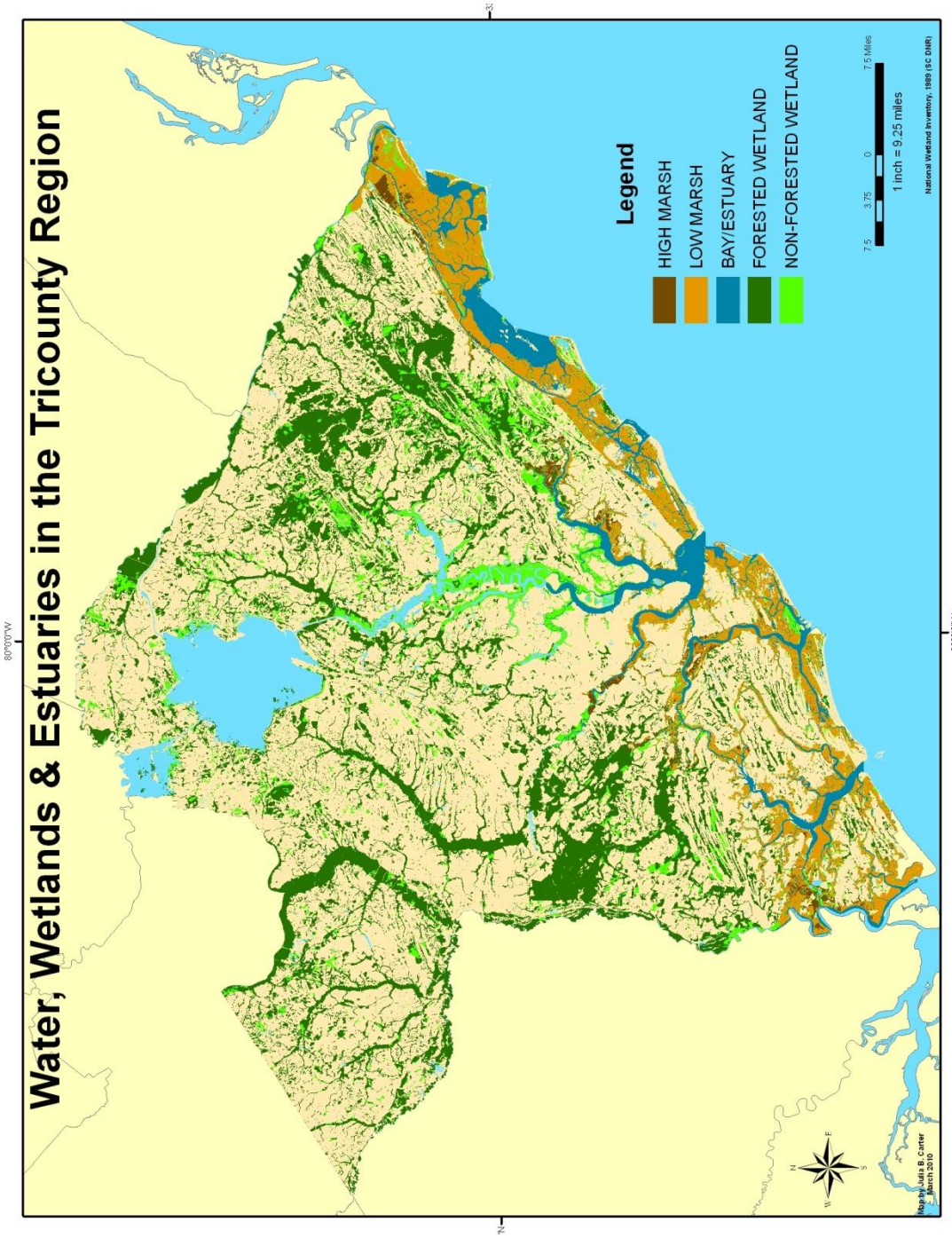


Figure 4. Forest cover in Tricounty region

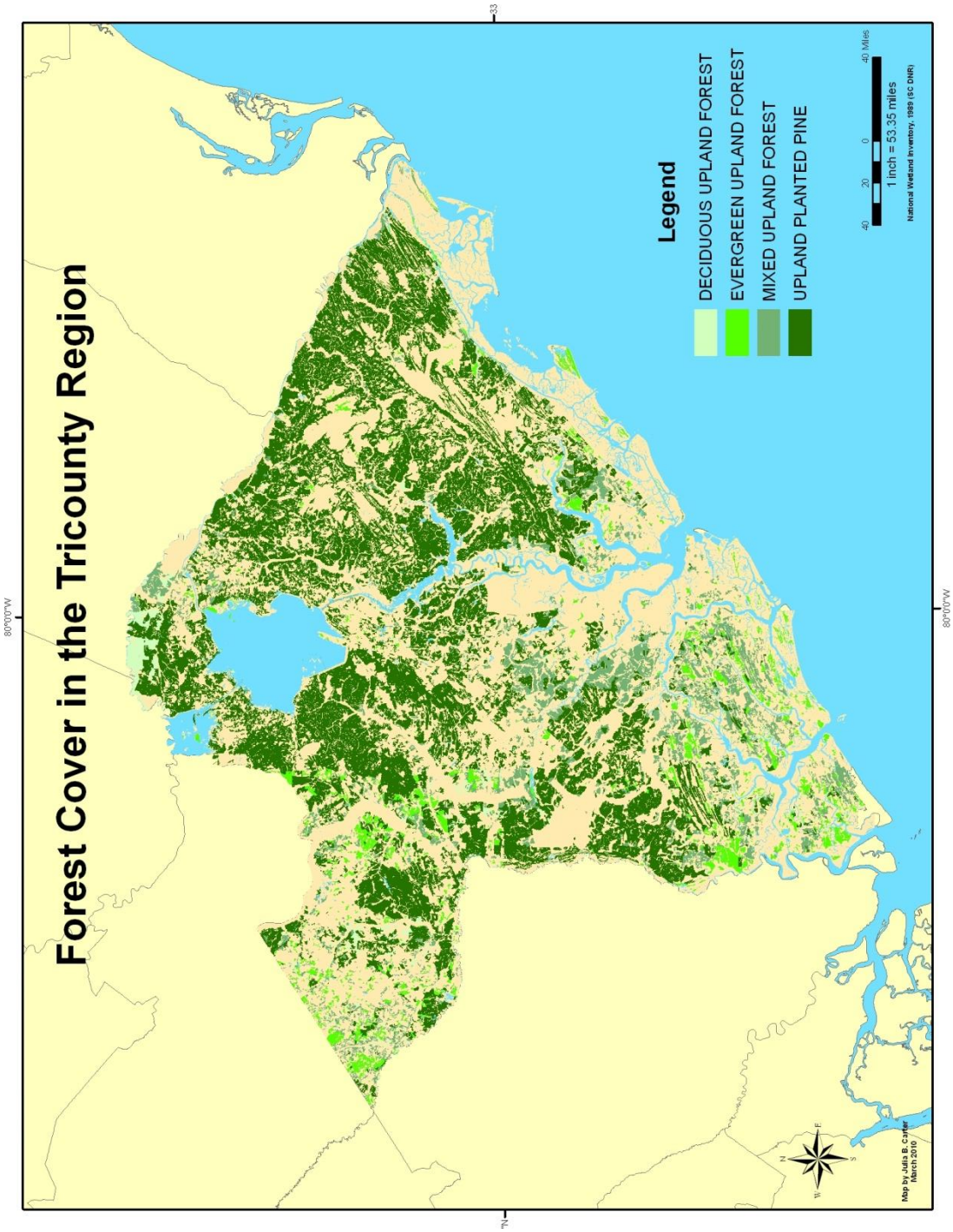


Figure 5. Agricultural land in the Tricounty

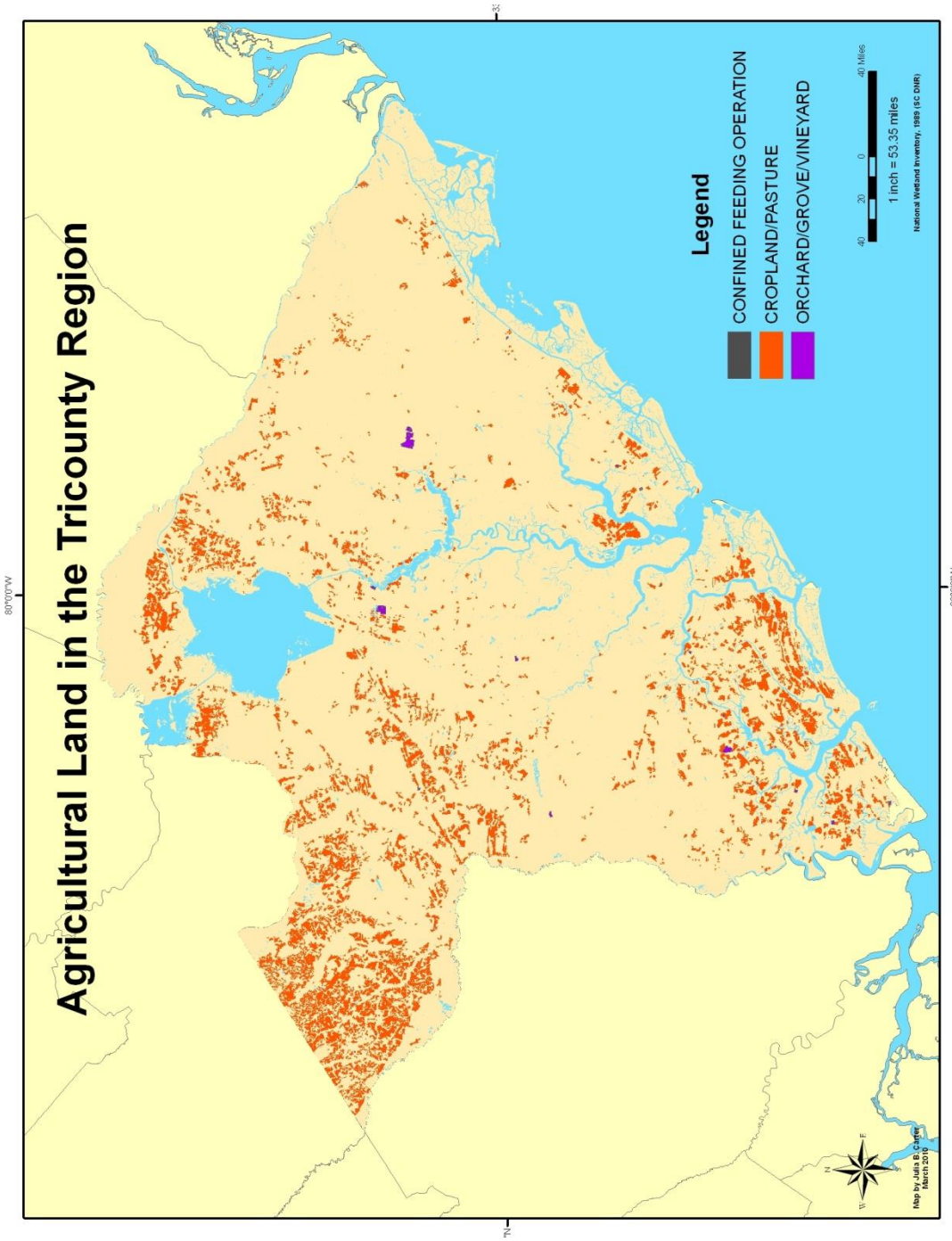


Figure 6. Land development in the Tricounty

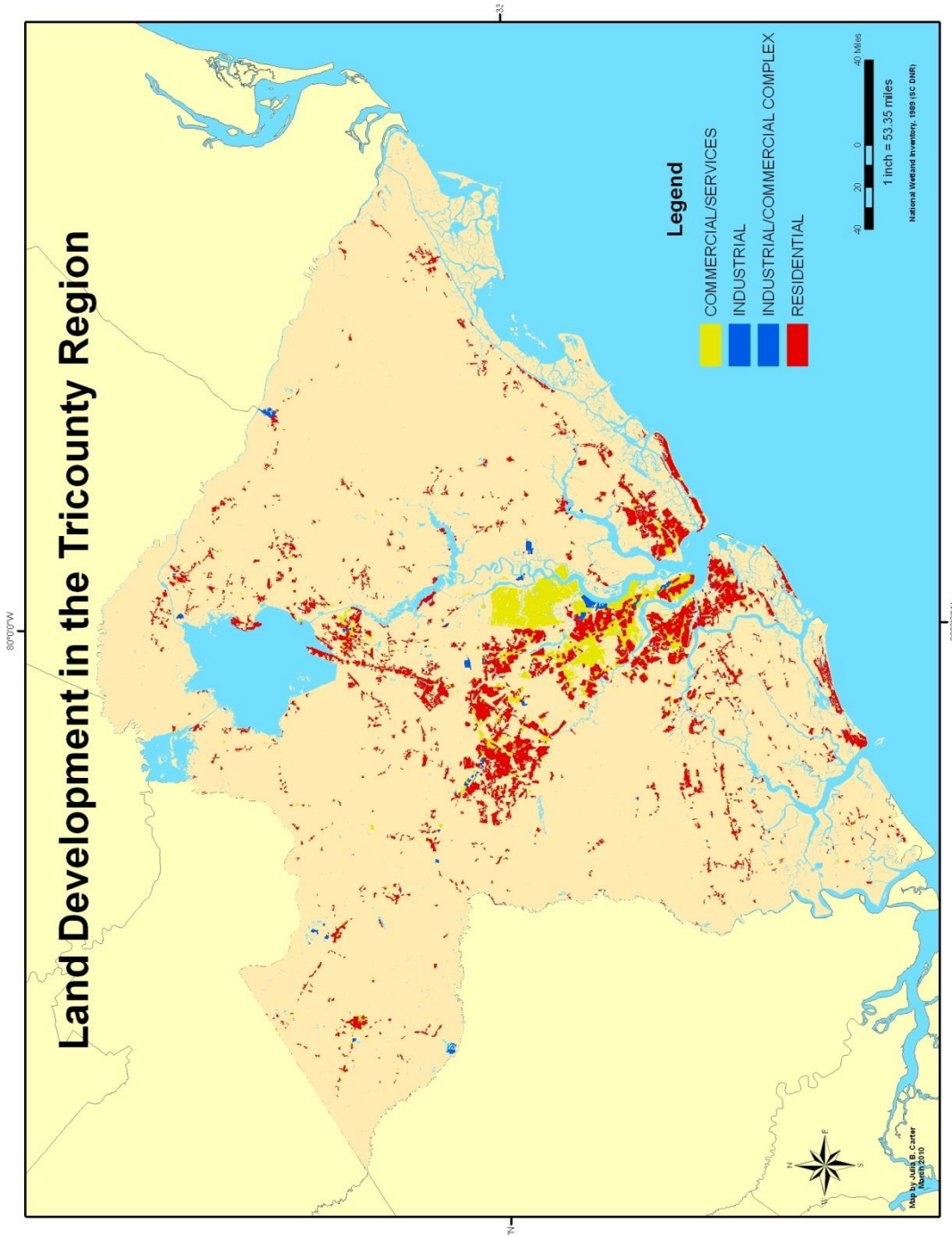


Table 2. Tricounty water cover

Land-use	Area (acres)	% of Total Area
Other	1340777.28	65.66
Forested Wetland	385941.94	18.89
Non-forested Wetland	231850.05	11.35
Bay/Estuary	83854.14	4.1

Chart 2. Tricounty water cover

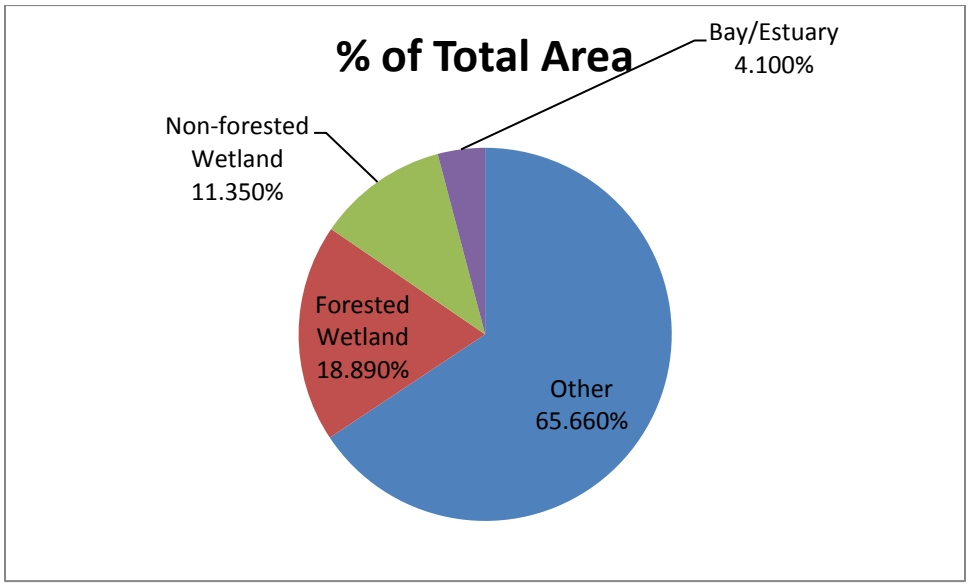


Table 3. Tricounty forest cover

Land-use	Area (acres)	% of Total Area
Other	1315122.8	64.4
Upland Planted Pine	544329.04	26.65
Mixed Upland Forest	109569.11	5.36
Evergreen Upland Forest	56510.44	2.77
Deciduous Upland Forest	16892.02	0.82

Chart 3. Tricounty forest cover

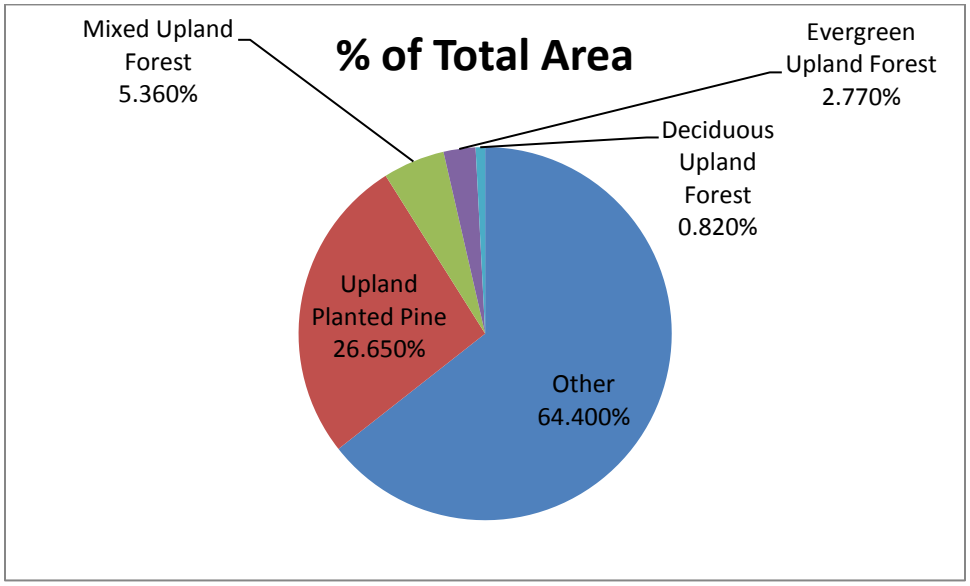


Table 4. Agricultural land in the Tricounty

Land-use	Area (acres)	% of Total Area
Other	1877112.67	91.89
Cropland/Pasture	163716.62	8.01
Orchard/Vineyard	1588.89	0.07
Confined Feeding Operation	5.23	0.03

Chart 4. Agricultural land in the Tricounty

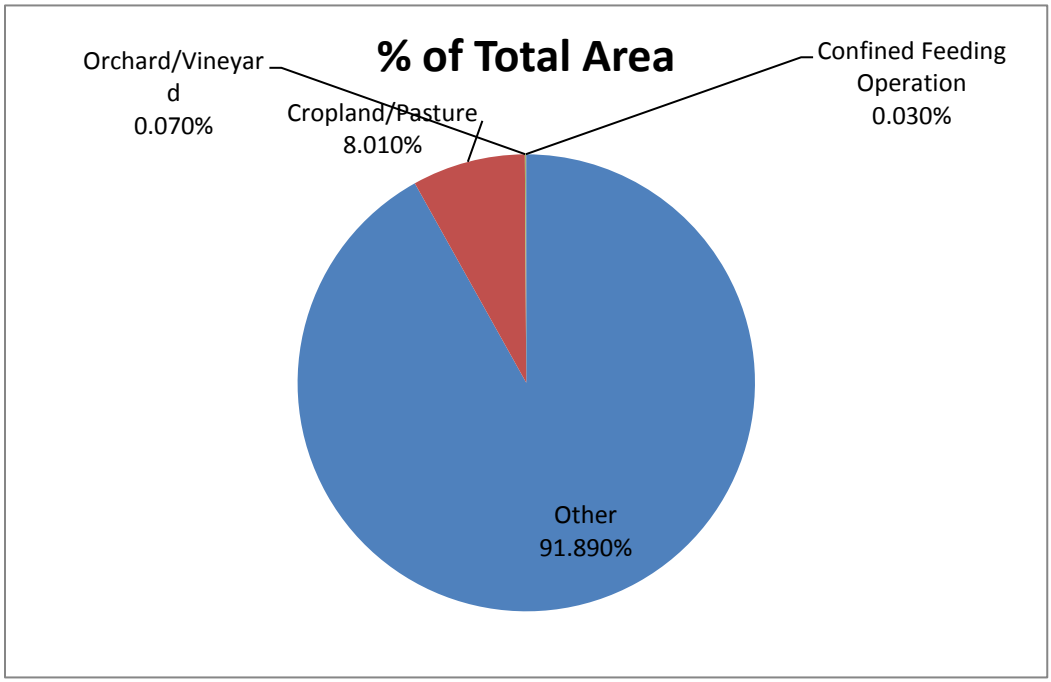


Table 5. Developed land in the Tricounty

Land-use	Area (acres)	% of Total Area
Other	1900053.87	93.03
Residential	102874.57	5.04
Commercial	35710.67	1.75
Industrial/Commercial	1940.52	0.09
Industrial	1843.78	0.09

Chart 5. Developed land in the Tricounty

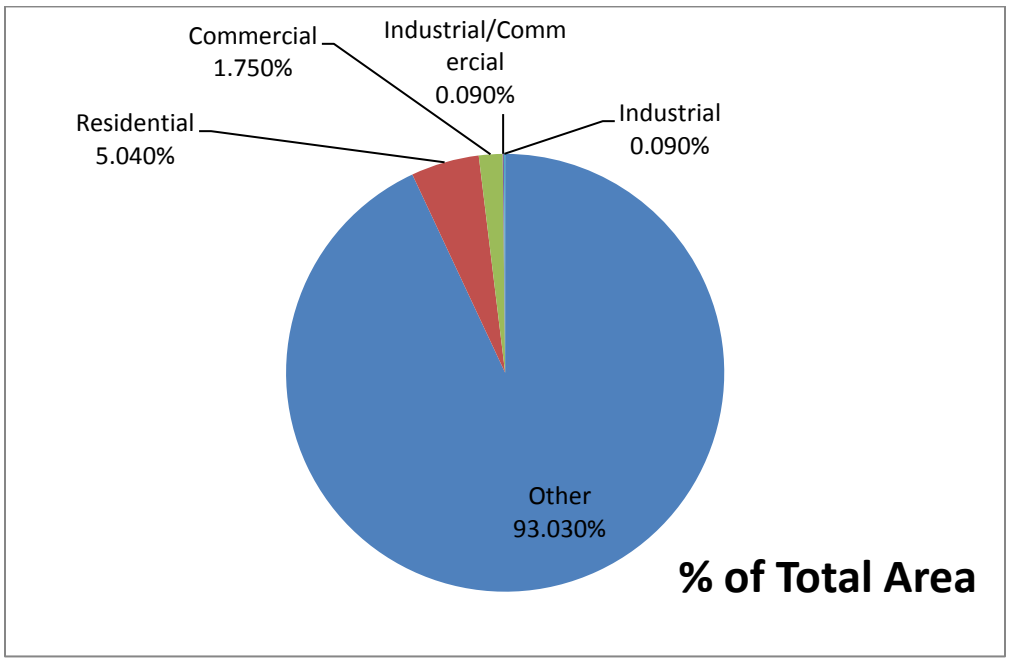


Figure 7. Tricounty impervious surfaces

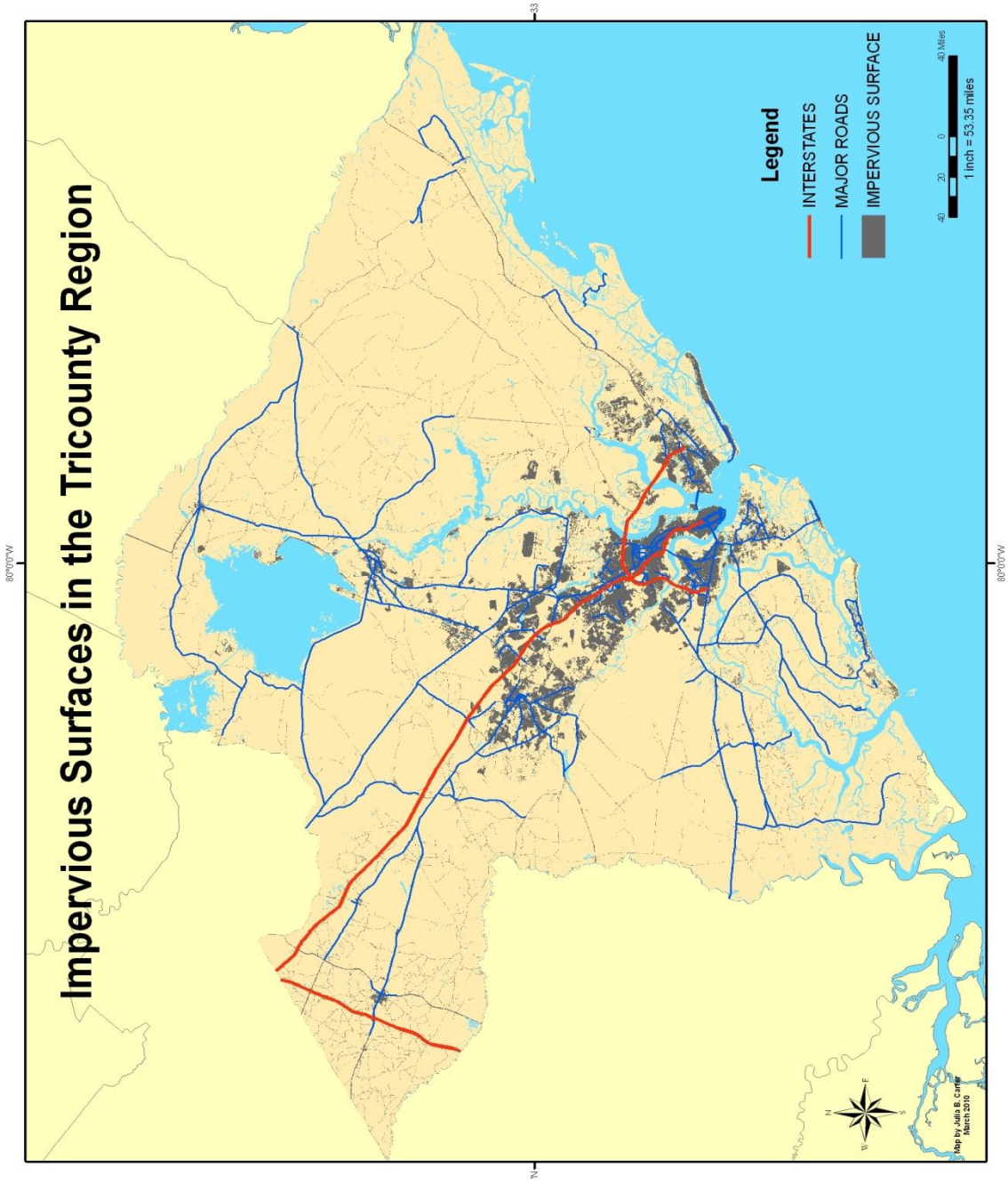


Figure 8. Tricounty sewer systems

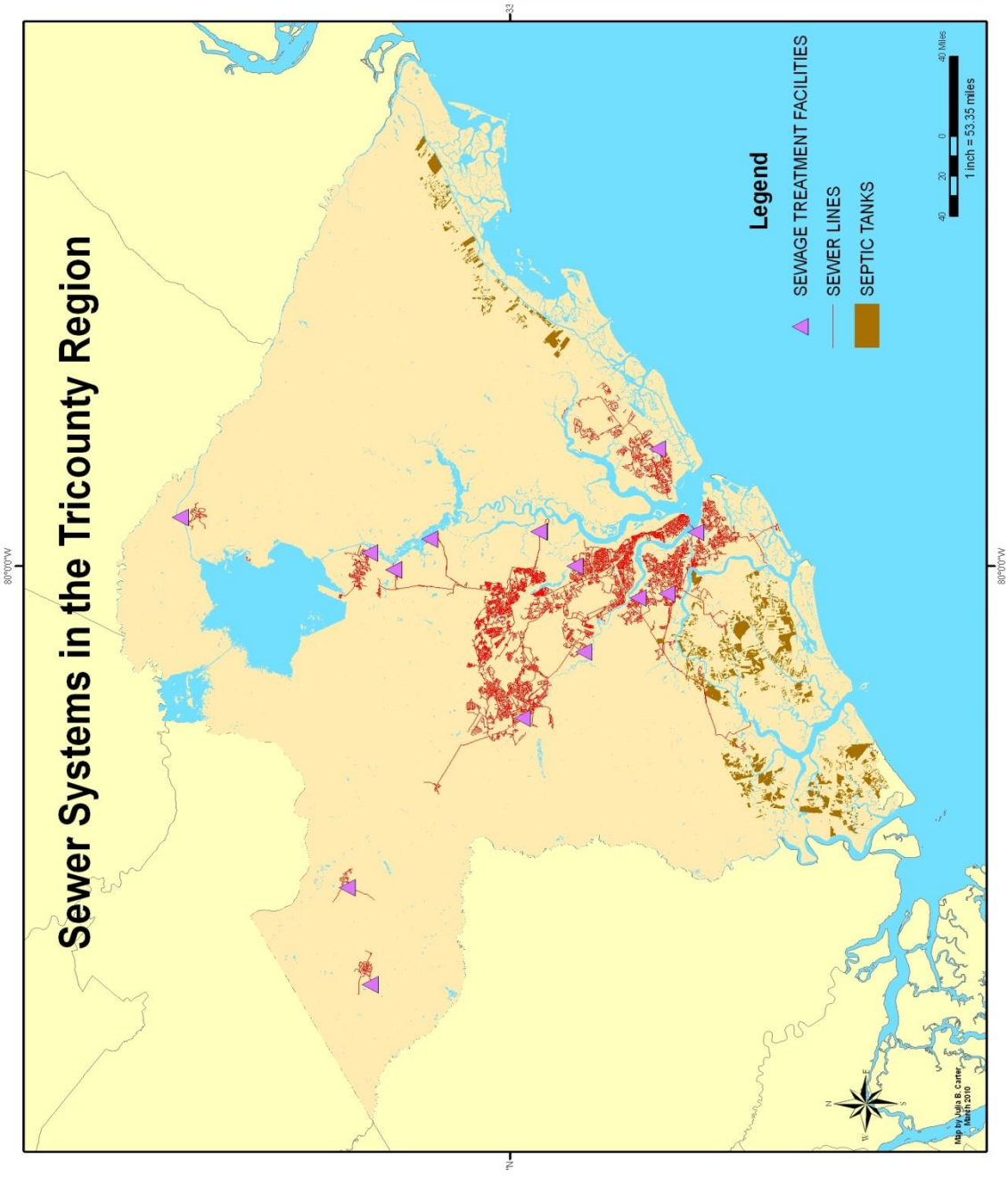


Figure 9. Tricounty water systems

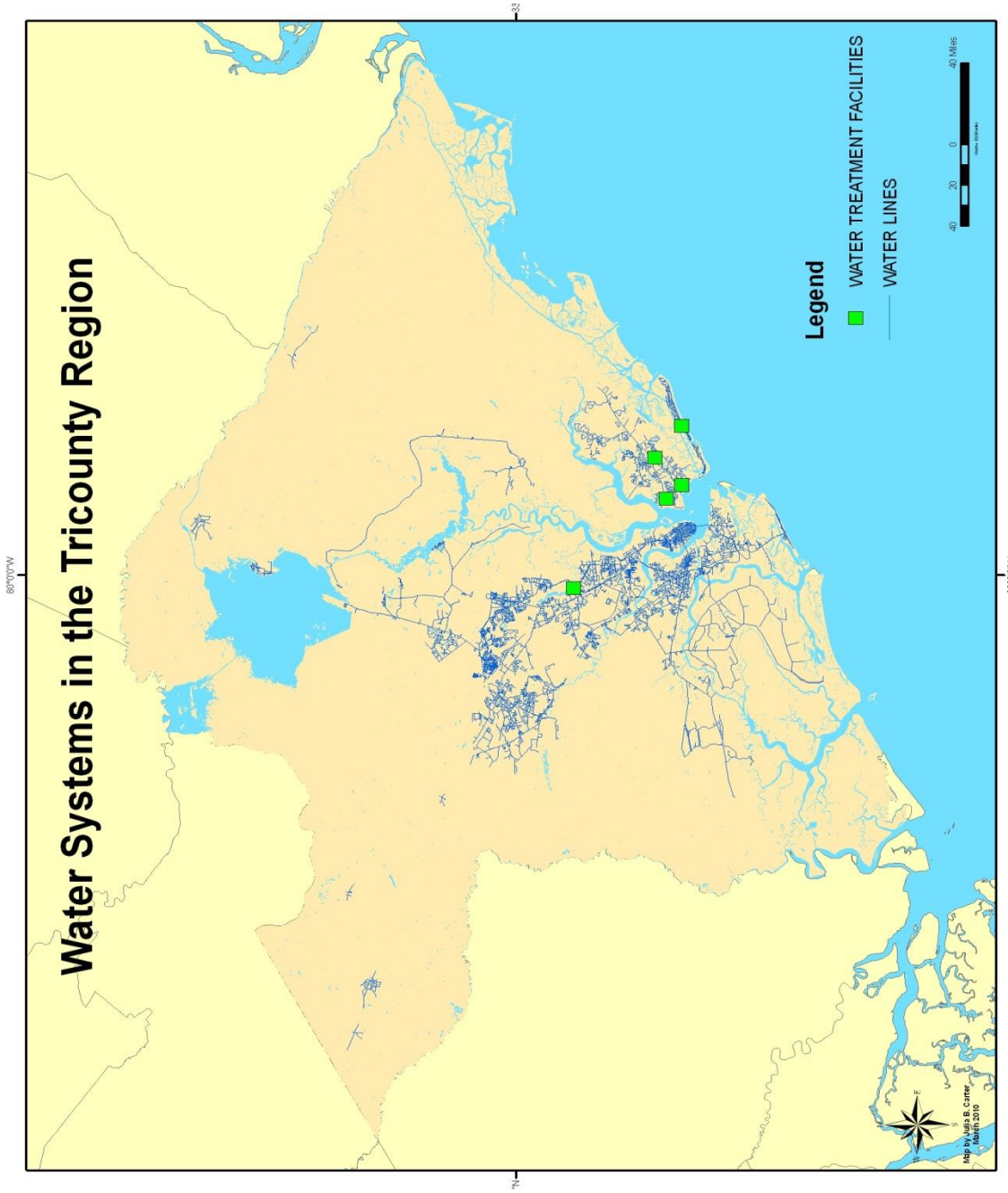


Figure 10. Tricounty protected land

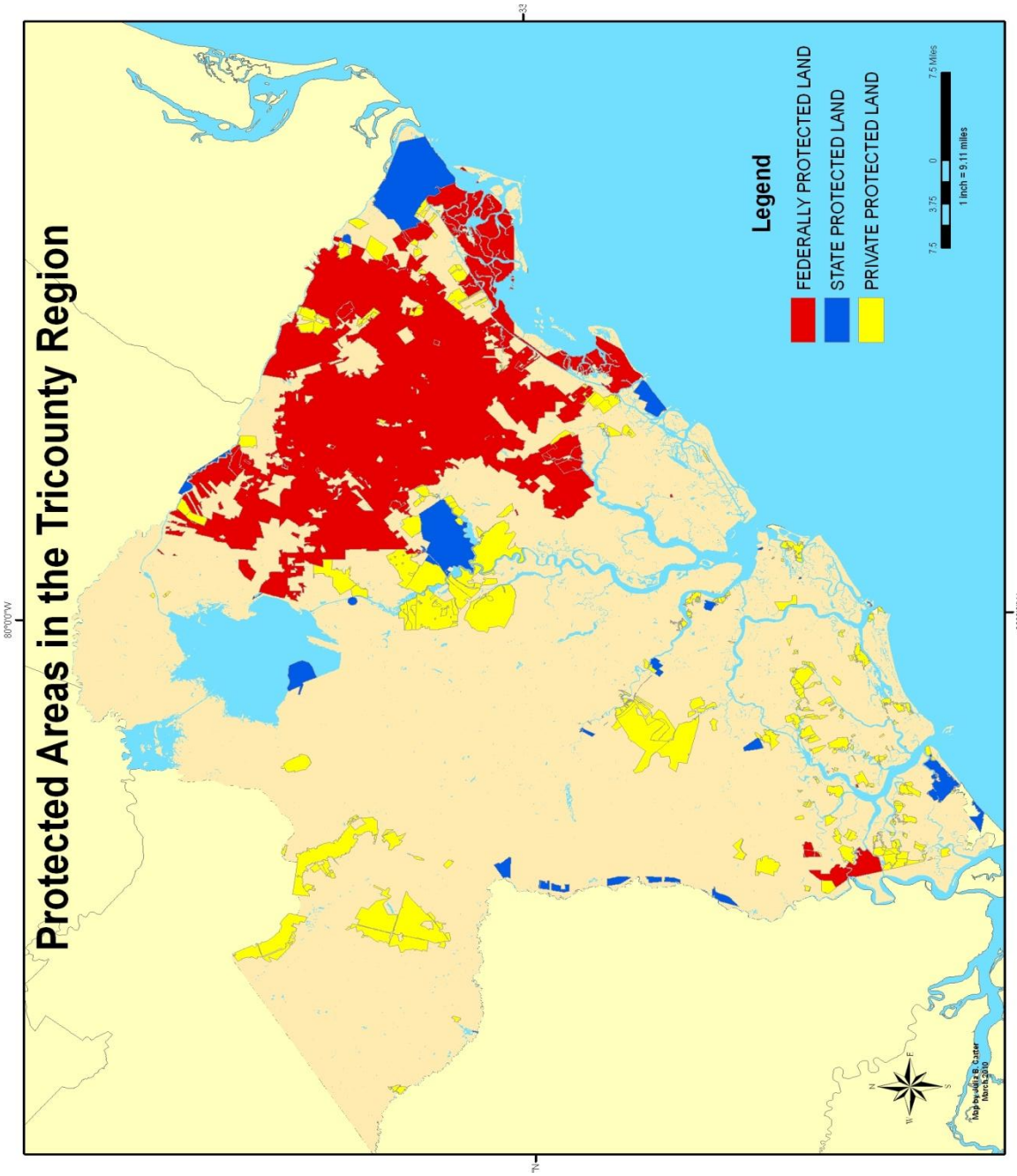


Figure 11. Tricounty schools

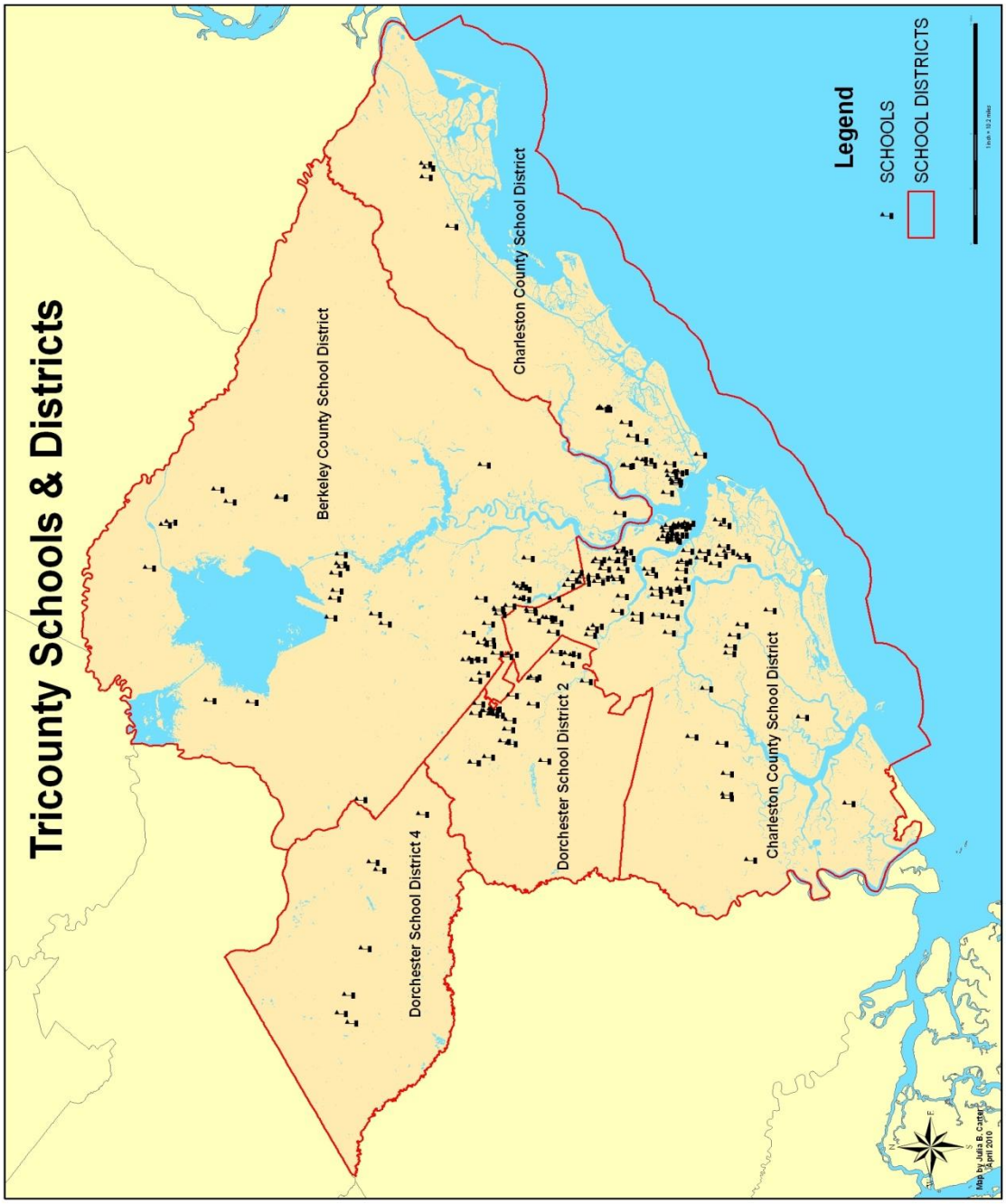


Figure 12. Tricounty population

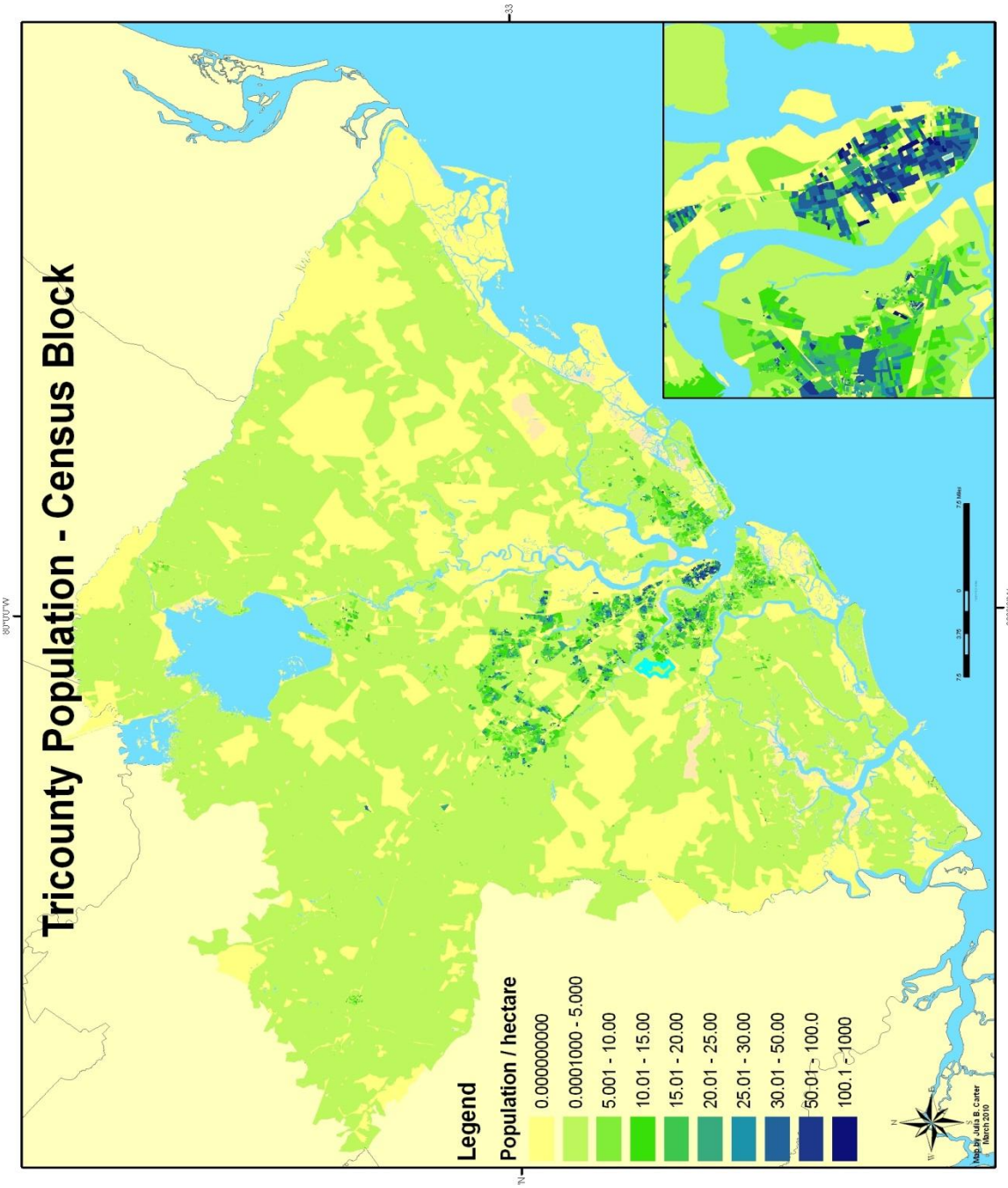
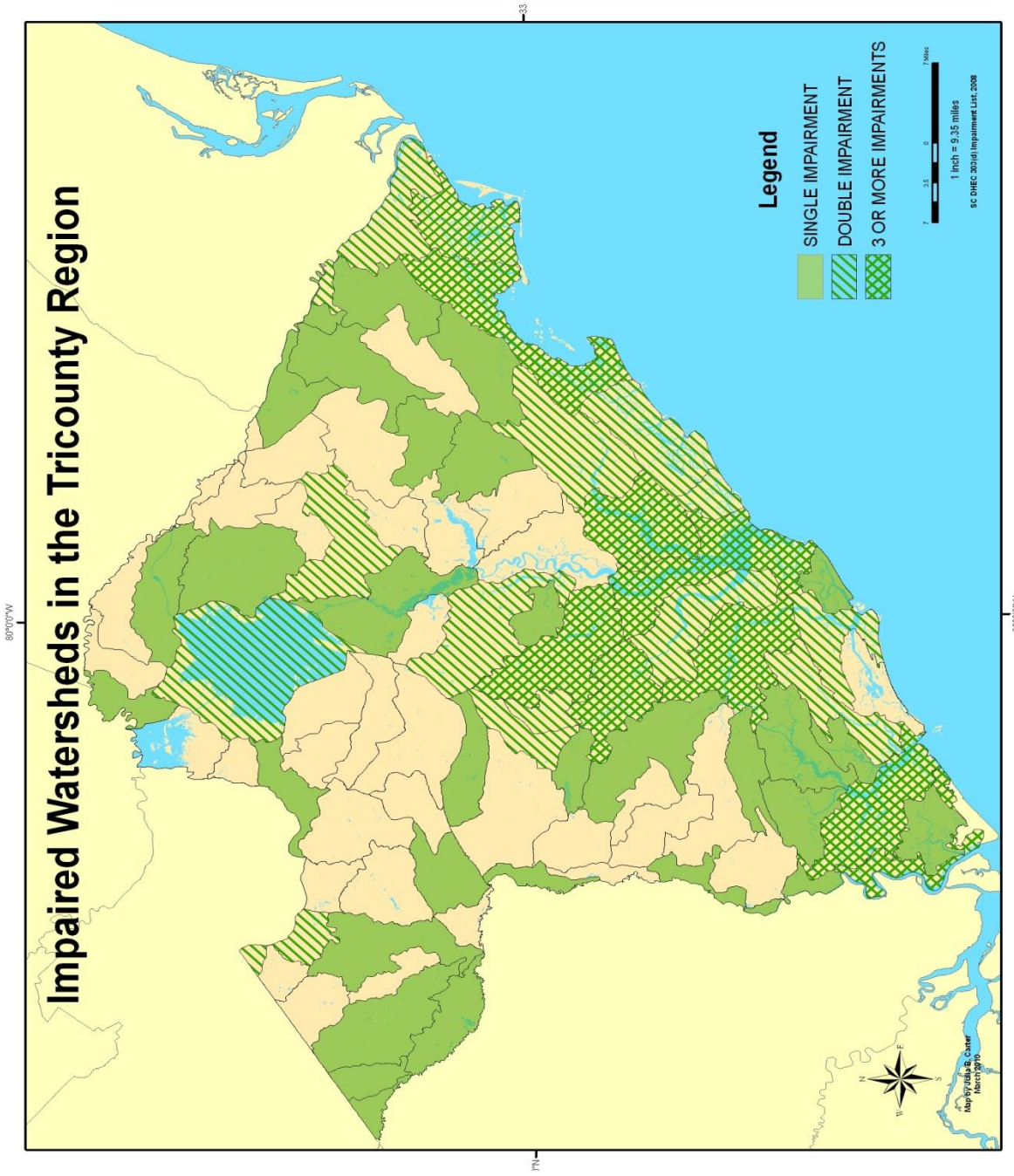


Figure 13. Impaired watersheds at HUC 12



4.2 Watersheds Impaired for Specific Contaminants

4.2.1 Fecal Coliform

Figure 14 represents the watersheds within the Tricounty that are impaired for fecal coliform. There are a total of 33 out of 91 watersheds impaired for fecal coliform, the majority of which fall in Charleston County.

4.2.2 Dissolved Oxygen

Figure 15 represents the Tricounty watersheds that are impaired for dissolved oxygen. There are a total of 14 out of 91 watersheds impaired for dissolved oxygen, the majority of which fall in Charleston County.

4.2.3 Turbidity

Figure 16 represents the watersheds that are impaired for turbidity, of which there are a total of nine (out of 91 Tricounty watersheds); two of the nine are located in Dorchester County while the rest are located in Charleston County.

4.2.4 Heavy Metals

Figure 17 represents watersheds that are impaired with heavy metals. There are a total of 21 contaminated watersheds. Seven of the watersheds are impaired with copper and are found solely in Charleston County, and 16 of the watersheds are impaired with mercury and are found mainly in Dorchester and Berkeley Counties.

4.2.5 Nutrients

Figure 18 represents watersheds that are impaired with nutrient overload. There are a total of four contaminated watersheds; three are impaired with ammonia nitrogen (NH_3N) and one is impaired with both total phosphorous (TP) and Chlorophyll A (CHLA). Charleston County and Dorchester County share these watersheds.

Figure 14. Fecal coliform – Tricounty

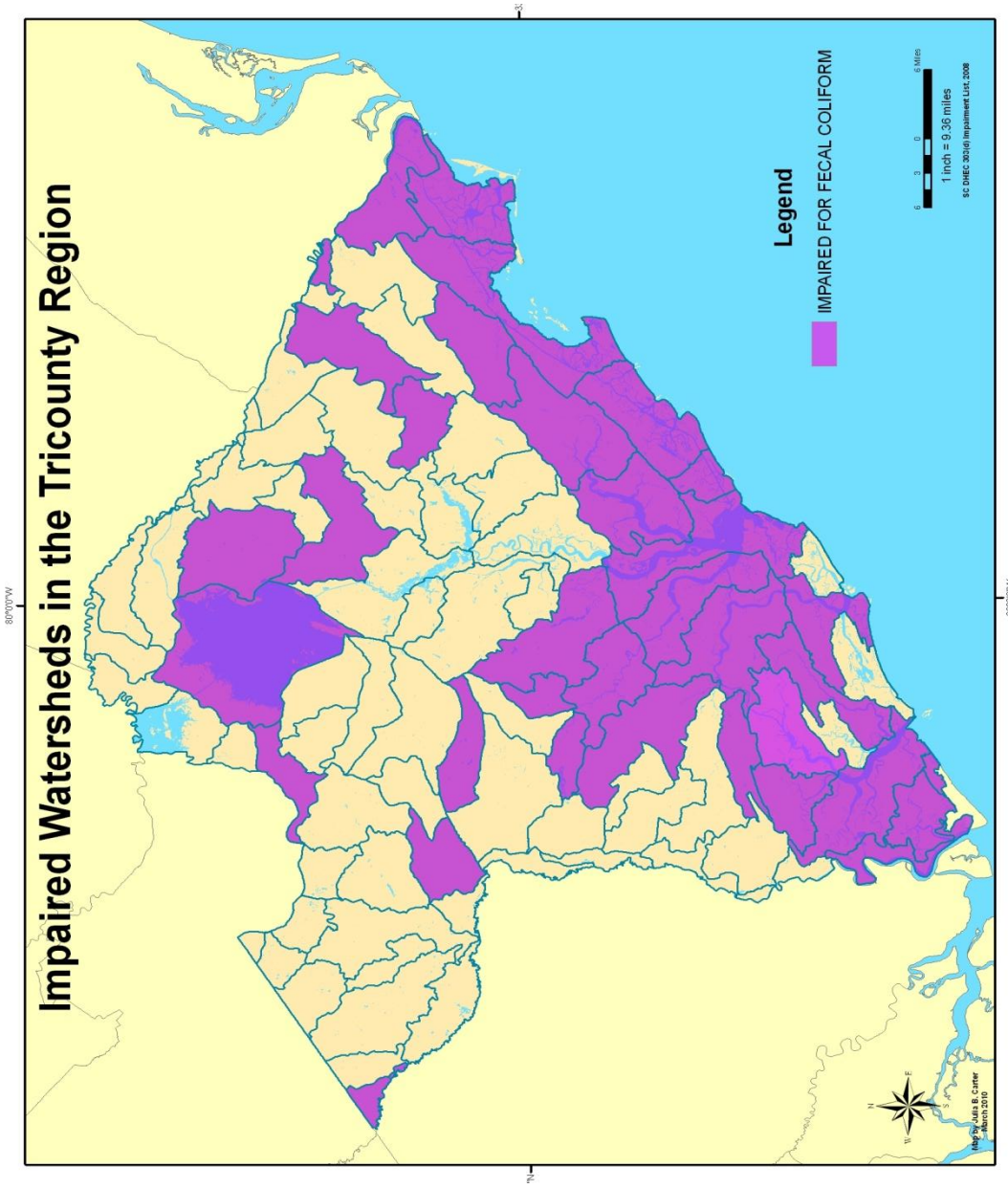


Figure 15. Dissolved Oxygen – Tricounty

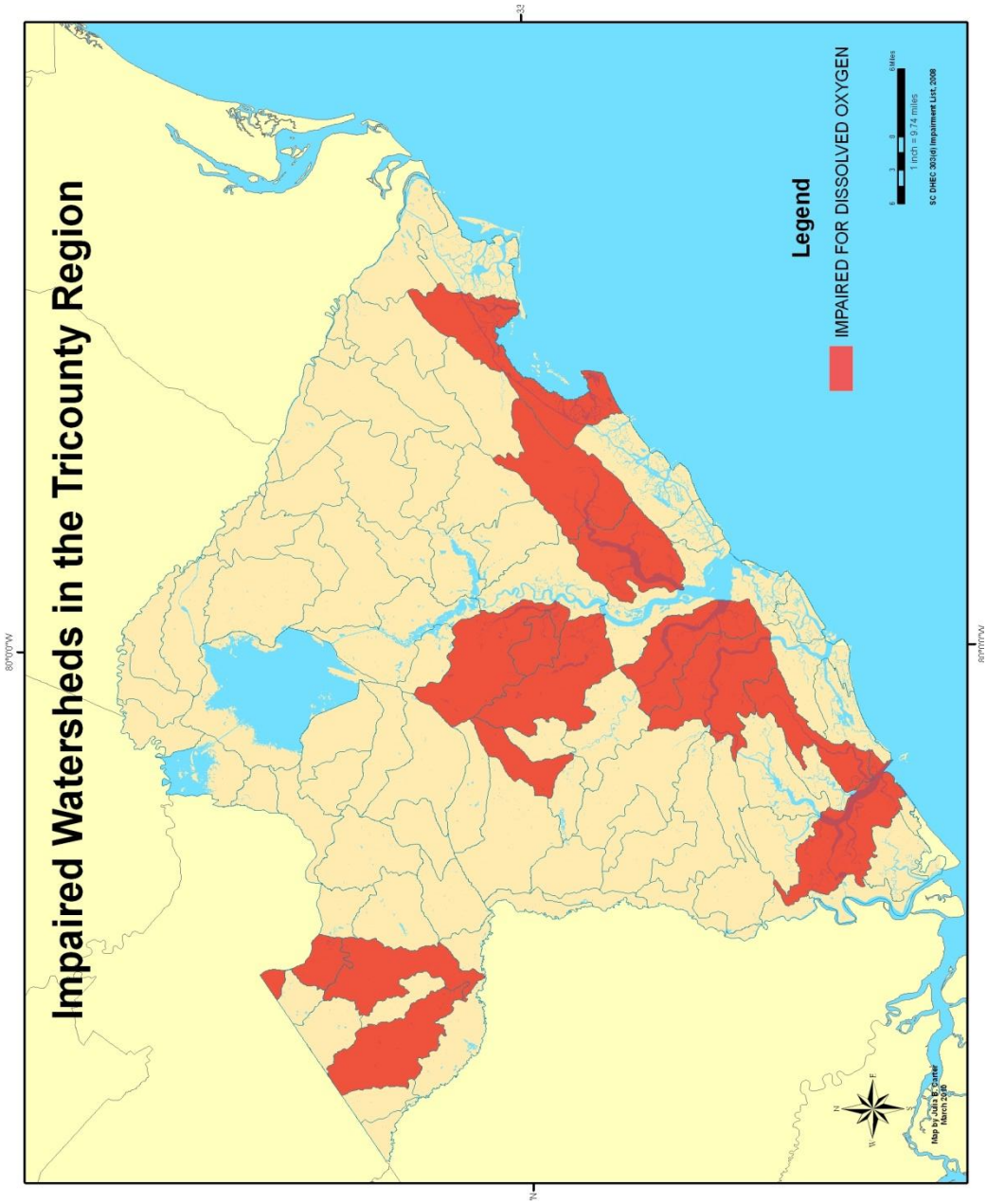


Figure 16. Turbidity – Tricounty

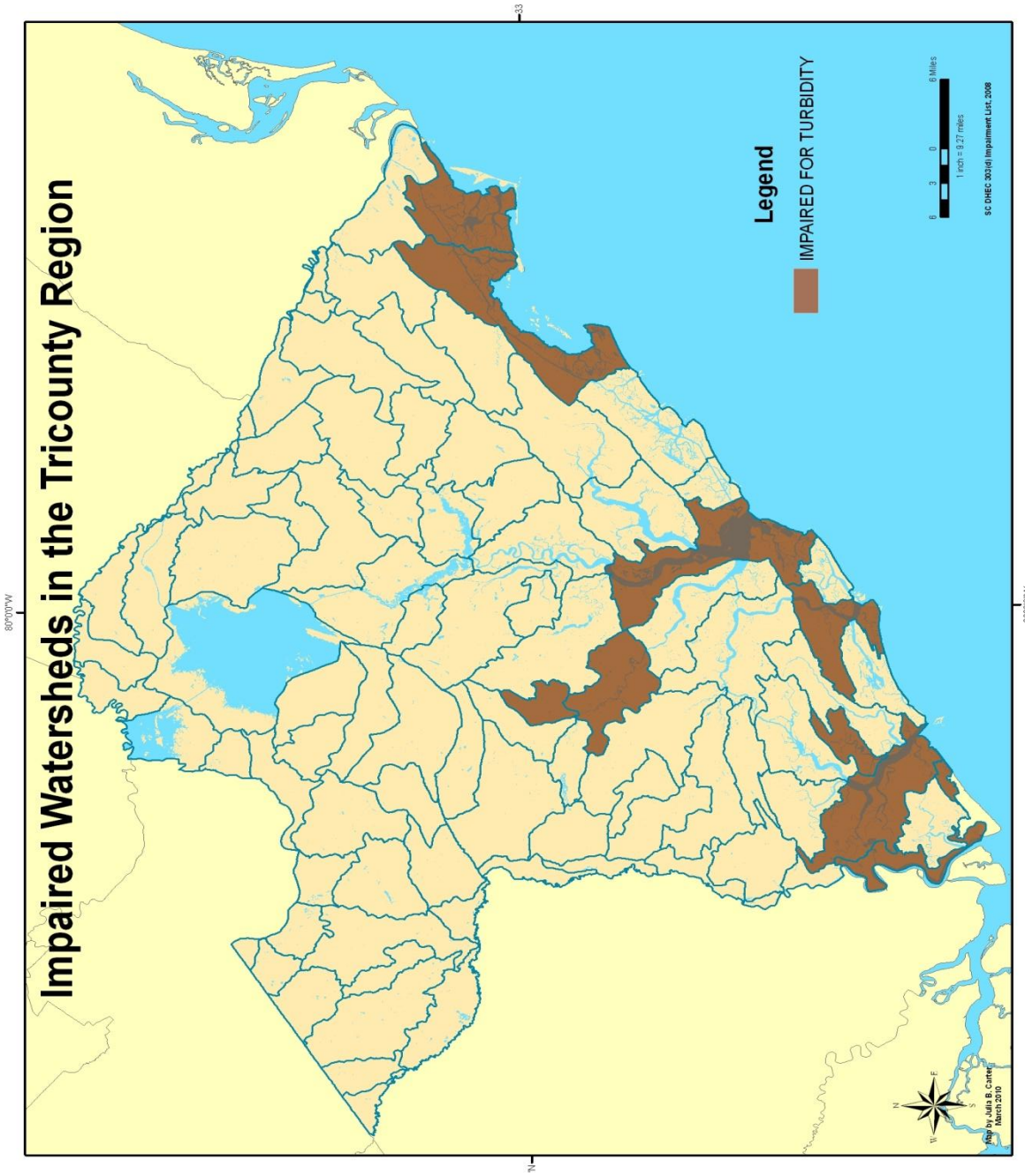


Figure 17. Heavy metals – tricounty

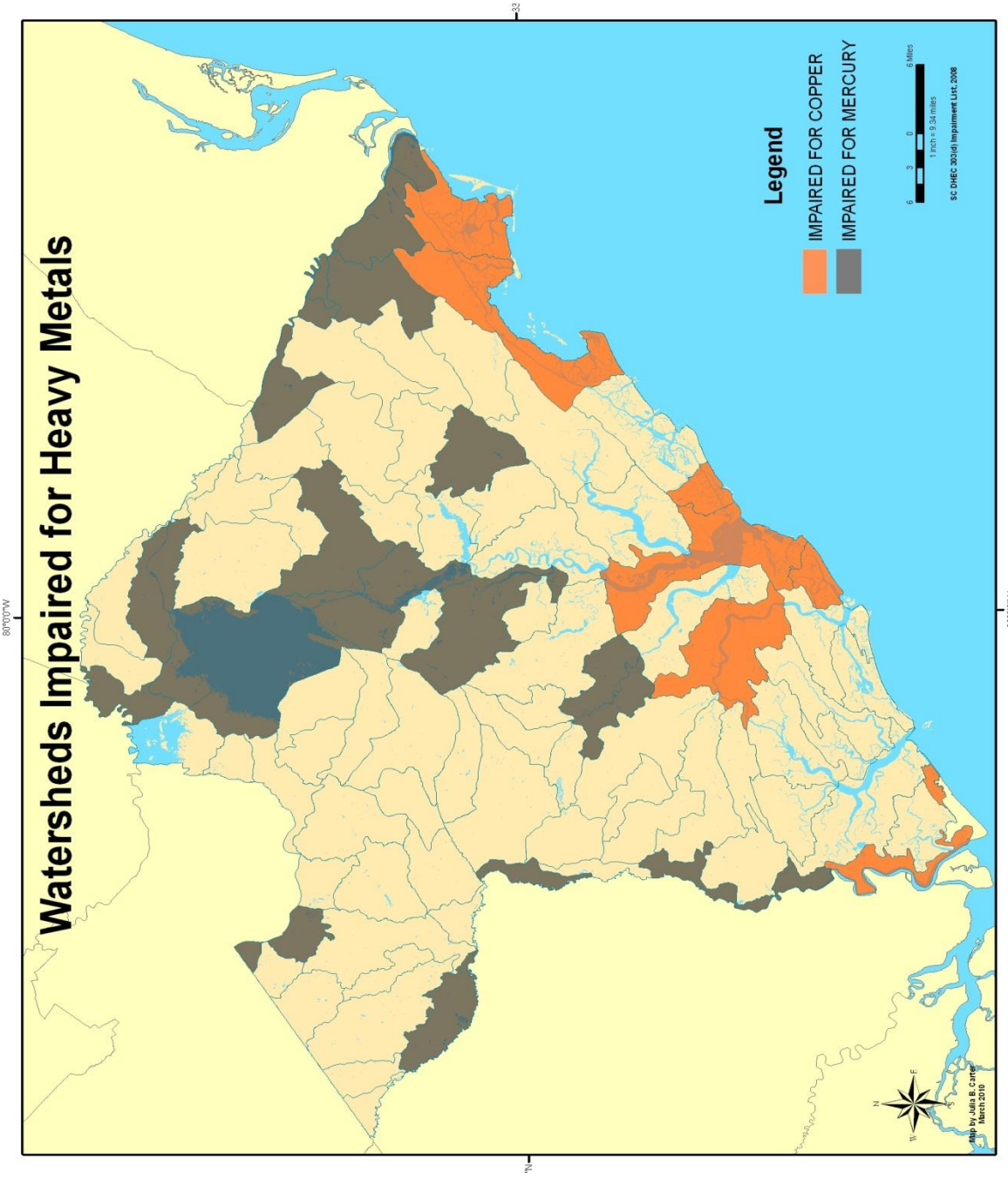
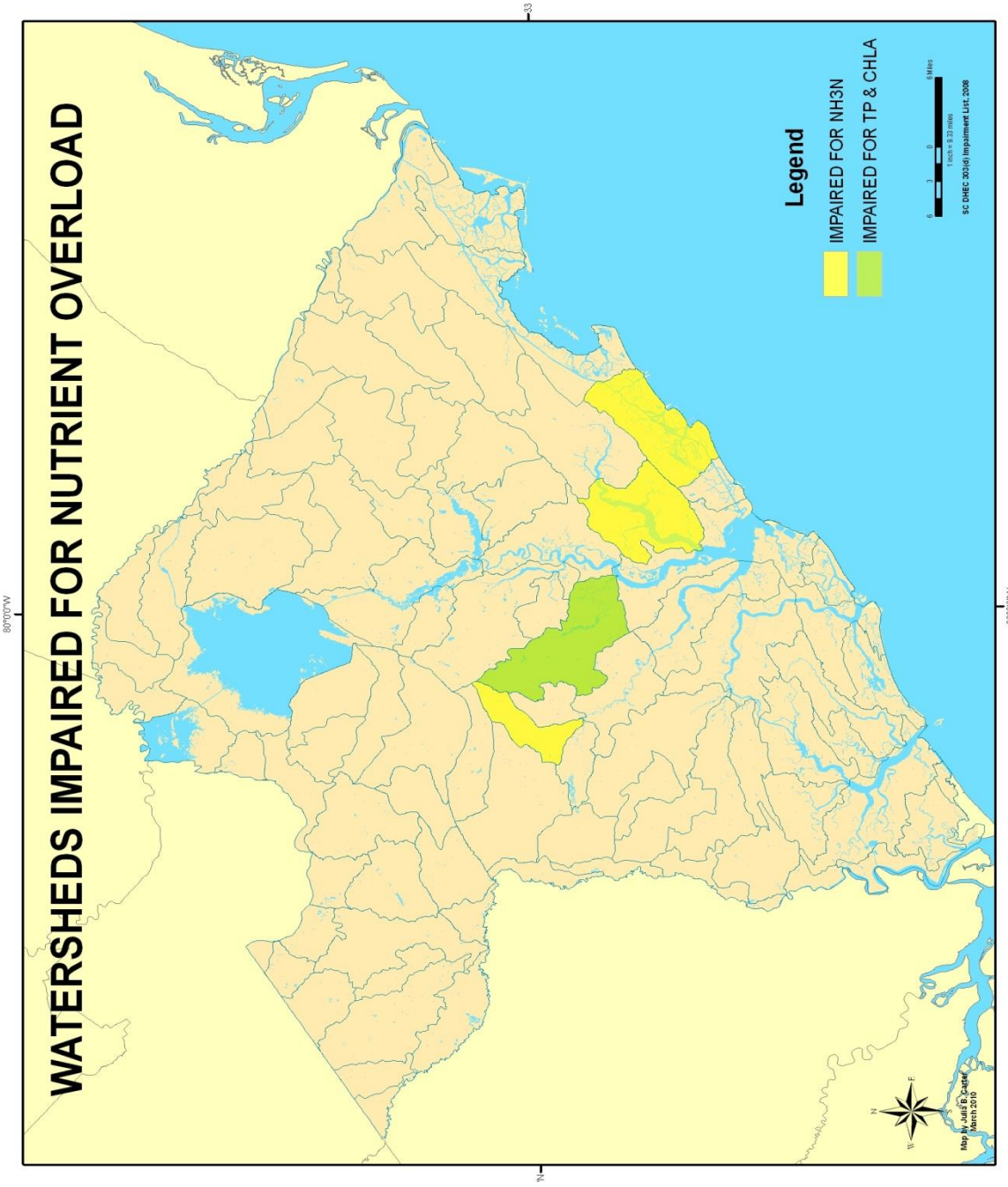


Figure 18. Nutrient overloads – Tricounty



4.3 Watersheds in Urbanized Area

There are 14 watersheds within the boundary for the urbanized area; 12 of the 14 urbanized watersheds fall in Charleston County.

4.3.1 Copahee Sound – HUC 030502090203

The Copahee Sound watershed is located on the coast of Charleston County and incorporates the northeastern corner of Isle of Palms and the southwestern corner of Bull Island and is a total of 31,432 acres. A number of bays, sounds and marshland run through the interior of the watershed along with the Atlantic Intracoastal Waterway, with Isle of Palms and Bull Island on one side and Mt. Pleasant on the other side (Figure 19). This watershed, though within the urbanized area is on the outskirts, with the Isle of Palms and the Town of Mt. Pleasant being considered the urbanized portion of the watershed. Figures 19-24, Table 6 & Chart 6 represent the characterizations of this watershed. A total of 55.39% of this watershed is bay/estuary and non-forested wetland, with forested wetlands located on the northern and southern edges of the watershed and accounting for 4.36% of the watershed (Figure 19). Figure 20 shows deciduous upland forest, evergreen upland forest and mixed upland forest along the Mt. Pleasant side of the watershed with evergreen upland forest scattered along the Isle of Palm side; the forest cover makes up 12.21% of the watershed. There are no deciduous upland forests in this watershed. Figure 21, representing the agricultural land, shows that there is cropland and pasture along the Mt. Pleasant side of the watershed only (6.04%) and there are no orchard/vineyards or confined feeding operations in this watershed. Figure 22,

representing the land development, shows the Mt. Pleasant and Isle of Palm portions of the watershed to be mainly residential (7.4%); the Mt. Pleasant side has a small portion of commercial land (0.12%) and there is no industrial land in this watershed. There are very few impervious surfaces (Figure 23) in this watershed; they fall only on the Mt. Pleasant and Isle of Palm quadrants; there are no major roads or interstates. The only representations of sewer systems (Figure 23) in this watershed are in the form of sewer lines on the Mt. Pleasant portion of the watershed; sewer information for Isle of Palms is not available. There are several waterlines (Figure 23) on the portion of Isle of Palms depicted and there are a few waterlines and one water well on the mainland (Mt. Pleasant); there are no water treatment facilities. Caper's Island is state protected land (Figure 24), Bull Island is federally protected, and there are some parcels directly across from these two islands that are privately protected, as well as a small area on Isle of Palms. This watershed is impaired for both fecal coliform bacteria and ammonia nitrogen.

Table 6. Copahee Sound watershed
HUC 030502090203 – Total area: 31,432 acres

Land-use	Area (acres)	% of Total Area
Non-forested Wetland	12969	41.26
Bay/Estuary	4442	14.13
Sandy Areas	3484	11.08
Residential	2326	7.4
Cropland/Pasture	1897	6.04
Upland Planted Pine	1657	5.27
Forested Wetland	1371	4.36
Mixed Upland Forest	1198	3.81
Evergreen Upland Forest	984	3.13
Other Urban	502	1.6
Beaches	295	0.94
Open Water	196	0.62
Trasportation Utilities	43	0.14
Commercial Services	38	0.12
Transitional Areas	30	0.1

Chart 6. Copahee Sound watershed land-use

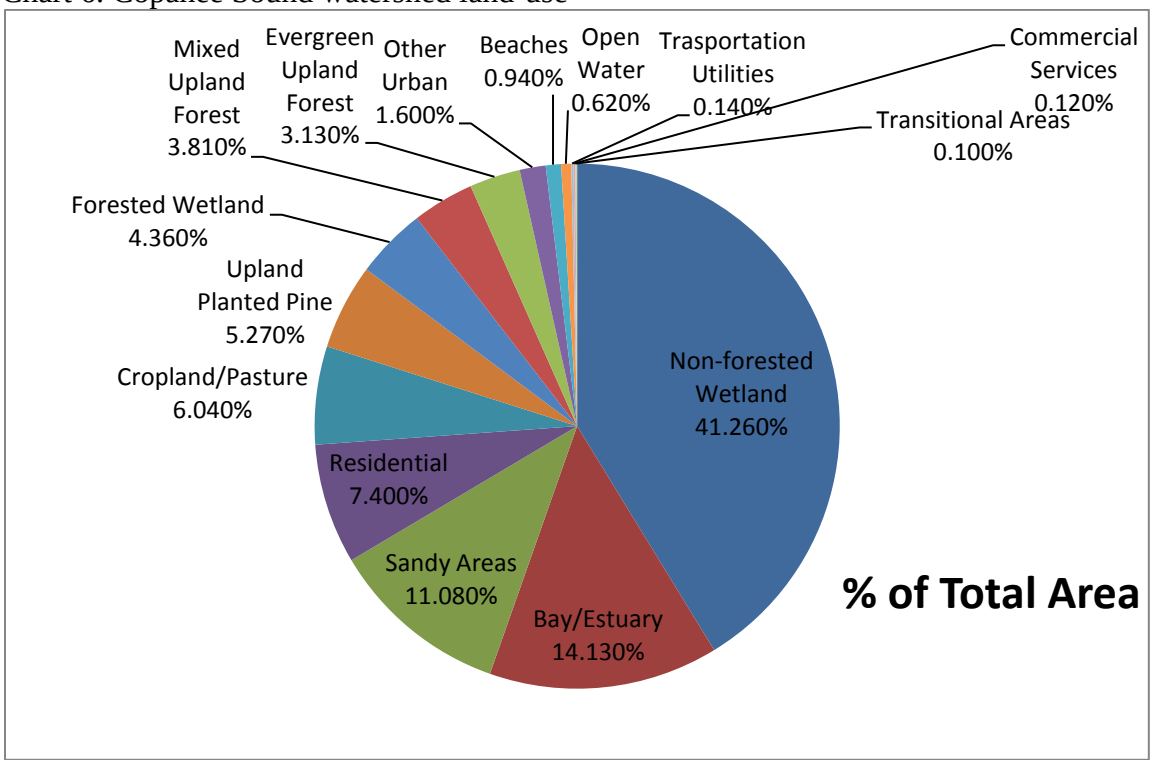


Figure 19. Copahee Sound watershed water cover

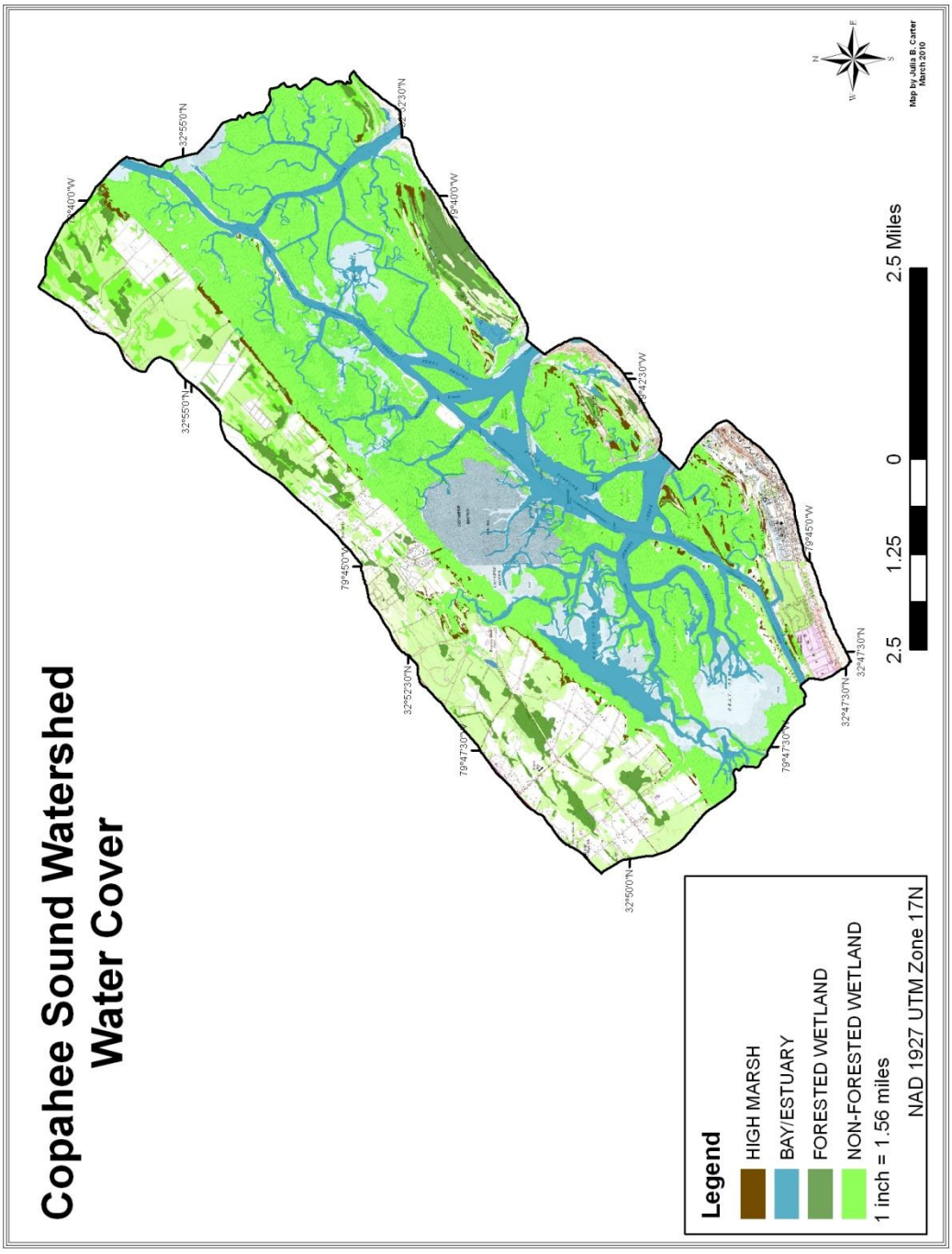


Figure 20. Copahee Sound watershed forest cover

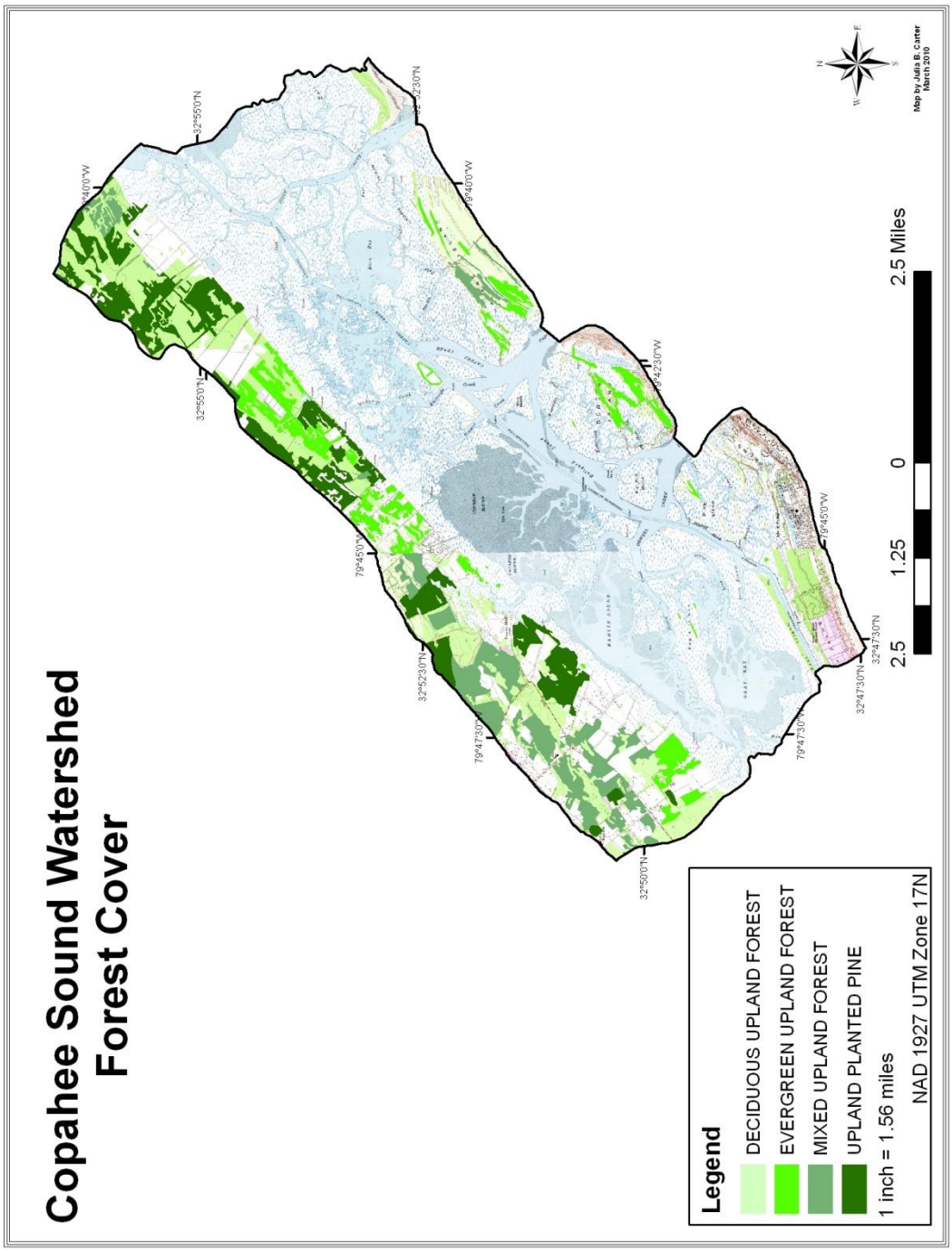


Figure 21. Copahee Sound watershed agricultural land

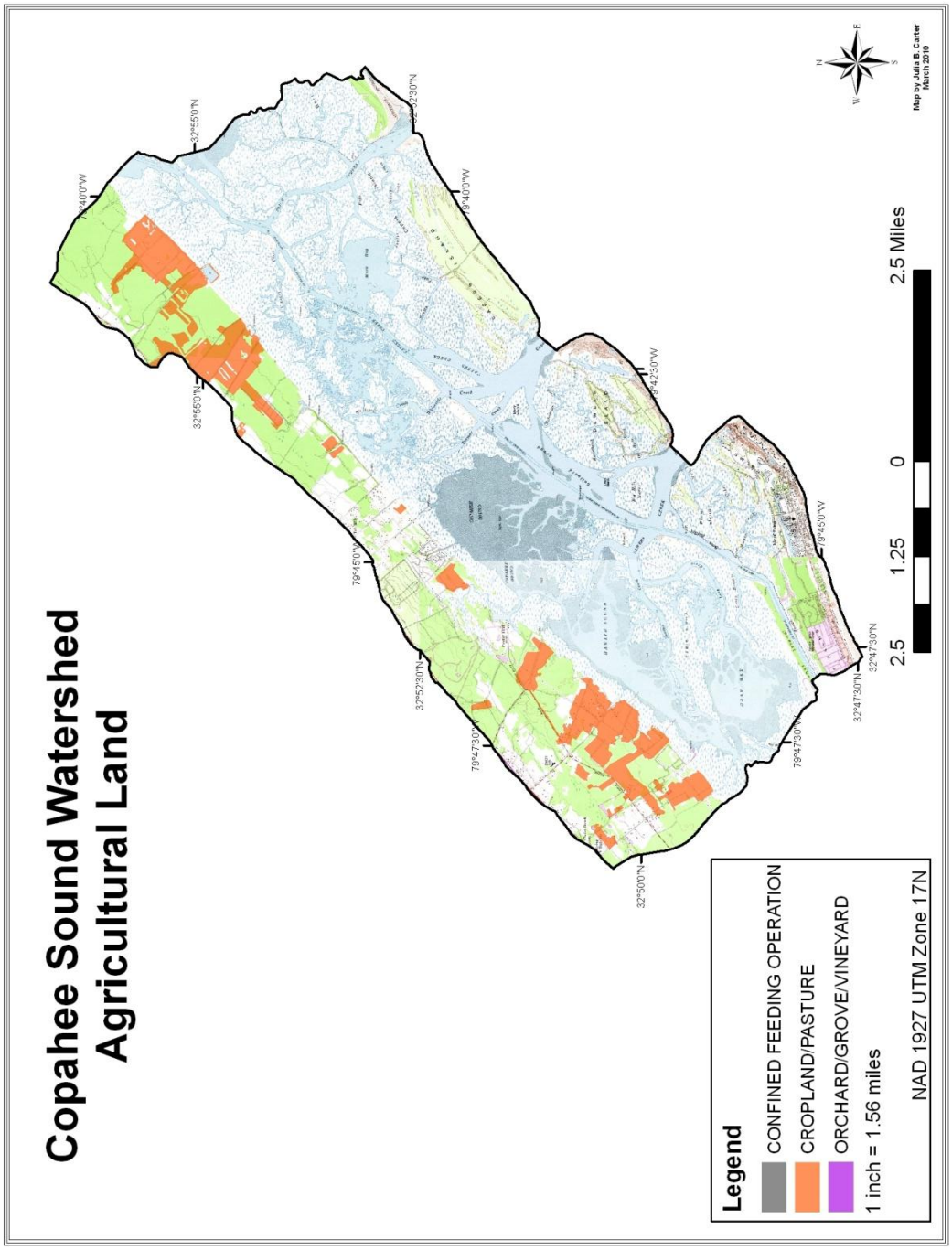


Figure 22. Copahee Sound watershed developed land

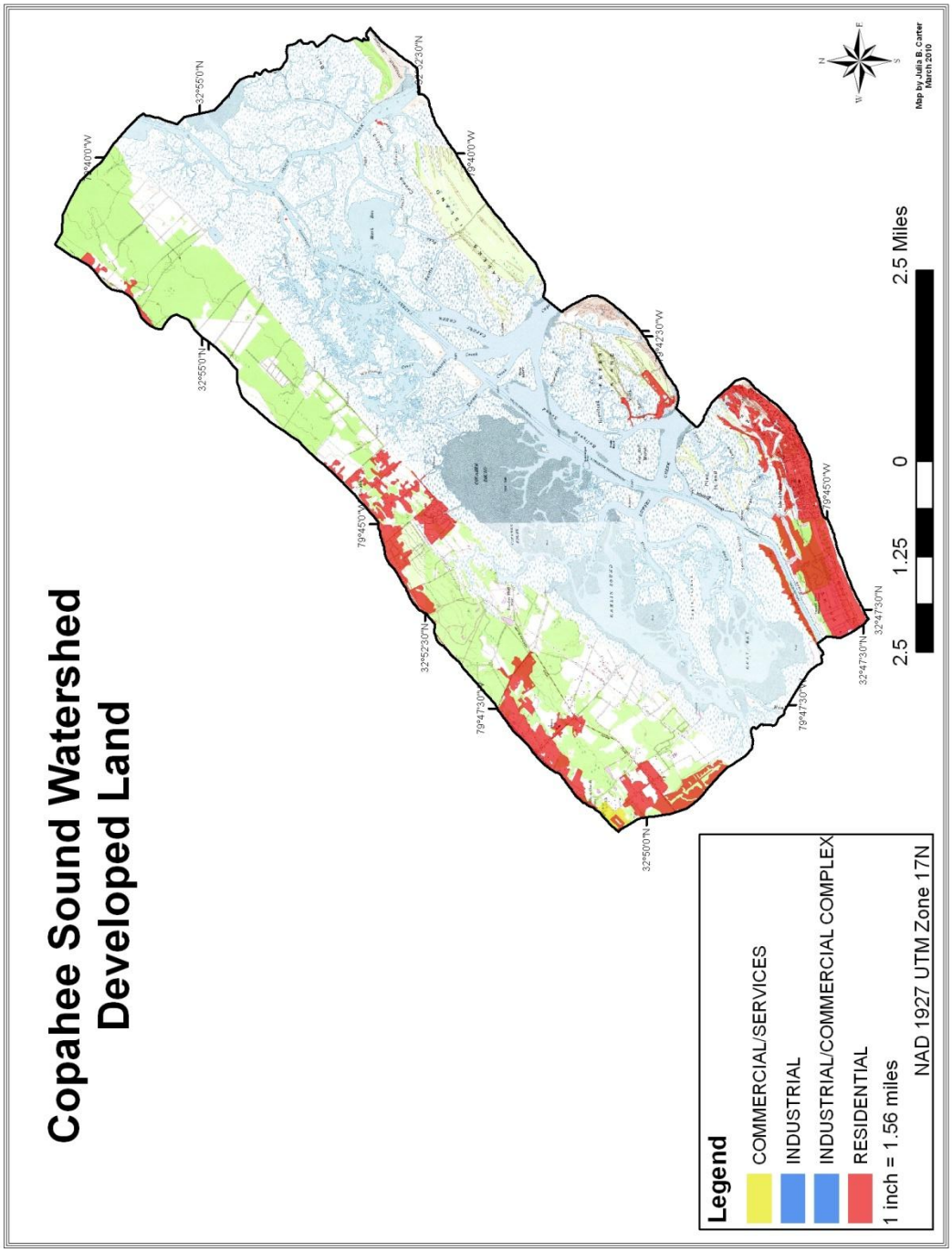


Figure 23. Copahee Sound watershed impervious surfaces, and sewer and water systems

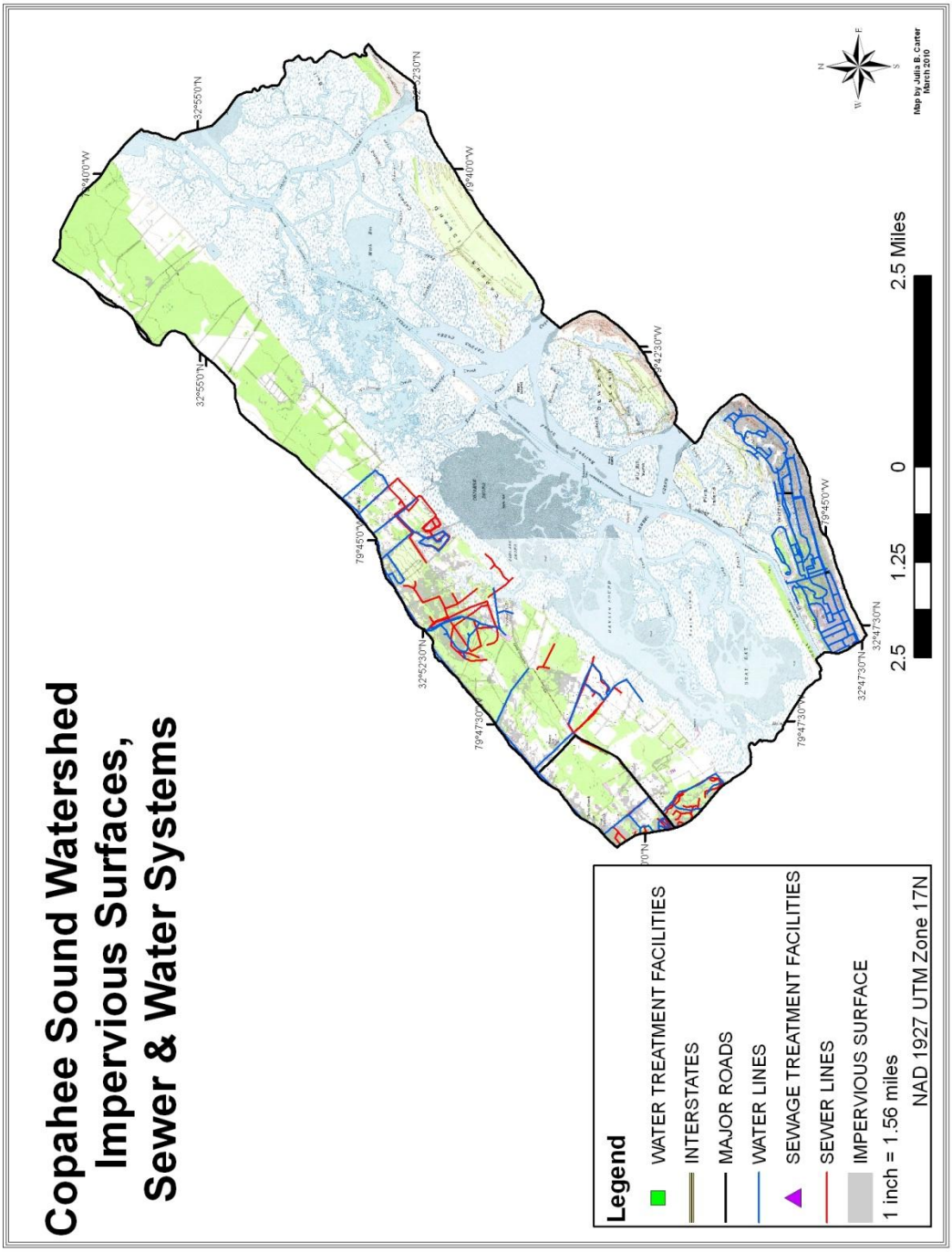
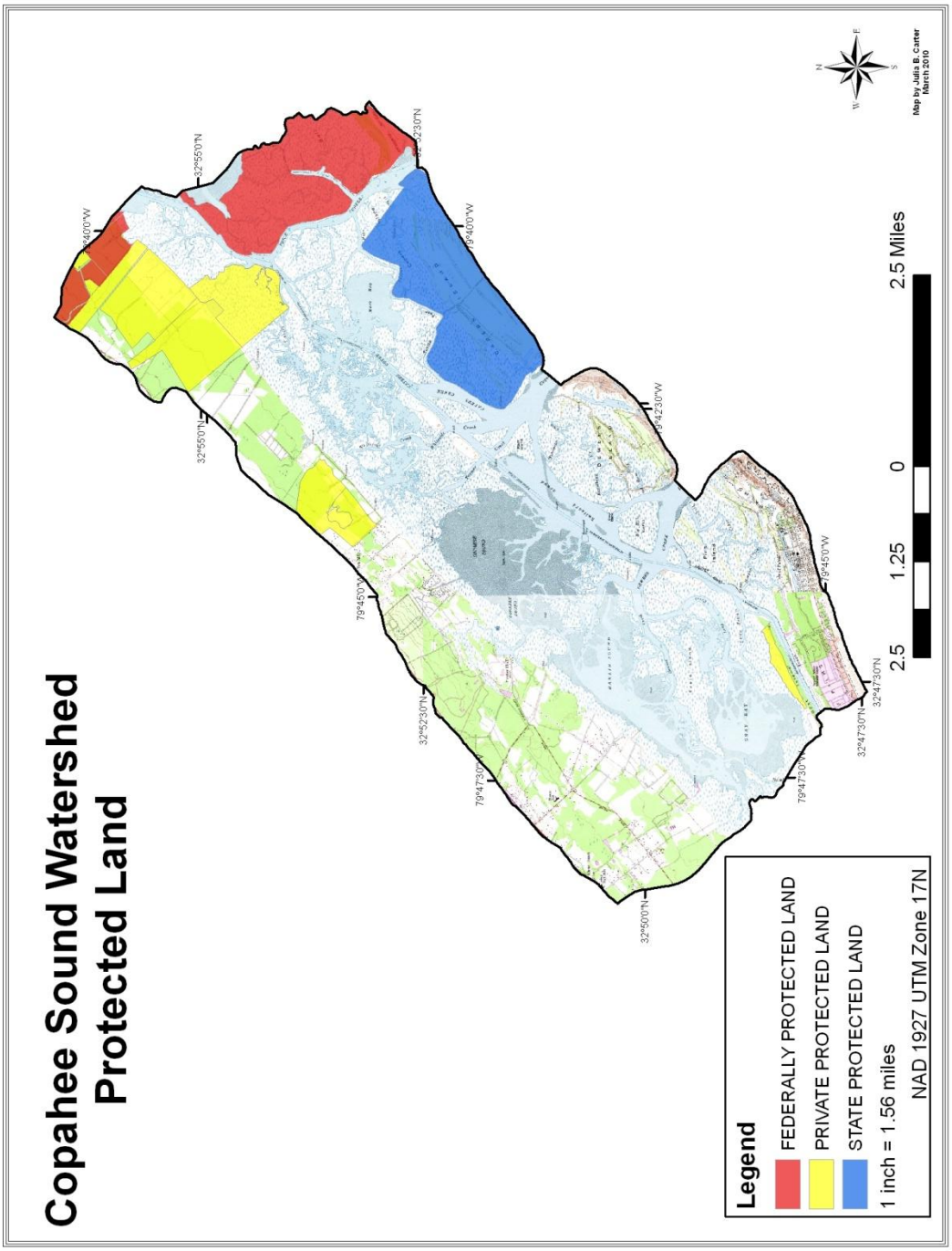


Figure 24. Copahee Sound watershed protected land



4.3.2 Breach Inlet Watershed – HUC 030502090204

Breach Inlet Watershed is found in Charleston County and incorporates the eastern half of Sullivan's Island, the western third of Isle of Palm, the mainland directly across from these islands, and the waterways in between and is 8,028 acres. Figures 25-29, Table 7 & Chart 7 represent the characterization of this watershed. This water cover (Figure 25) in this watershed consists of bay/estuary and non-forested wetland (52.09%) and a few pockets of forested wetland which account for 1.67% of the watershed. The Atlantic Intracoastal Waterway bisects the watershed. Only the northern tip of the watershed consists of large forest cover and is dominated by mixed upland forest and upland planted pine (4.01%); there are other small spots throughout the watershed that represent evergreen upland forest (1%) (Figure 26). The only agricultural land is in the form of crop/pastureland (2.95%) and is on the mainland (Figure 27). Figure 28 represents developed land and shows that the majority of the watershed is residential (23.82%) with a couple of pockets of commercial land (0.83%) and no industrial land. Impervious surfaces cover almost all of the land in the watershed; there are three major roads and no interstates (Figure 29). All of the sewer system components are found on the mainland for this watershed; there is one sewage treatment facility and the rest of the mainland is covered in sewer lines (Figure 29). There are waterlines on both land portions of the watershed (Figure 29); there is one water treatment plant on the portion of Isle of Palm and one on the portion of Mt. Pleasant in the Breach Inlet watershed. There is no protected land in this watershed. This watershed is impaired for both fecal coliform bacteria and copper.

Table 7. Breach Inlet watershed
HUC 030502090204 – Total area: 8,028 acres

Land-use	Area (acres)	% of Total Area
Non-forested Wetland	3352	41.75
Reisdential	1912	23.82
Bay/Estuary	894	11.14
Mixed Upland Forest	512	6.38
Sandy Areas	273	3.4
Upland Planted Pine	258	3.21
Cropland/Pasture	237	2.95
Transitional Areas	206	2.57
Forested Wetland	134	1.67
Evergreen Upland Forest	80	1
Beach	68	0.85
Commercial	67	0.83
Transportation Utilities	23	0.29
Other Urban	12	0.15

Chart 7. Breach Inlet land-use

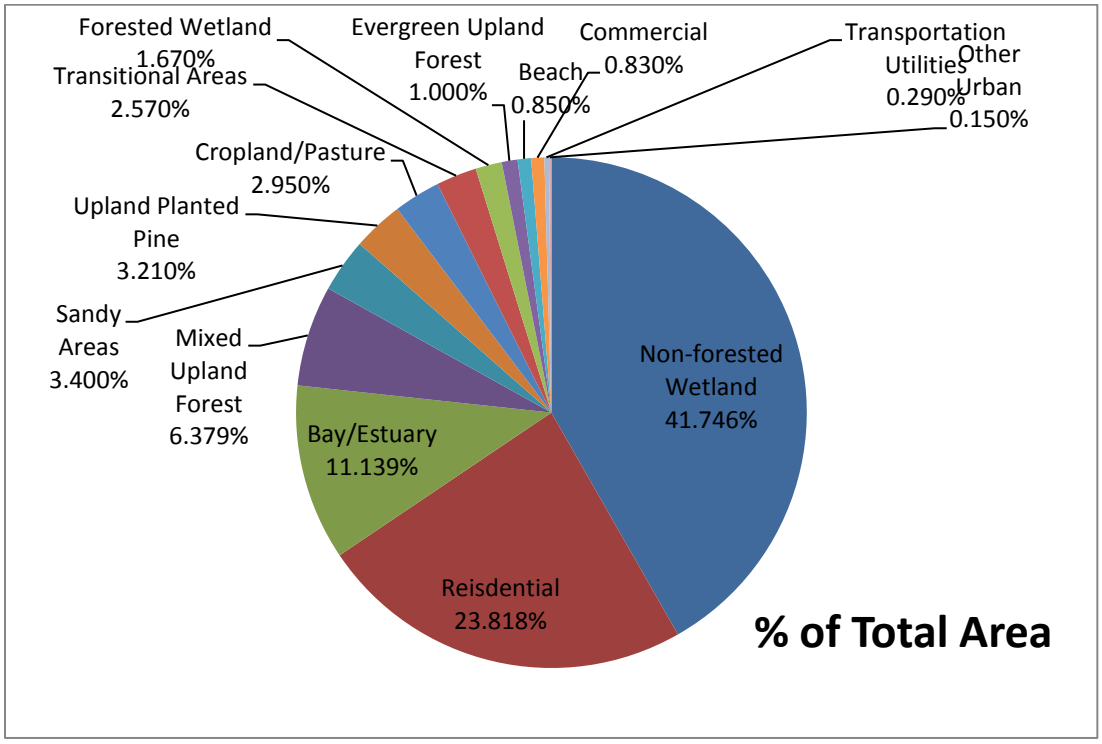


Figure 25. Breach Inlet watershed water cover

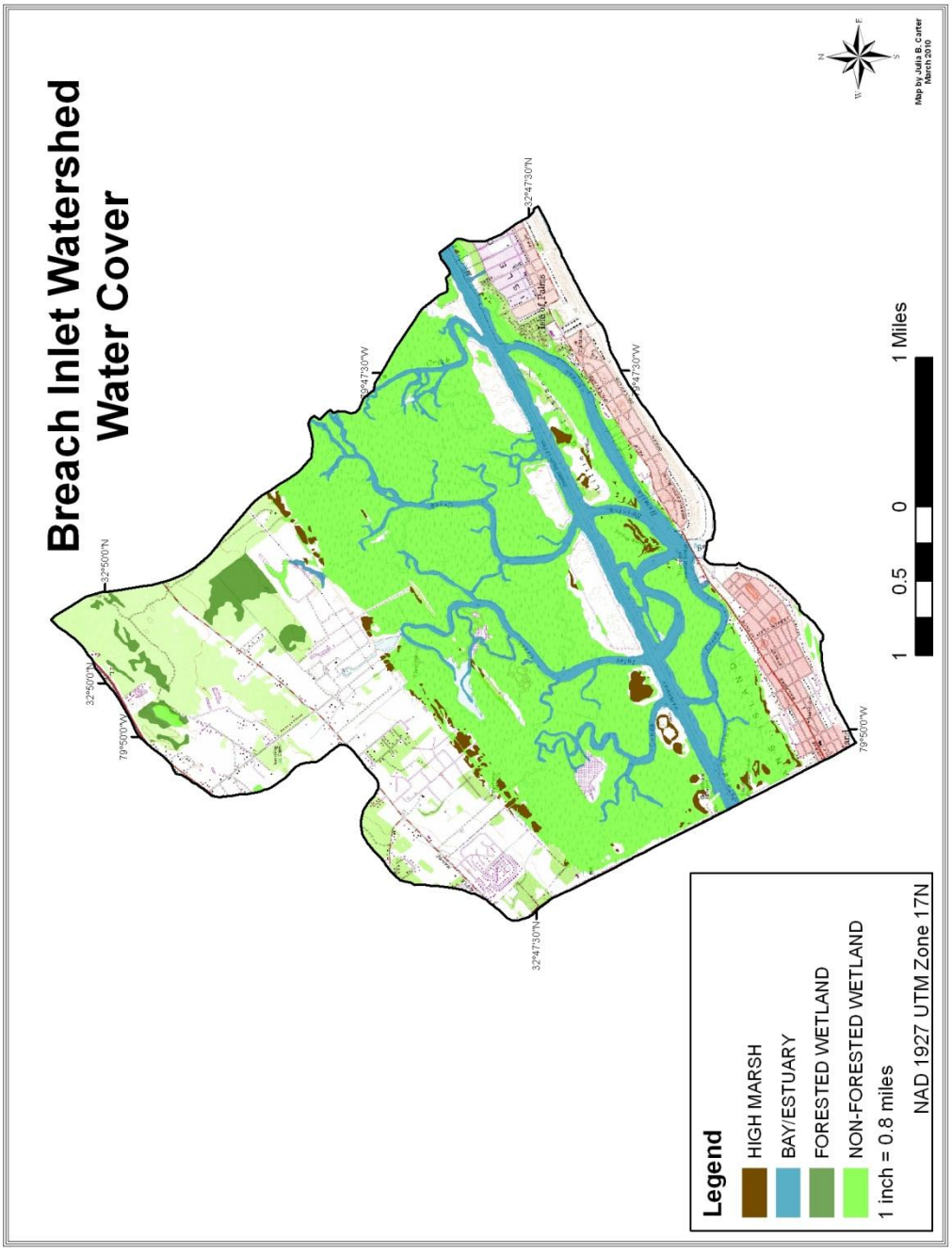


Figure 26. Breach Inlet watershed forest cover

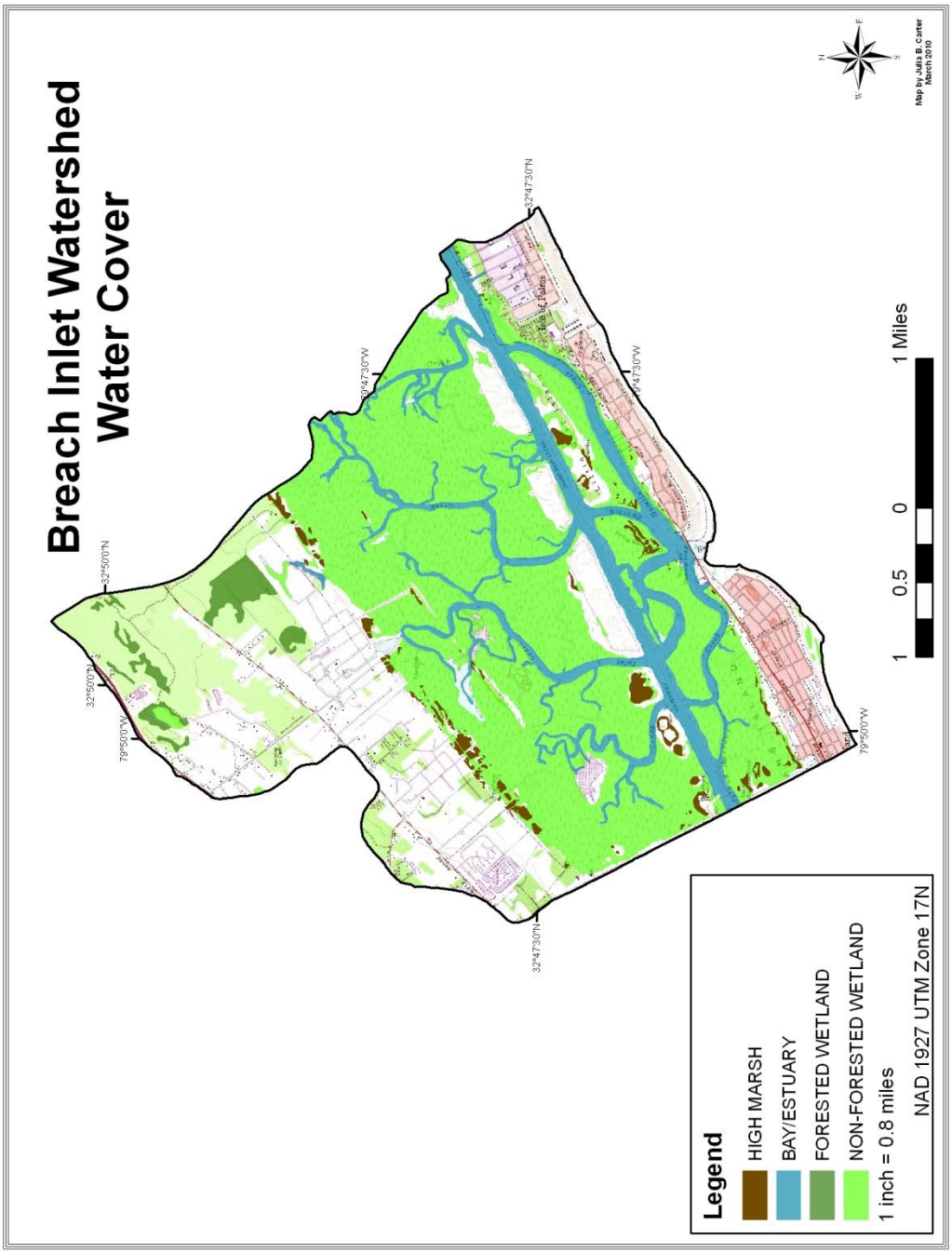


Figure 27. Breach Inlet watershed agricultural land

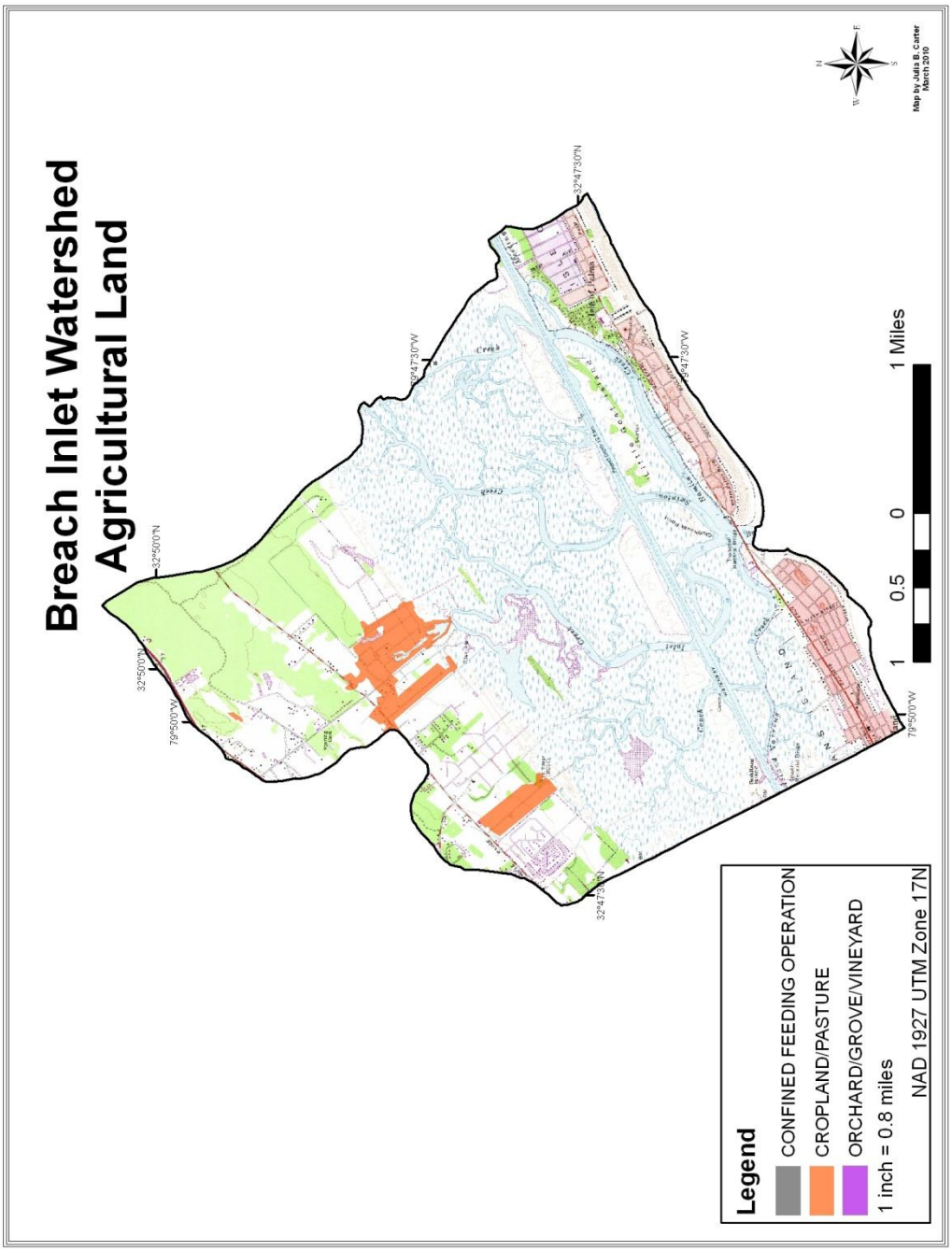


Figure 28. Breach Inlet watershed developed land

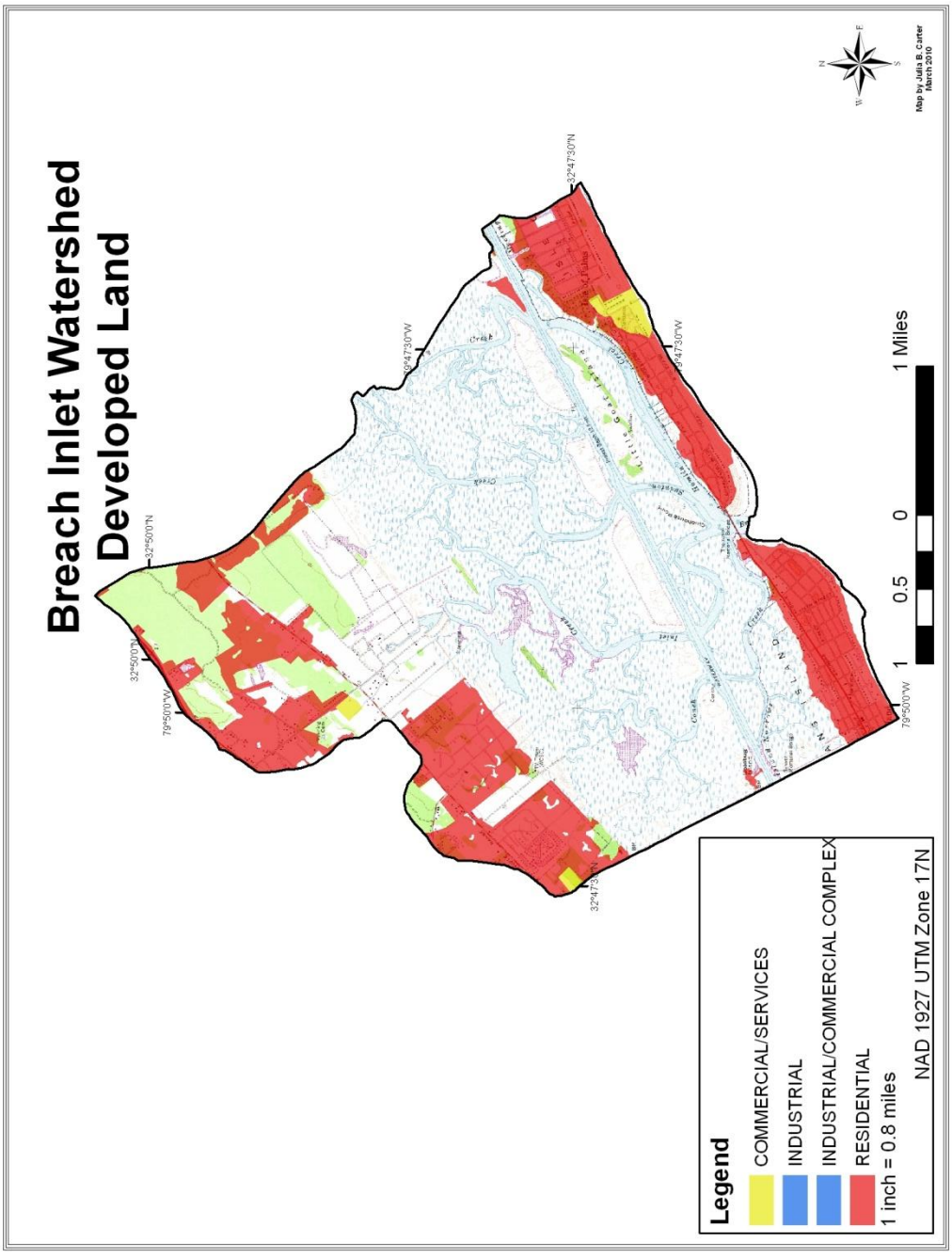
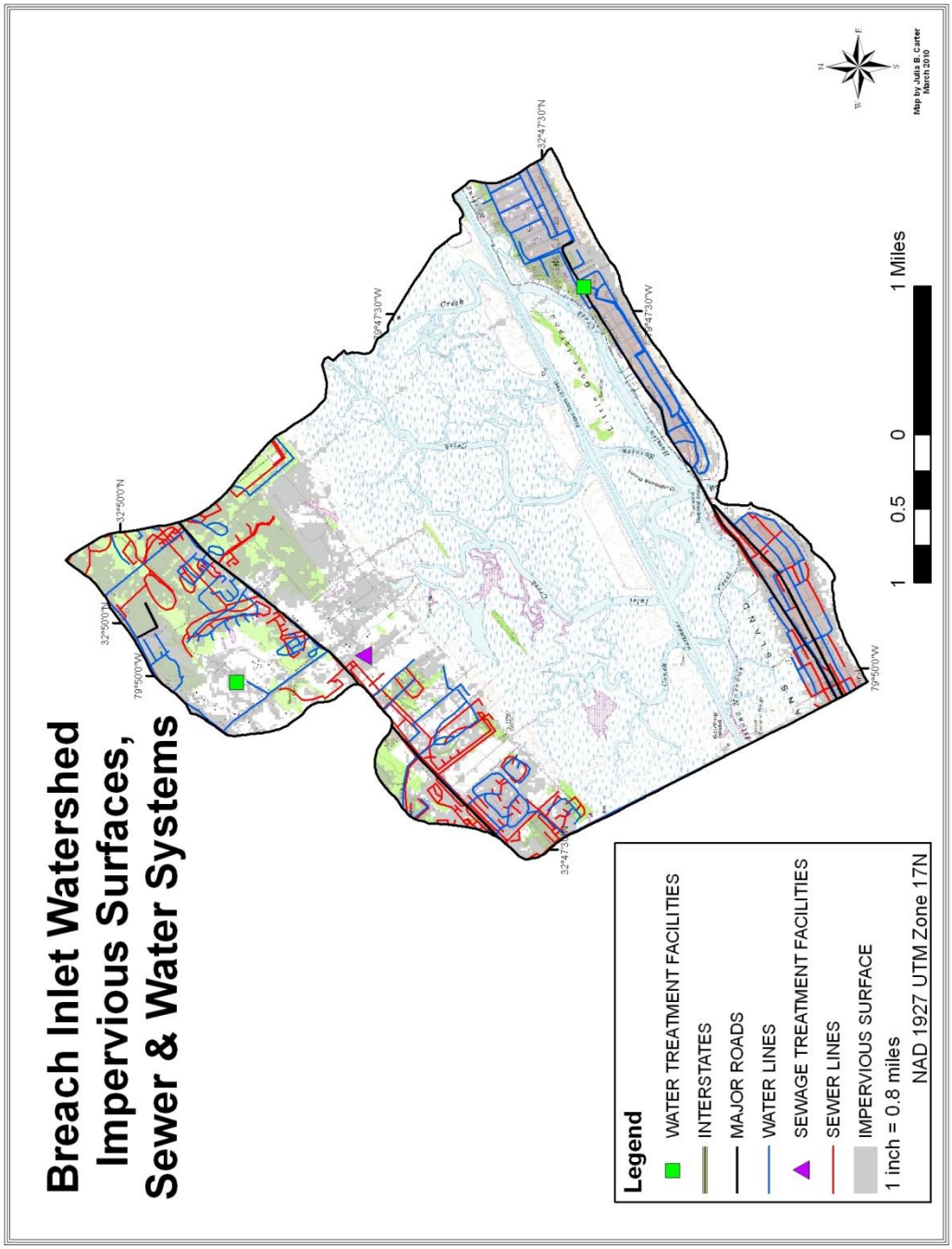


Figure 29. Breach Inlet watershed impervious surfaces, and sewer and water systems



4.3.3 Folly Creek Watershed – HUC 030502020204

The majority of the Folly Creek watershed is the Folly River, Folly Creek and other creeks that branch of off these waterways. The main land formation is the barrier island of Folly Beach, which falls on the southeastern side of the watershed. The other land formations are small islands between Folly Beach and the mainland of James Island and a small fragment of James Island. The total area for Folly Creek watershed is 8162 acres. Figures 30-34, Table 8 & Chart 8 represent the characterization of this watershed. Water cover includes bay/estuary and non-forested wetland (73.79%) (Figure 30). The only forest cover is evergreen upland forest and mixed upland forest (4.05%) on the small islands between Folly Beach and the mainland and mixed upland forest on Folly Beach and the mainland (Figure 31). The one small fragment of James Island that falls within this watershed makes up the entire amount of cropland/pasture (0.49%) in this watershed (Figure 32). The only developed land is the residential portions (10.81) of James Island and Folly Beach and two commercial areas (0.61%) – one on Folly Beach, and one along Folly Road between Folly Beach and James Island (Figure 33). The only impervious surfaces are on Folly Beach and James Island and Folly Road is the major road shown in Figure 34. There is one sewer line that runs along Folly Road to Folly Beach and along the beach and there are a few sewer lines on James Island within this watershed; there are no sewage treatment plants (Figure 34). Similarly, there are waterlines on James Island and Folly Beach and one that runs from James Island to Folly Beach; there are no water treatment facilities in this watershed (Figure 34). There are no protected areas in this watershed and Folly Creek watershed has a single impairment of copper.

Table 8. Folly Creek Watershed, impaired for copper
HUC 030502020204 – Total area: 8162 acres

Land-use	Area (acres)	% of Total Area
Non-forested Wetland	4584	56.16
Bay/Estuary	1439	17.63
Residential	882	10.81
Sandy Areas	722	8.85
Evergreen Upland Forest	283	3.47
Beaches	63	0.77
Commercial	50	0.61
Mixed Upland Forest	48	0.58
Cropland/Pasture	40	0.49
Transportation Utilities	39	0.48
Open Water	12	0.48

Chart 9. Folly Creek Watershed

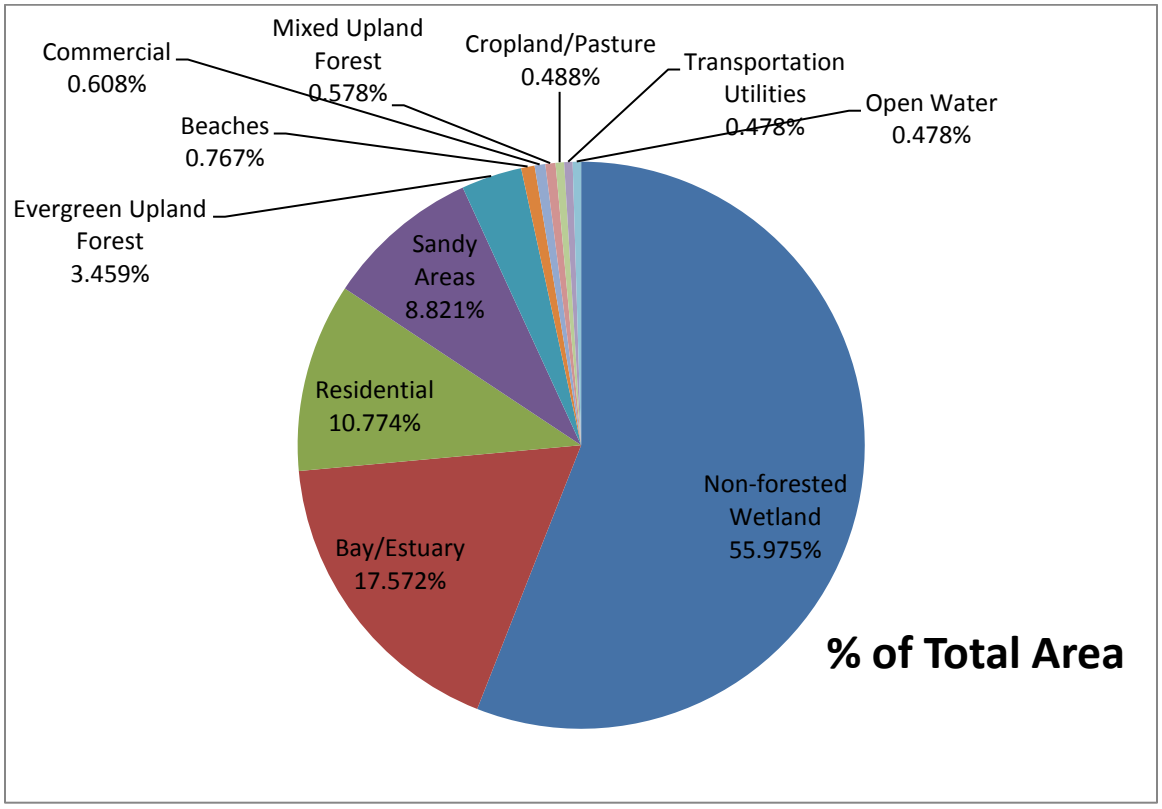


Figure 30. Folly Creek watershed water cover

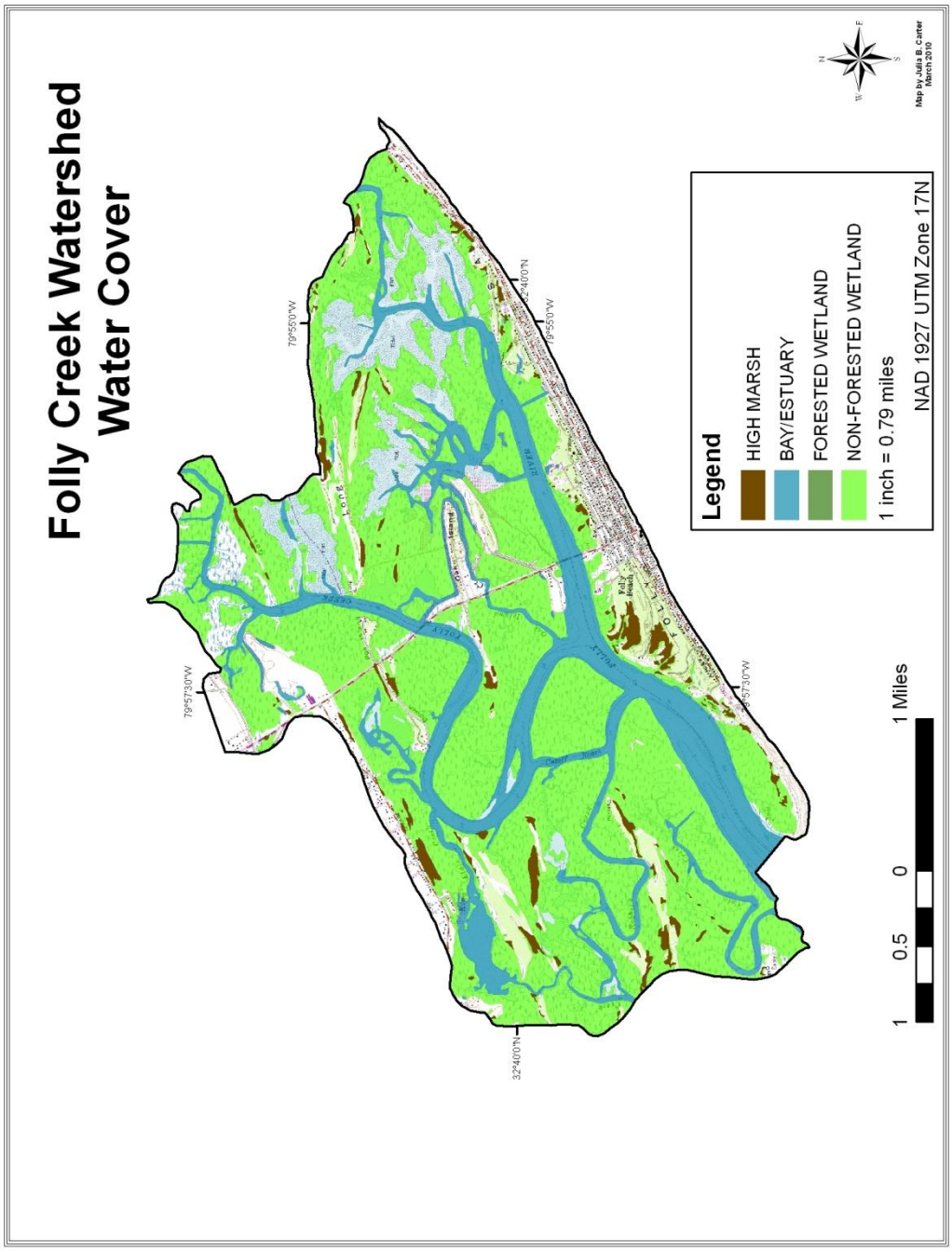


Figure 31. Folly Creek watershed forest cover

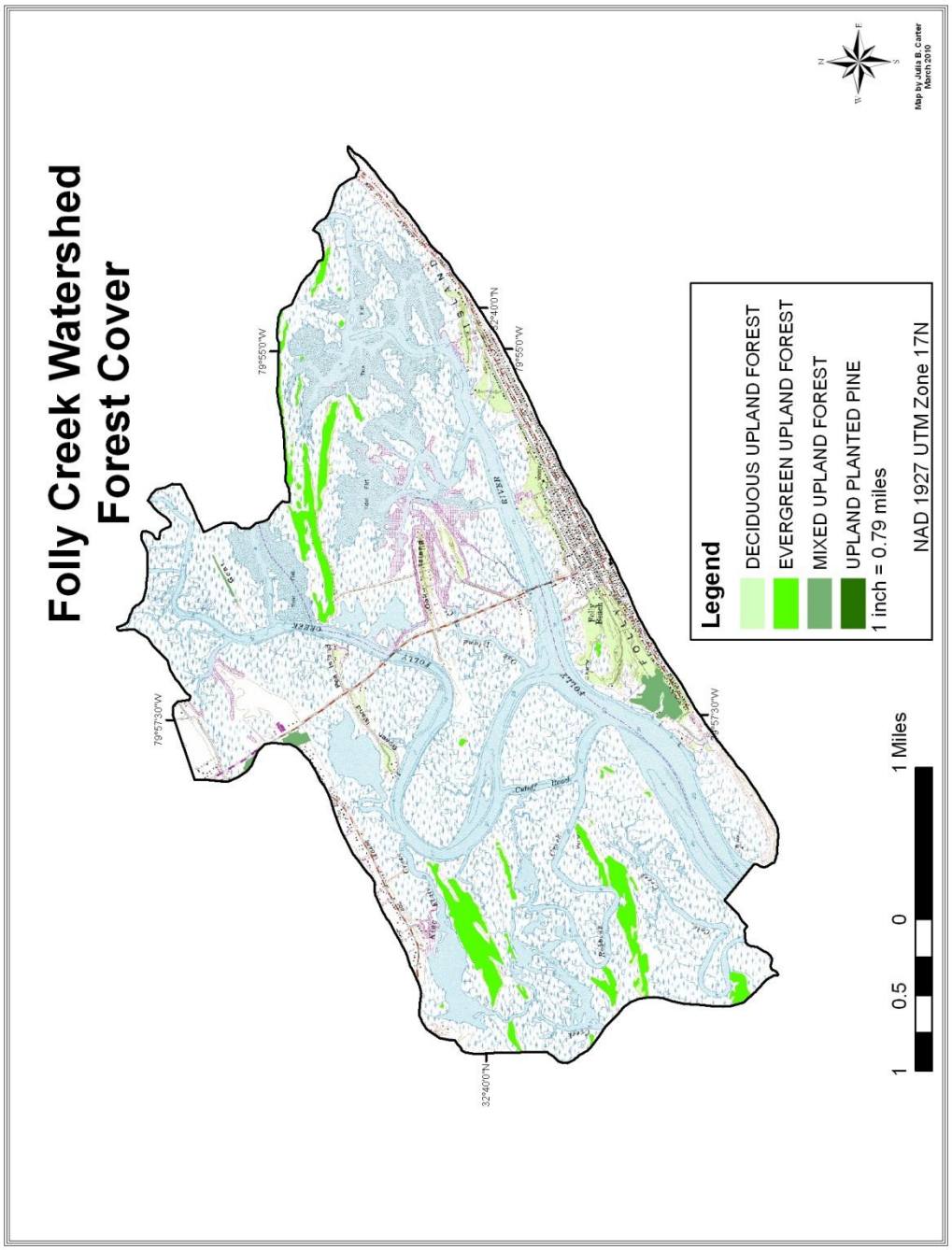


Figure 32. Folly Creek watershed agricultural land

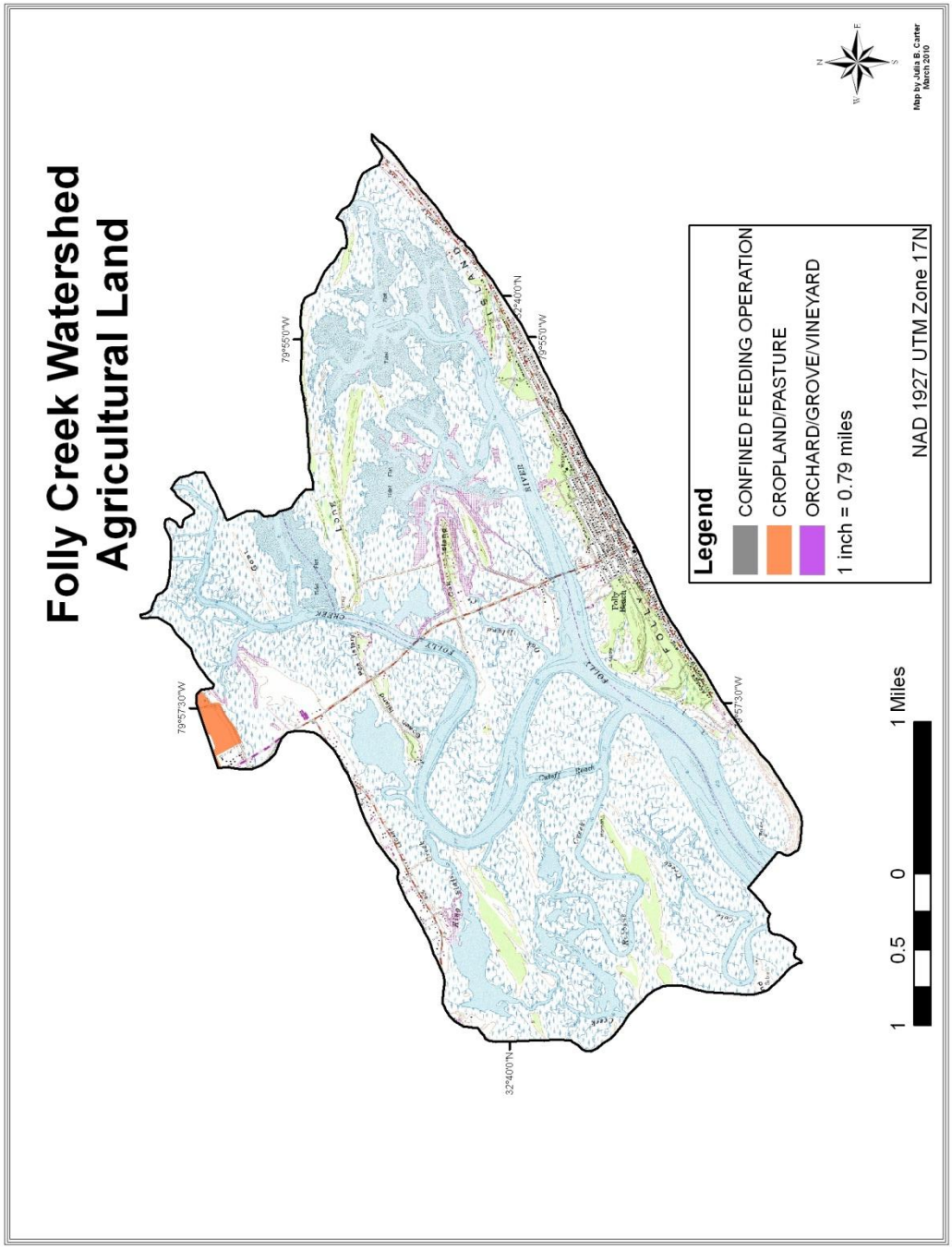


Figure 33. Folly Creek watershed developed land

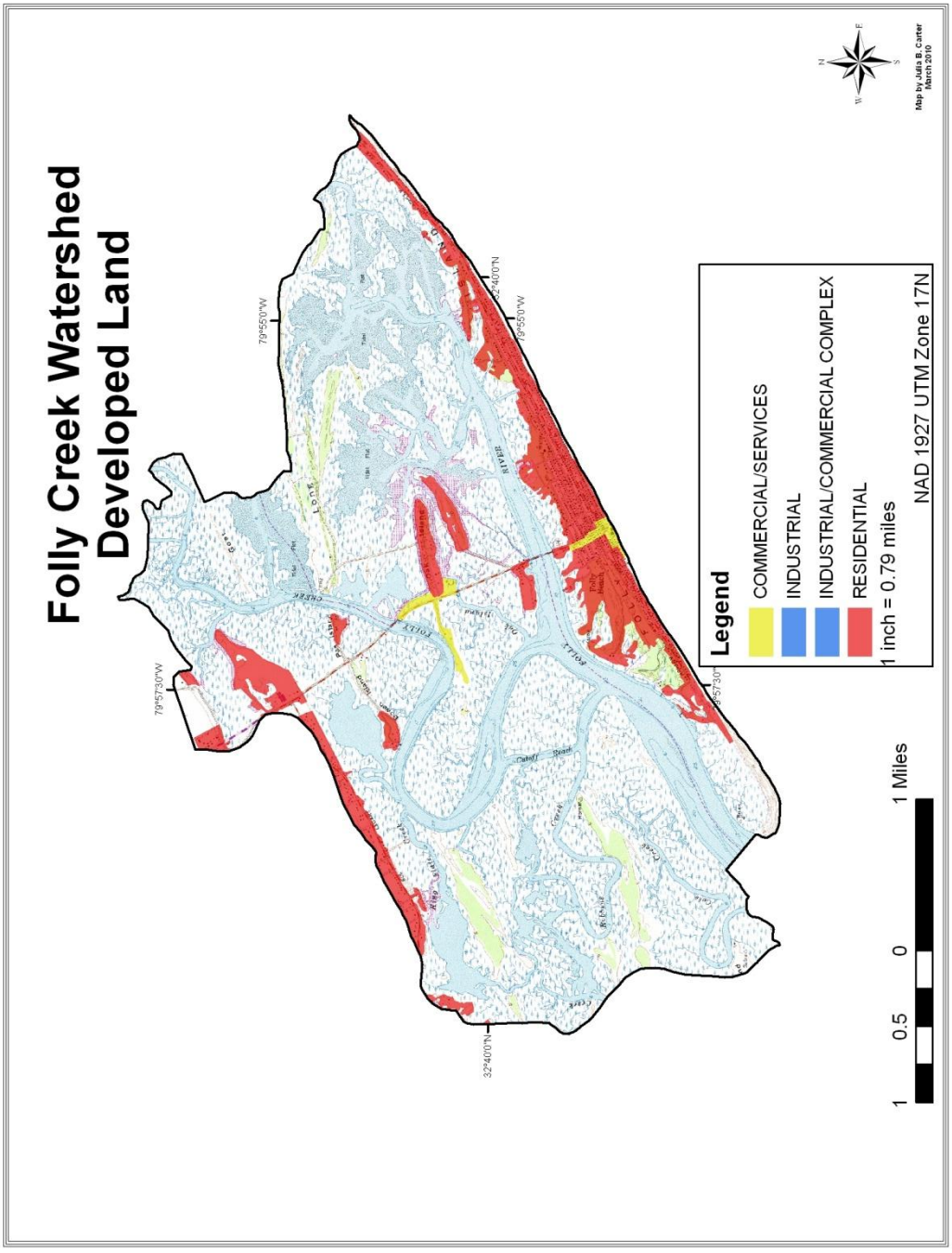
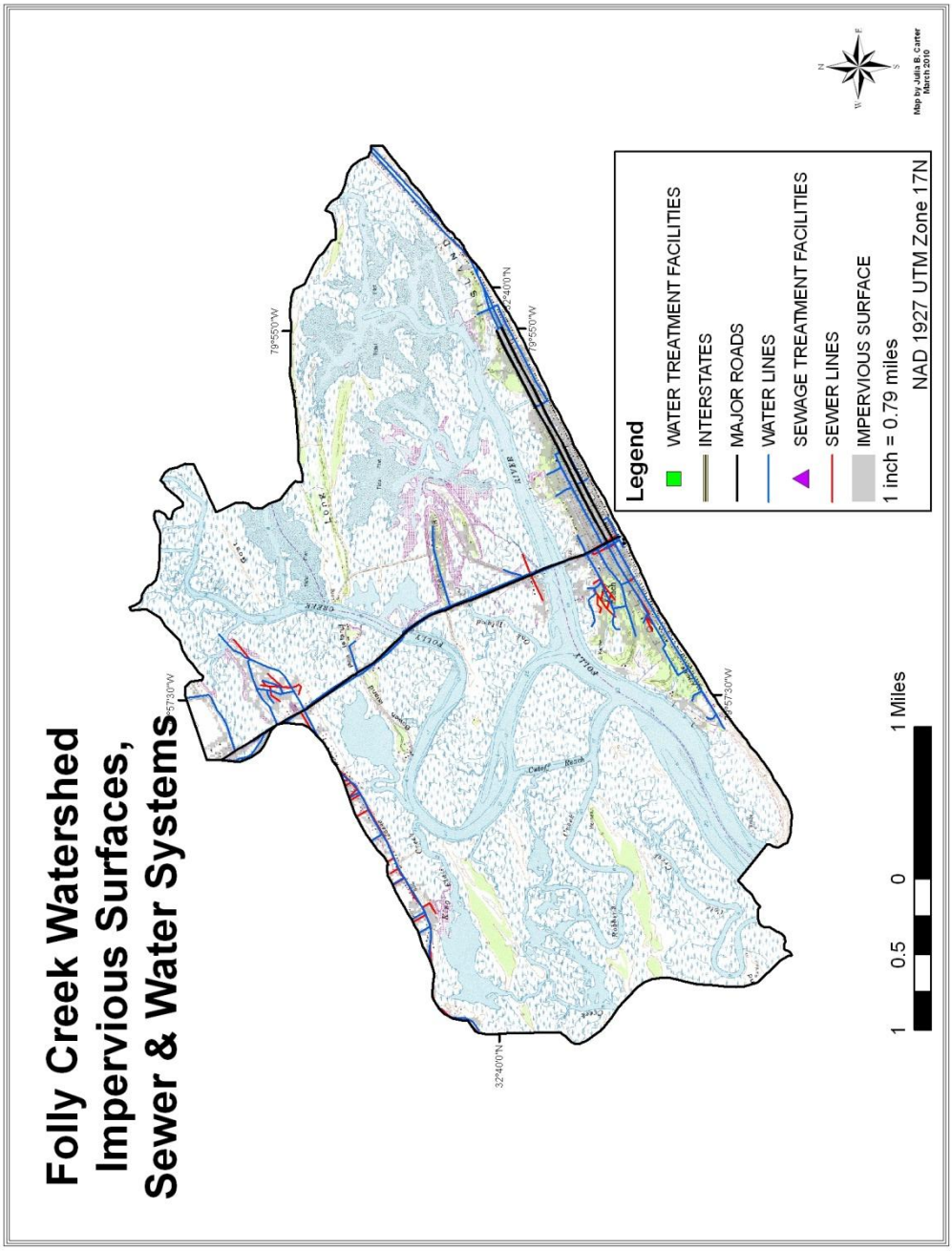


Figure 34. Folly Creek watershed impervious surfaces, and sewer and water systems



4.3.4 Stono River Atlantic Intracoastal Waterway (AIW) Watershed – HUC 030502020202

The Stono River (AIW) watershed is bisected by the AIW; on the southern side of the AIW is Johns Island, while the northern side is the area of the City of Charleston known as West of the Ashley (or West Ashley) and the eastern side is a portion of James Island; this watershed has a total area of 39,093 acres. Figures 35-40, Table 9 & Chart 9 represent the characterization of this watershed. This watershed has a fairly even distribution of forested wetlands and non-forested wetlands (27.92%), with high marsh located along the center estuary, i.e. the Stono River (Figure 35). There is also a fairly even distribution of forest cover on either side of the Stono River, though the majority is mixed upland forest (24.86%) with smaller amounts of upland planted pine (5.15%) and evergreen upland forest (4.84%) (Figure 36). The agricultural land layer (Figure 37) shows that there is more agricultural land on the Johns Island side, though there is some cropland/pasture on both the West Ashley and James Island sides; the total amount of cropland/pasture is 8.3%. There is one orchard/vineyard (0.05%) within this watershed on Johns Island along River Road. The majority of the residential and commercial land uses are found on parcels in West Ashley, while Johns Island has some scattered residential and commercial land cover (Figure 38); residential accounts for 16.17% of the total area, while commercial accounts for 2.93%. Figure 39 shows that the vast majority of impervious surface coverage is in West Ashley and James Island, though major roads run through each of the three main areas (West Ashley, James Island, and Johns Island). The Stono River AIW watershed is the only watershed within the Charleston County

urbanized area that has septic tanks and they are located on Johns Island; the sewer lines are predominantly in West Ashley along with the single sewage treatment facility for this watershed (Figure 39). The waterlines coincide with the scattered residences on Johns Island and the condensed residential cover in West Ashley; there are no water treatment facilities in this watershed (Figure 39). The only protected lands in this watershed are a few parcels of privately protected land on Johns Island, James Island and West Ashley (Figure 40). This watershed is impaired with fecal coliform bacteria, dissolved oxygen, and copper.

Table 9. Stono River AIW Watershed
HUC 030502020202 – Total Area: 39,093 acres

Land-use	Area (acres)	% of Total Area
Mixed Upland Forest	9720	24.86
Non-forested Wetland	7379	18.88
Residential	6322	16.17
Forested Wetland	3534	9.04
Cropland/Pasture	3245	8.3
Bay/Estuary	2787	7.13
Upland Planted Pine	2013	5.15
Evergreen Upland Forest	1893	4.84
Commercial	1146	2.93
Open Water	238	0.61
Mines/Quarries/Pits	235	0.6
Sandy Areas	170	0.43
Transportation Utilities	138	0.35
Other Urban	131	0.34
Herbaceous Rangeland	48	0.12
Shrub/Brush Rangeland	34	0.09
Tranistional Areas	33	0.08
Orchard/Vineyard	19	0.05
Dry Salt Flats	8	0.02

Chart 9. Stono River AIW Watershed

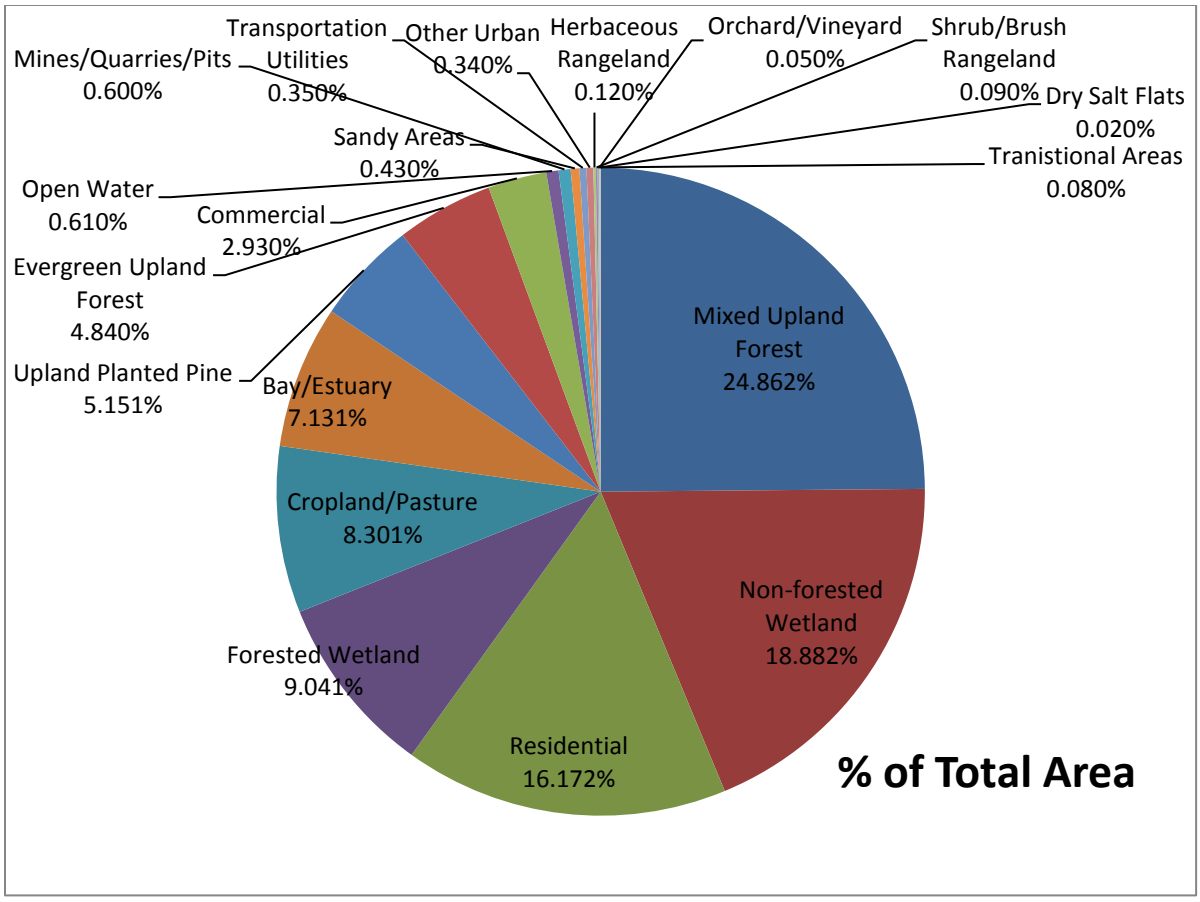


Figure 35. Stono River AIW watershed water cover

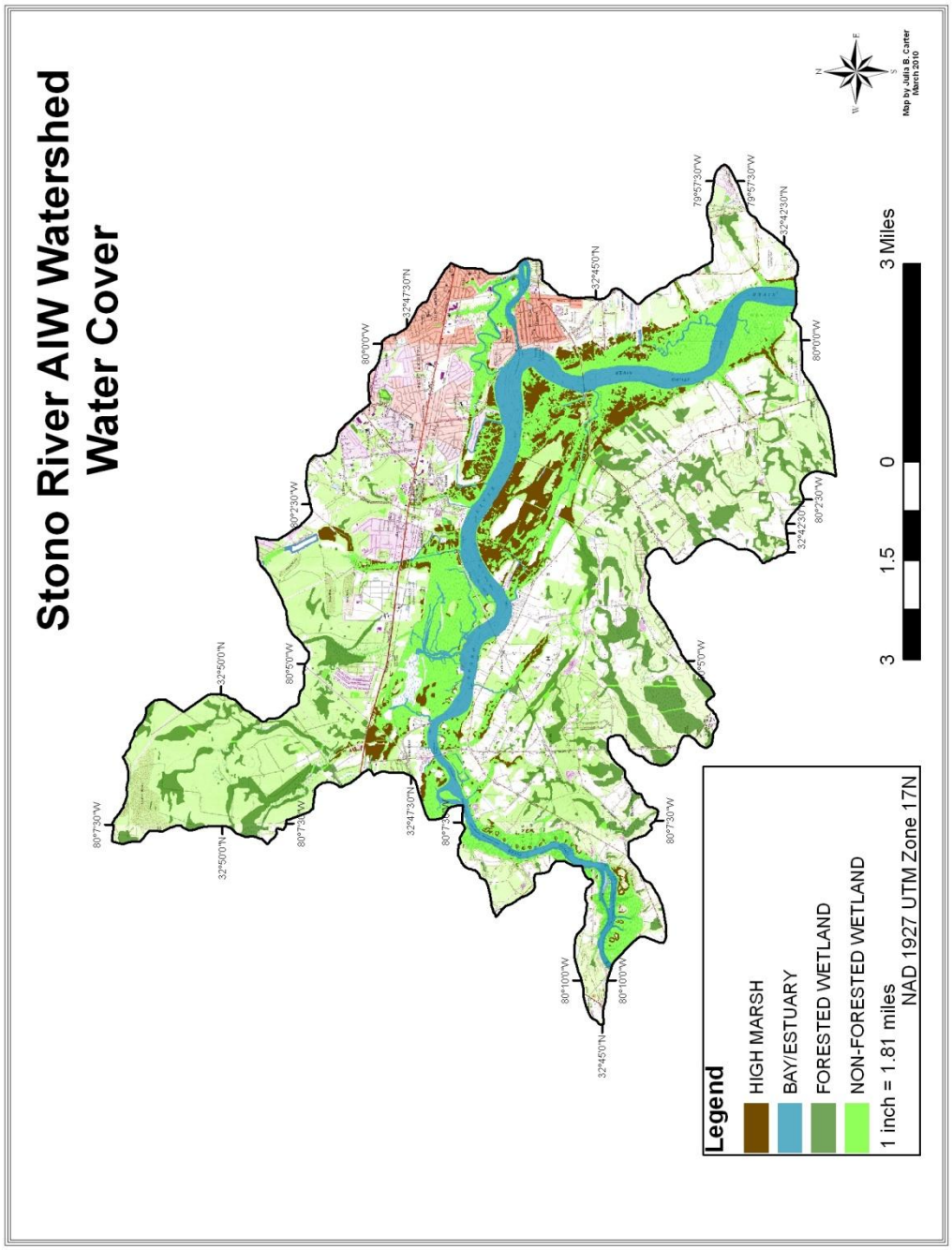


Figure 36. Stono River AIW watershed forest cover

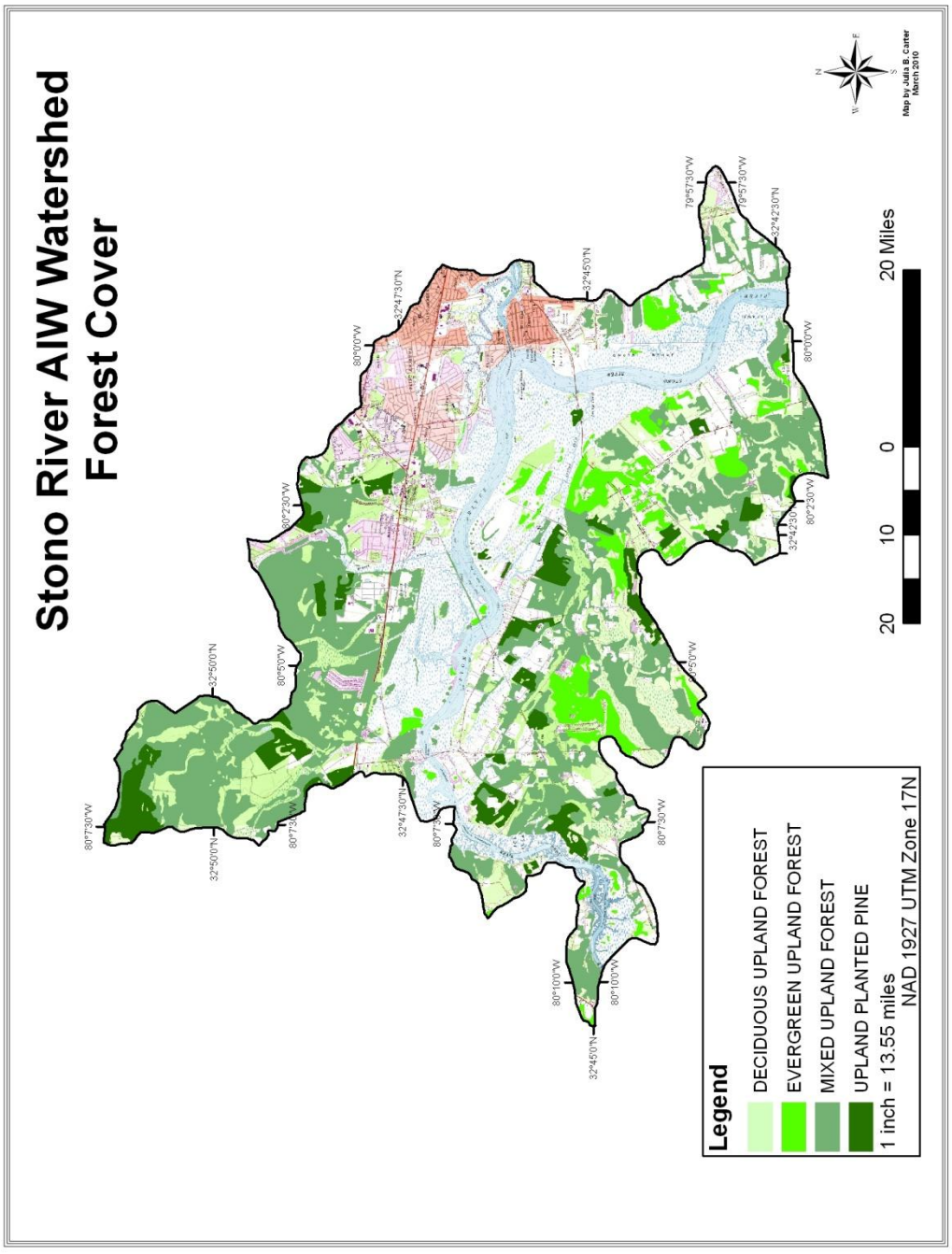


Figure 37. Stono River AIW watershed agricultural land

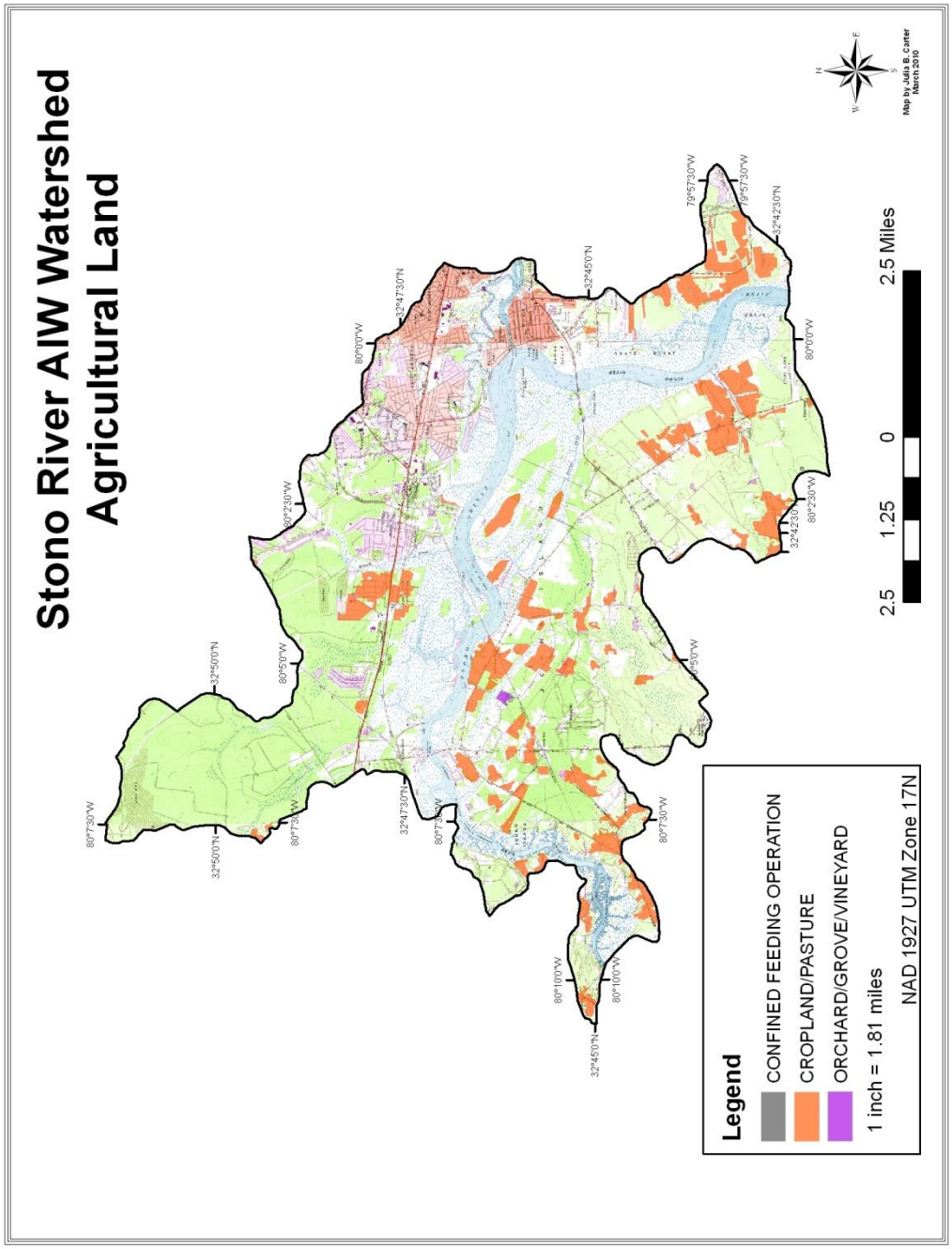


Figure 38. Stono River AIW watershed developed land

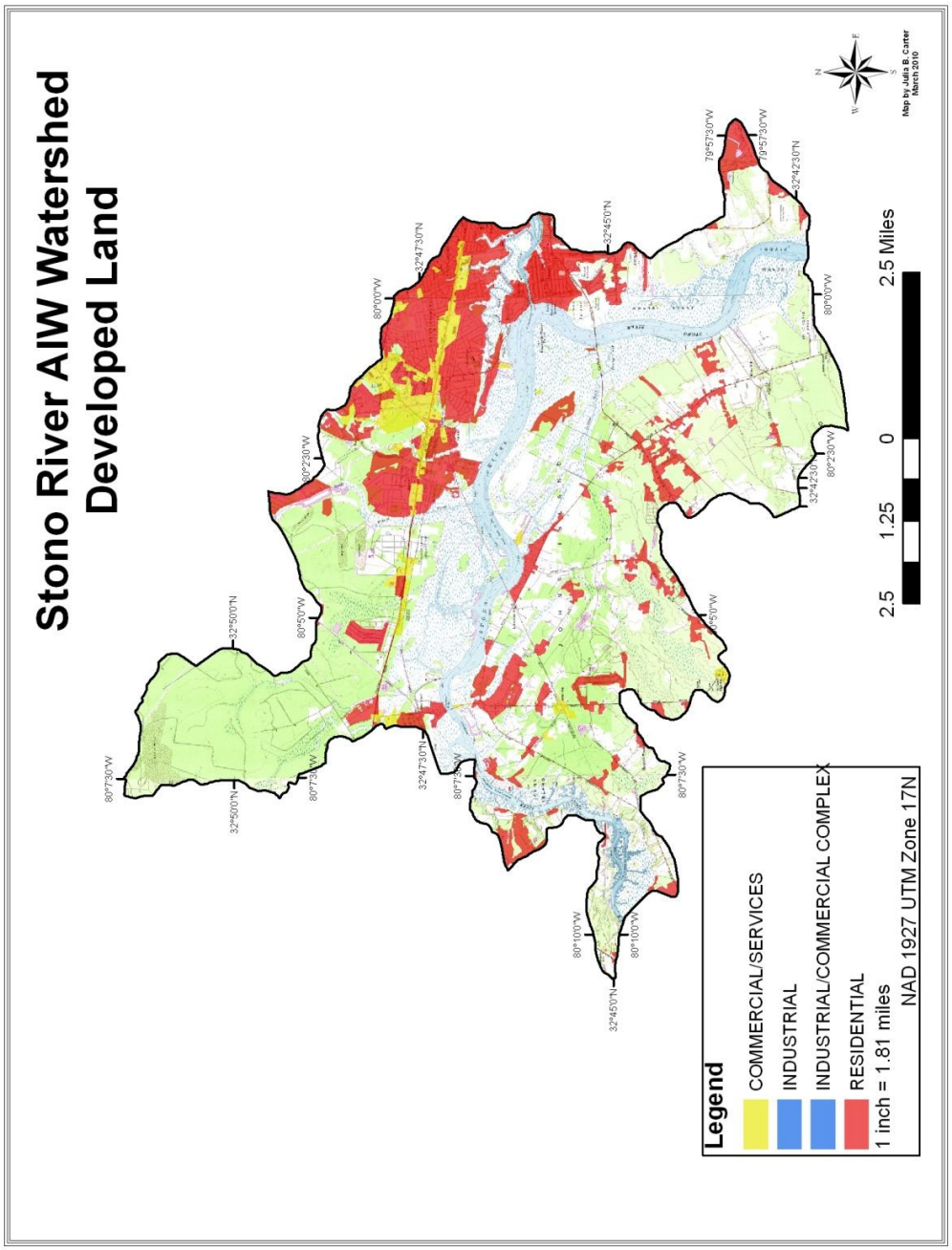


Figure 39. Stono River AIW watershed impervious surfaces, and water and sewer systems

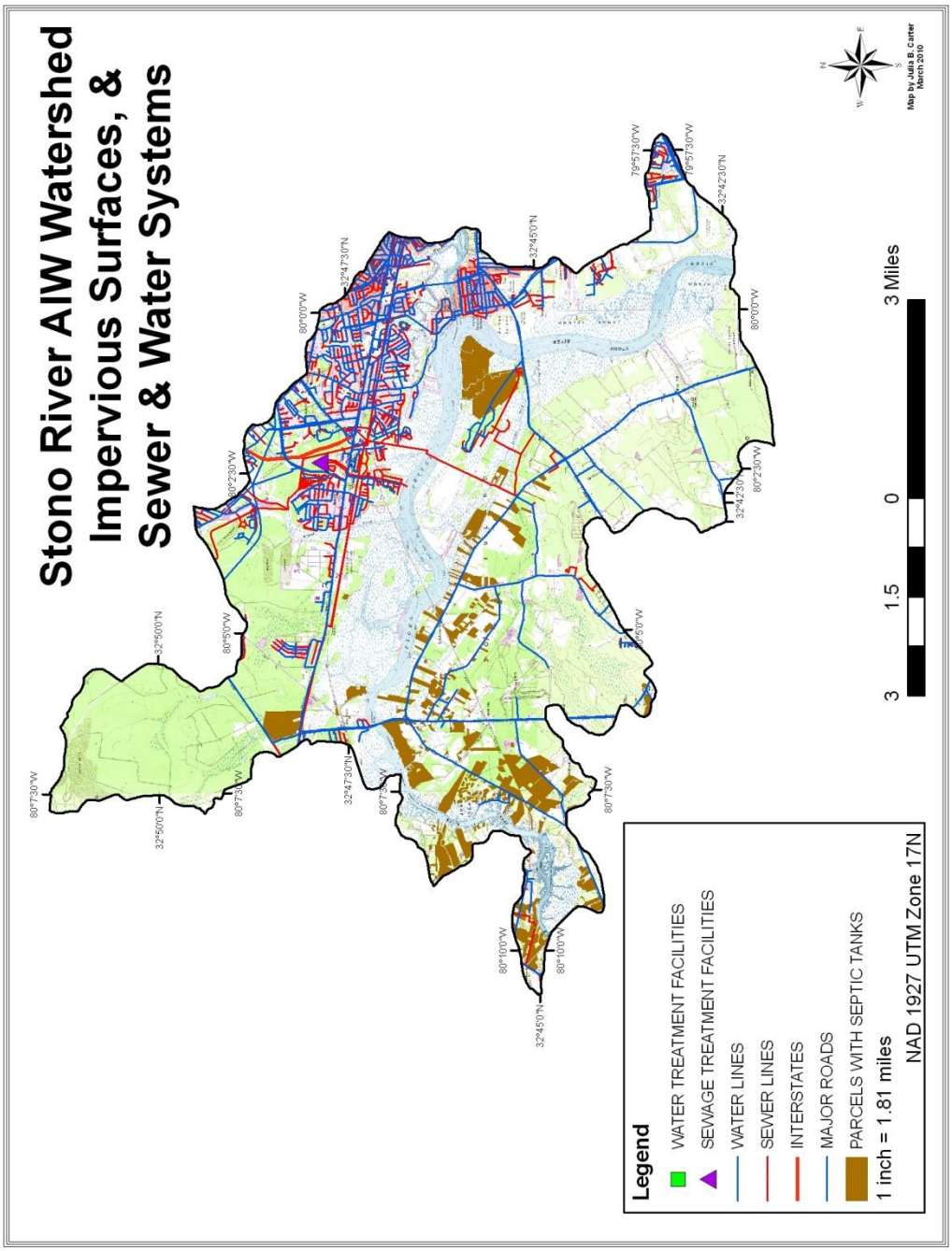
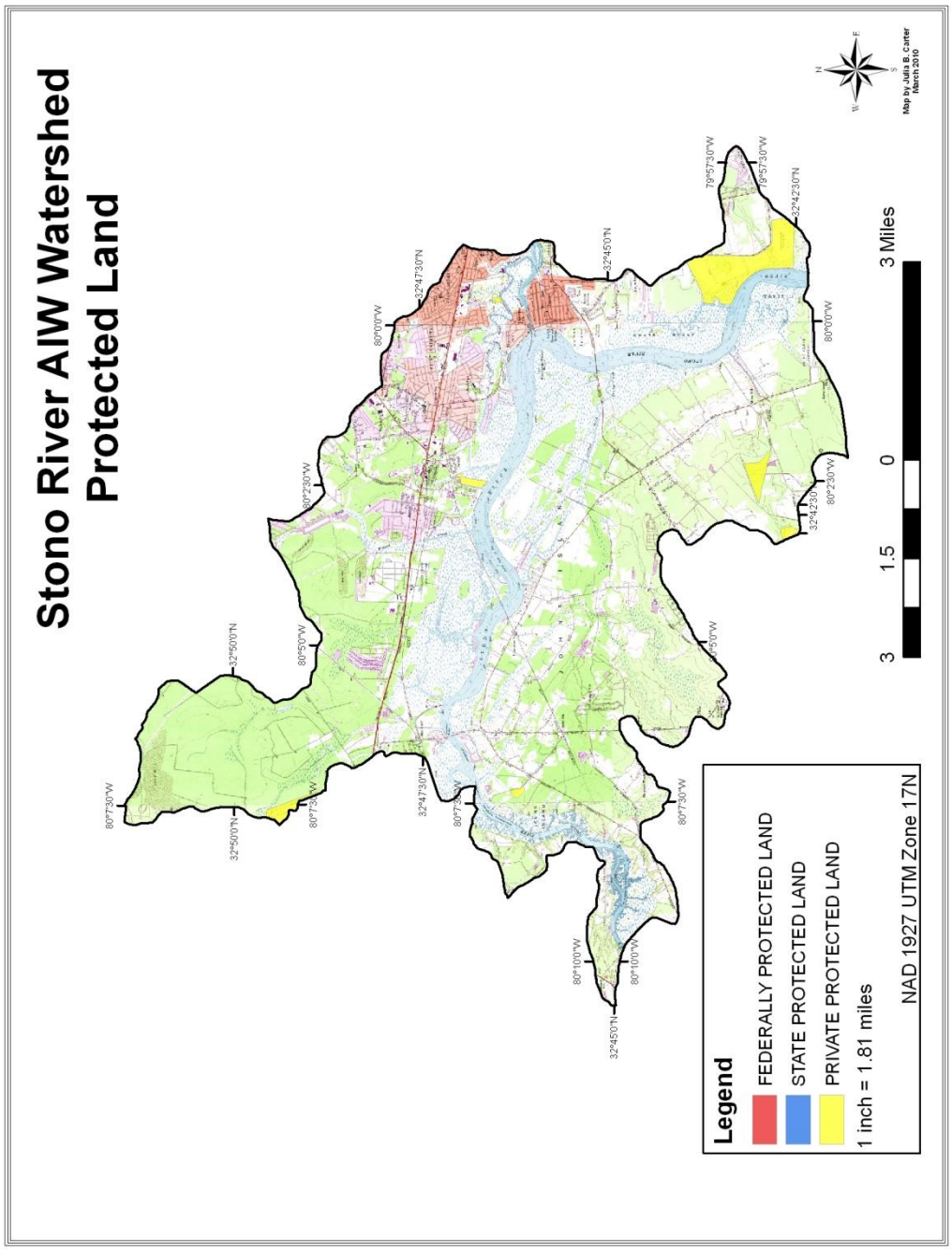


Figure 40. Stono River AIW watershed protected land



4.3.5 Lower Ashley River Watershed – HUC 030502010605

The Lower Ashley River Watershed is bisected by the (lower) Ashley River and is surrounded by a small portion of James Island, West of the Ashley, and half of the Charleston peninsula; the total area in this watershed is 31,010 acres. One of the boundary lines for this watershed bisects the Charleston peninsula. Figures 41-46, Table 10 and Chart 10 characterize this watershed. Both non-forested wetland (18.3%) and high marsh are found centered along the Ashley River throughout the watershed, while forested wetland (3.13%) is found only in the northwestern section of the watershed (Figure 41). The forest coverage follows the same pattern as the forested wetland and is comprised of upland planted pine and mixed upland forest; a few land parcels in the southern tip of the watershed contain mixed upland forest and evergreen upland forest (Figure 42); the total forest cover accounts for 15.66% of the watershed. There is very little agricultural land within this watershed and it is in the form of cropland/pasture (1%) and orchard/vineyard (0.03%) (Figure 43). Residential areas comprise the largest part of the watershed (33.86%), and commercial and industrial land are 13.41% and 0.36%, respectively (Figure 44). An estimated 80% of the watershed is covered in impervious surfaces including both major roads and interstates (Figure 45). Sewer lines run throughout the developed portions of the watersheds; there are two sewage treatment facilities, one on James Island and one in West of the Ashley – both adjacent to the Ashley River (Figure 45). Waterlines run throughout the developed portion of this watershed, however there are no water treatment facilities (Figure 45). There are two state protected areas, i.e. Drayton Hall and Charles Towne Landing and four sections of

privately protected areas (Figure 46). This watershed is impaired with both fecal coliform and dissolved oxygen.

Table 10. Lower Ashley River Watershed
HUC 030502010605 – Total Area: 31,010 acres

Land-use	Area (acres)	% of Total Area
Residential	10506	33.86
Non-forested Wetland	5678	18.3
Commercial	4160	13.41
Mixed Upland Forest	3721	12
Bay/Estuary	3364	10.84
Forested Wetland	970	3.13
Upland Planted Pine	961	3.1
Other Urban	419	1.35
Cropland/Pasture	310	1
Open Water	241	0.78
Sandy Areas	208	0.67
Evergreen Upland Forest	173	0.56
Transportation Utilities	155	0.5
Industrial/Commercial Complex	113	0.36
Transitional Areas	22	0.07
Industrial	20	0.64
Orchard/Vineyard	9	0.03

Chart 10. Lower Ashley River Watershed

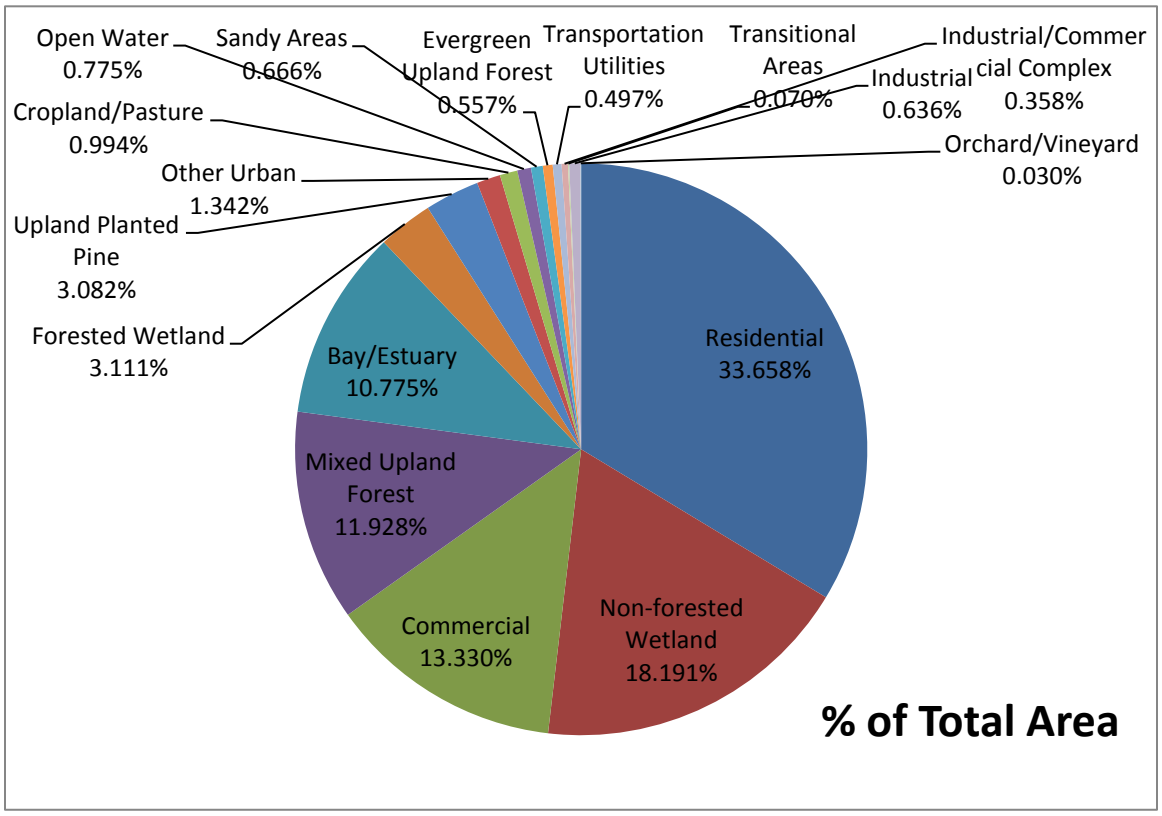


Figure 41. Lower Ashley River watershed water cover

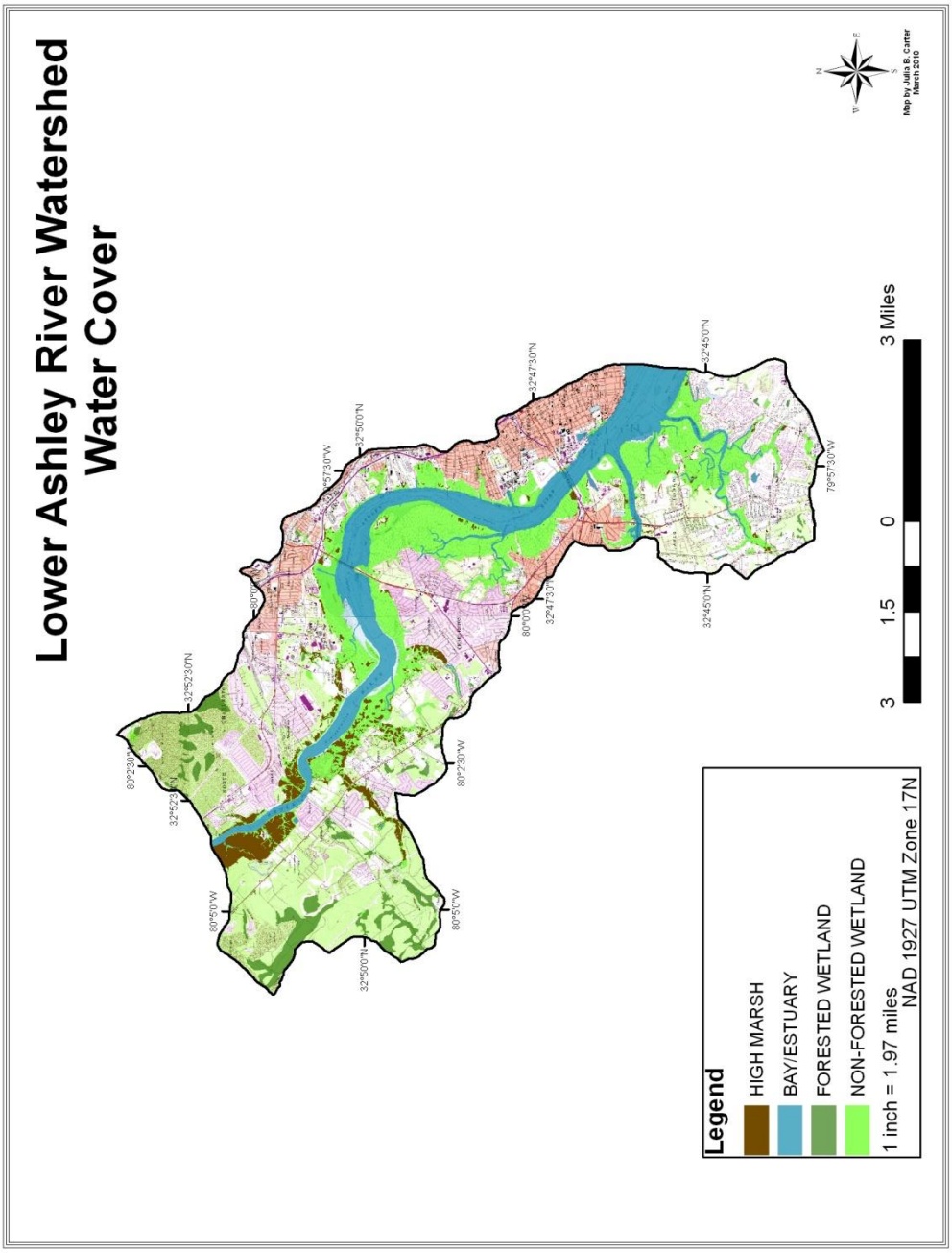


Figure 42. Lower Ashley River watershed forest cover

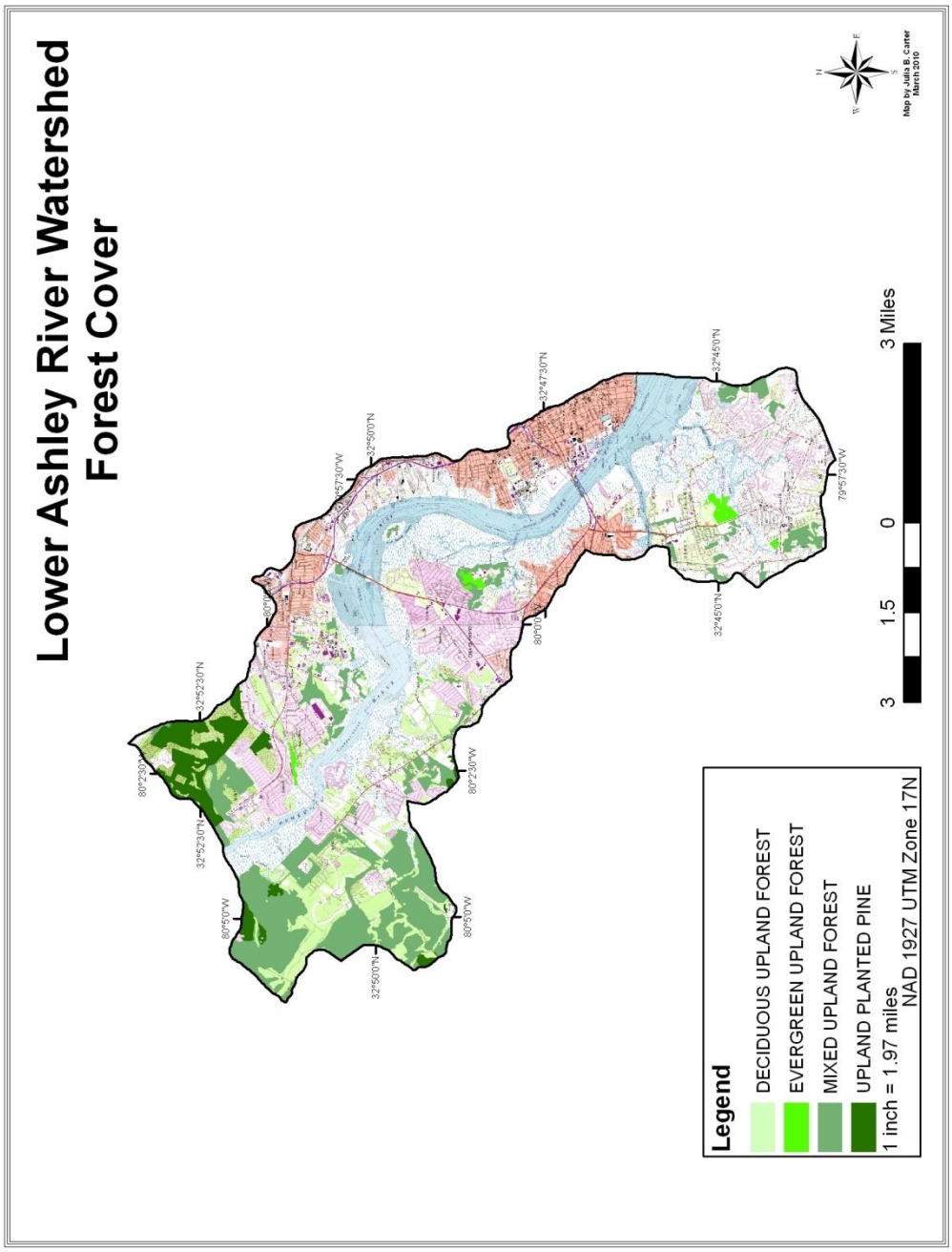


Figure 43. Lower Ashley River watershed agricultural land

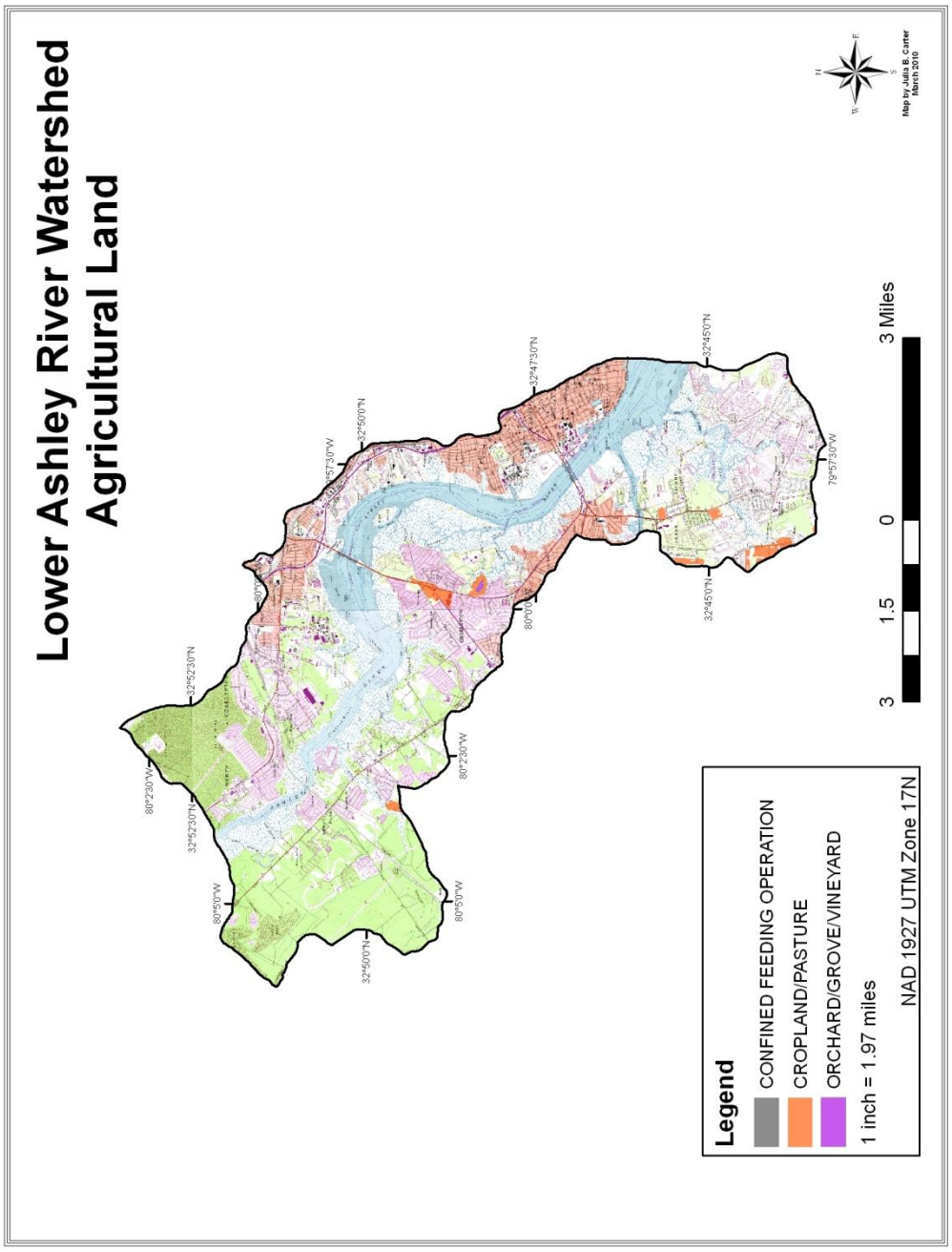


Figure 44. Lower Ashley River watershed developed land

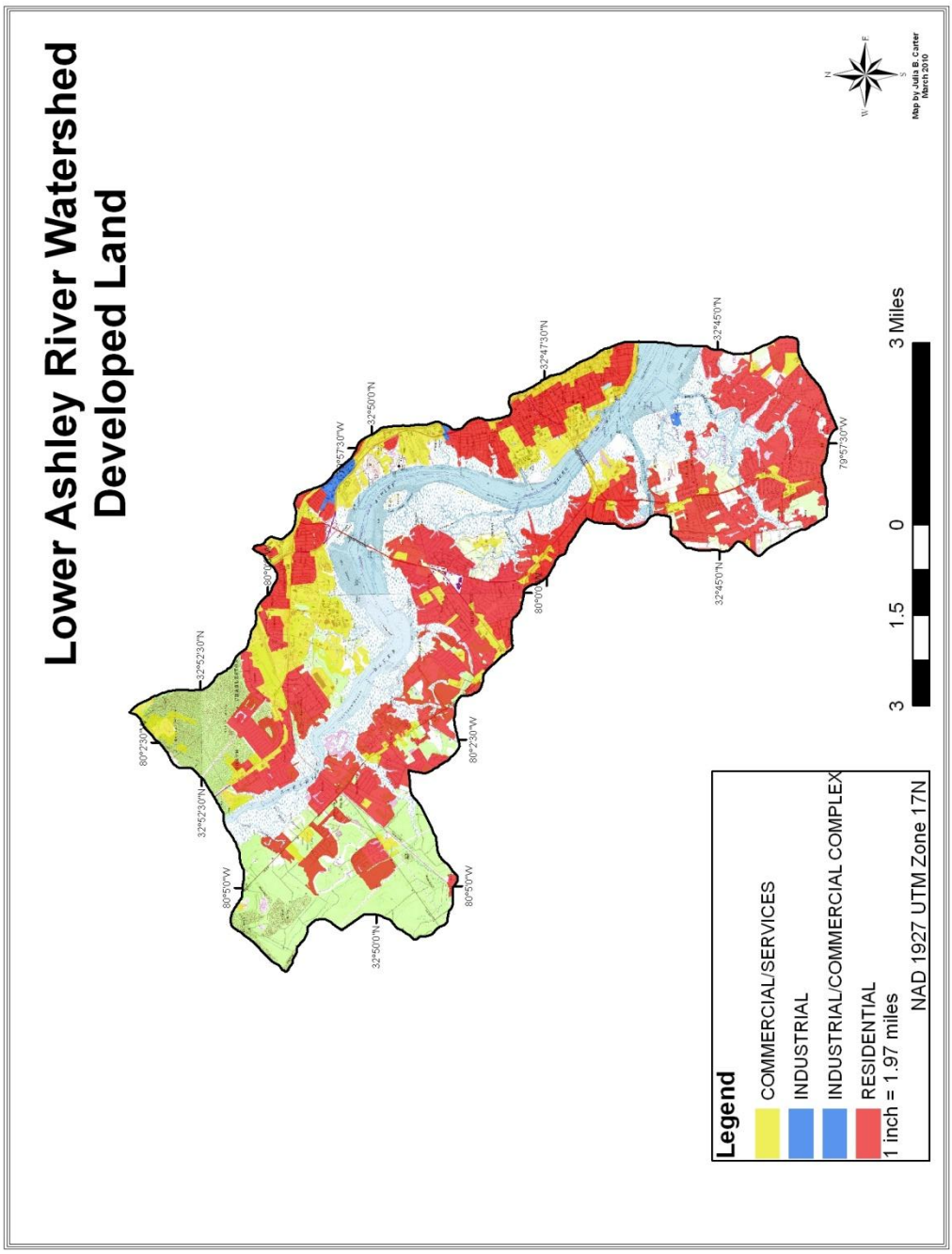


Figure 45. Lower Ashley River watershed impervious surfaces, and sewer and water systems

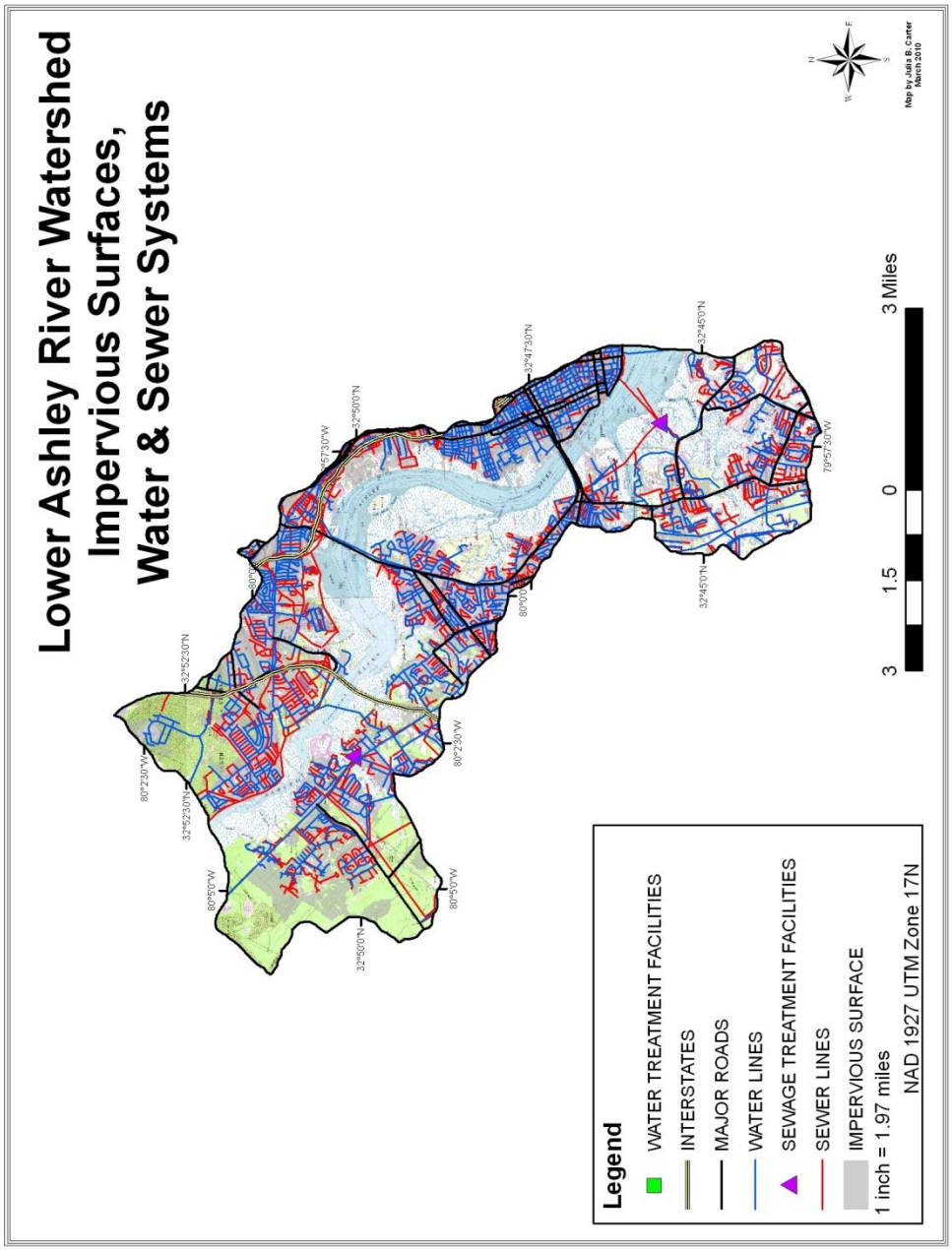
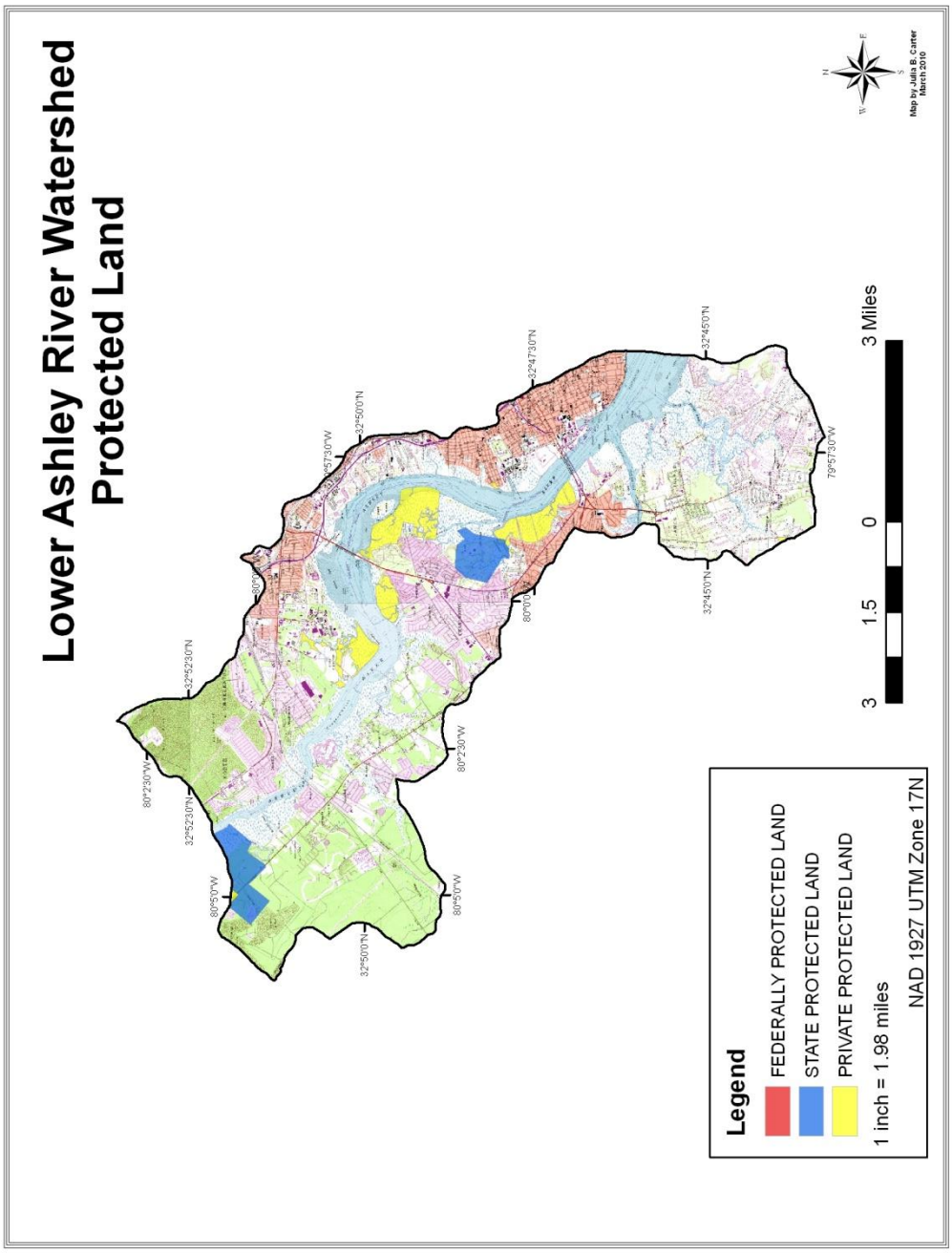


Figure 46. Lower Ashley River watershed protected land



4.3.6 Lower Cooper River Watershed – HUC 030502010707

The Lower Cooper River Watershed shares its western boundary with the Lower Ashley Watershed that bisects the Charleston peninsula, therefore the eastern half of the Charleston peninsula falls in the Lower Cooper watershed, along with a small portion of Daniel Island, the western end of Mt. Pleasant and Sullivan's Island, Charleston Harbor, and the southeastern end of James Island that faces Charleston Harbor; the total area for Lower Cooper River watershed is 44414 acres. Figures 47-52, Table 11 and Chart 11 characterize this watershed. The Cooper River and Charleston Harbor bisect this watershed, 46.77% of the watershed consists of bay/estuary and non-forested wetlands, while the only forested wetlands (0.88%) are in the northwestern tip of the watershed is (Figure 47). Likewise, the majority of the forest cover is in the same portion of the northwestern tip of the watershed; while all four types of forest cover are represented in the Lower Cooper River watershed, the total area amounts to 2,437 acres or 5.49% of the watershed (Figure 48). Cropland/pasture accounts for 4.58% and can be found in two main portions of the watershed: Daniel Island and James Island (Figure 49). Figure 50 shows the developed portions of the watershed: residential (17.7%), commercial (11.54%) and industrial (2.04%) land uses, totaling 13893 acres or 31.28% of the watershed. The Charleston peninsula, Mt. Pleasant, and half of James Island are covered in impervious surfaces, with major roads and interstates on the peninsula and in Mt. Pleasant (Figure 51). Sewer lines and water lines run through all of the watershed except for the small portion of Daniel Island that is within the watershed boundary that is unpopulated; there are no sewage treatment facilities in this watershed, however there are

two water treatment facilities on the Mount Pleasant side of the watershed (Figure 51). There is one privately protected parcel of land on James Island and two state protected parcels on James Island, one is next to SC DNR Fort Johnson and one is near Successionville Creek (Figure 52). This watershed is impaired for fecal coliform, copper, and turbidity.

Table 11. Lower Cooper River Watershed
HUC 030502010707 – Total Area: 44,414 acres

Land-use	Area (acres)	% of Total Area
Bay/Estuary	12141	27.34
Non-forested Wetland	8631	19.43
Residential	7862	17.7
Commercial	5127	11.54
Cropland/Pasture	2033	4.58
Transitional Areas	1482	3.34
Open Water	1360	3.06
Mixed Upland Forest	1304	2.94
Industrial/Commercial Complex	904	2.04
Sandy Areas	875	1.97
Transportation Utilities	623	1.4
Upland Planted Pine	575	1.29
Evergreen Upland Forest	527	1.19
Forested Wetland	392	0.88
Other Urban	349	0.79
Mines/Quarries/Pits	134	0.3
Beaches	64	0.14
Deciduous Upland Forest	31	0.07

Chart 11. Lower Cooper Watershed

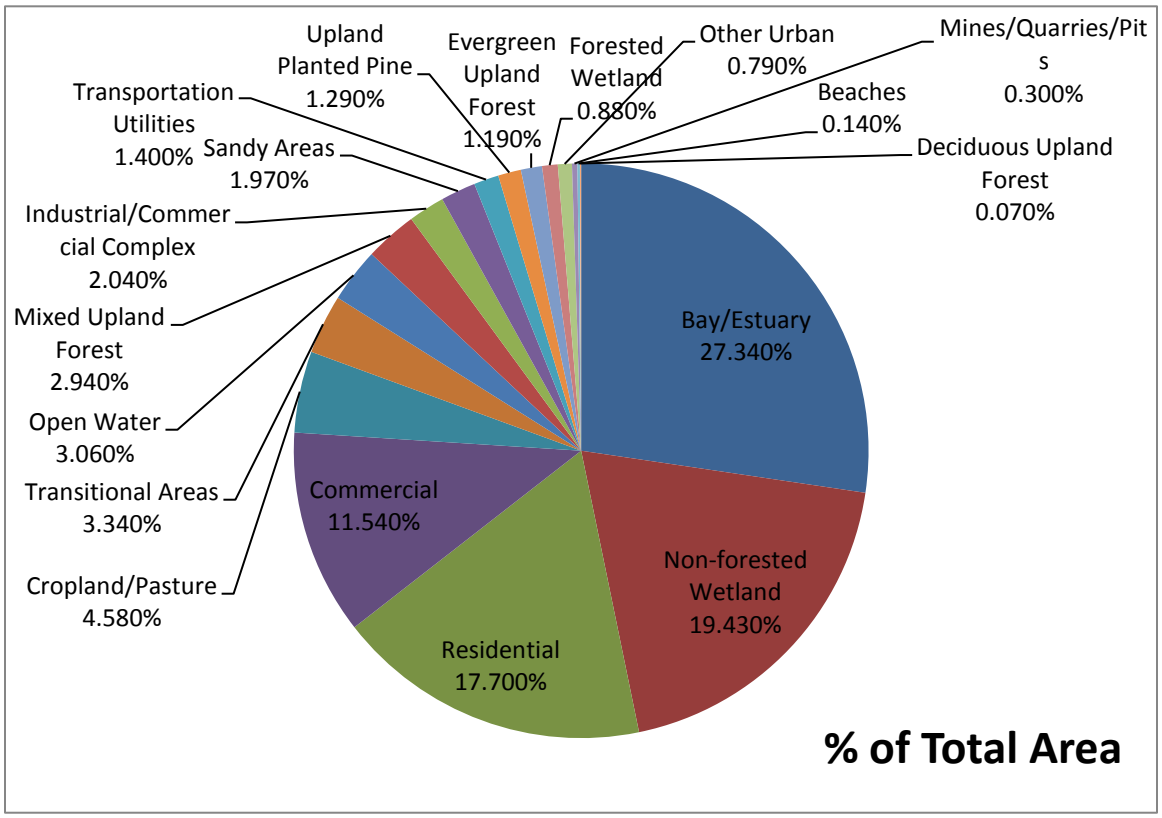


Figure 47. Lower Cooper River watershed water cover

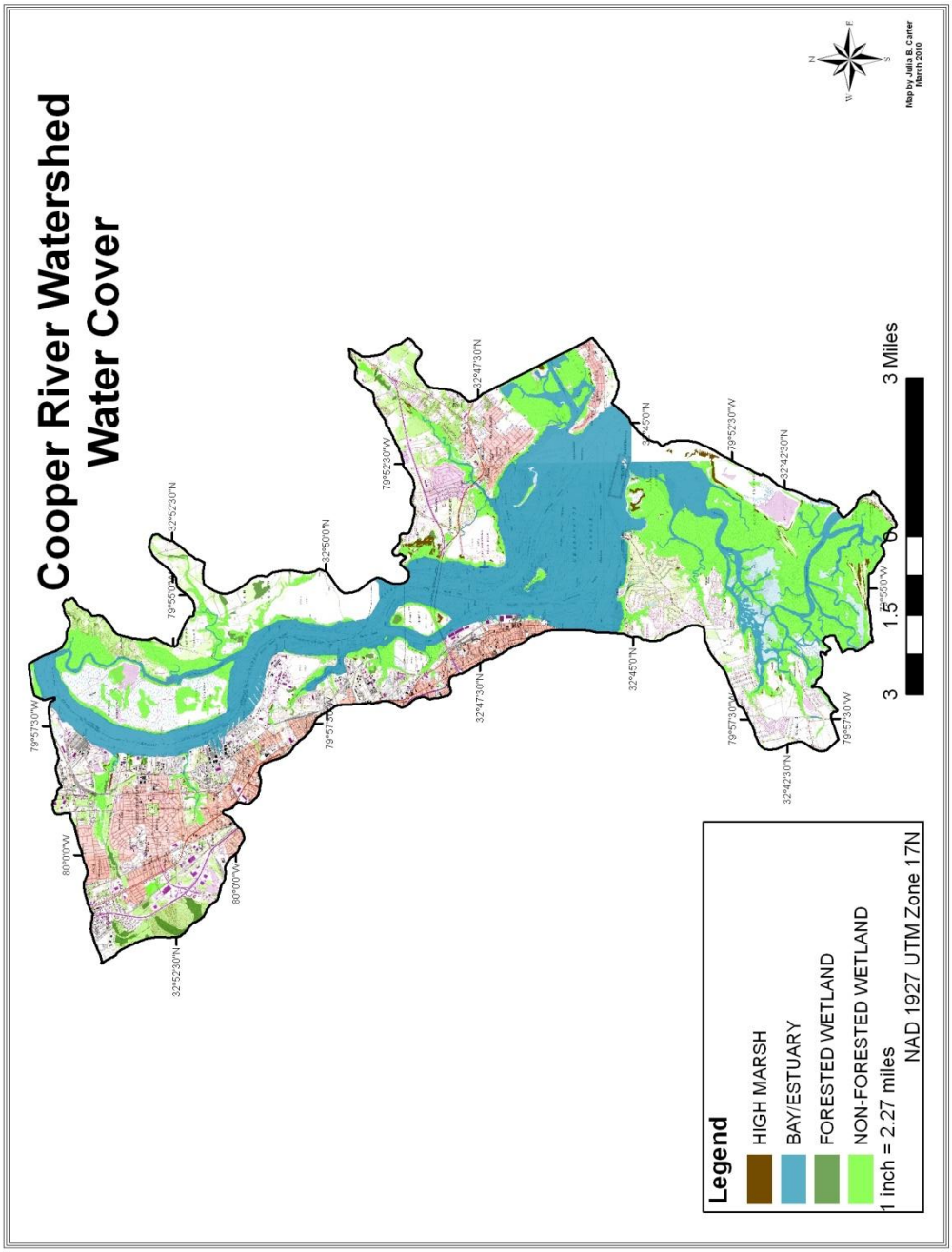


Figure 48. Lower Cooper River watershed forest cover

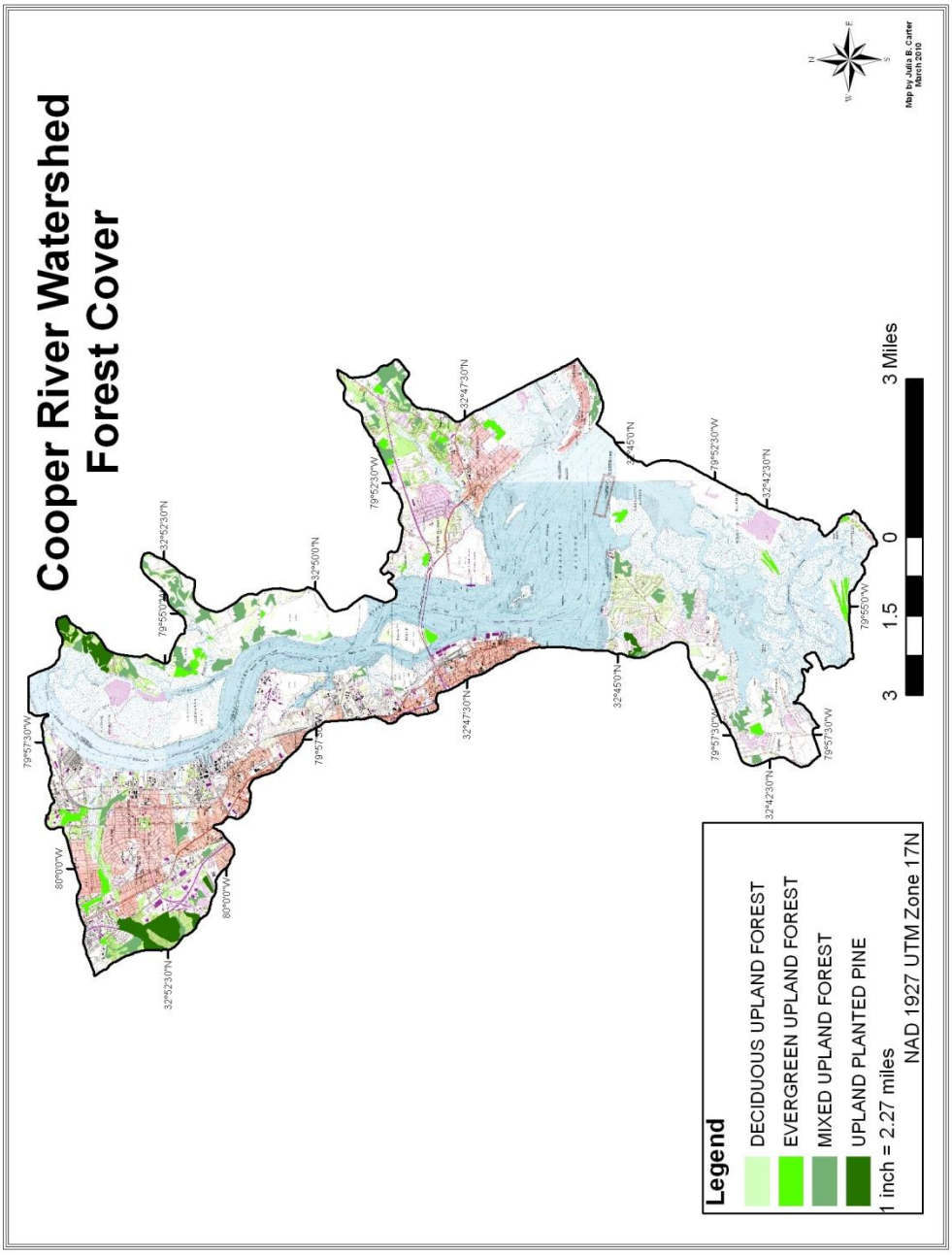


Figure 49. Lower Cooper River watershed agricultural land

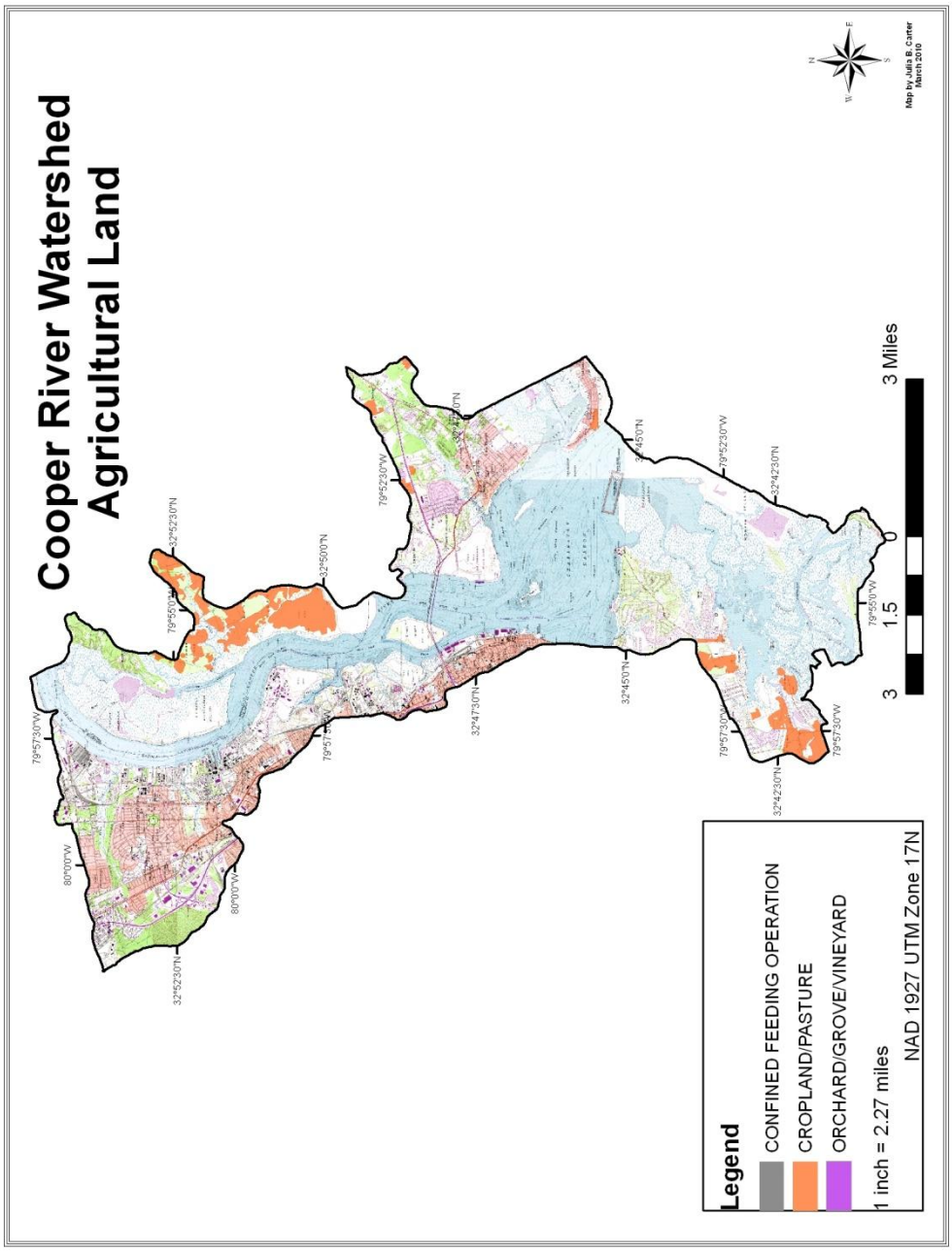


Figure 50. Lower Cooper River watershed developed land

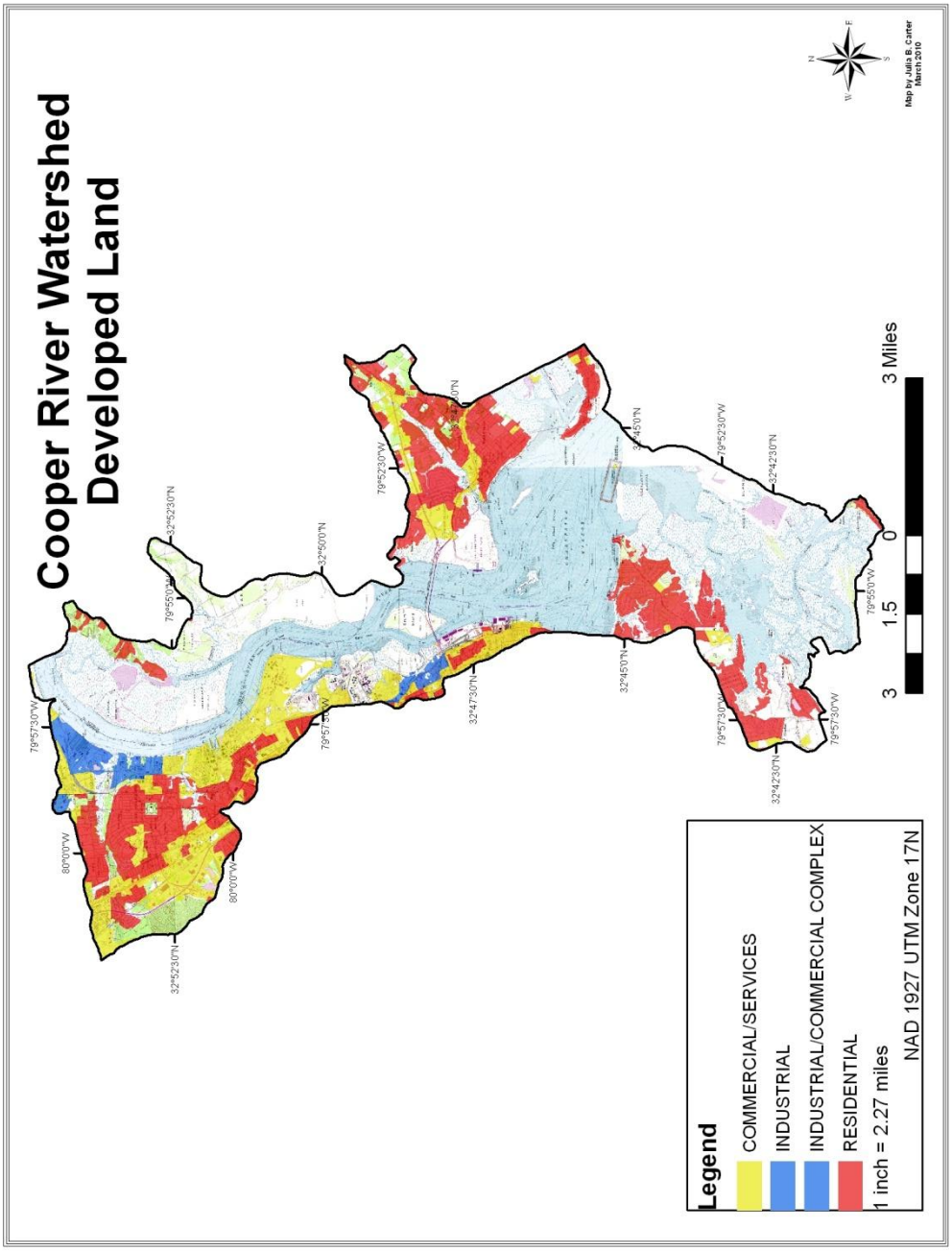


Figure 51. Lower Cooper River watershed impervious surfaces, and sewer and water systems

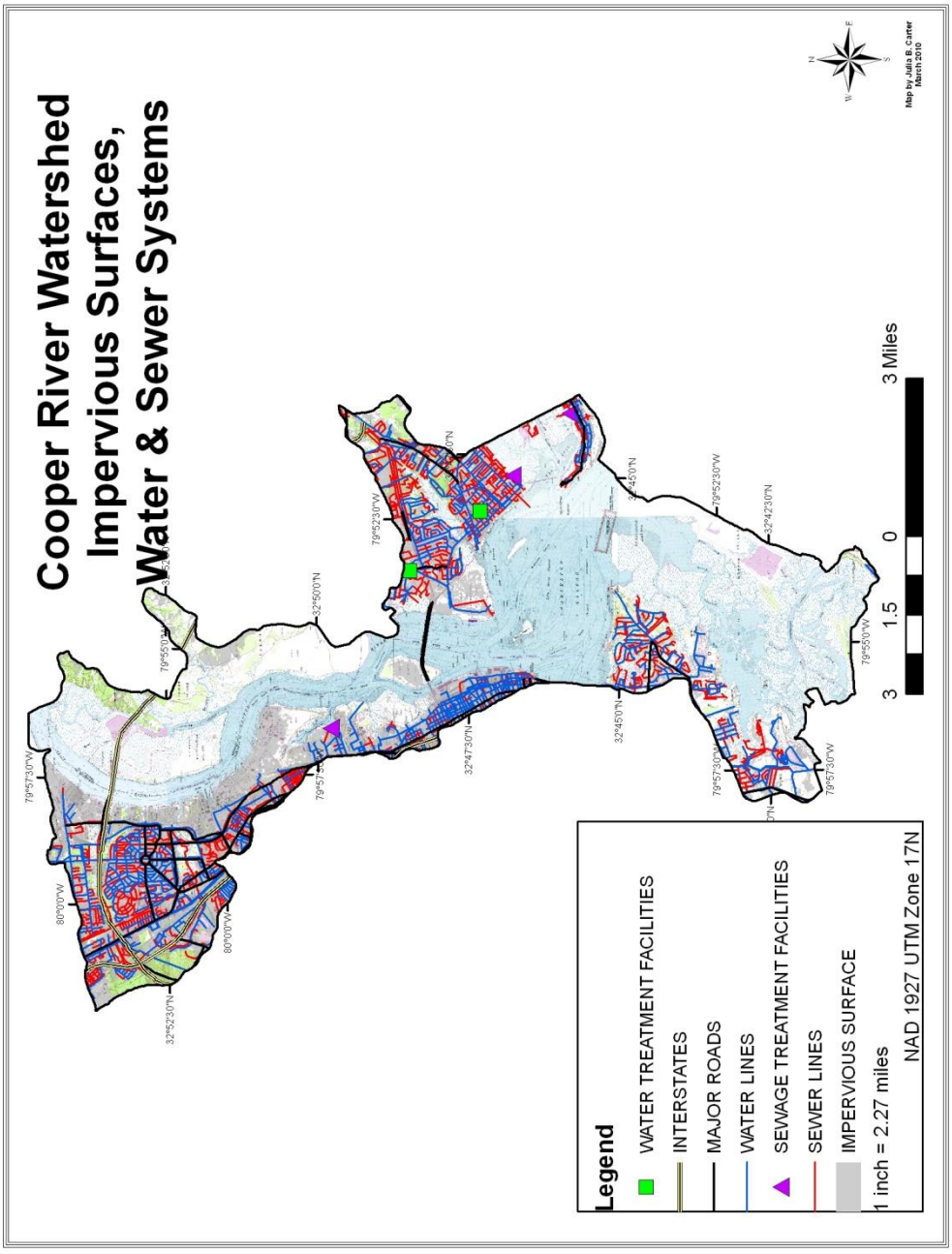
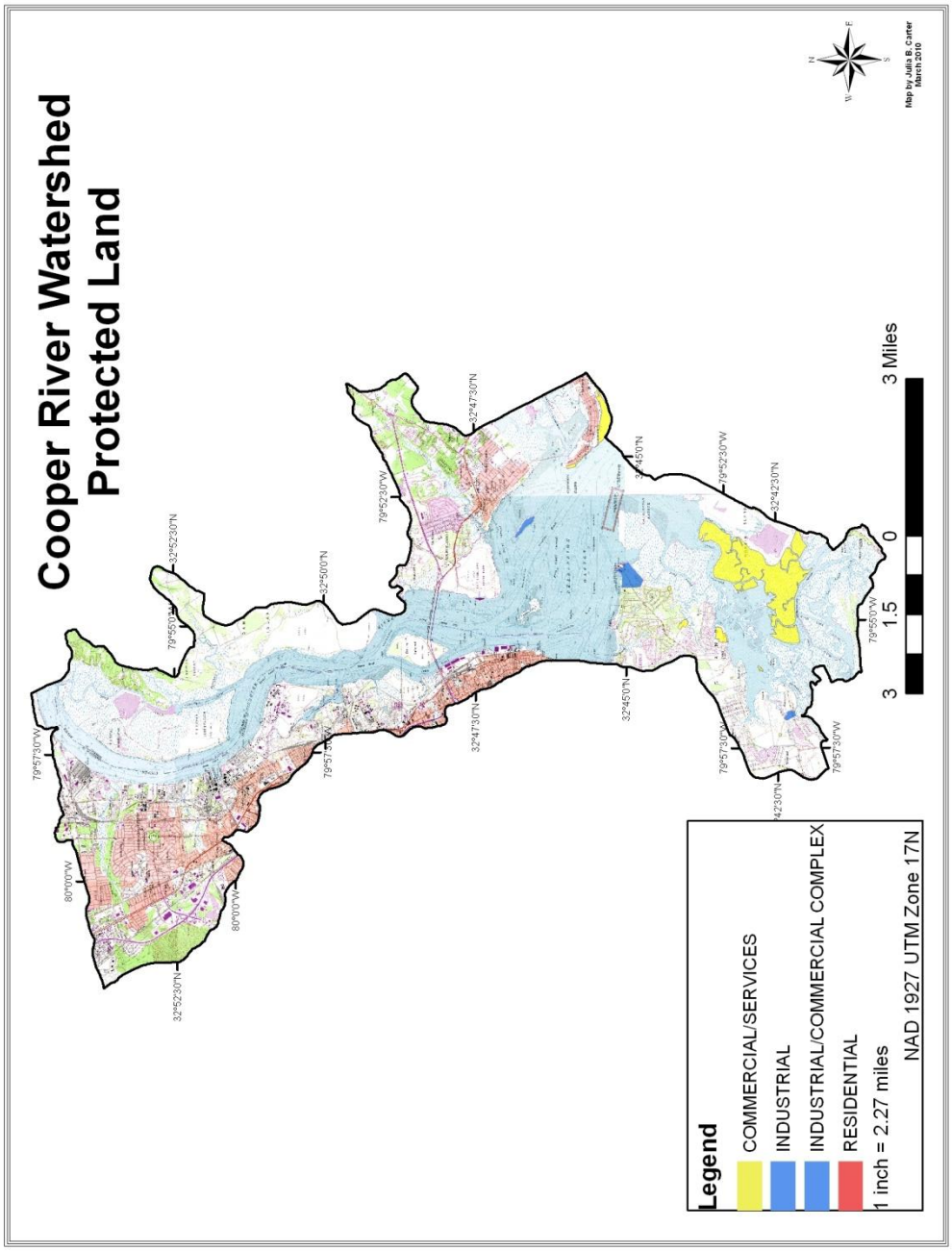


Figure 52. Lower Cooper River watershed protected land



4.3.7 Lower Wando River Watershed – HUC 030502010402

The Lower Wando River Watershed is directly adjacent to the Lower Cooper Watershed on the eastern side and therefore contains the other portion of Daniel Island along with the northern portion of Mt. Pleasant; the total area for this watershed is 32,319 acres. Figures 53-58, Table 12 and Chart 12 represent the characterization of this watershed. The Wando River bisects this watershed, therefore non-forested wetlands and high marsh immediately surrounding the Wando River comprise the water coverage for this watershed, the non-forested wetlands accounting for 21.44% of the area; there are forested wetlands (4.73%) on the northern edge of the watershed (Figure 53). Figure 54 depicts the forest coverage, totaling 36.41% of the watershed, predominantly consisting of upland planted pine and mixed upland forest. There is cropland/pasture (6.54%) both on the Daniel Island and Mount Pleasant sides along with two orchard/vineyard sites (0.16%) (Figure 55). The residential areas account for 12.07% of the watershed, while commercial development accounts for 0.46% and is only found in the Mount Pleasant area (Figure 56). Impervious cover, major roads, and interstates are centered on the Mt. Pleasant portion of the watershed (Figure 57). Both the sewer lines and water lines are predominantly in Mt. Pleasant; there are no sewage treatment or water treatment facilities in this watershed (Figure 57). There are two areas that are federally protected; one is an unidentified parcel in the northern most tip of the watershed and the other is Boone Hall Plantation (Figure 58). This watershed is impaired with fecal coliform, dissolved oxygen, and ammonia nitrogen.

Table 12. Lower Wando River Watershed
HUC 030502010402 – Total Area: 32, 319 acres

Land-use	Area (acres)	% of Total Area
Non-forested Wetland	6928	21.44
Upland Planted Pine	6608	20.45
Bay/Estuary	4707	14.56
Residential	3900	12.07
Mixed Upland Forest	3552	11
Cropland/Pasture	2114	6.54
Evergreen Upland Forest	1602	4.96
Forested Wetland	1529	4.73
Transitional Areas	491	1.52
Transportation Utilities	277	0.86
Commercial	149	0.46
Other Urban	123	0.38
Open Water	114	0.35
Sandy Areas	101	0.31
Industrial	72	0.22
Orchard/Vineyard	52	0.16

Chart 12. Lower Wando River Watershed

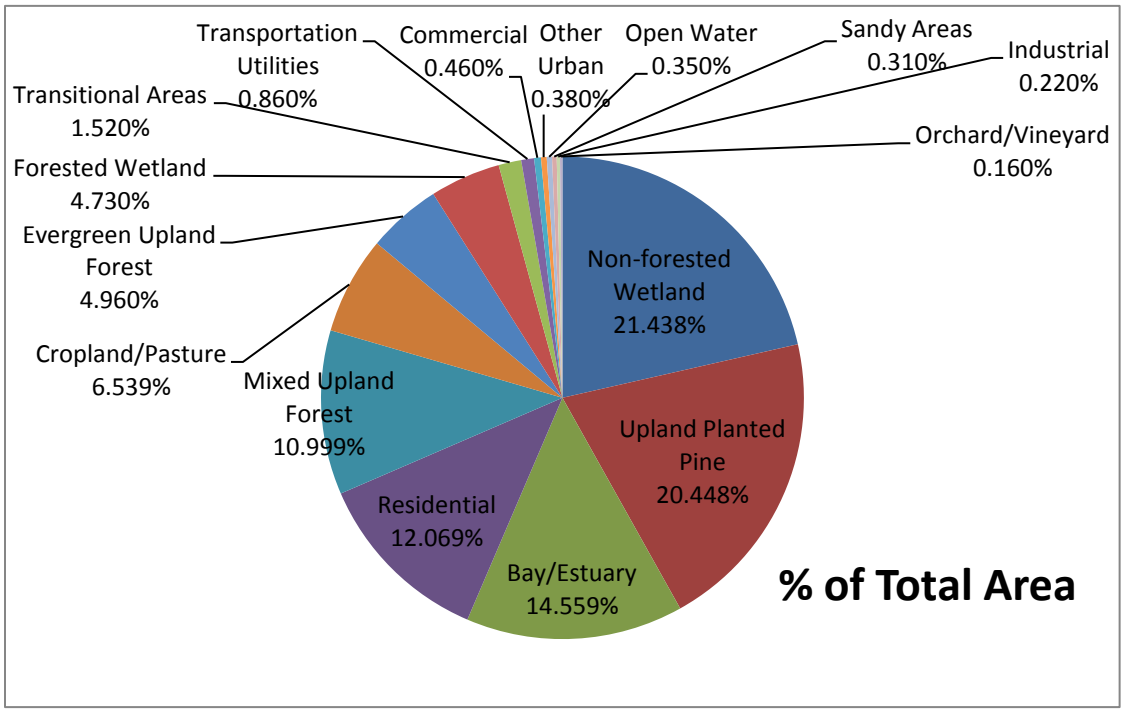


Figure 53. Lower Wando River watershed water cover

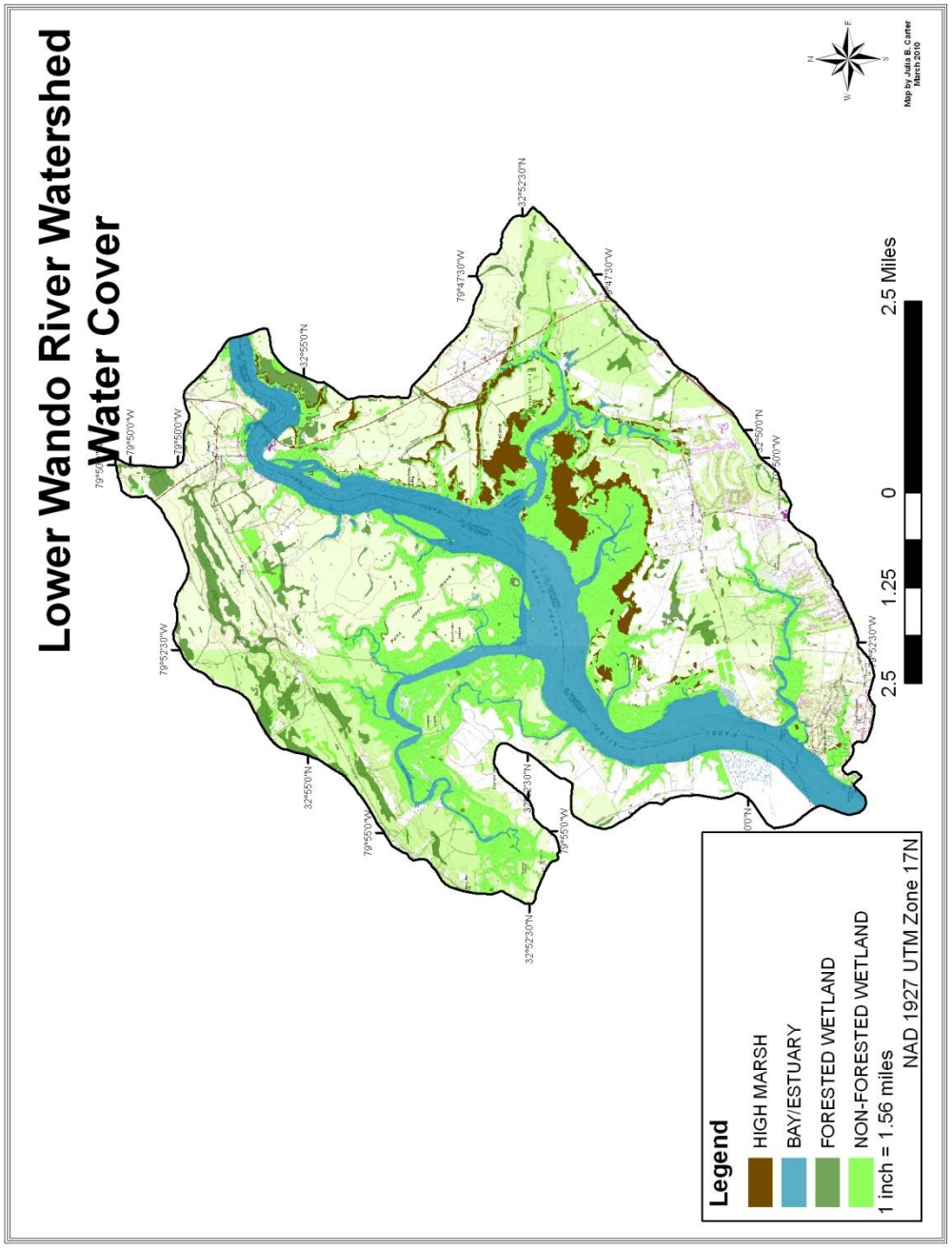


Figure 54. Lower Wando River watershed forest cover

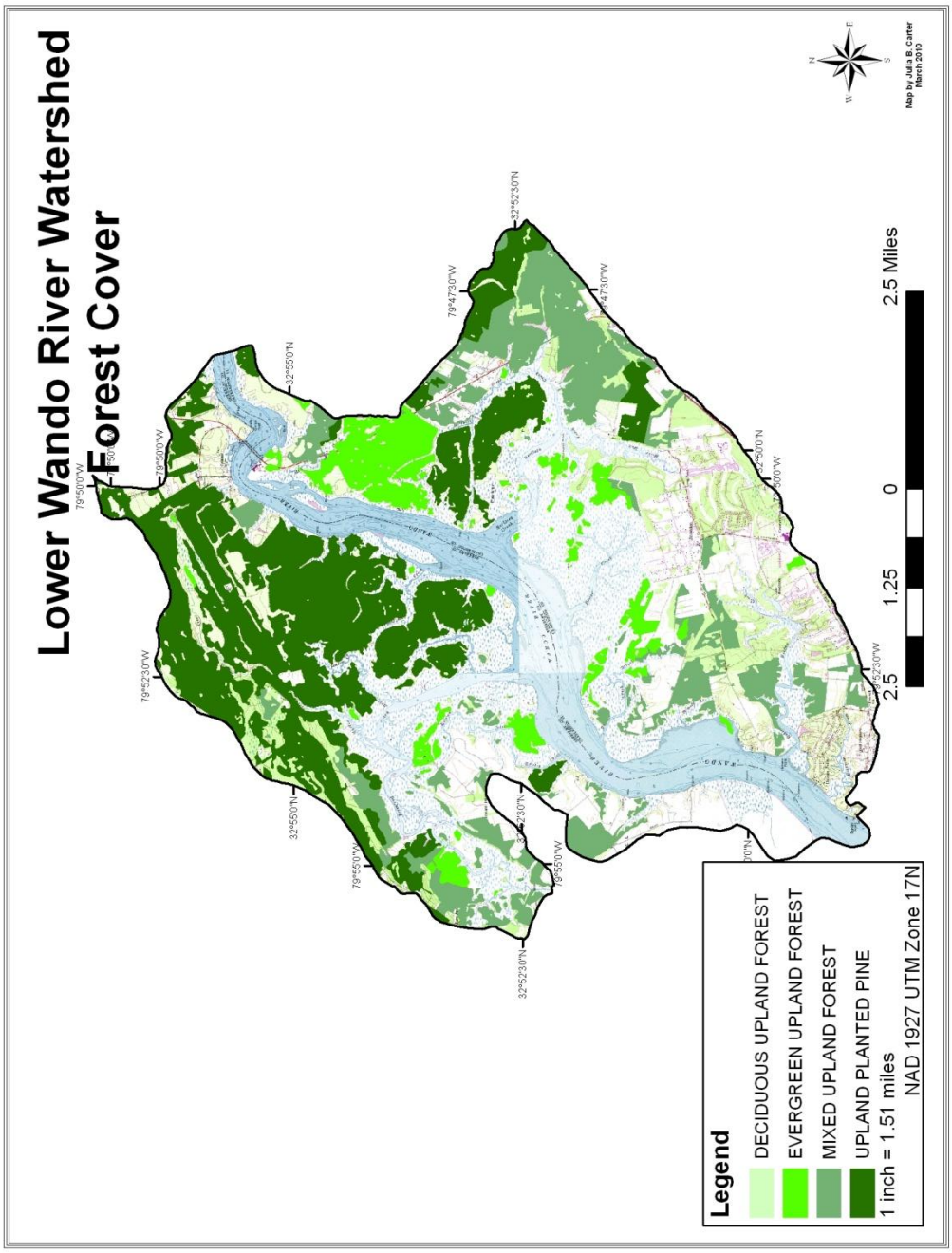


Figure 55. Lower Wando River watershed agricultural land

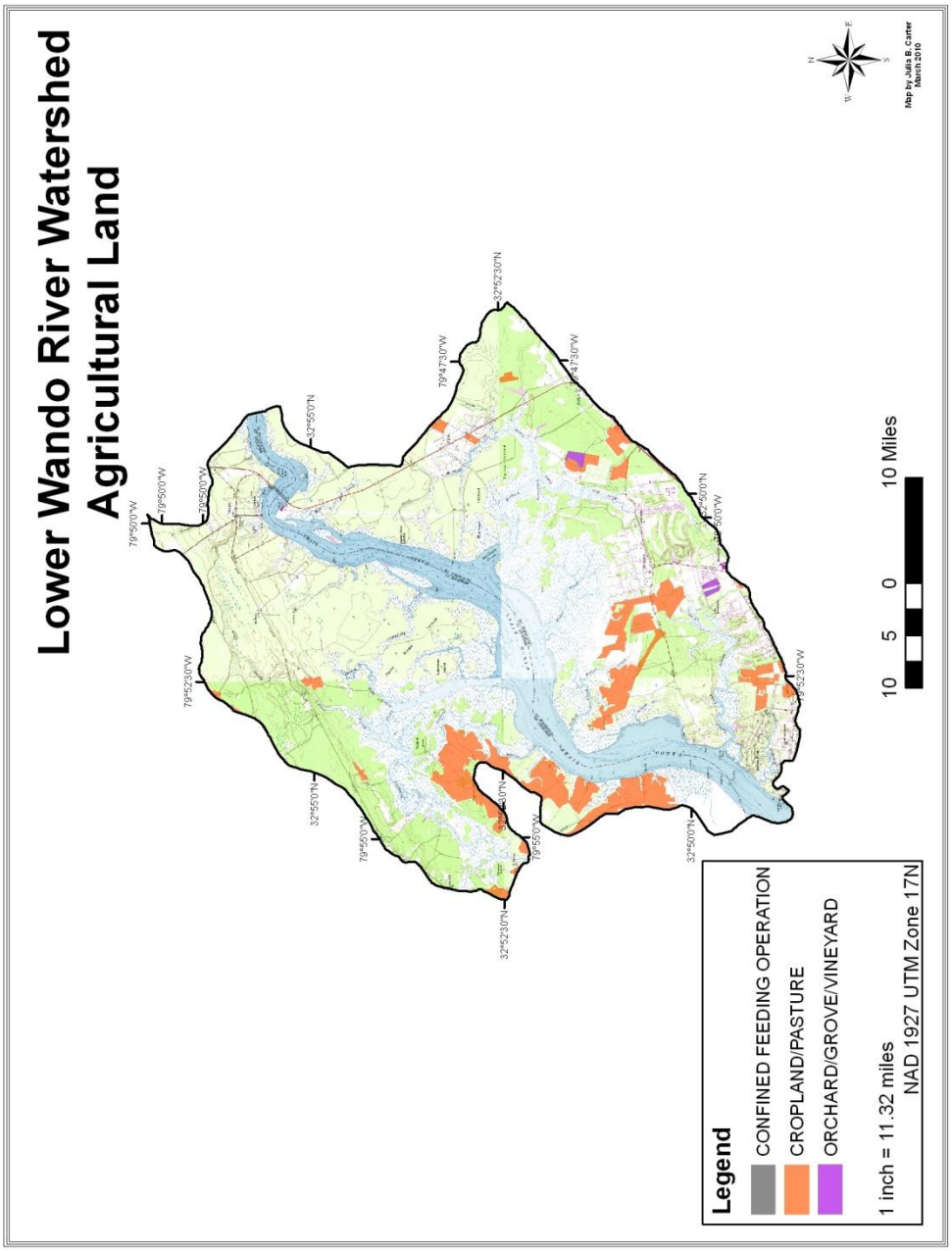


Figure 56. Lower Wando River watershed developed land

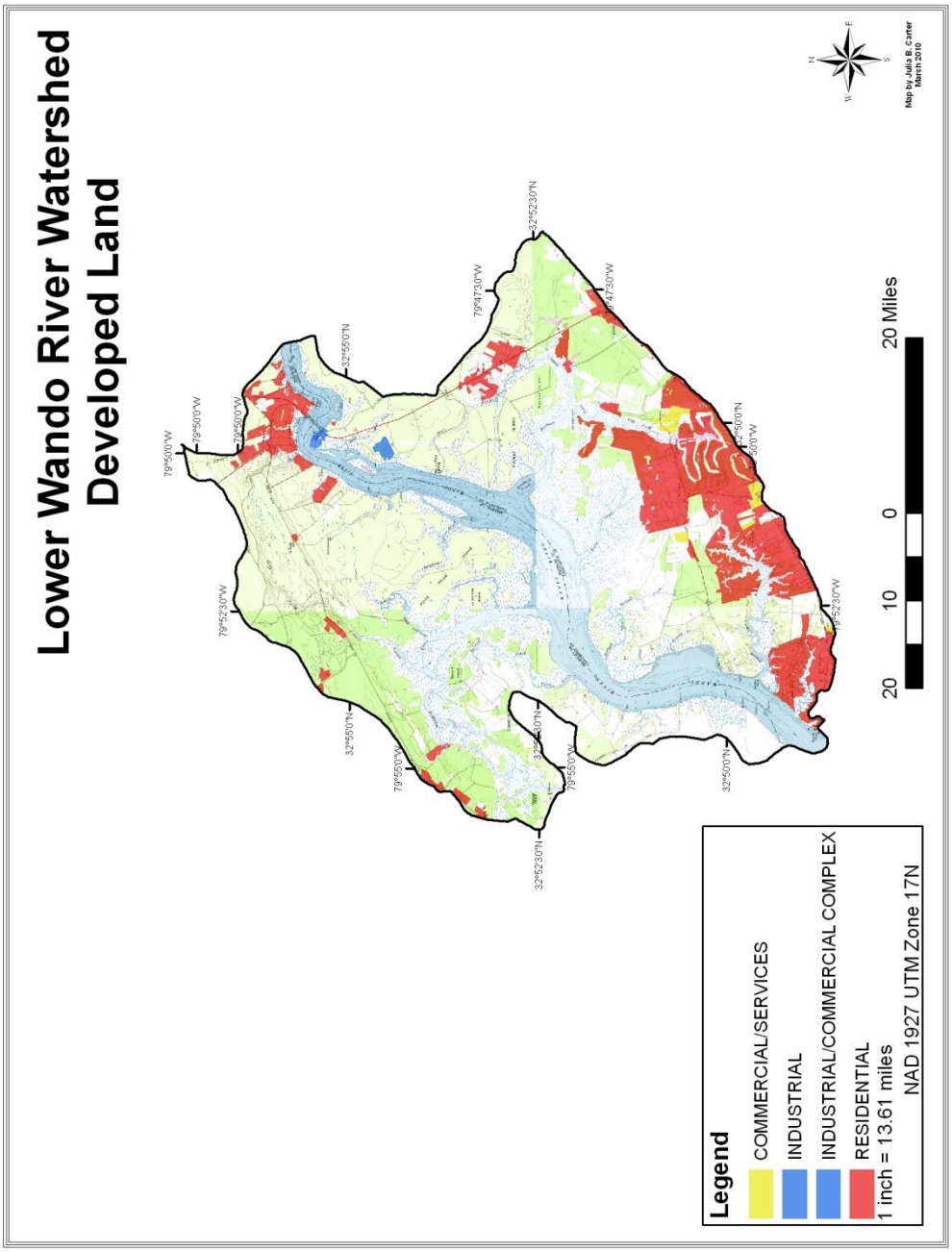


Figure 57. Lower Wando River watershed impervious surfaces, and sewer and water systems

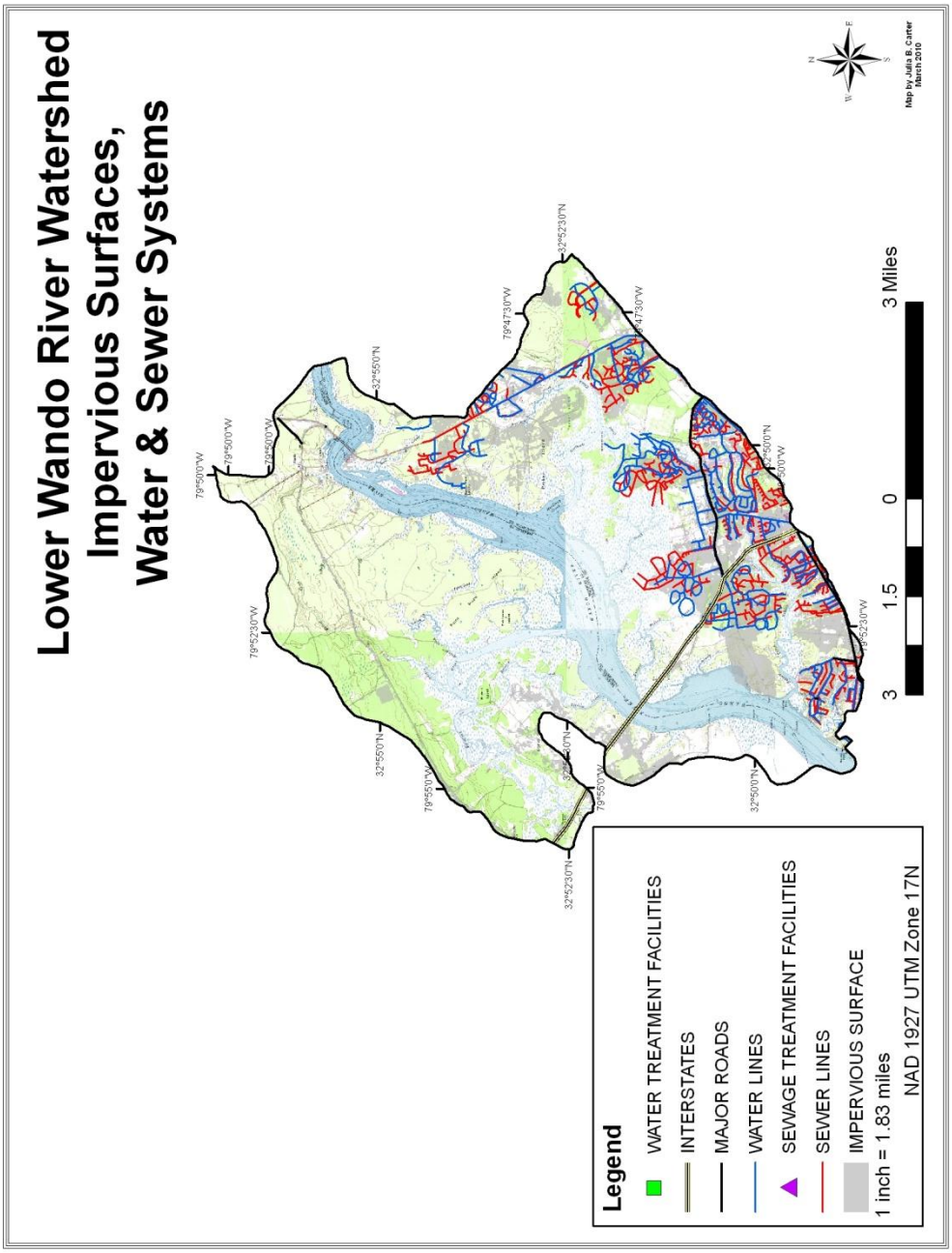
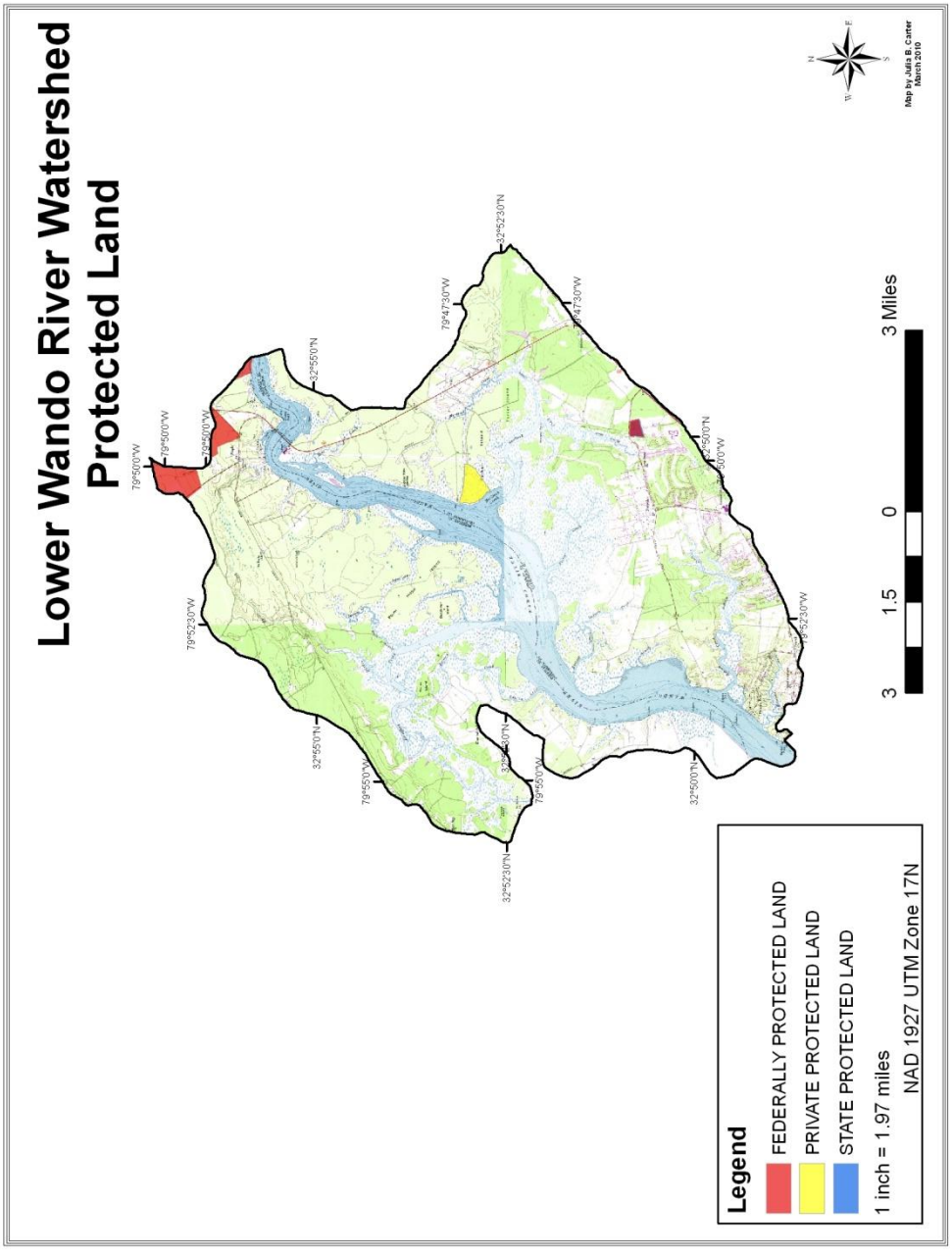


Figure 58. Lower Wando River watershed protected land



4.3.8 Middle Ashley River Watershed – HUC 030502010604

The Ashley River bisects the Middle Ashley River Watershed, with North Charleston falling on the eastern side and Middleton Plantation, Magnolia Gardens and Drayton Hall all along the river on the western side; the total area for this watershed is 20405 acres. Table 13, Chart 13, and Figures 59-64 represent the characterization of this watershed. With the Ashley River running through the center of this watershed, non-forested wetlands (10.46%) and high marsh are centered around the river, while forested wetlands (22.24%) are found away from the river (Figure 59). Forest cover falls on either side of the river in the form of upland planted pine, evergreen upland forest and mixed upland forest and a small sliver of deciduous upland forest in the northern most corner of the watershed and accounts for a total of 54.19% forested area (Figure 60). Cropland/pasture (0.57%) is found directly adjacent to the western side of Magnolia Gardens and on Middleton Plantation (Figure 61). Residential and commercial areas make up 23.53% of the watershed and are found predominantly in North Charleston (Figure 62), likewise, the impervious surface coverage, sewer lines and water lines as well as one sewage treatment facility are found predominantly on the North Charleston side of the watershed (Figure 63). Drayton Hall is protected by the State, while the privately protected areas are predominantly Middleton Plantation and Magnolia Gardens (Figure 64). This watershed is impaired for mercury, fecal coliform and turbidity.

Table 13. Middle Ashley River Watershed
HUC 030502010604 – Total Area: 20,405 acres

Land-use	Area (acres)	% of Total Area
Upland Planted Pine	5613	27.51
Mixed Upland Forest	5171	25.34
Forested Wetland	4539	22.24
Commercial	2492	12.21
Residential	2310	11.32
Non-forested Wetland	2134	10.46
Mines/Quarries/Pits	579	2.84
Bay/Estuary	544	2.67
Other Urban	417	2.04
Open Water	201	0.99
Evergreen Upland Forest	152	0.74
Deciduous Upland Forest	123	0.6
Cropland/Pasture	117	0.57
Transportation Utilities	7	0.03
Sandy Area	6	0.03

Chart 13. Middle Ashley River Watershed

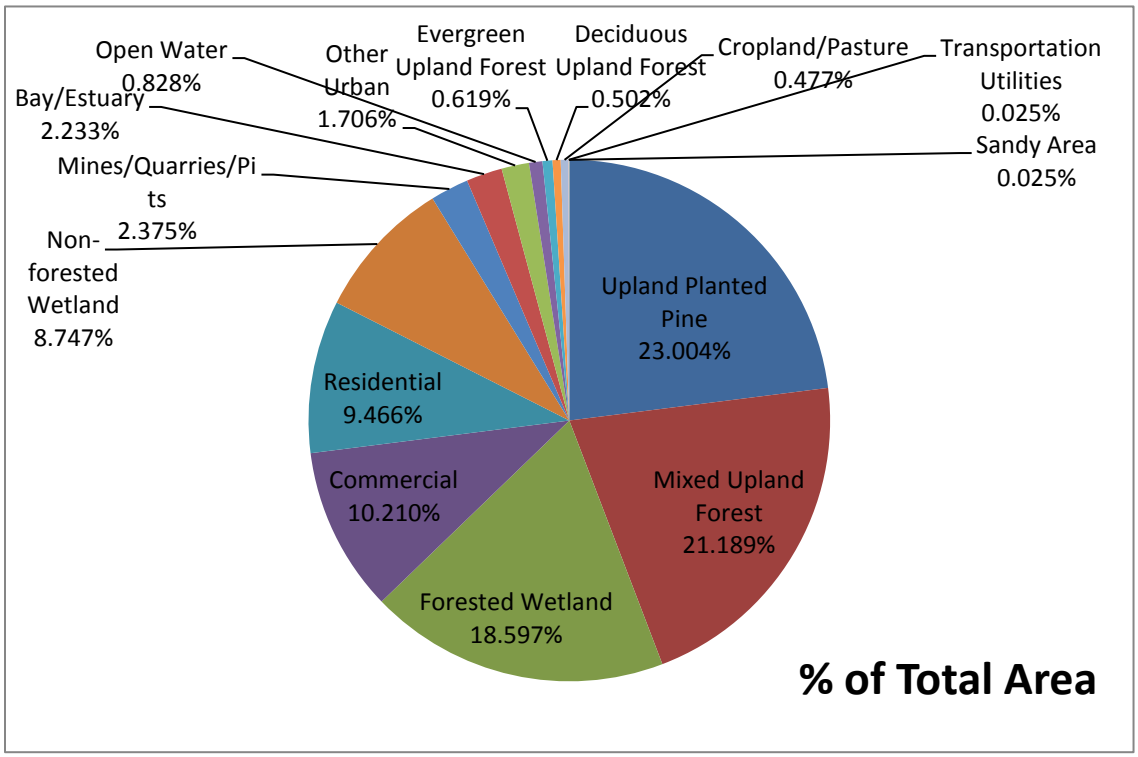


Figure 59. Middle Ashley River watershed water cover

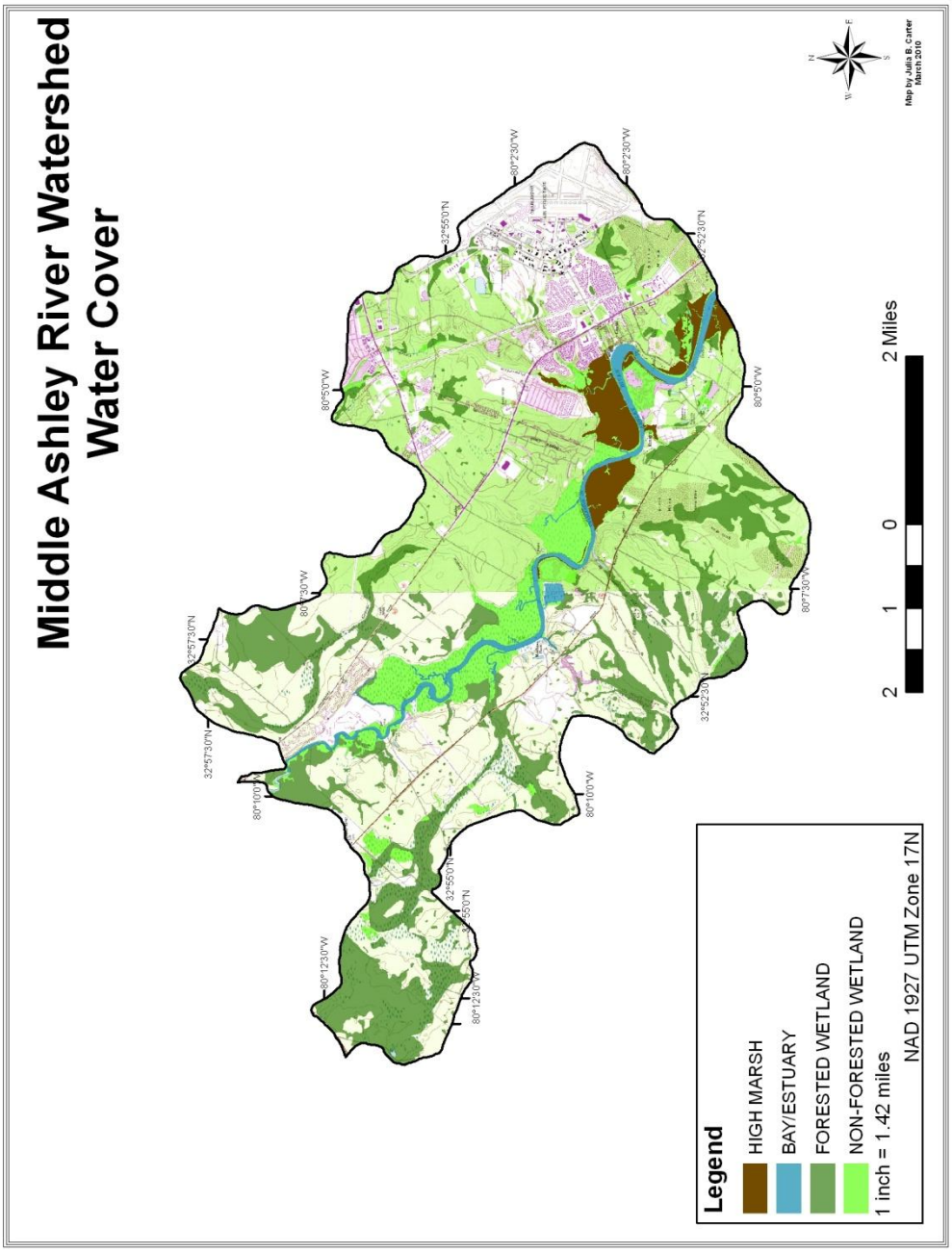


Figure 60. Middle Ashley River watershed forest cover

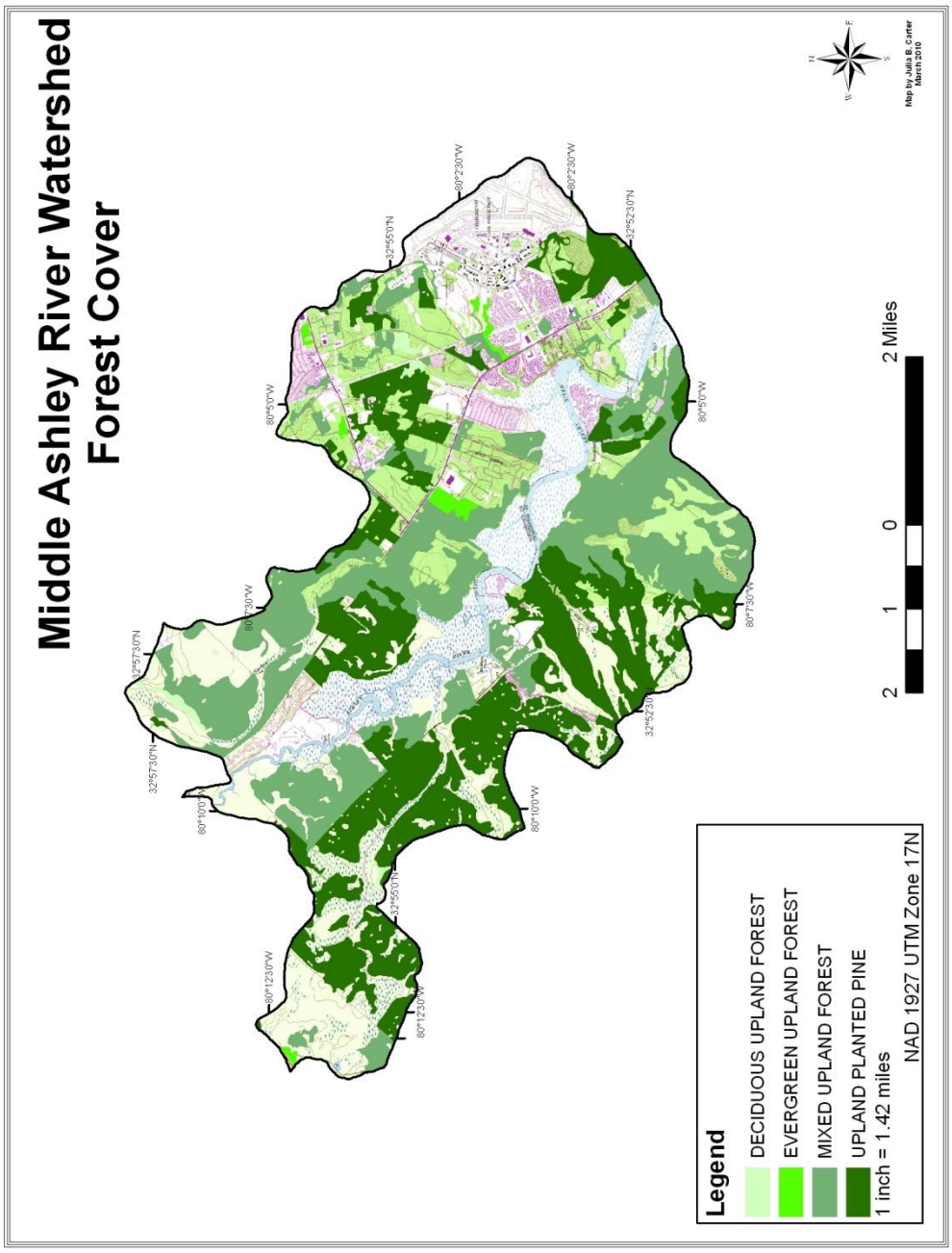


Figure 61. Middle Ashley River watershed agricultural land

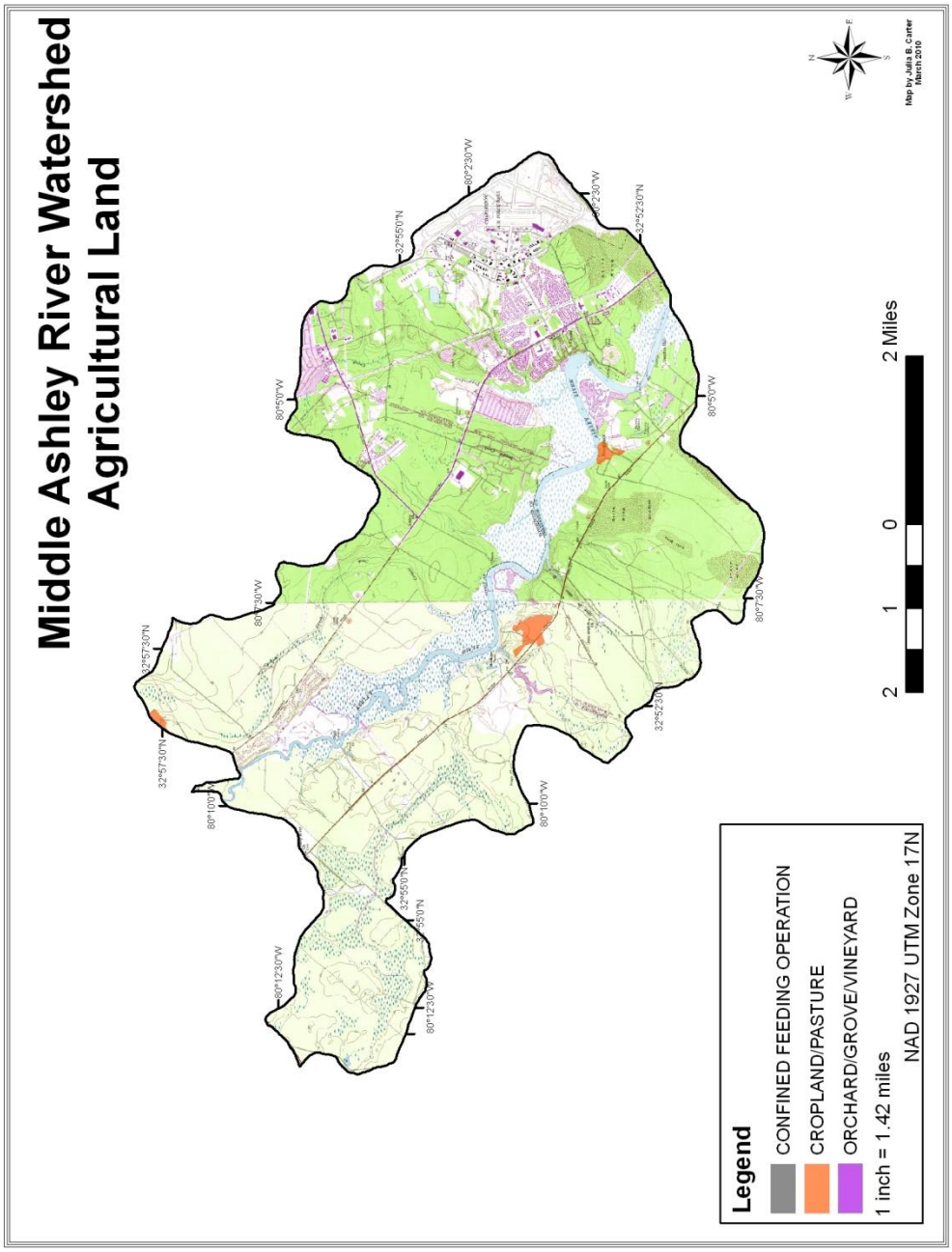


Figure 62. Middle Ashley River watershed developed land

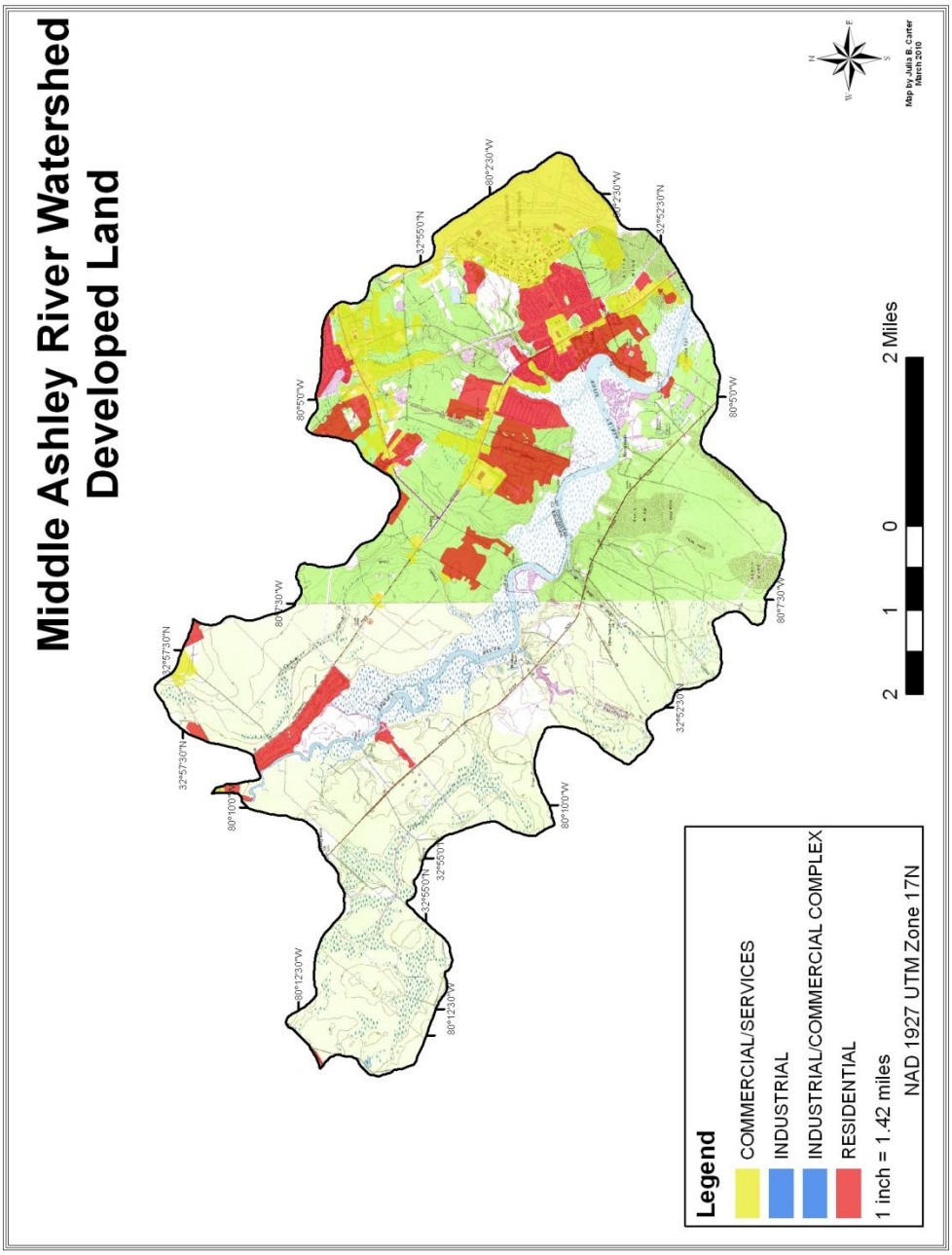


Figure 63. Middle Ashley River watershed impervious surfaces, and sewer and water systems

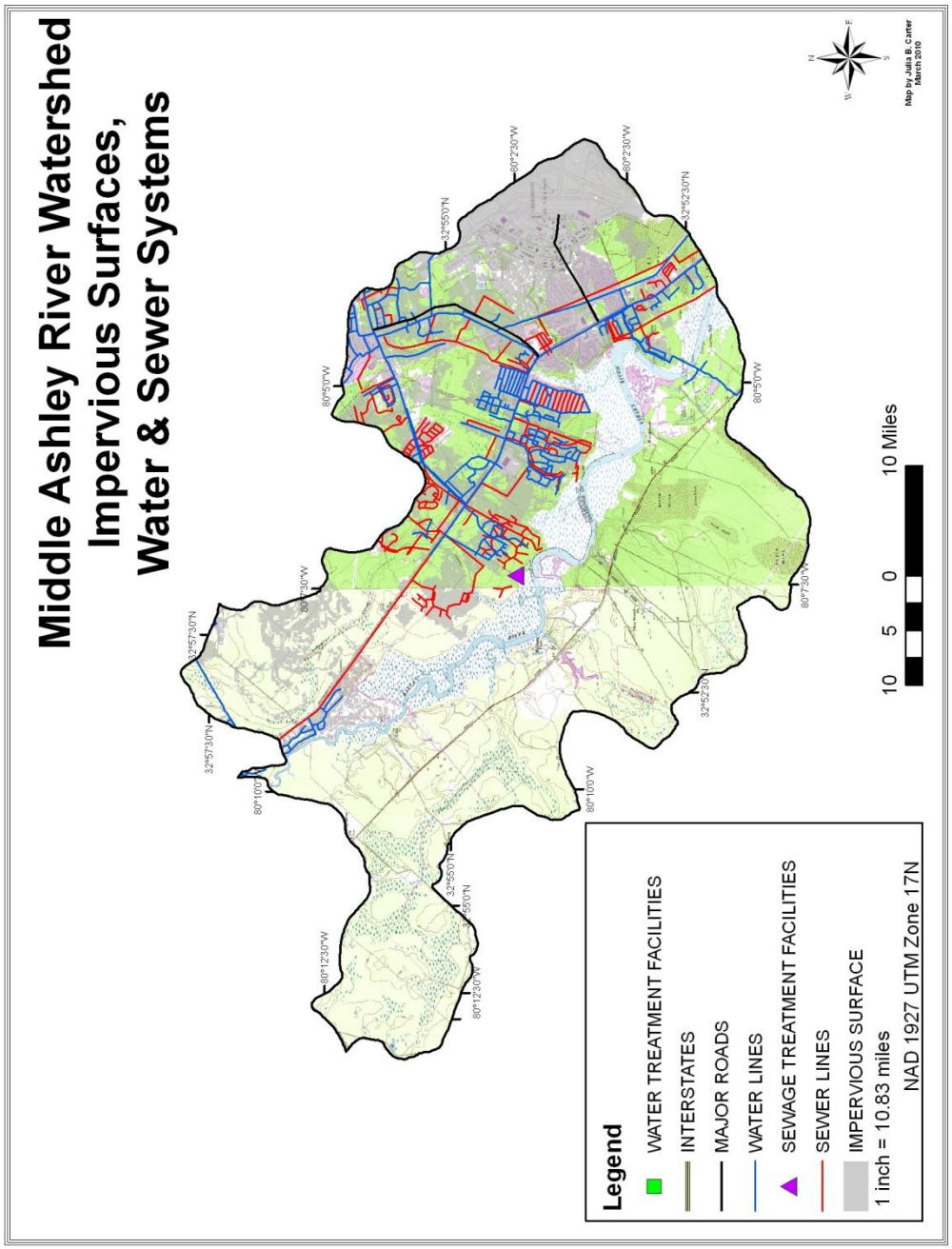
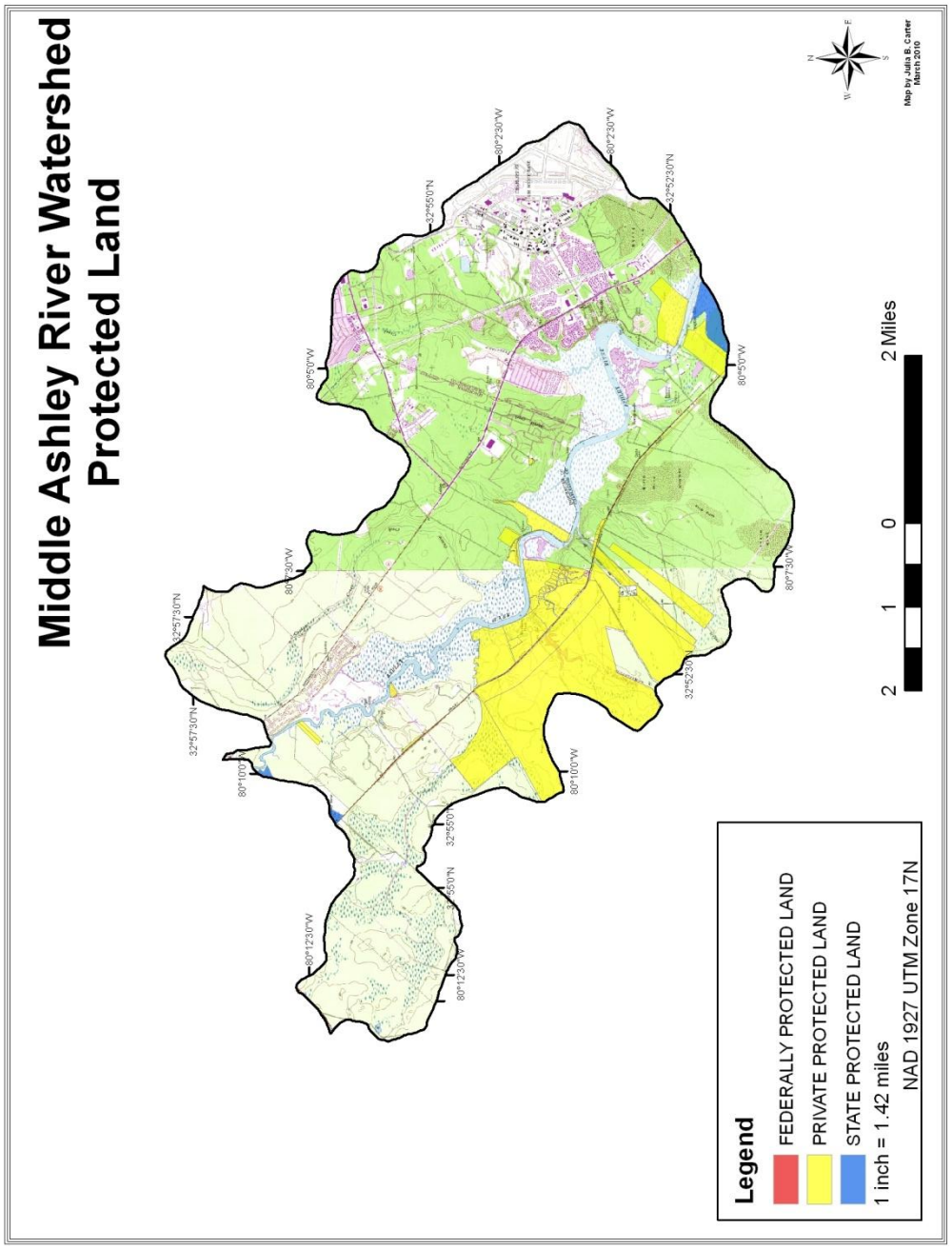


Figure 64. Middle Ashley River watershed protected land



4.3.9 Goose Creek Watershed – HUC 030502010706

The Goose Creek Watershed is directly adjacent to the Middle Ashley River watershed to the east and the waterway known as Goose Creek runs through the watershed. This watershed is located within Berkeley County and contains not only the towns of Ladson and Goose Creek but also the U.S. Naval Weapons Station; the total area for this watershed is 38,026 acres. Table 14, Chart 14, and Figures 65-69 characterize this watershed. Non-forested wetlands follow the river (7.25% of the watershed), while forested wetlands predominantly follow the swamp or inland marsh (10.33% of watershed) (Figure 65). Forest cover (32.36%) is concentrated in the middle third of the watershed and is composed of upland planted pine and mixed upland forest (Figure 66). There is very little agricultural land, however there are small concentrations along the western and northern edges of the watershed; the agricultural land is predominantly cropland/pasture (0.74%), however there is an orchard/vineyard just south of Ladson (0.12%) (Figure 67). High concentrations of residential and commercial areas can be found throughout the watershed with two small industrial spots in the western and southern portions of the watershed, developed land totaling 44.71% of the watershed (Figure 68); likewise, impervious surfaces span the watershed and are most concentrated in the same areas as residential and commercial development (Figure 69). Water and sewer lines are both found in the middle corridor of the watershed and there is one sewage and one water treatment facility, both in the southern portion of the watershed (Figure 69). There are no protected areas in this watershed, and the watershed is impaired for fecal coliform, dissolved oxygen, chlorophyll A, and total phosphorous.

Table 14. Goose Creek Watershed
HUC 030502010706 – Total Area: 38,026 acres

Land-use	Area (acres)	% of Total Area
Residential	9830	25.86
Commercial	7021	18.46
Mixed Upland Forest	6035	15.87
Upland Planted Pine	5935	15.61
Forested Wetland	3929	10.33
Non-forested Wetland	2755	7.25
Open Water	840	2.21
Mines/Quarries/Pits	350	0.92
Cropland/Pasture	282	0.74
Bay/Estuary	252	0.66
Evergreen Upland Forest	172	0.45
Deciduous Upland Forest	162	0.43
Transportation Utilities	155	0.41
Industrial/Commercial Complex	147	0.39
Other Urban	72	0.19
Orchard/Vineyard	45	0.12
Industrial	44	0.12

Chart 14. Goose Creek Watershed

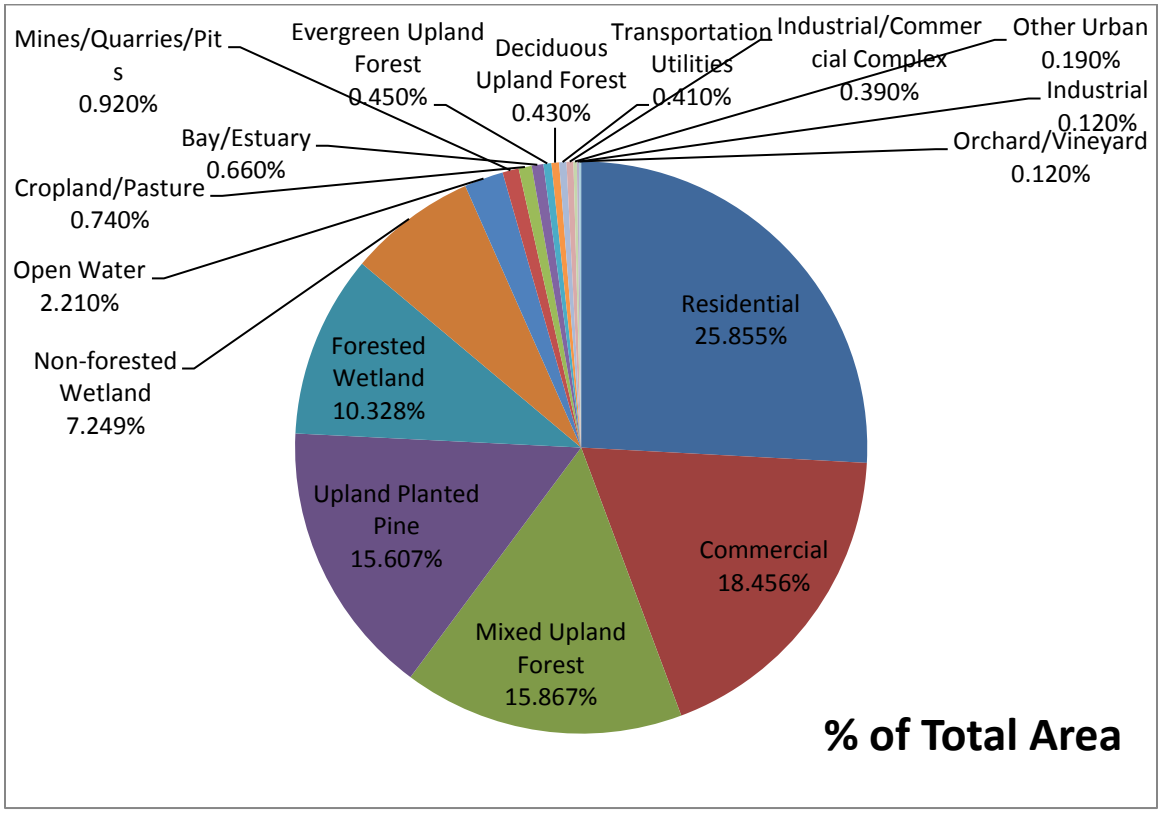


Figure 65. Goose Creek watershed water cover

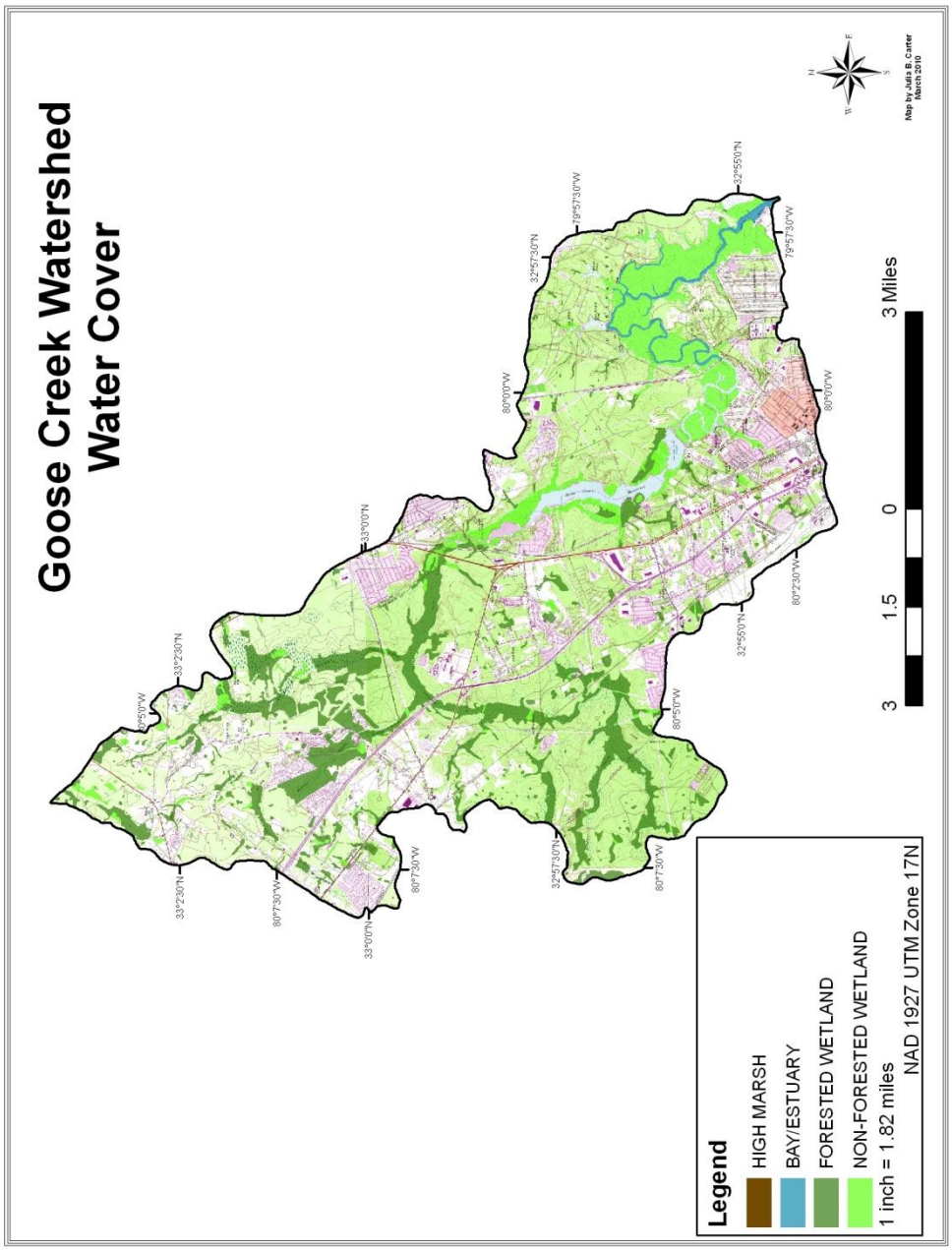


Figure 66. Goose Creek watershed forest cover

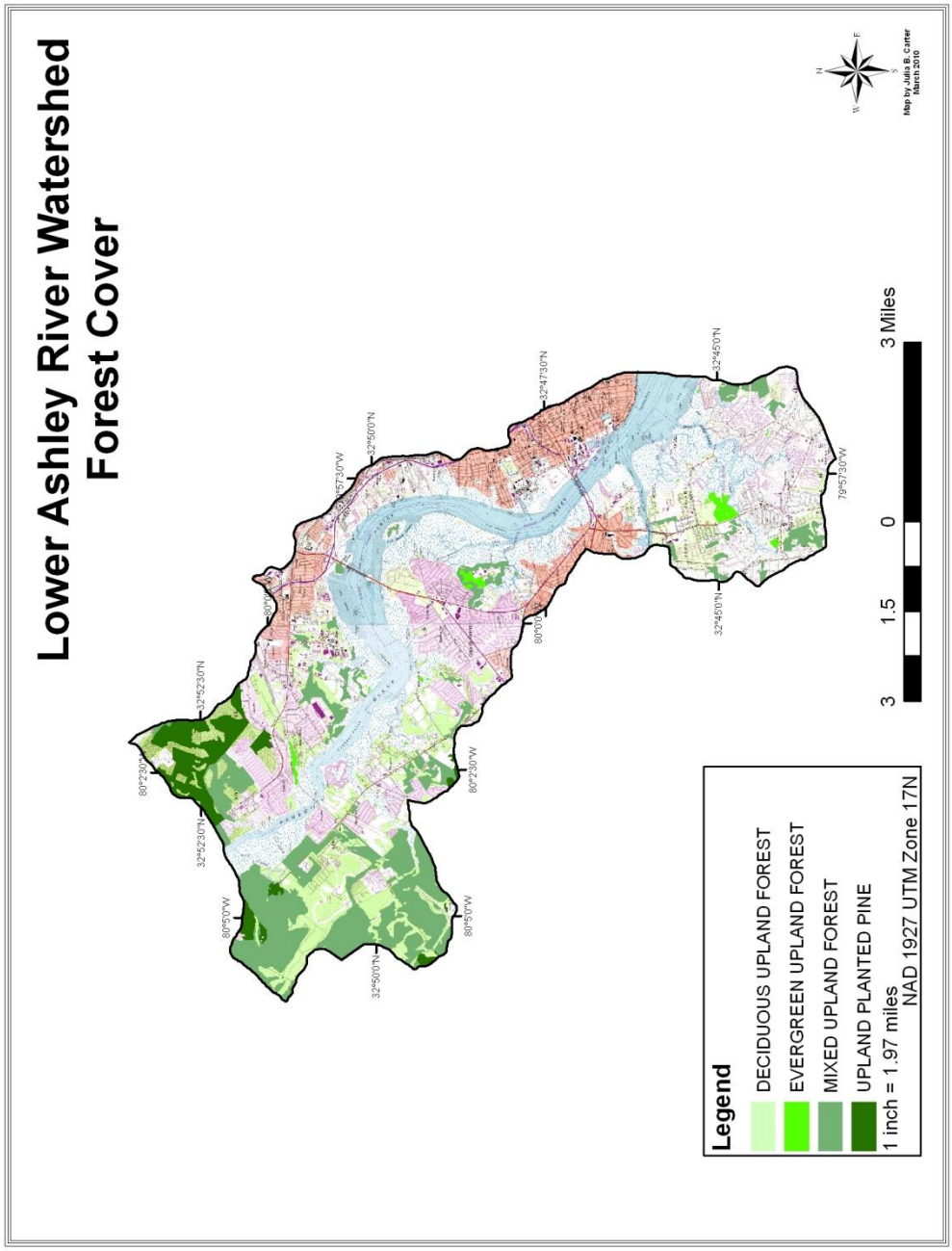


Figure 67. Goose Creek watershed agricultural land

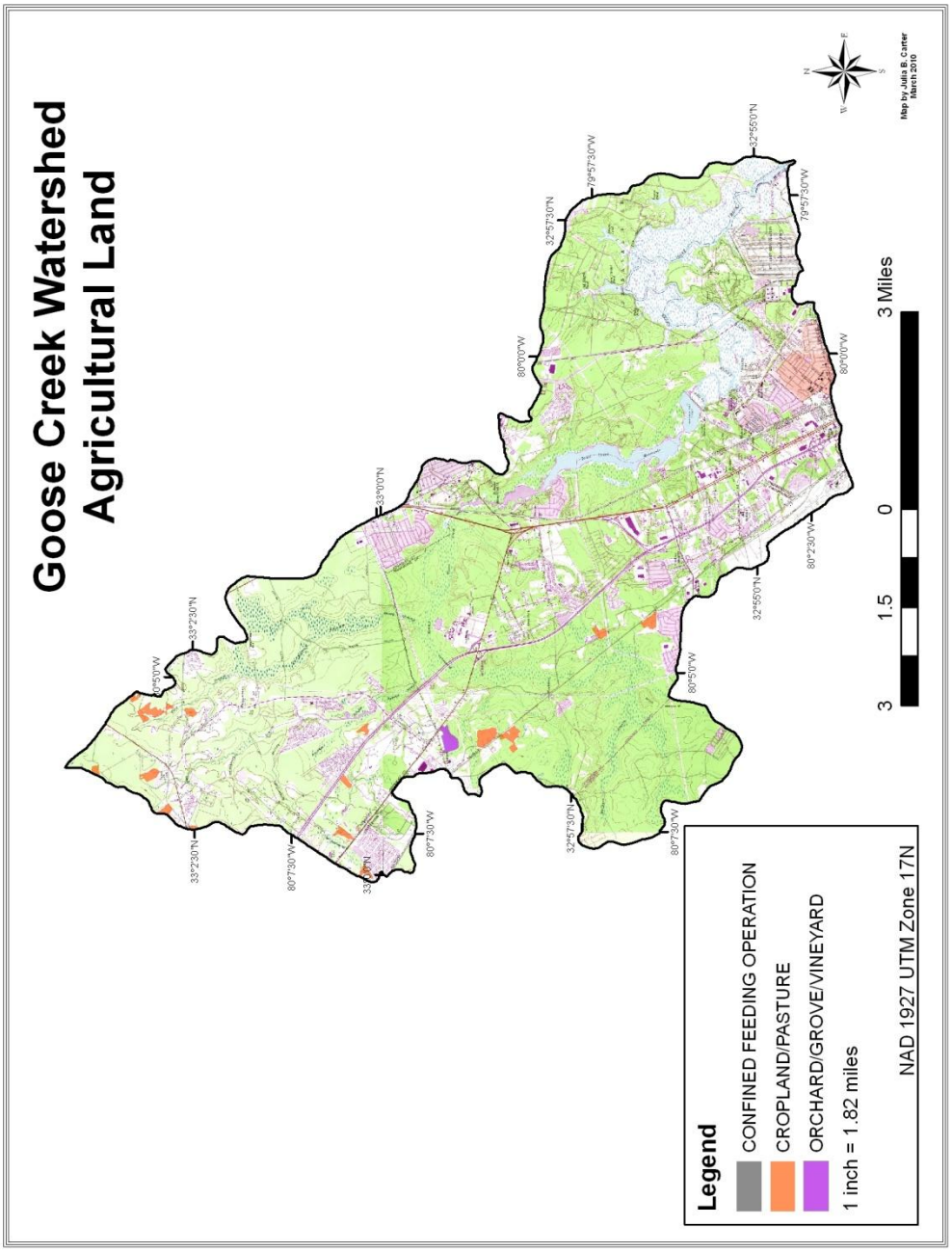


Figure 68. Goose Creek watershed developed land

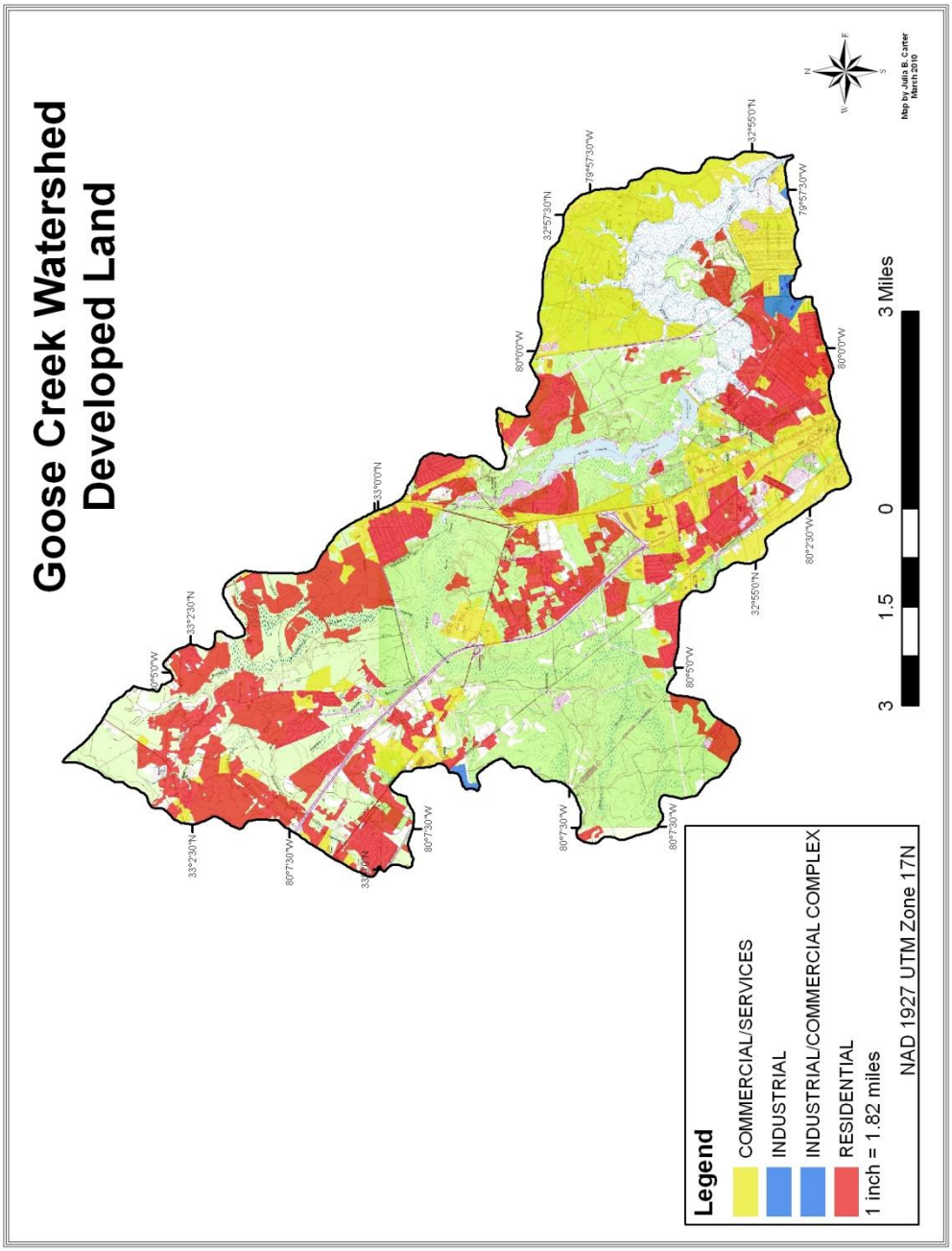
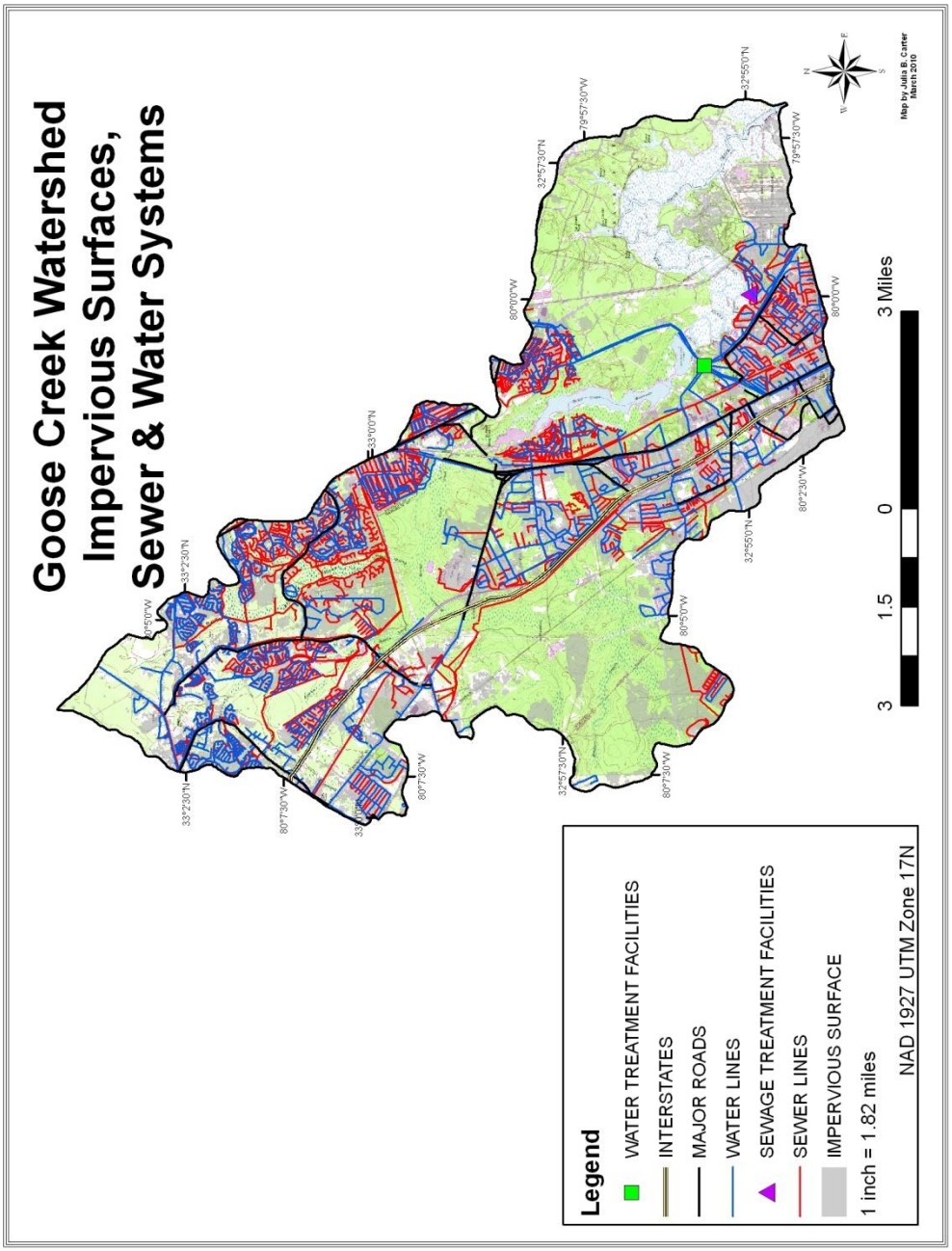


Figure 69. Goose Creek watershed impervious surfaces, and sewer and water systems



4.3.10 Foster Creek Watershed – HUC 030502010703

The Foster Creek watershed falls in Berkeley County and the total area is 9,365 acres. This watershed is a third of the size of and is directly east of the Goose Creek watershed. Foster Creek, which branches off of the Black River, runs through a portion of this watershed. Half of the watershed is the U.S. Naval Weapons Station and half is adjacent to the town of Goose Creek. Figures 70-74, Table15 and Chart 15 characterize this watershed. Non-forested wetland (8.04%) runs along Foster Creek where it merges into forested wetland (13.91%) that follows the outline of Brick Bound Swamp and branches out into the town of Goose Creek (Figure 70). All four forest types are represented in the western half of the watershed and account for 15.45% (Figure 71). There are three cropland/pasture sites (0.63%) on the western-most side of the watershed (Figure 72). The entire eastern half of the watershed is commercial land use, whereas the western half of the watershed is a mix of residential and commercial areas; commercial accounts for 44.15% of the watershed, while residential accounts for 15.48% (73). Impervious surface cover is scattered throughout the watershed but is predominantly on the western half of the watershed, along with sewer and water lines (Figure 74). There is no protected land and this watershed has a single impairment for dissolved oxygen.

Table 15. Foster Creek watershed
HUC 030502010703 – Total Acres: 9,365 acres

Land-use	Area (acres)	% of Total Area
Commercial	4135	44.15
Residential	1450	15.48
Forested Wetland	1303	13.91
Upland Planted Pine	900	9.61
Non-forested Wetland	753	8.04
Mixed Upland Forest	510	5.45
Open Water	163	1.74
Cropland/Pasture	59	0.63
Transportation Utilities	43	0.46
Deciduous Upland Forest	34	0.36
Other Urban	12	0.13
Evergreen Upland Forest	3	0.03

Chart 15. Foster Creek watershed

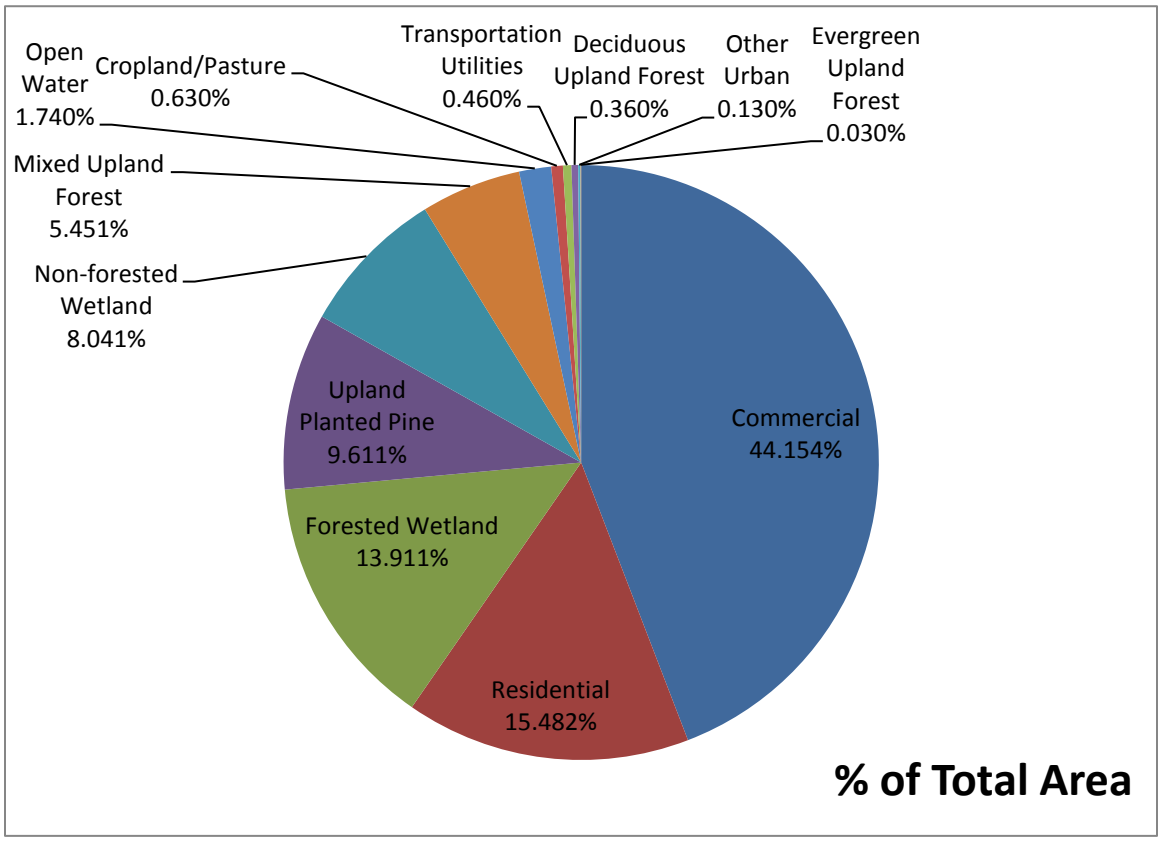


Figure 70. Foster Creek watershed water cover

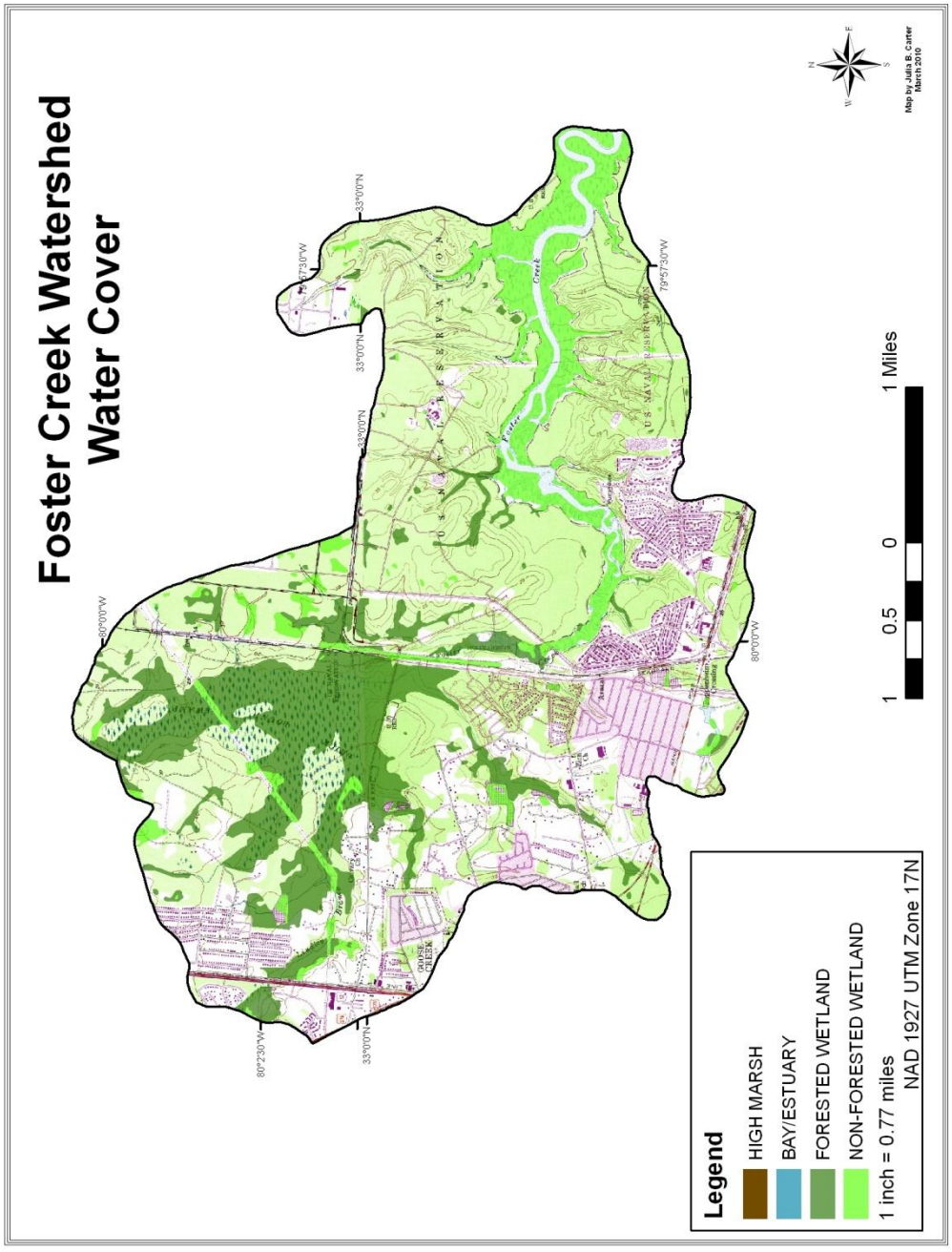


Figure 71. Foster Creek watershed forest cover

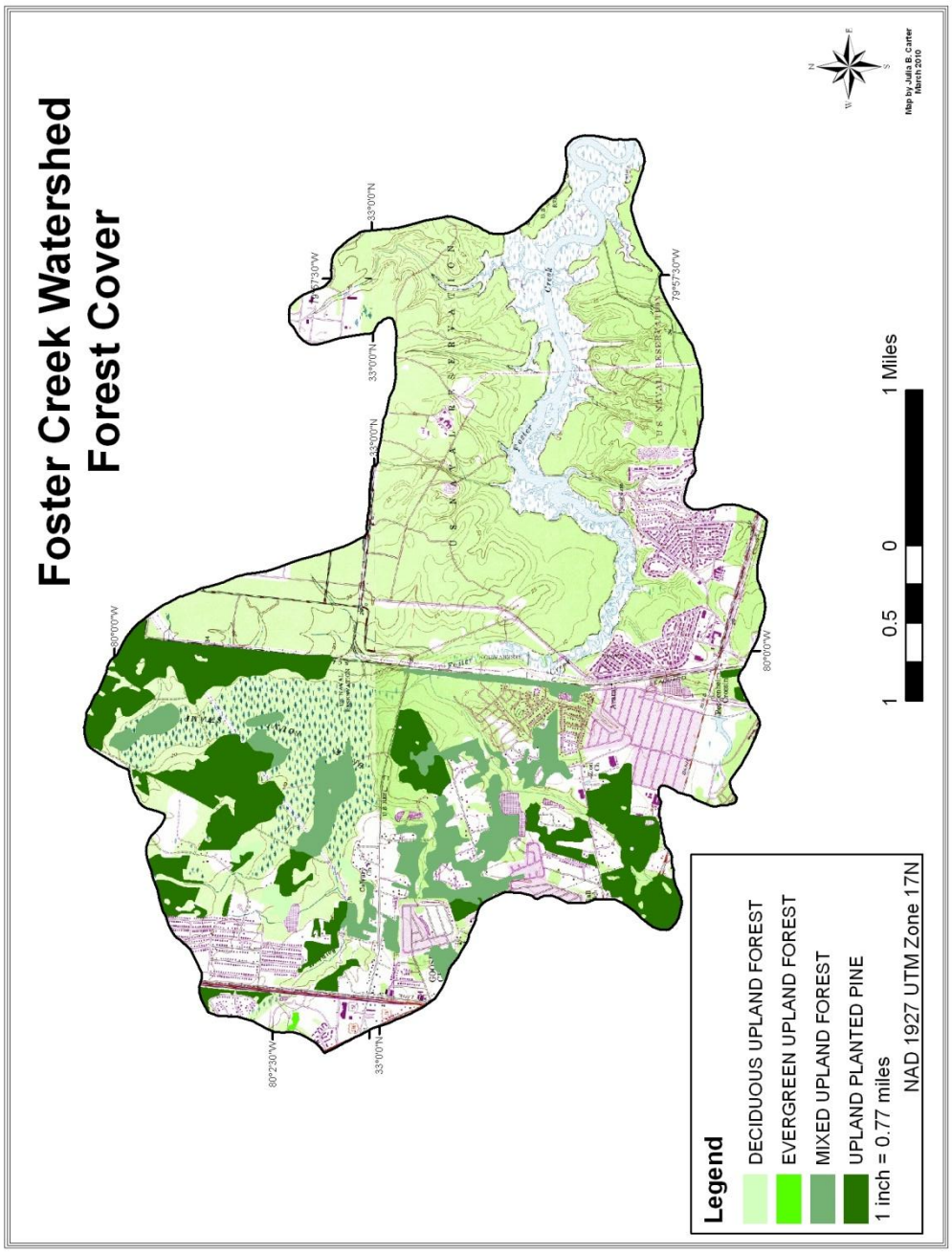


Figure 72. Foster Creek watershed agricultural land

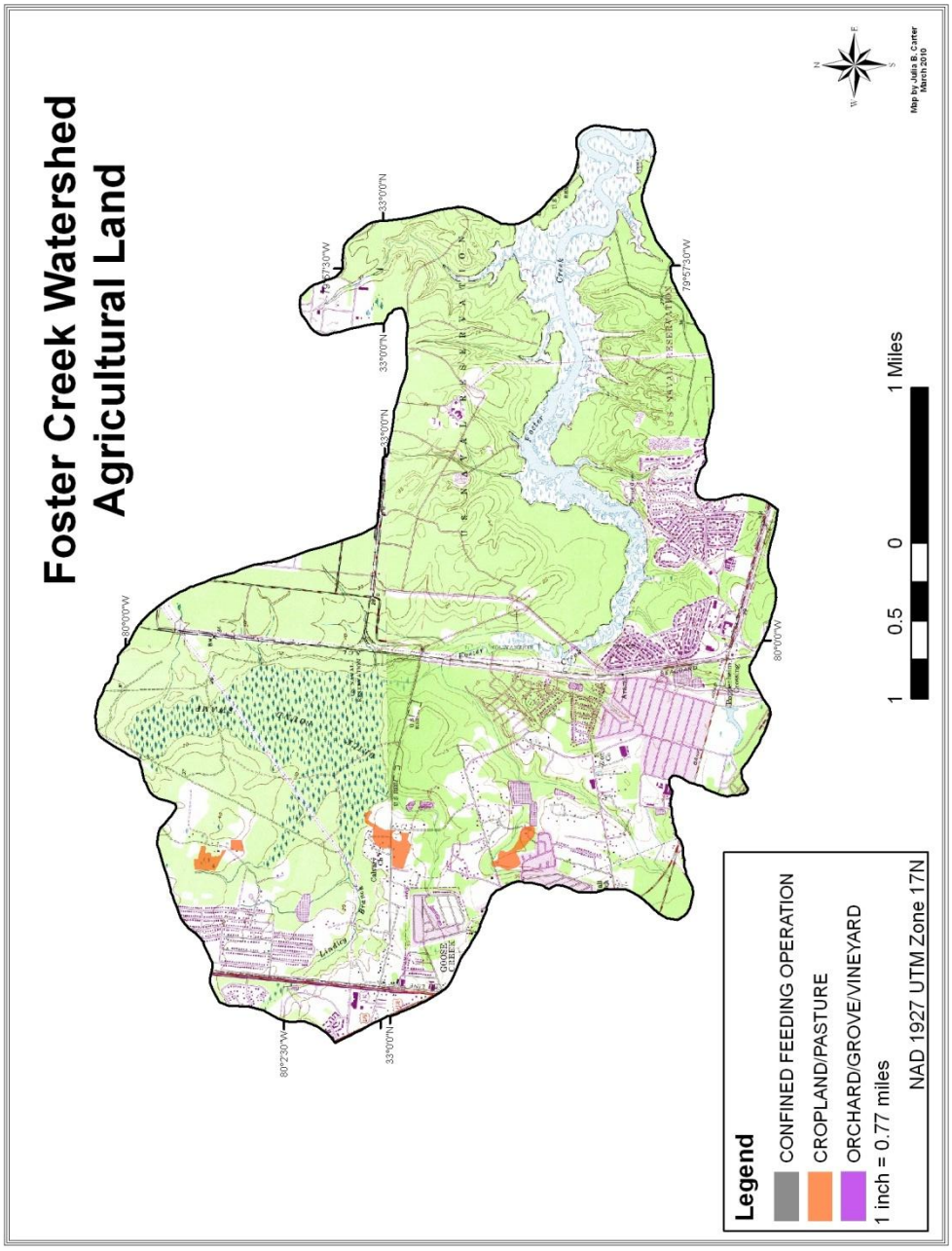


Figure 73. Foster Creek watershed developed land

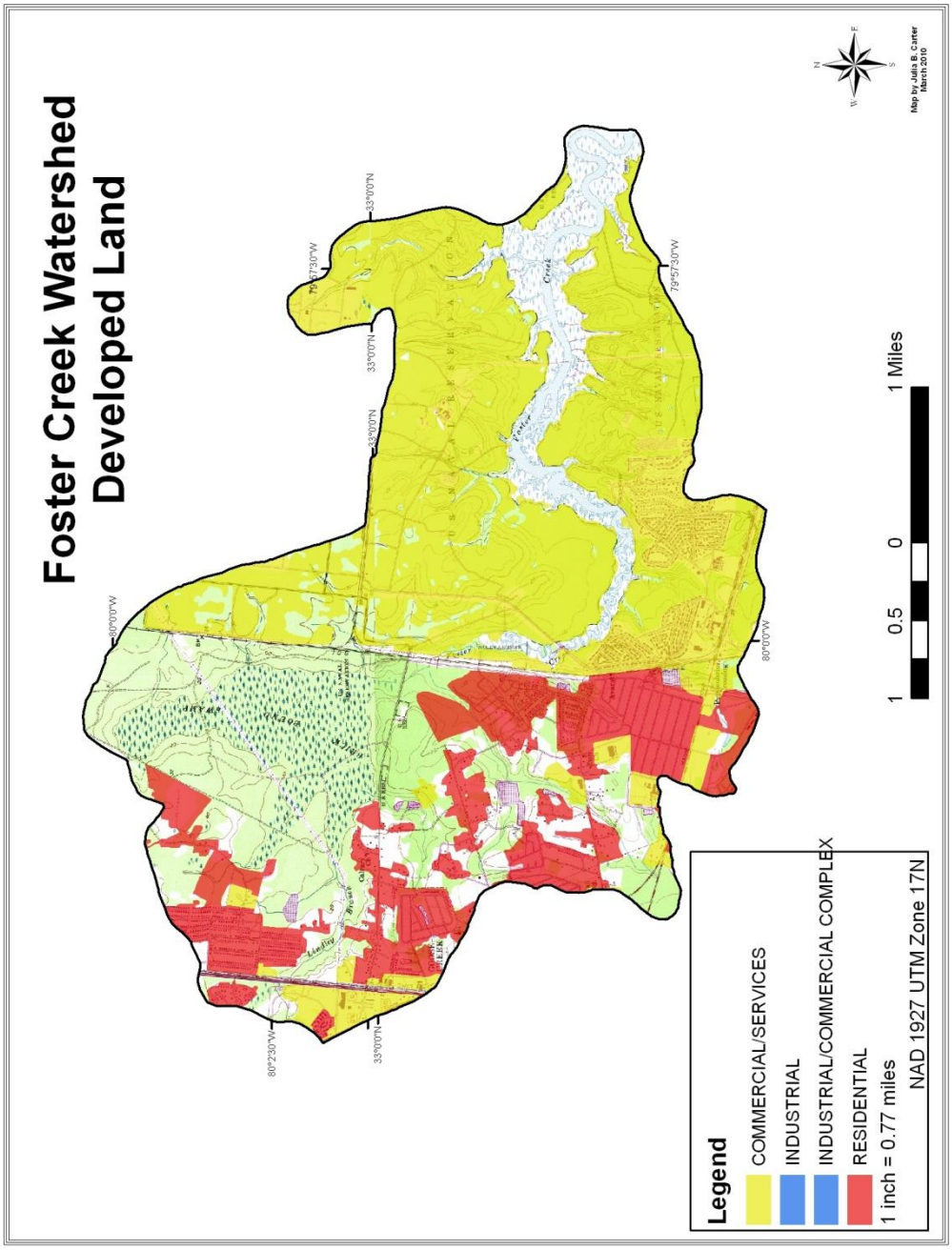
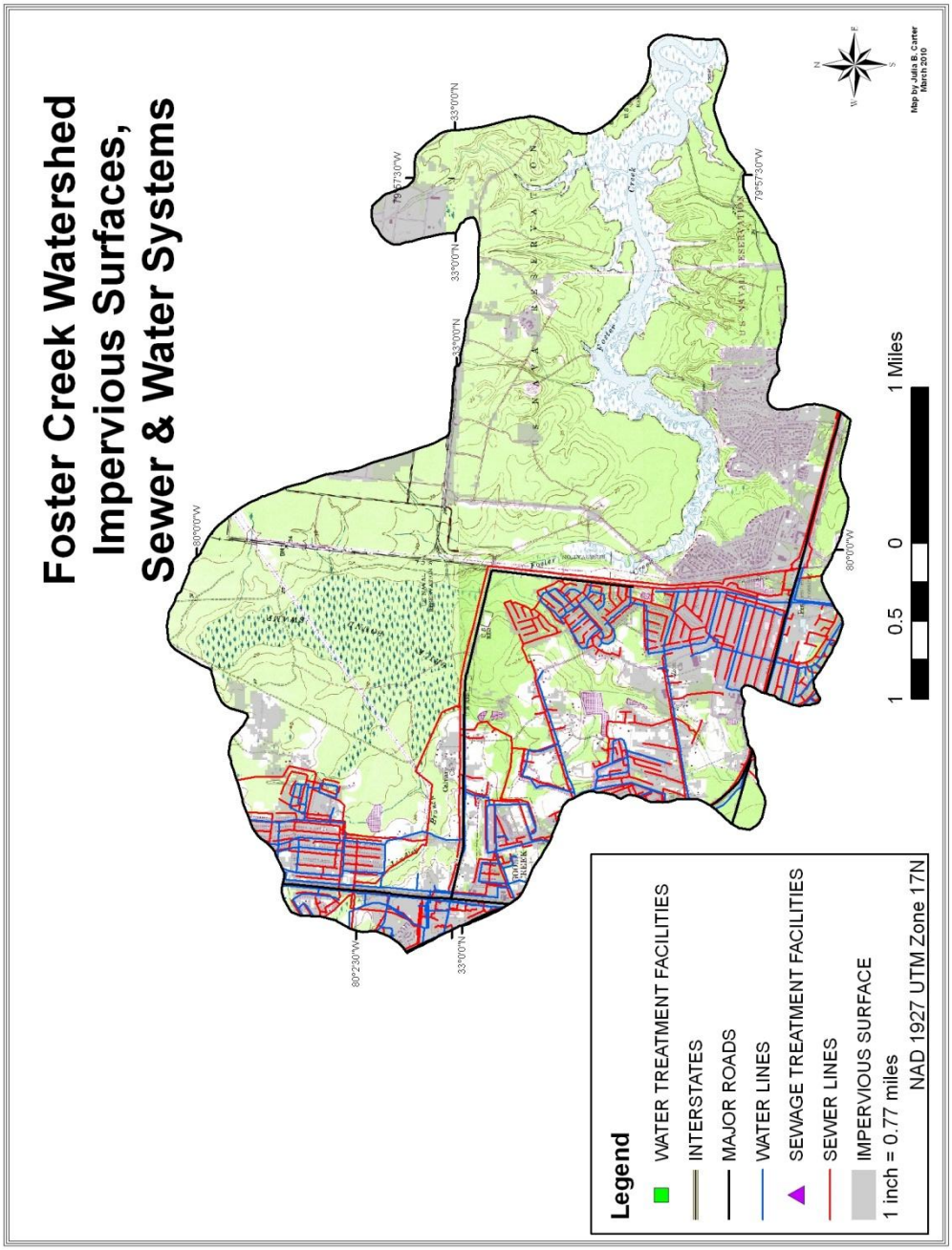


Figure 74. Foster Creek watershed impervious surfaces, and sewer and water systems



4.3.11 Black River Watershed – HUC 030502010704

The Black River watershed has a total area of 39,794 acres and wraps partially around the Foster Creek Watershed. The Black River runs along the eastern side of the watershed, while the rest of the watershed is composed of swampland and development. Table 16, Chart 16 and Figures 75-80 characterize this watershed. Non-forested wetland follows the Black River through the watershed and accounts for 9.77% of the watershed, and where the river feeds into a series of swamps, the non-forested wetlands merge into a series of branching forested wetlands which account for 19.52% of the watershed (Figure 75). All four types of forest cover are within this watershed: upland planted pine (37.88%), mixed upland forest (1.88%), deciduous upland forest (0.22%) and evergreen upland forest (0.05%) (Figure 76). Small pockets of cropland/pasture (1.93%) are scattered throughout the watershed, while residential (11.53%) areas make up the western side of the watershed and commercial (10.98%) areas make up the eastern side (Figures 77 & 78). The impervious surface cover follows the same pattern as the residential and commercial areas (Figure 79). There are very few sewer lines and one sewage treatment facility (Figure 79); waterlines are predominant on the western side of the watershed, but there are no water treatment facilities (Figure 79). There is a large section of privately protected land in the middle third of the wetland (Figure 80). This wetland is impaired for dissolved oxygen and mercury.

Table 16. Black River watershed
HUC 030502010704 – Total Acres: 39,794 acres

Land-use	Area (acres)	% of Total Area
Upland Planted Pine	15074	37.88
Forested Wetland	7769	19.52
Residential	4588	11.53
Commercial	4330	10.88
Non-forested Wetland	3887	9.77
Open Water	1213	3.05
Cropland/Pasture	769	1.93
Mixed Upland Forest	749	1.88
Transportation Utilities	672	1.69
Industrial	348	0.87
Mines/Quarries/Pits	137	0.34
Other Urban	112	0.28
Deciduous Upland Forest	88	0.22
Industrial/Commercial Complex	38	0.1
Evergreen Upland Forest	20	0.05

Chart 16. Black River watershed

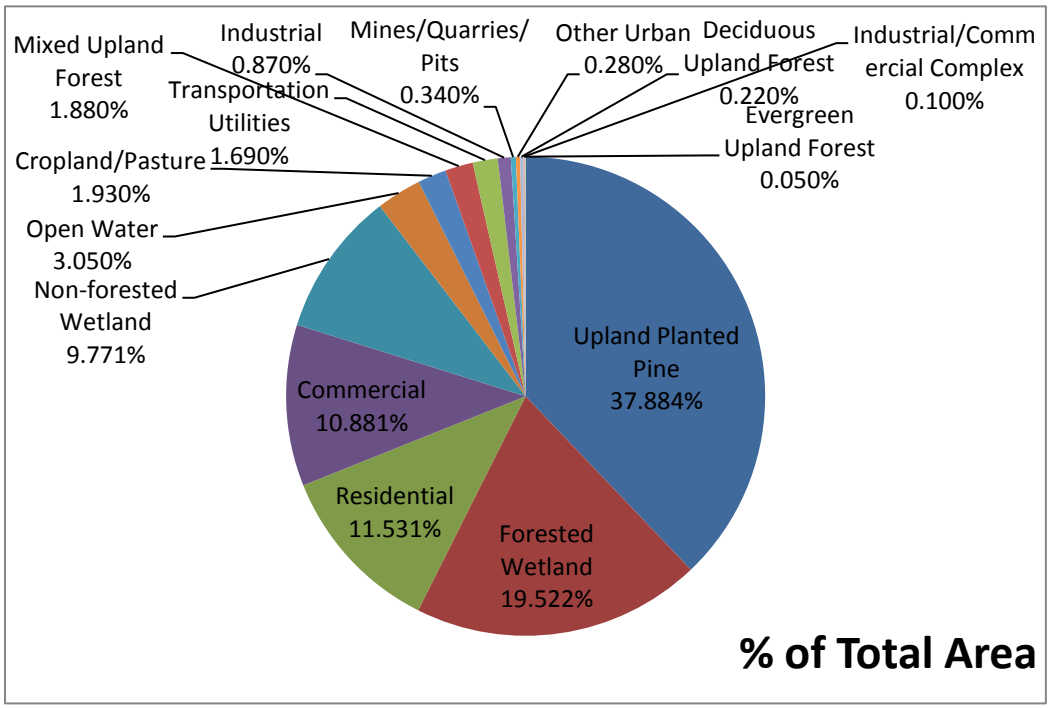


Figure 75. Black River watershed water cover

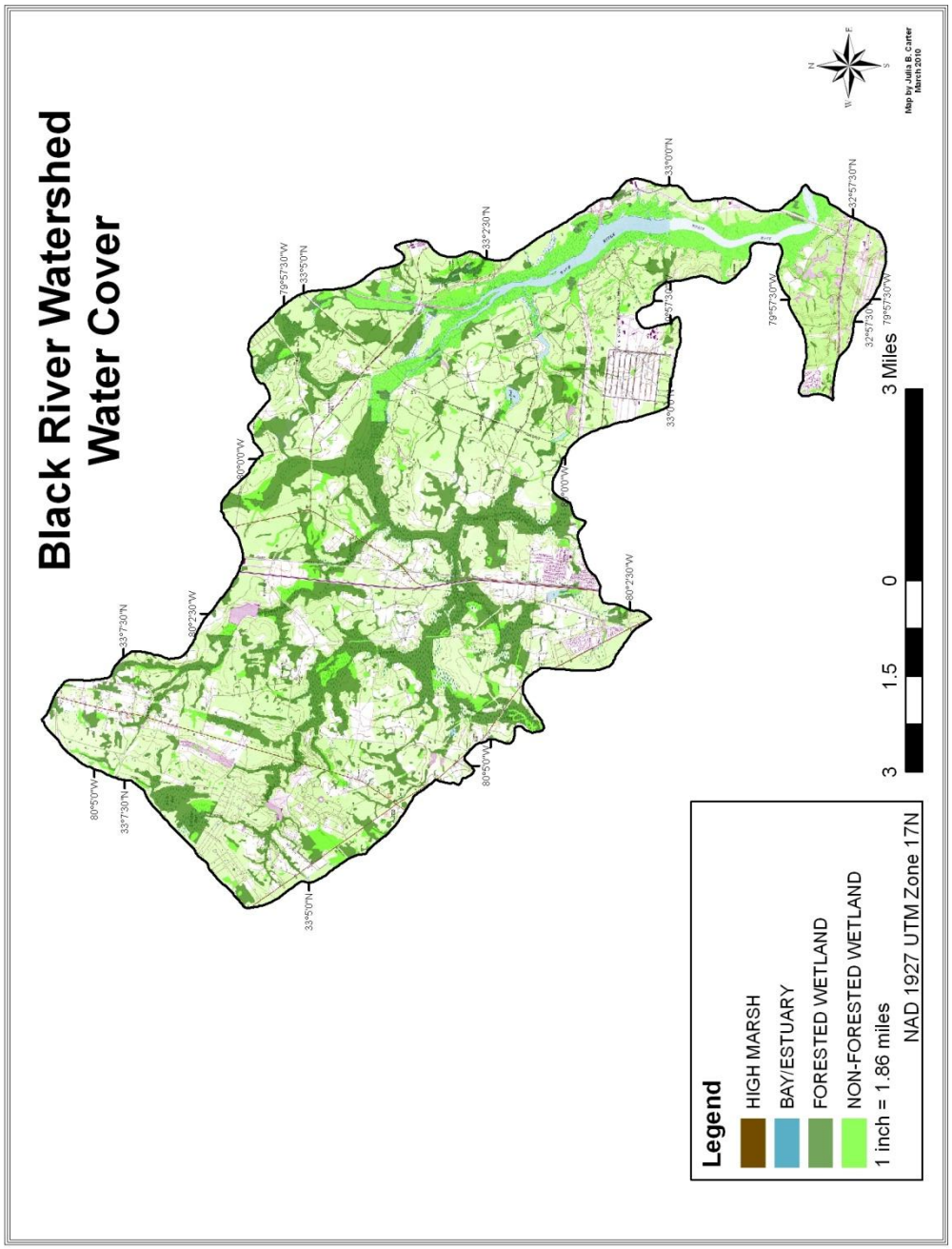


Figure 76. Black River watershed forest cover

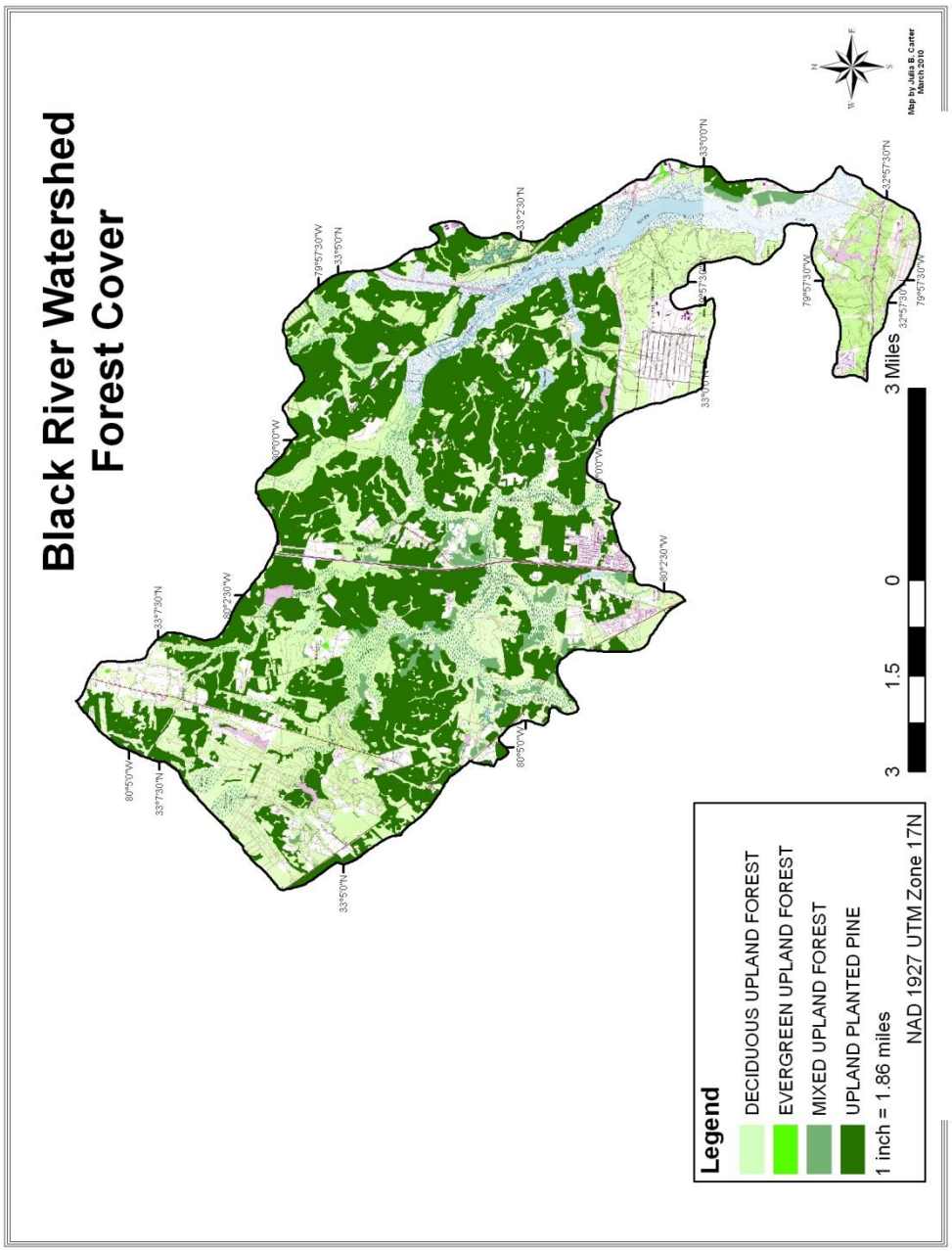


Figure 77. Black River watershed agricultural land

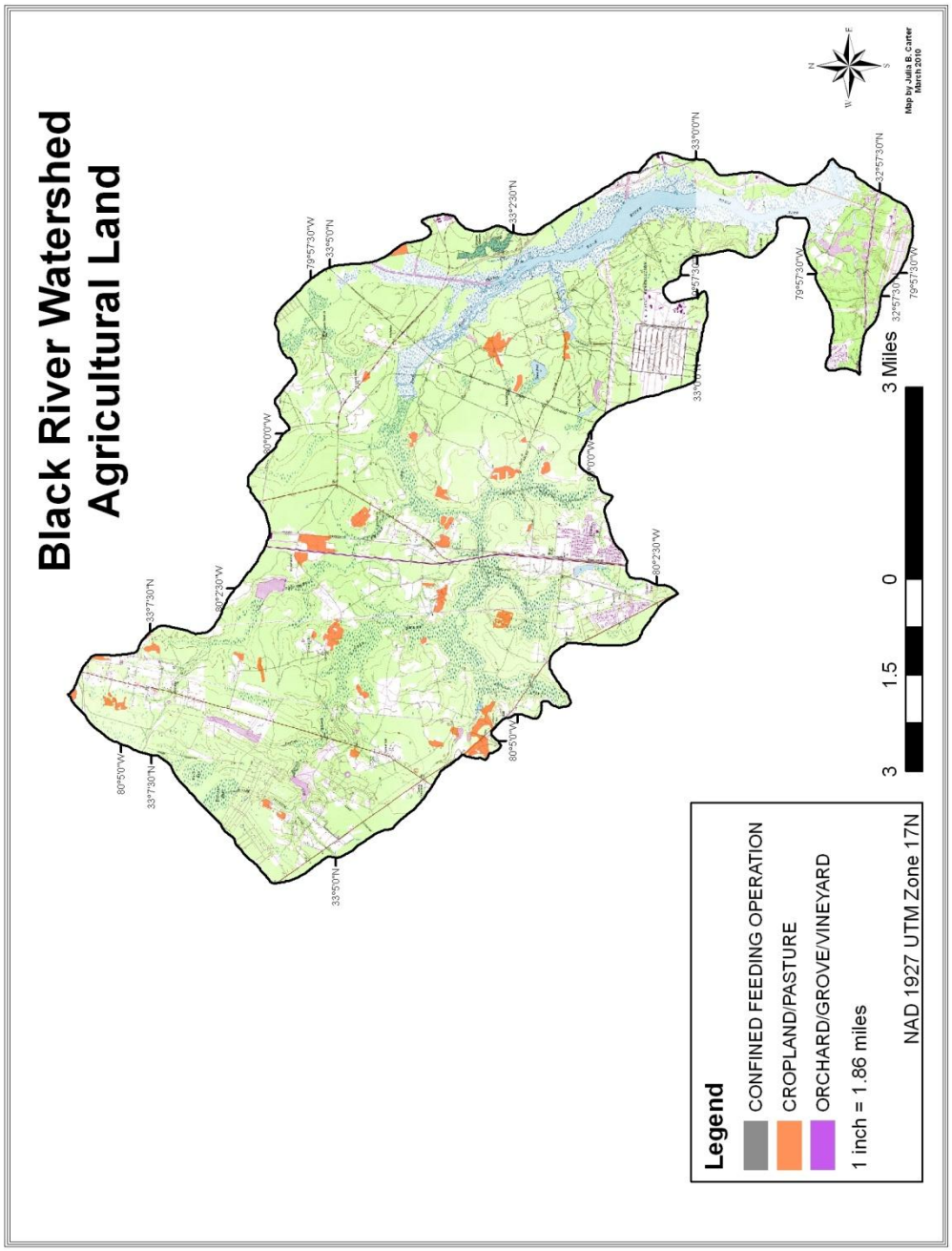


Figure 78. Black River watershed developed land

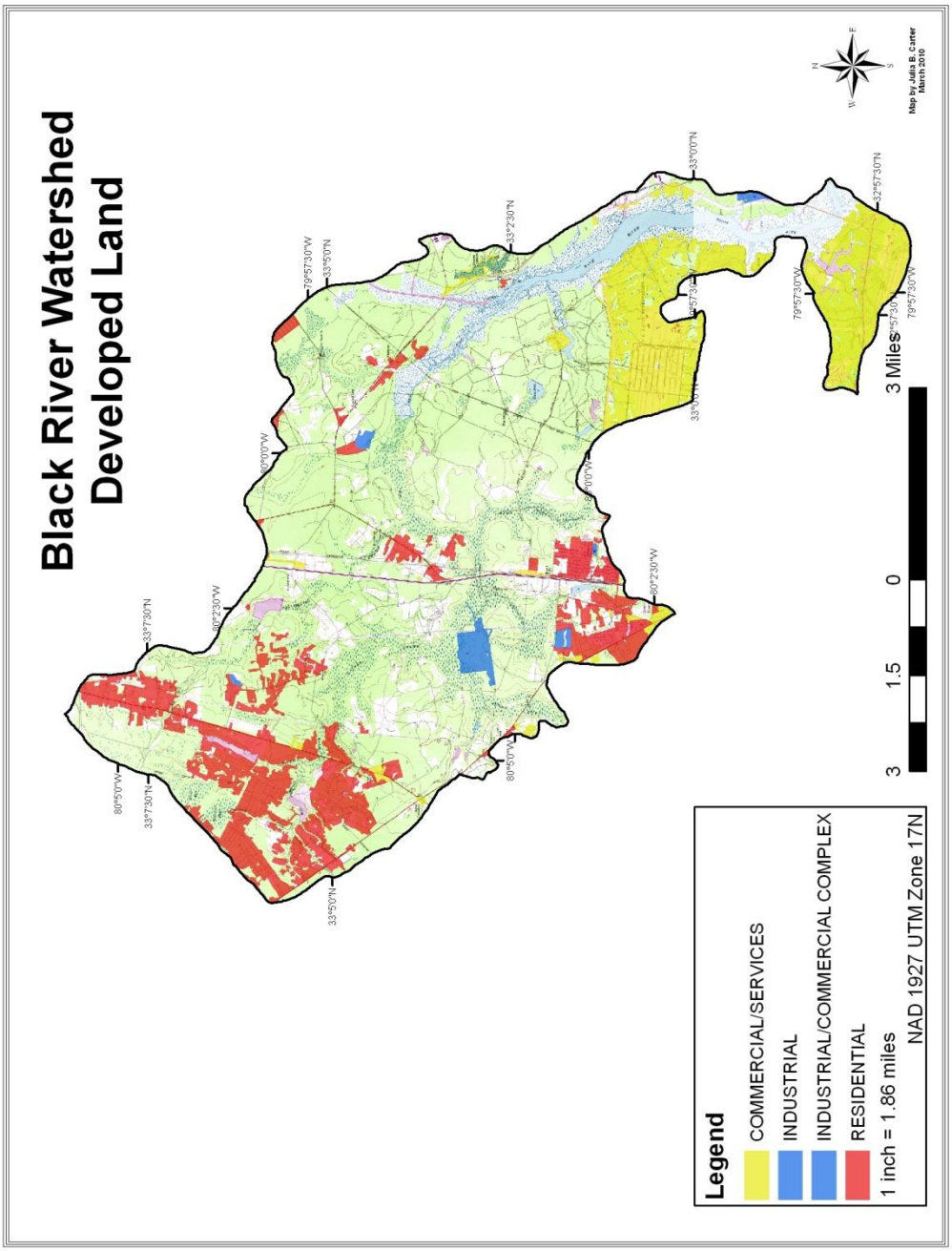


Figure 79. Black River watershed impervious surfaces, and sewer and water systems

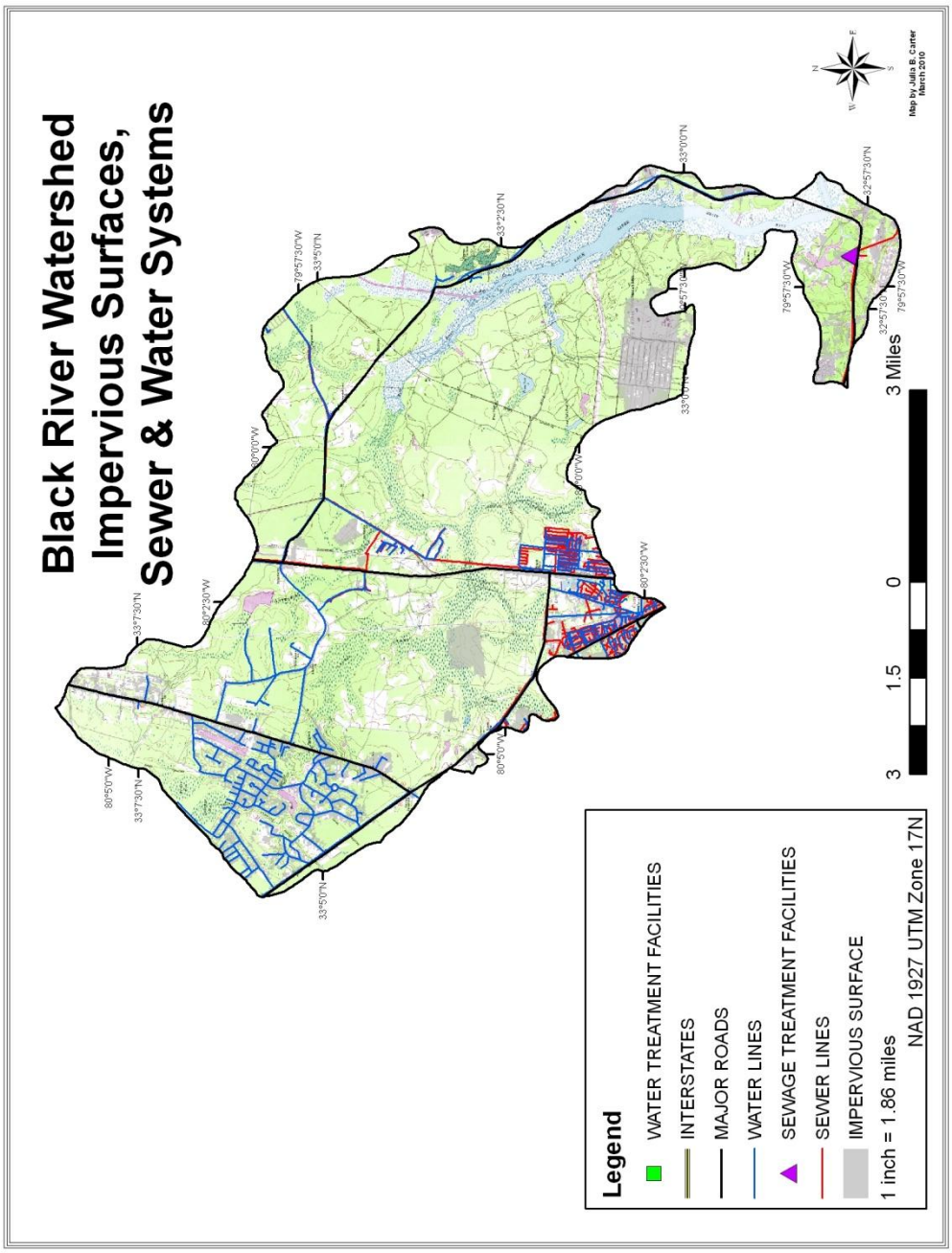
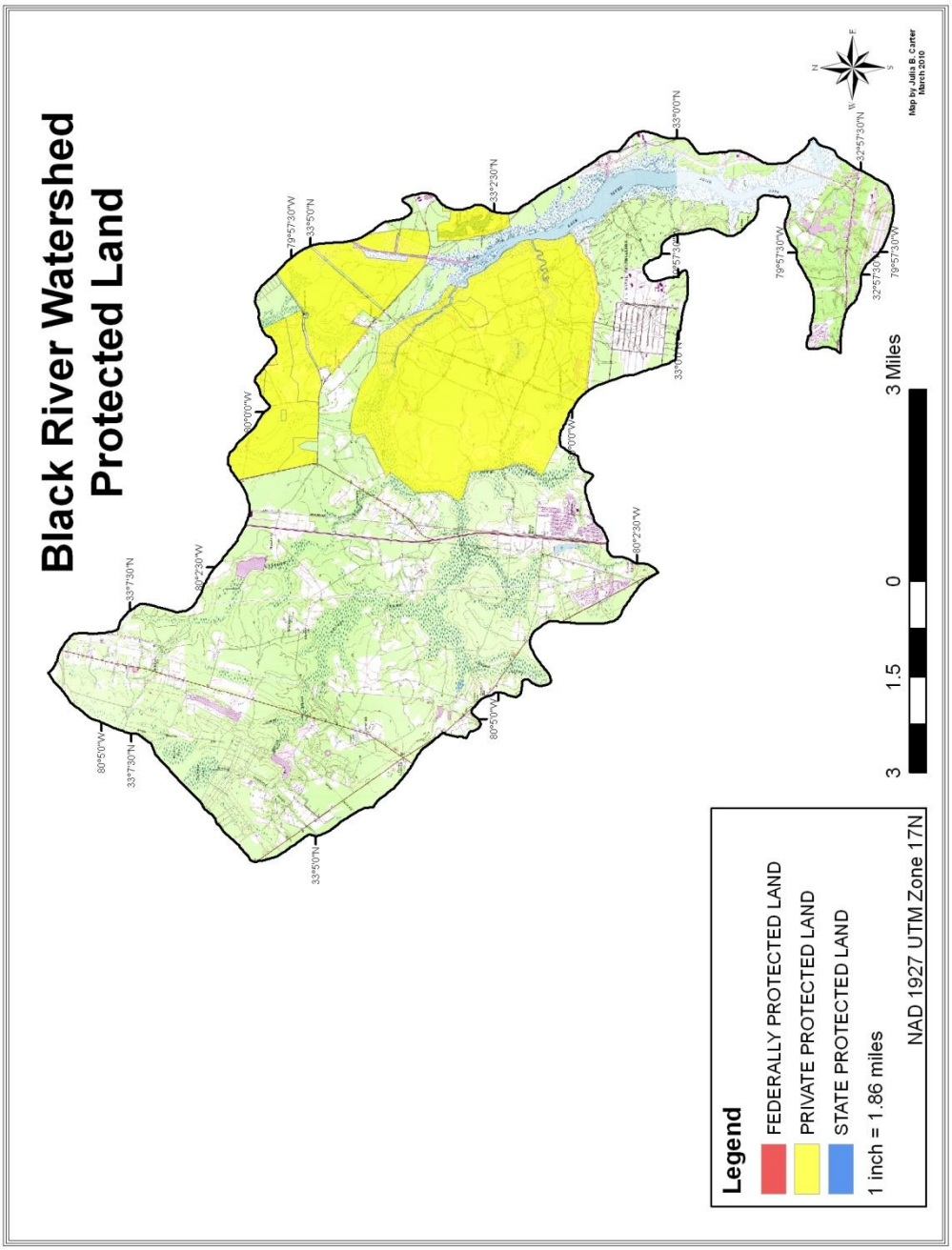


Figure 80. Black River watershed protected land



4.3.12 Sawmill Branch Watershed – HUC 030502010601

The Sawmill Branch watershed falls in all three counties, however the majority is split between Berkeley and Dorchester counties, while the total area in the watershed totals 13,899 acres. The town of Summerville falls directly in the middle of this watershed. Table 17, Chart 17, and Figures 81-85 characterize this watershed. Forested wetlands are scattered in the southern tip of the watershed and both forested and non-forested wetlands are intermixed in the northern tip of the watershed; forested wetlands account for 14.36% of the watershed while non-forested wetlands account for 1.76% (Figure 81). Forest cover totals 25.13% of the watershed and includes upland planted pine, mixed upland and evergreen upland forests (Figure 82). Cropland/pasture (2.42%) is scattered throughout the watershed (Figure 83). Residential areas make up 39.92% of the area within the watershed, while commercial makes up 9.24% (Figure 84). The impervious surfaces, sewer lines, and water lines follow the same layout as the commercial and residential (Figure 85). While water and sewer lines are on the same layout, there is one sewage treatment facility in the southwestern corner of the watershed and no water treatment facilities (Figure 85). There are no protected lands, and this watershed is impaired for both dissolved oxygen and ammonia nitrogen.

Table 17. Sawmill Branch watershed
HUC 030502010601 – Total Acres: 13,899 acres

Land-use	Area (acres)	% of Total Area
Residential	5548	39.92
Upland Planted Pine	2872	20.66
Forested Wetland	1996	14.36
Commercial	1284	9.24
Mixed Upland Forest	608	4.37
Cropland/Pasture	336	2.42
Non-forested Wetland	245	1.76
Mines/Quarries/Pits	210	1.51
Transportation Utilities	125	0.9
Other Urban	116	0.83
Open Water	45	0.32
Evergreen Upland Forest	14	0.1
Industrial	3	0.02

Chart 17. Sawmill Branch watershed

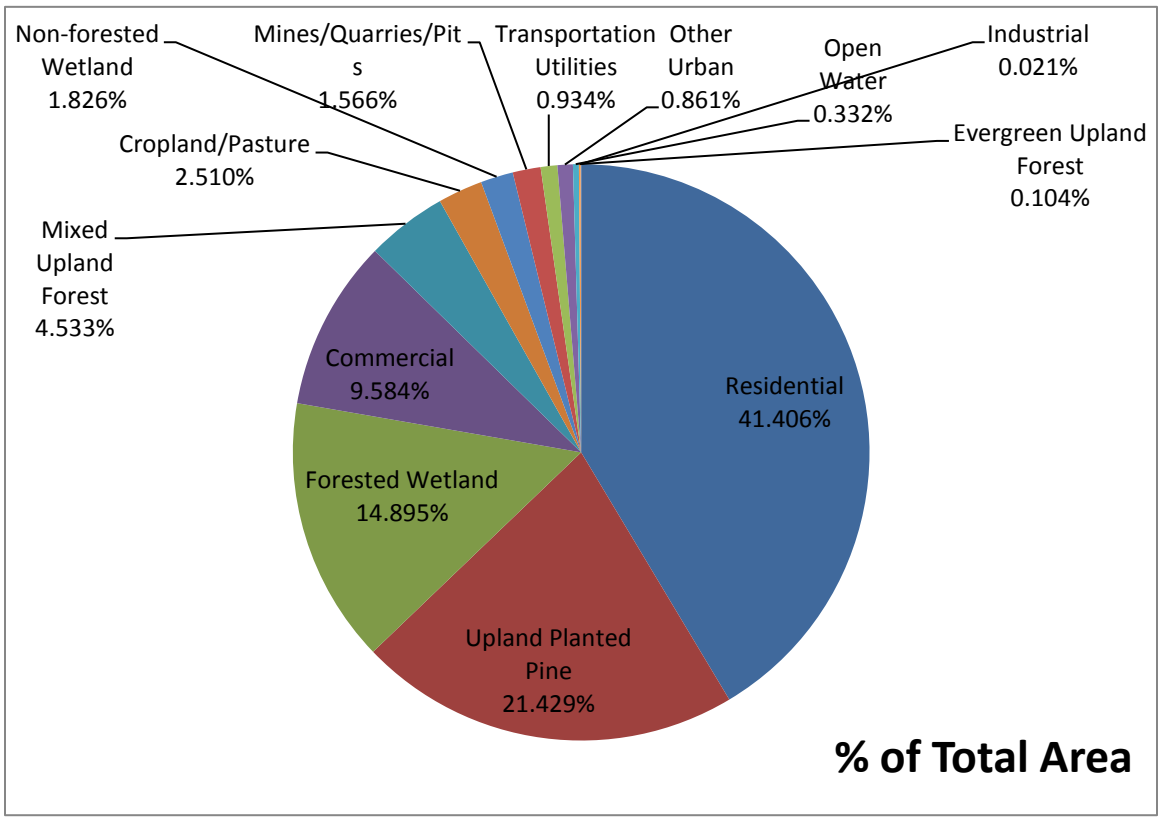


Figure 81. Sawmill Branch watershed water cover

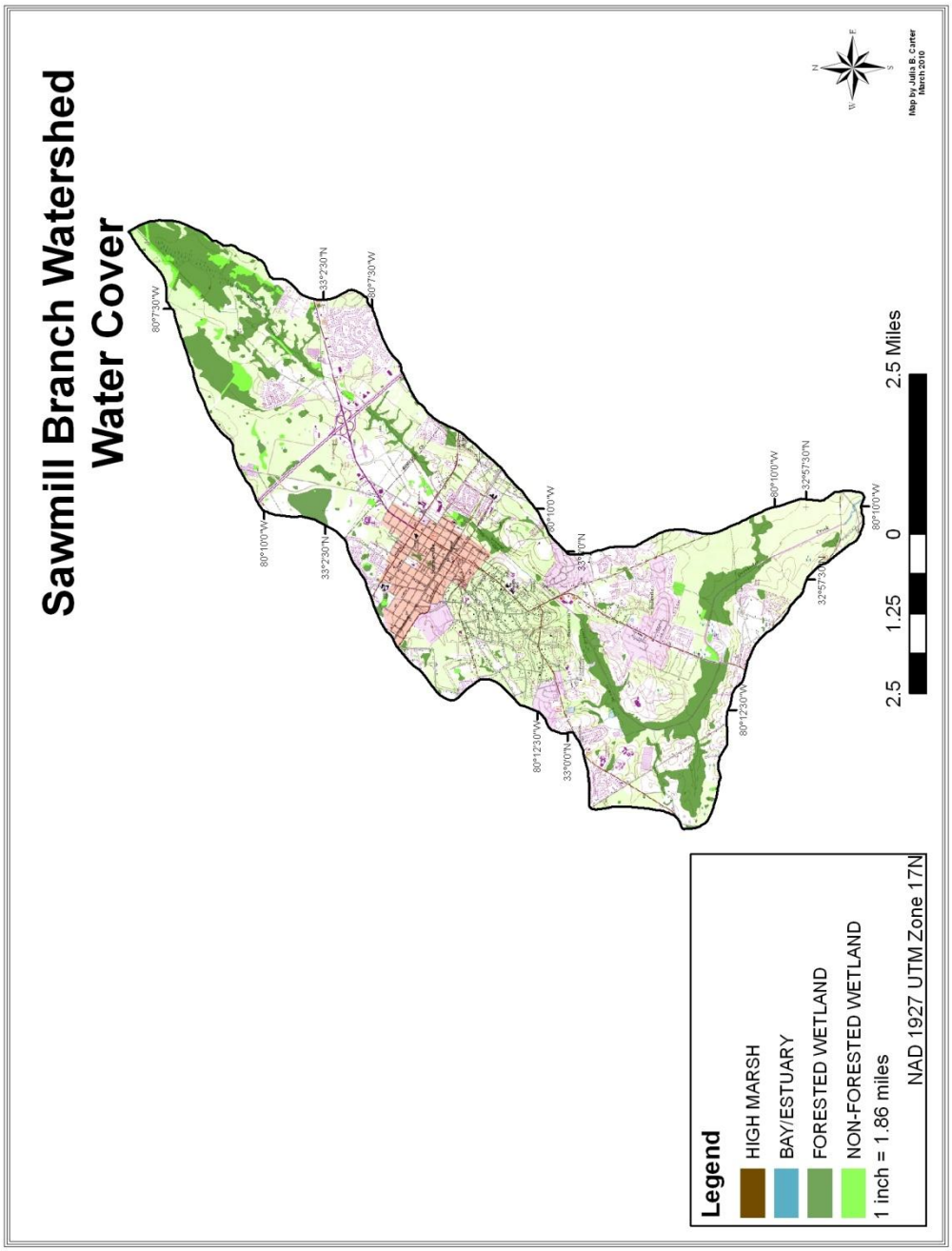


Figure 82. Sawmill Branch watershed forest cover

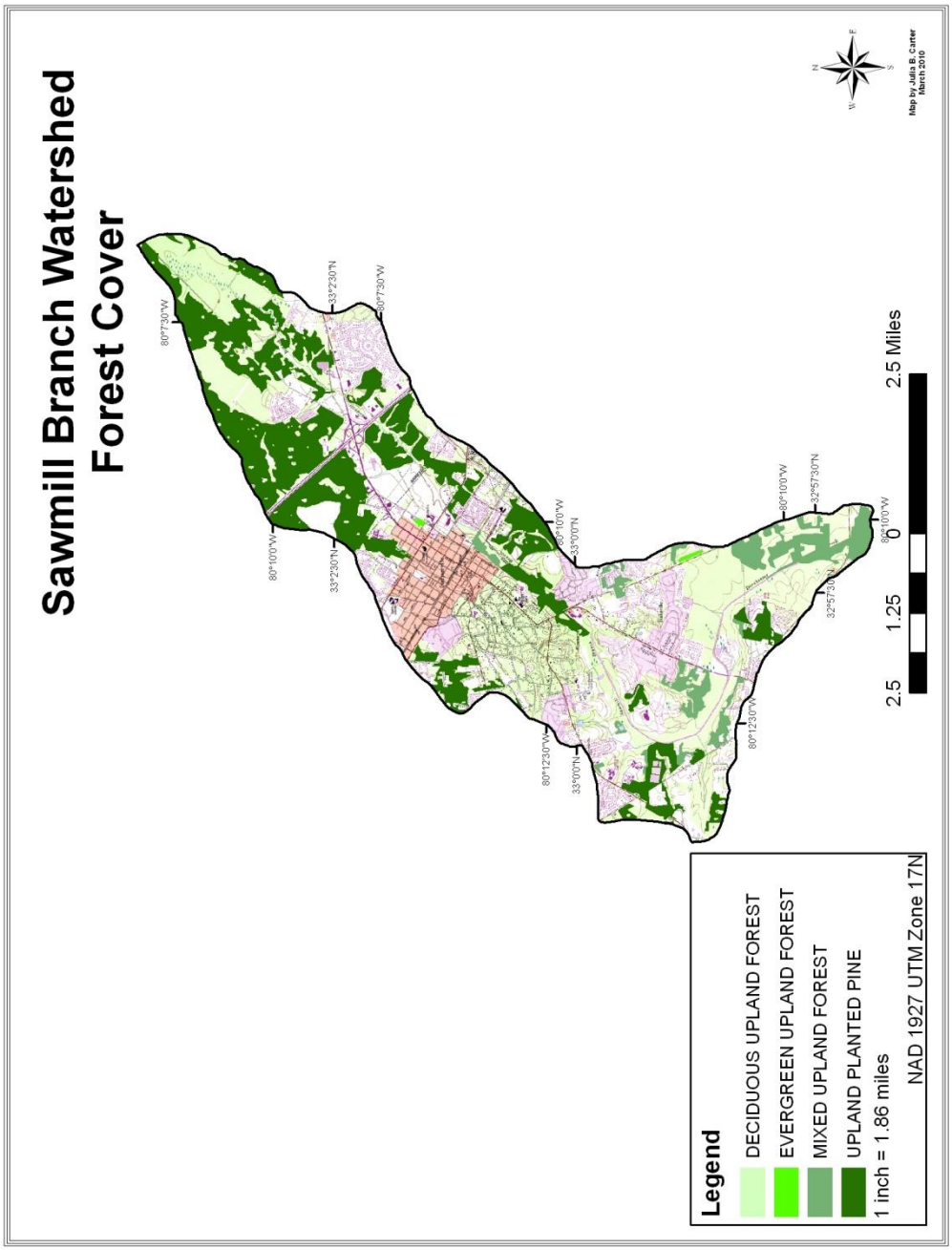


Figure 83. Sawmill Branch watershed agricultural land

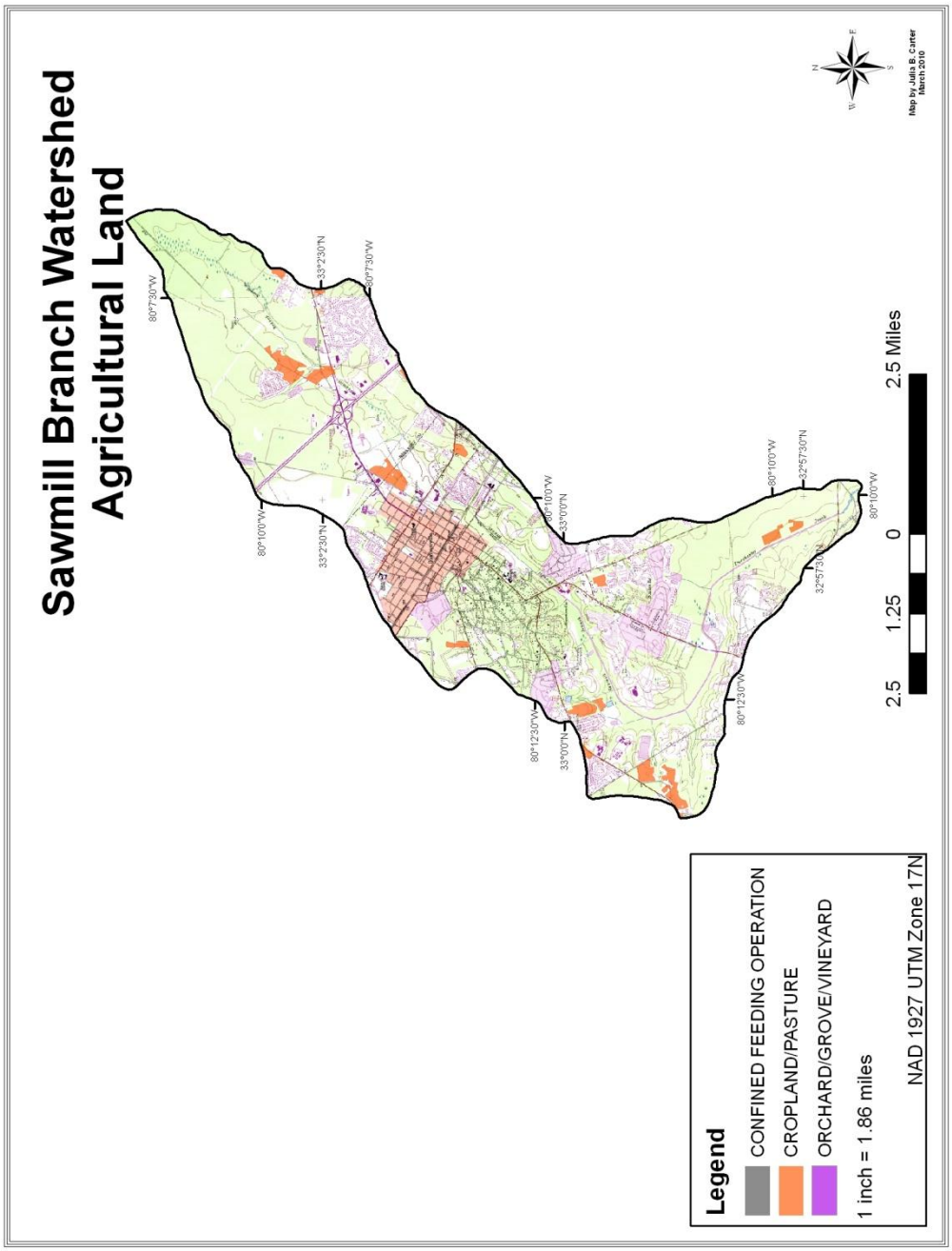


Figure 84. Sawmill Branch watershed developed land

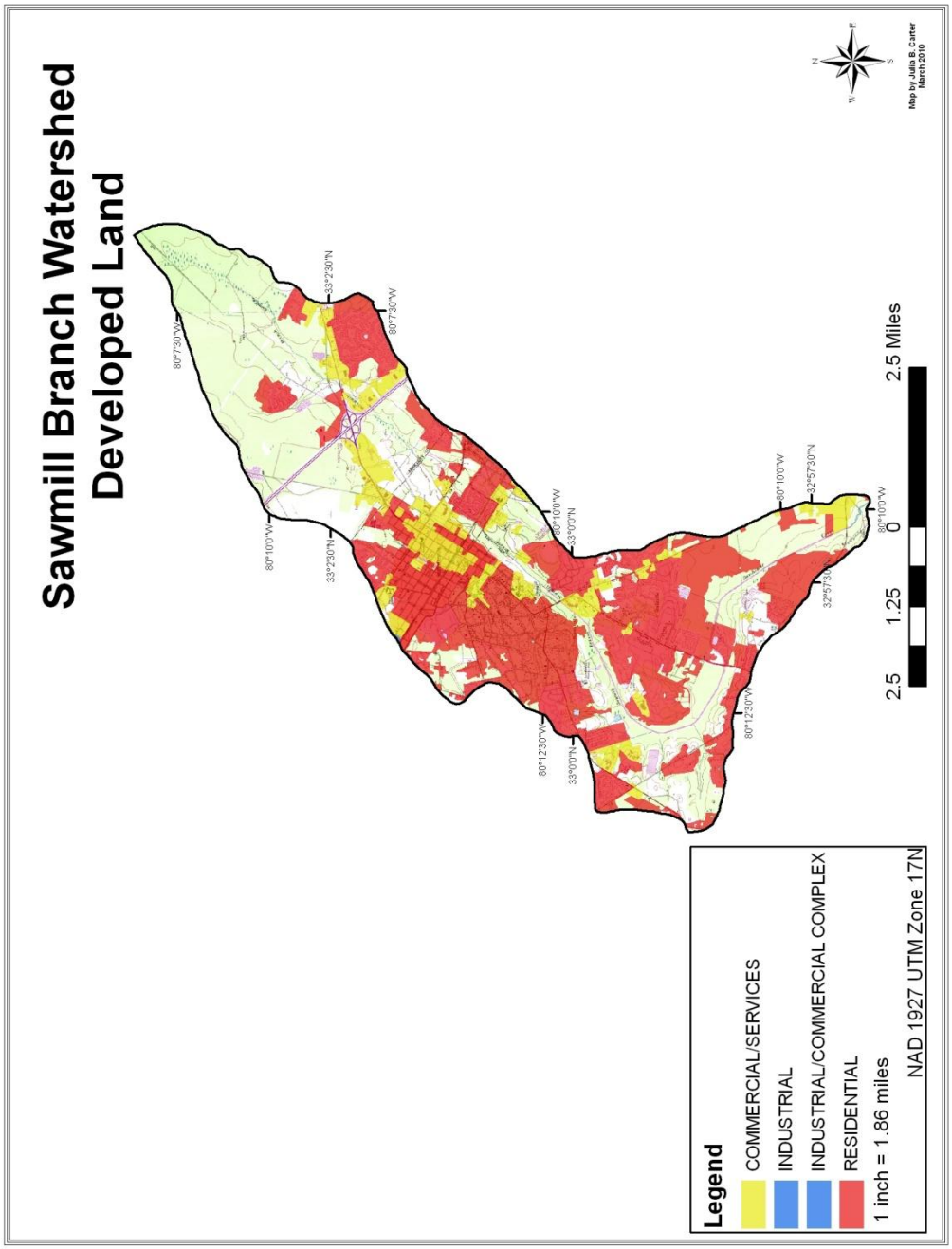
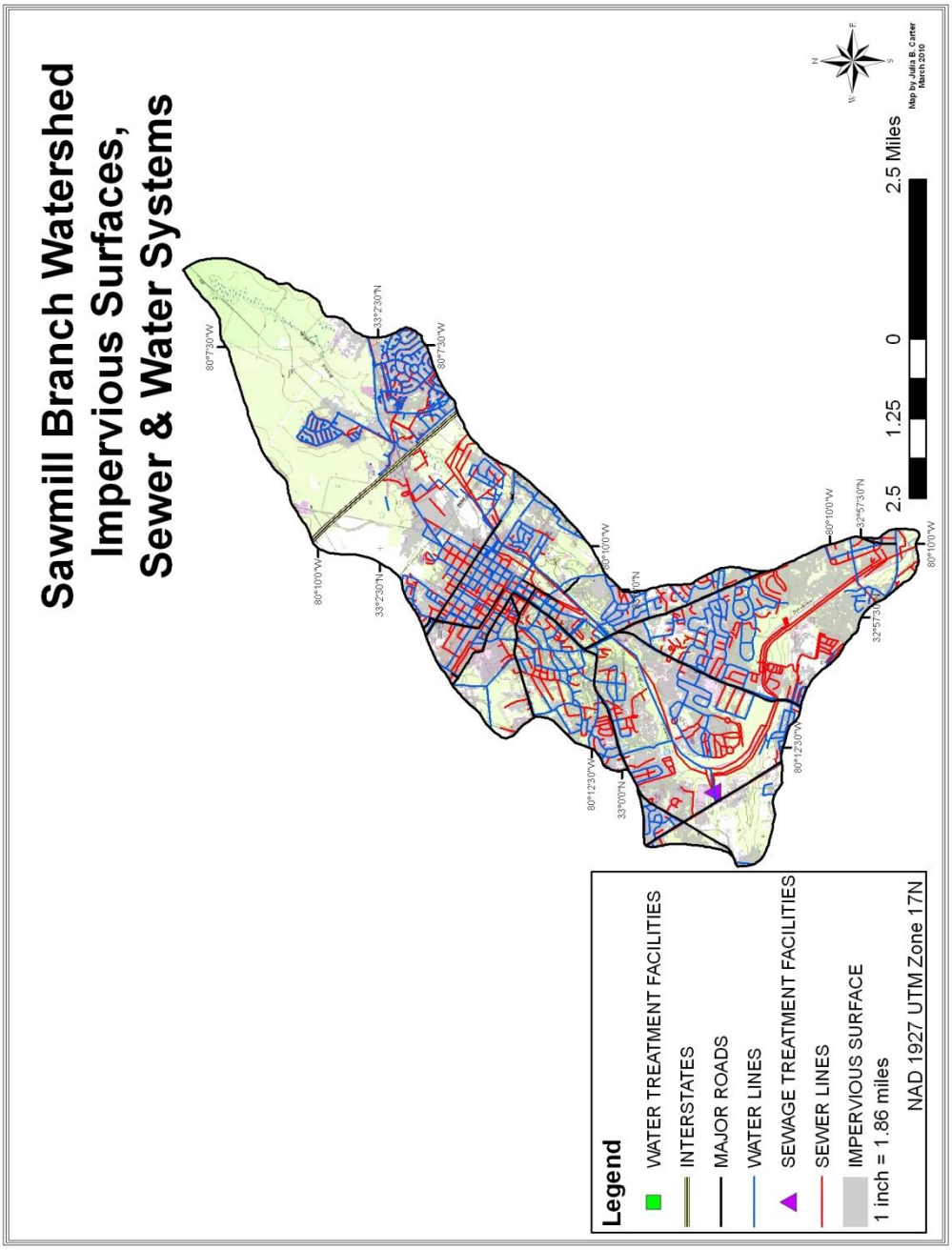


Figure 85. Sawmill Branch watershed impervious surfaces, and sewer and water systems



4.3.13 Spencer Branch Watershed – HUC 030502010603

The Spencer Branch watershed is directly south of the Sawmill Branch watershed, and also falls within all three counties and the total area is 8,488 acres. Both the towns of Lincolnville and Centerville are in this watershed, along with Chandler Bride Creek. Table 18, Chart 18, and Figures 86-90 characterize this watershed. Forested wetlands (19.26%) and non-forested wetlands (0.32%) are scattered throughout the area (Figure 86). Upland planted pine (29.06%), mixed upland forest (14.5%) and deciduous upland forest (1.2%) are the three forest types that densely cover the northern section of the watershed (Figure 87). Cropland/pasture (2.8%), commercial (5.64%), residential (25.66%) and industrial (0.53%) areas are all scattered throughout the watershed (Figures 88 & 89). Impervious surface cover follows the same layout as the residential, commercial and industrial areas; there is one interstate and no major roads in the watershed (Figure 90). The sewer and water lines follow the same layout and there are no sewage or water treatment facilities (Figure 90). There are no protected lands, and this watershed is impaired for both fecal coliform and turbidity.

Table 18. Spencer Branch watershed

HUC 030502010603 – Total Area: 8,488 acres

Land-use	Area (acres)	% of Total Area
Upland Planted Pine	2467	29.06
Residential	2178	25.66
Forested Wetland	1635	19.26
Mixed Upland Forest	1231	14.5
Commercial	479	5.64
Cropland/Pasture	238	2.8
Deciduous Upland Forest	102	1.2
Transportation Utilities	50	0.59
Industrial	45	0.53
Open Water	35	0.41
Non-forested Wetland	27	0.32
Estuary/Bay	1	0.01

Chart 18. Spencer Branch watershed

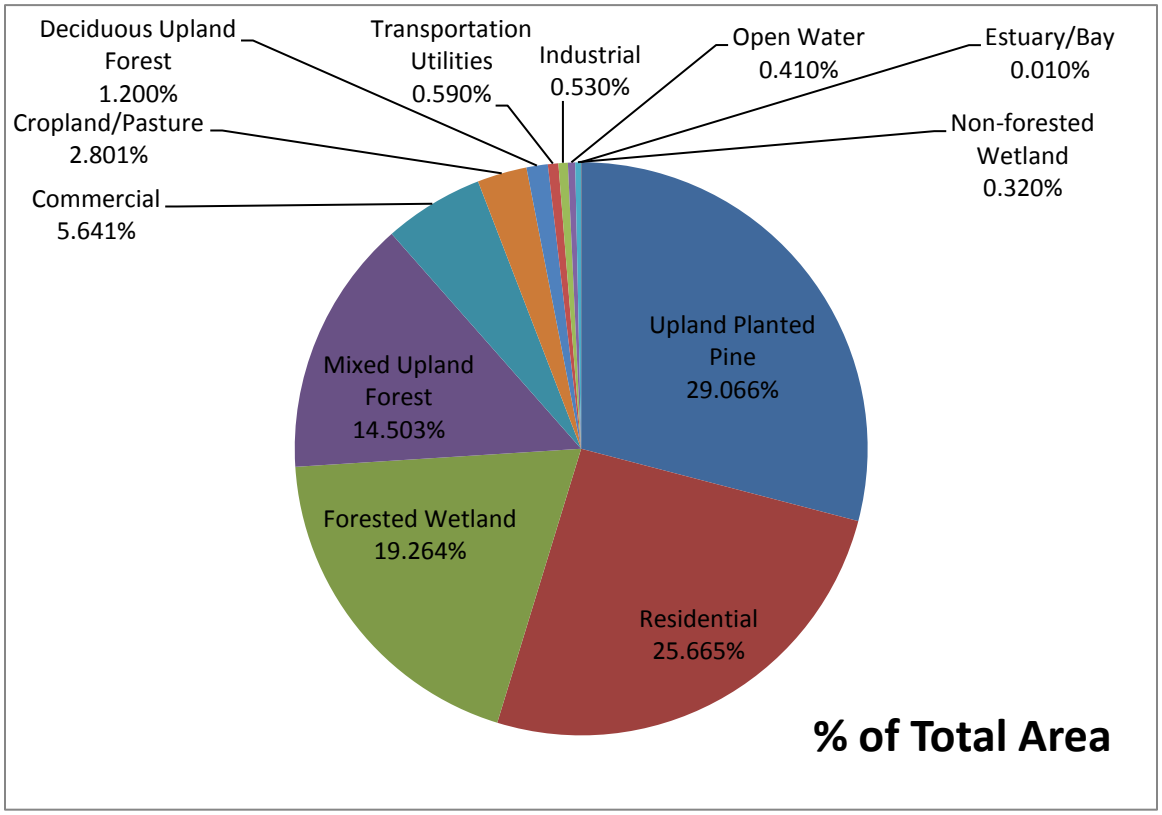


Figure 86. Spencer Branch watershed water cover

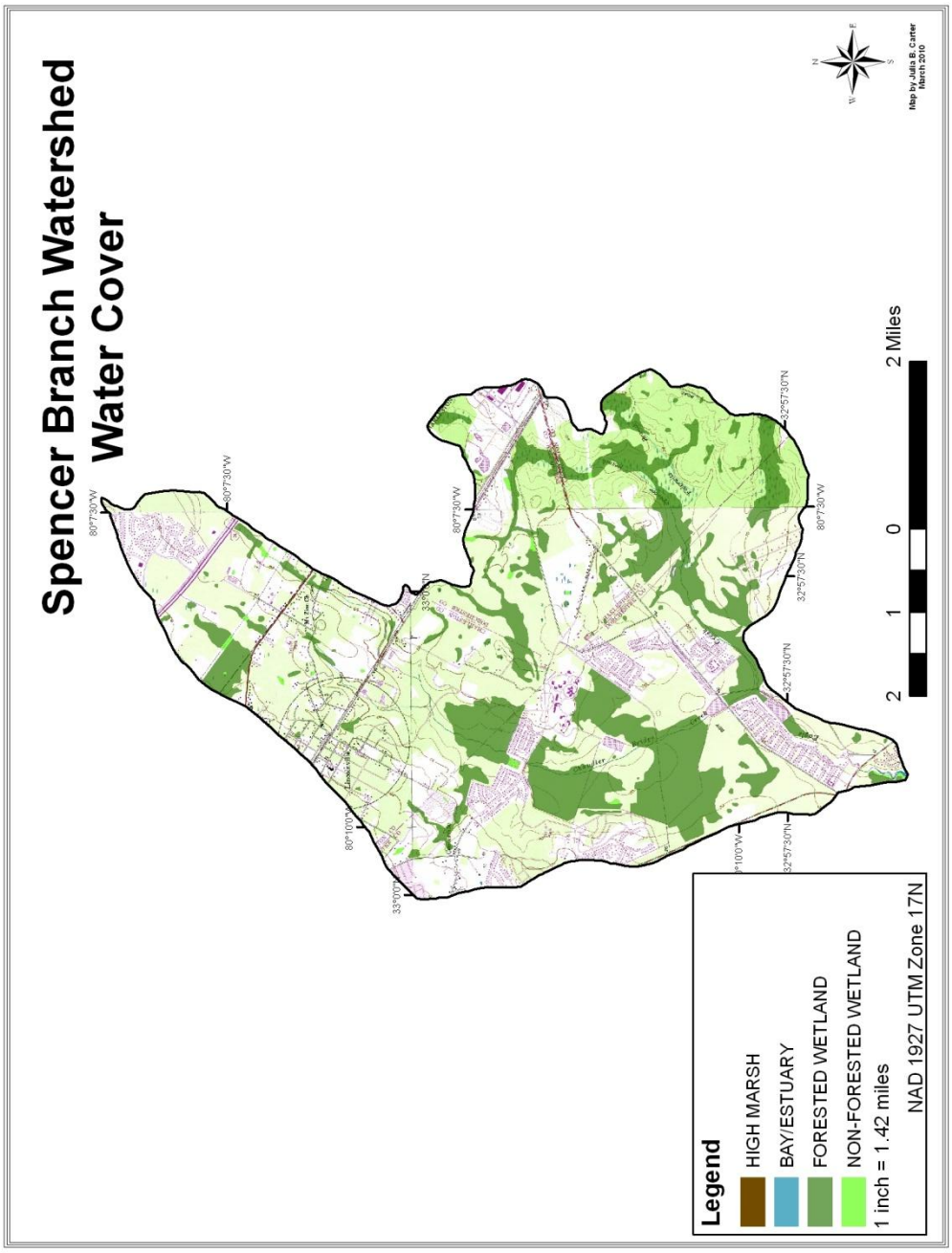


Figure 87. Spencer Branch watershed forest cover

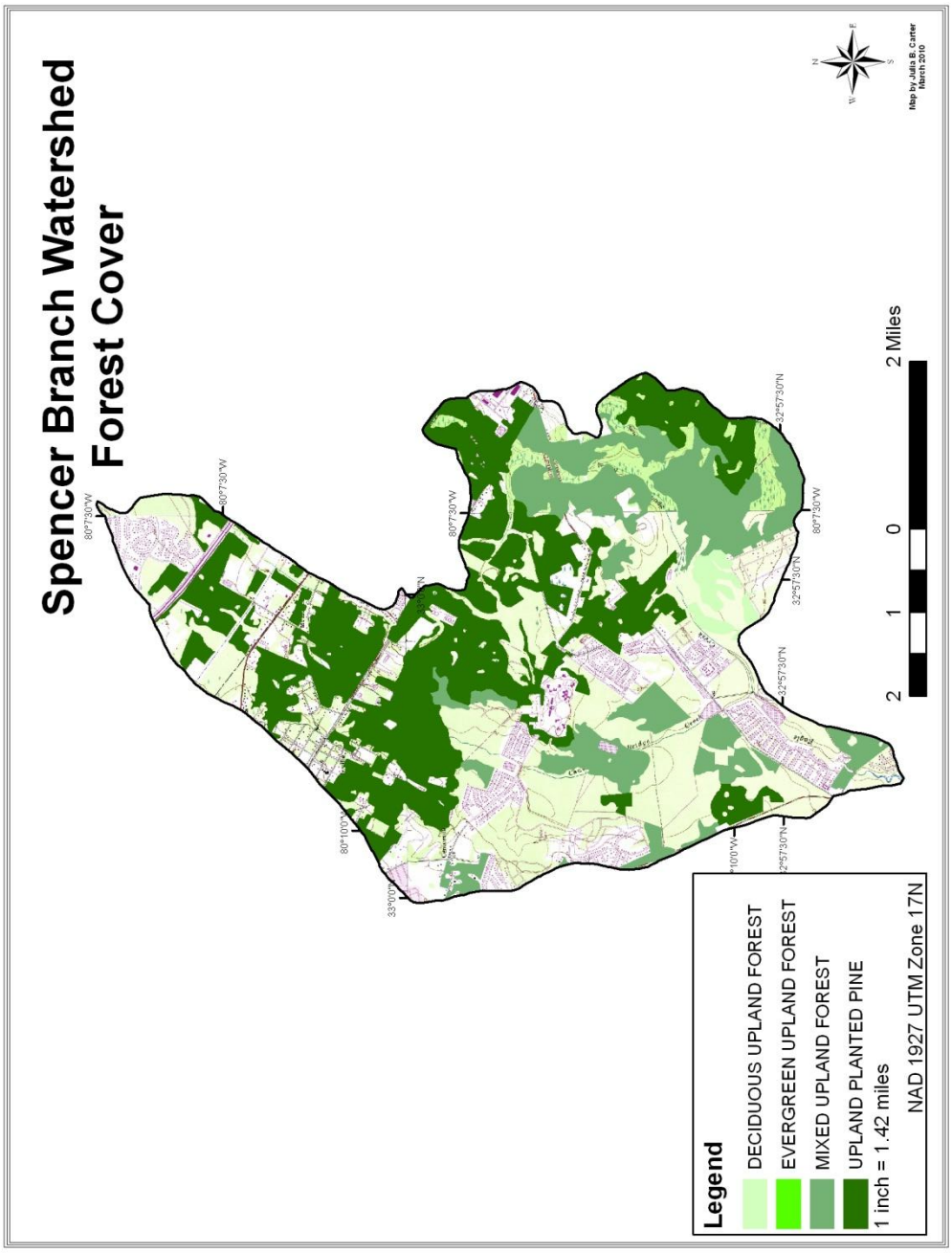


Figure 88. Spencer Branch watershed agricultural land

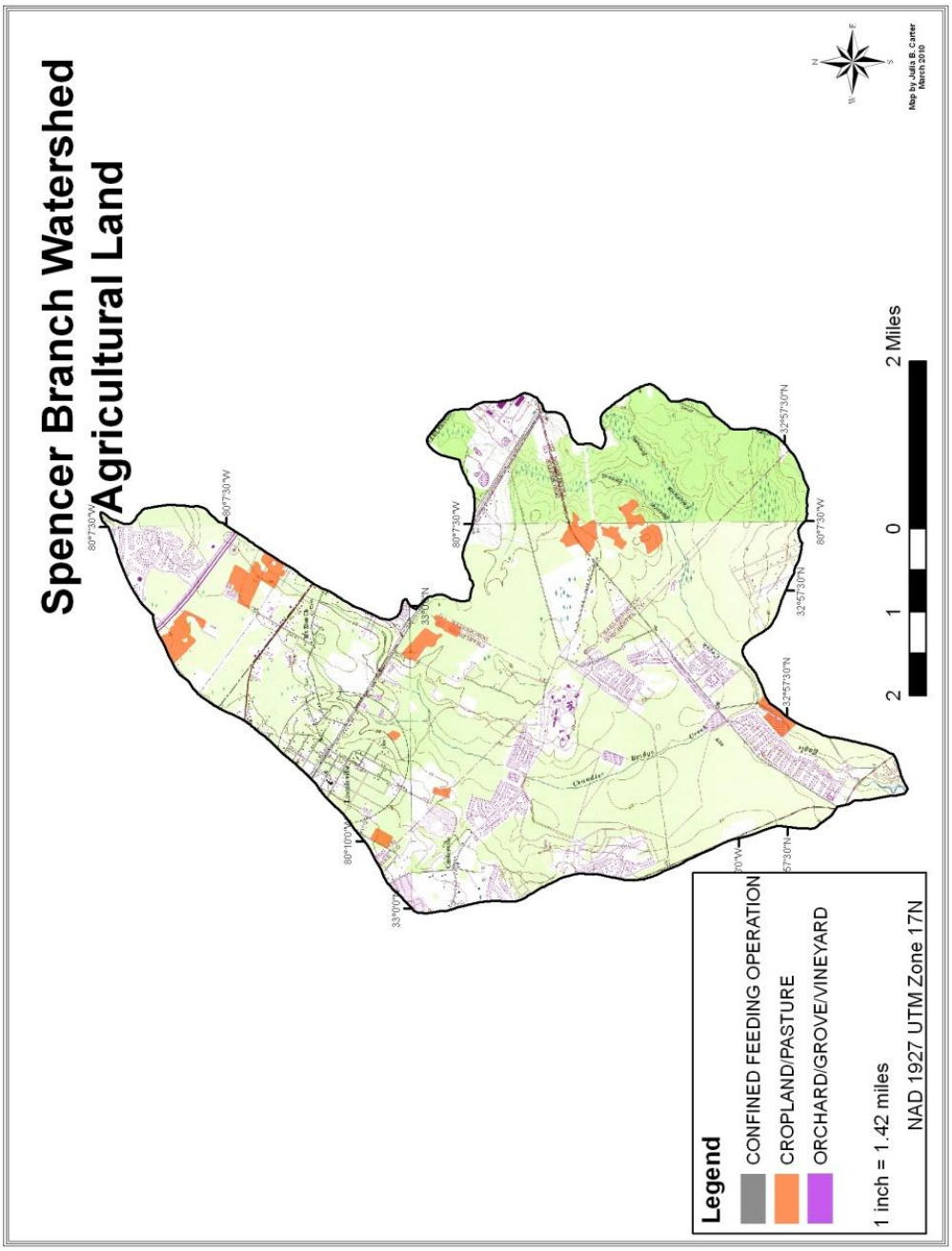


Figure 89. Spencer Branch watershed developed land

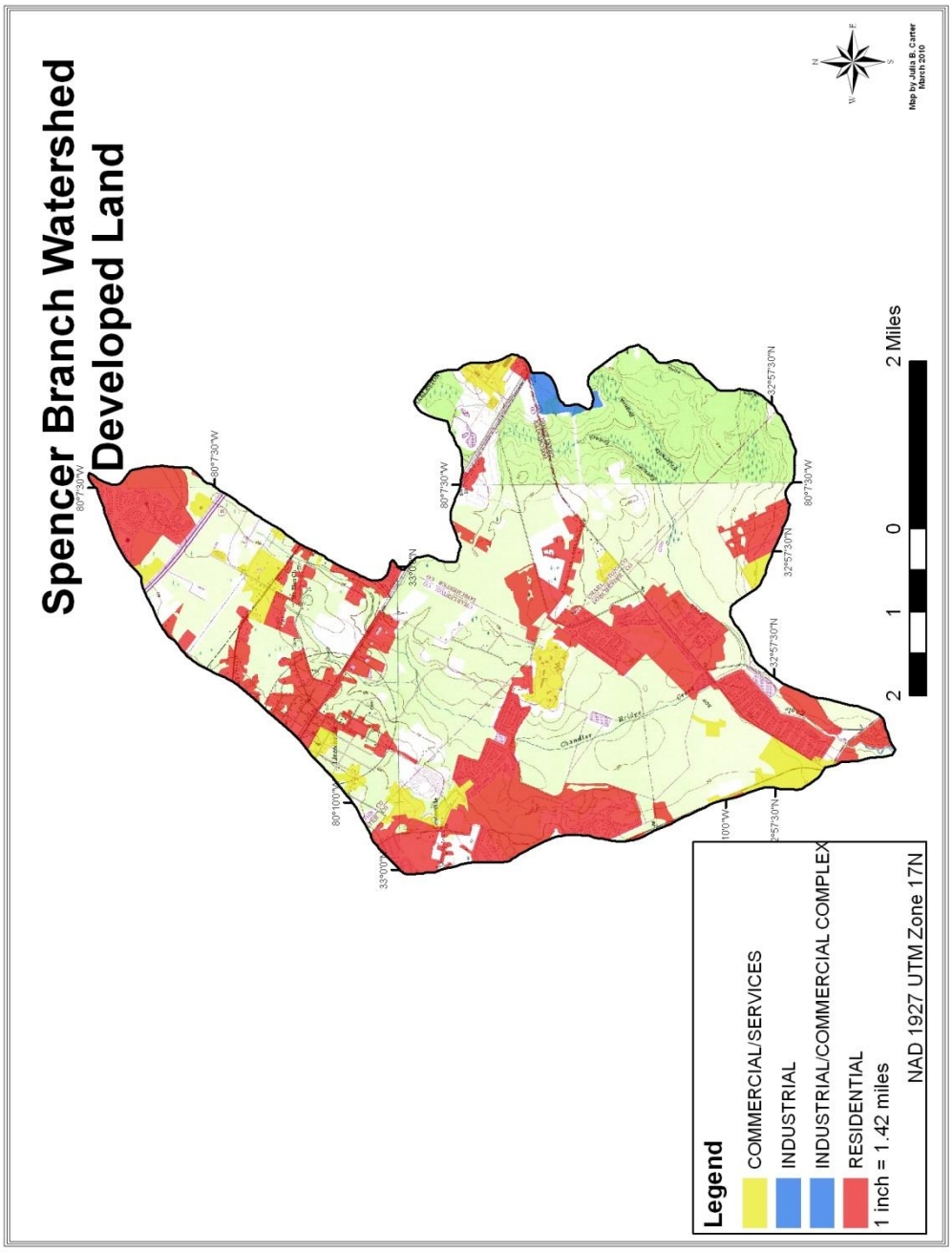
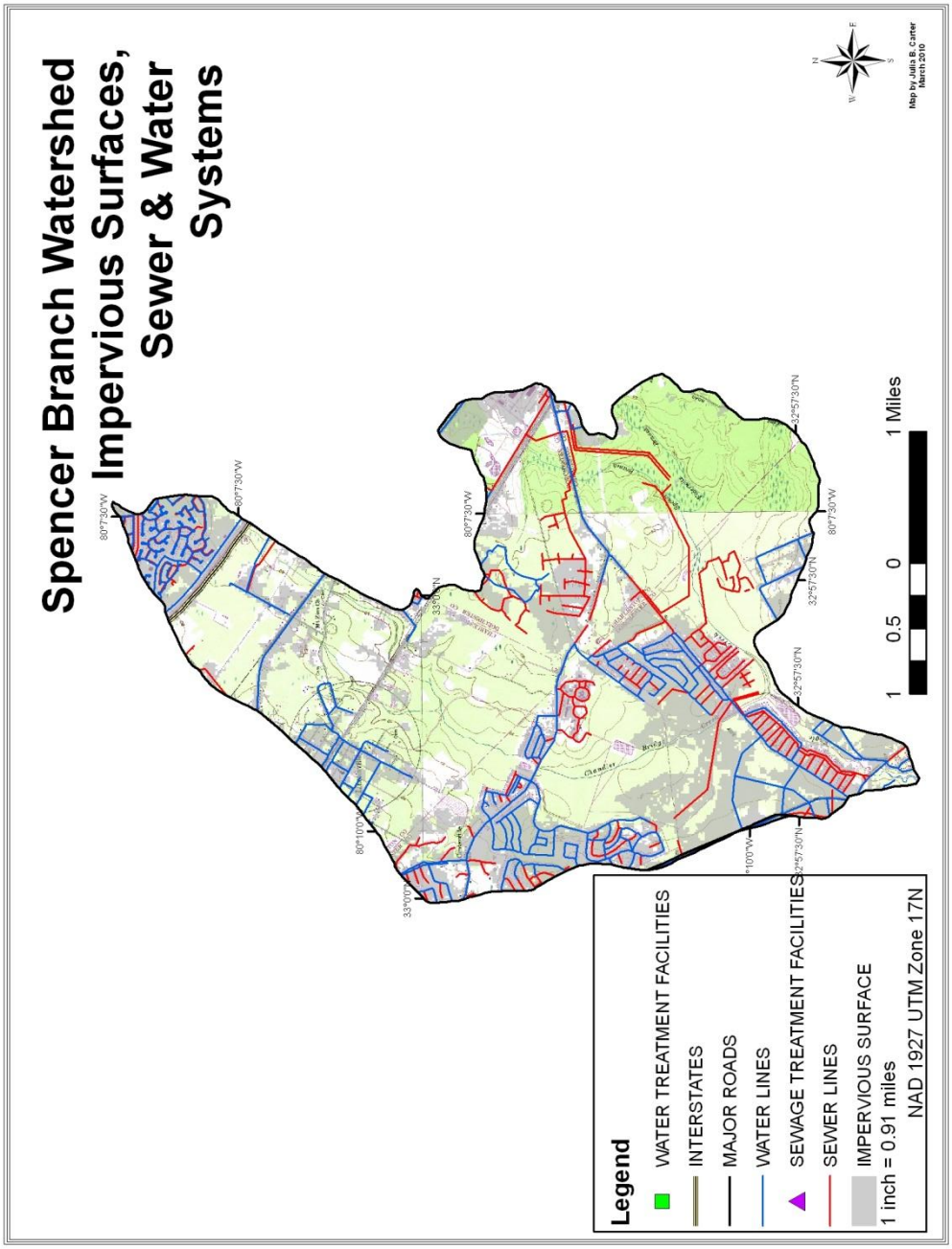


Figure 90. Spencer Branch watershed impervious surfaces, and sewer and water systems



4.3.14 Rumph's Hill Creek Watershed – HUC 030502010506

Rumph's Hill Creek Watershed is directly west of Sawmill Branch watershed, Cypress swamp bisects the watershed, and Givhan's Ferry State Park is on the far western side of the watershed; the total area for this watershed is 38,703 acres. Table 19, Chart 19, and Figures 91-96 characterize the watershed. There is a large portion of forested wetlands running through the center of the watershed (20.56% of the watershed), which coincides with Cypress Swamp, in addition there are small pockets of non-forested wetland (1.08%) where the main swamp (and forested wetlands) branch off (Figure 91). Forest coverage of all four types of forest are scattered throughout the watershed totaling 45% of the total area, with a concentration of upland planted pine on the western half of the watershed (Figure 92). There are a large number of cropland/pasture (16.99%) areas on both sides of Cypress Swamp, whereas the concentration of residential, commercial and industrial areas is mainly on the eastern side of Cypress Swamp (15.3%) (Figures 93 & 94). Impervious surfaces are concentrated on the eastern side of Cypress Swamp along with most major roads (95). All sewer and water lines are on the eastern side of Cypress Swamp; there are no sewage treatment or water treatment facilities (Figure 95). Givhan's Ferry State Park is the only protected land (Figure 96), and of all the watersheds that fall within the urbanized area, Rumph's Hill Creek is the only watershed that is not impaired.

Table 19. Rumph's Hill Creek Watershed
HUC 030502010506 – Total Area: 38,703 acres

Land-use	Area (acres)	% of Total Area
Upland Planted Pine	10027	25.91
Forested Wetland	7958	20.56
Cropland/Pasture	6574	16.99
Residential	5391	13.93
Mixed Upland Forest	3376	8.72
Evergreen Upland Forest	2152	5.56
Deciduous Upland Forest	1862	4.81
Non-forested Wetland	418	1.08
Industrial	276	0.71
Commercial	256	0.66
Shrub/Brush Rangeland	98	0.25
Open Water	87	0.22
Transition Utilities	70	0.18
Mines/Quarries/Pits	7	0.02

Chart 19. Rumph's Hill Creek Watershed

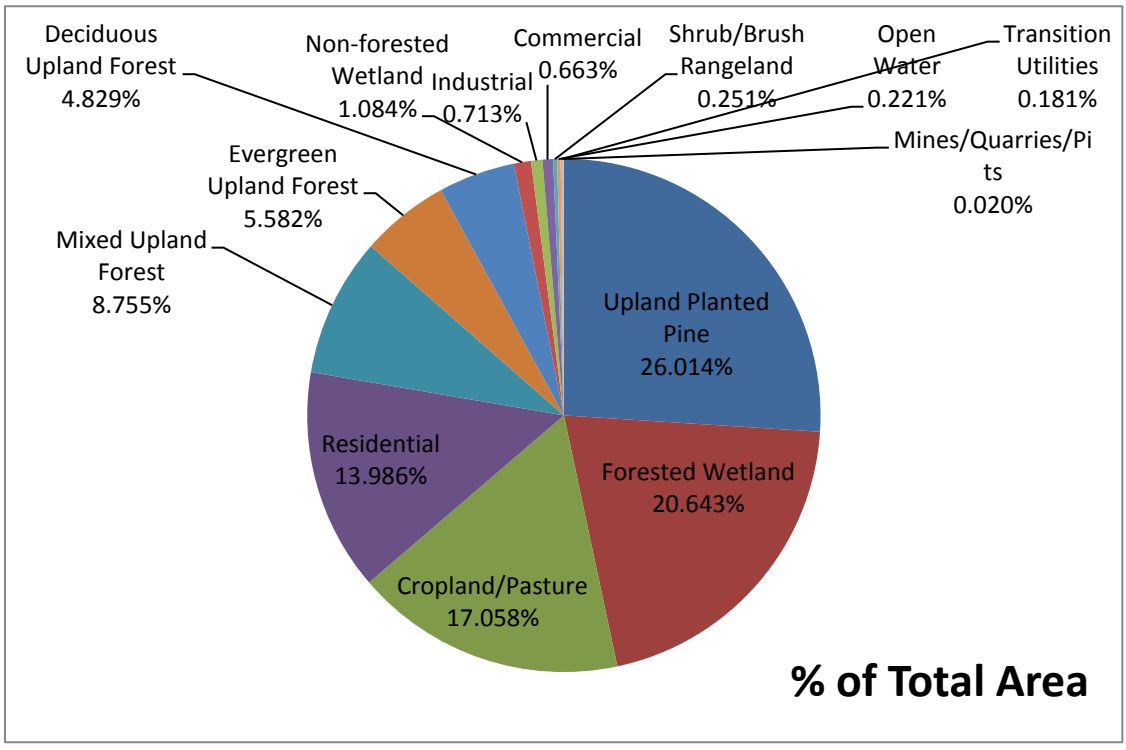


Figure 91. Rumph's Hill Creek watershed water cover

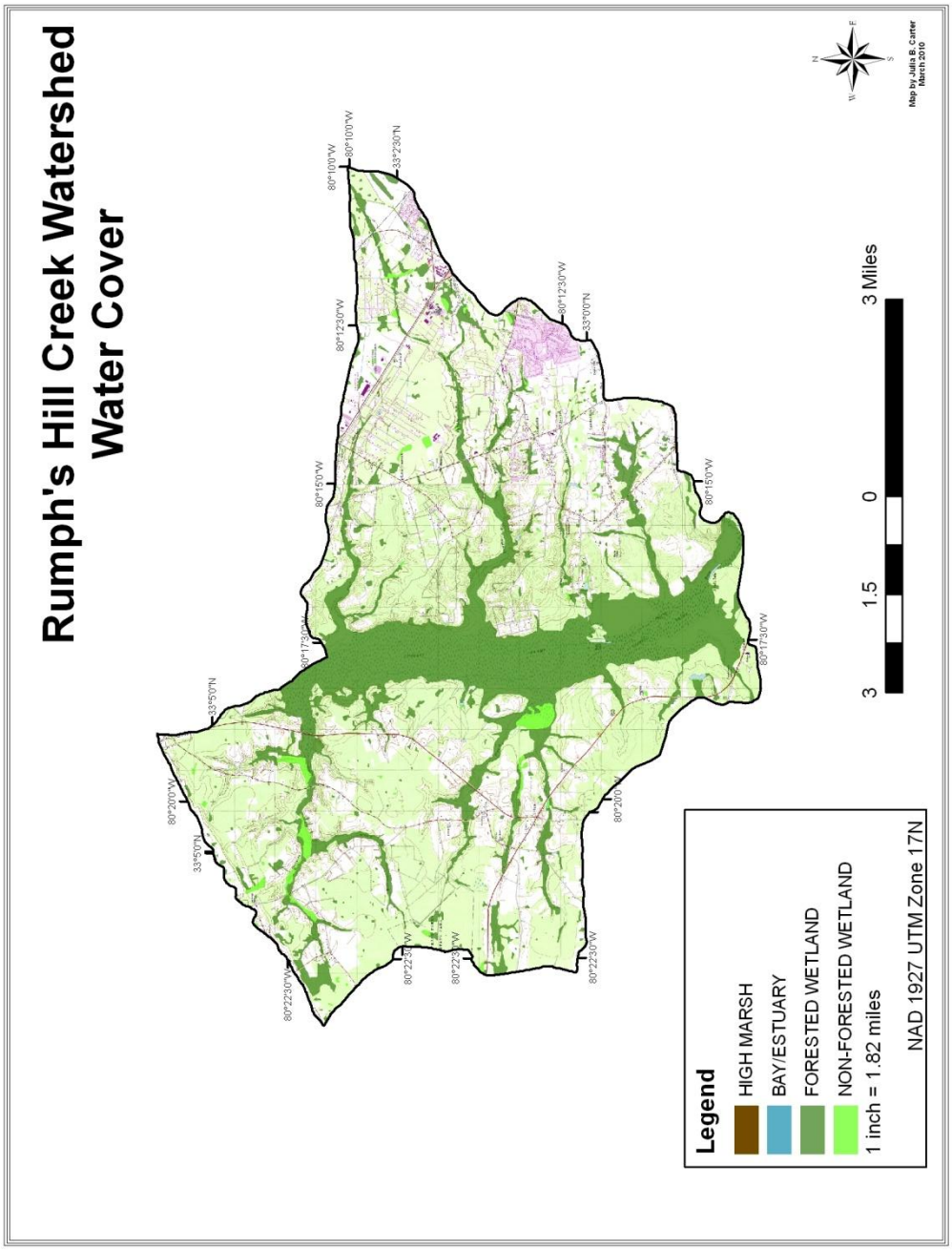


Figure 92. Rumph's Hill Creek watershed forest cover

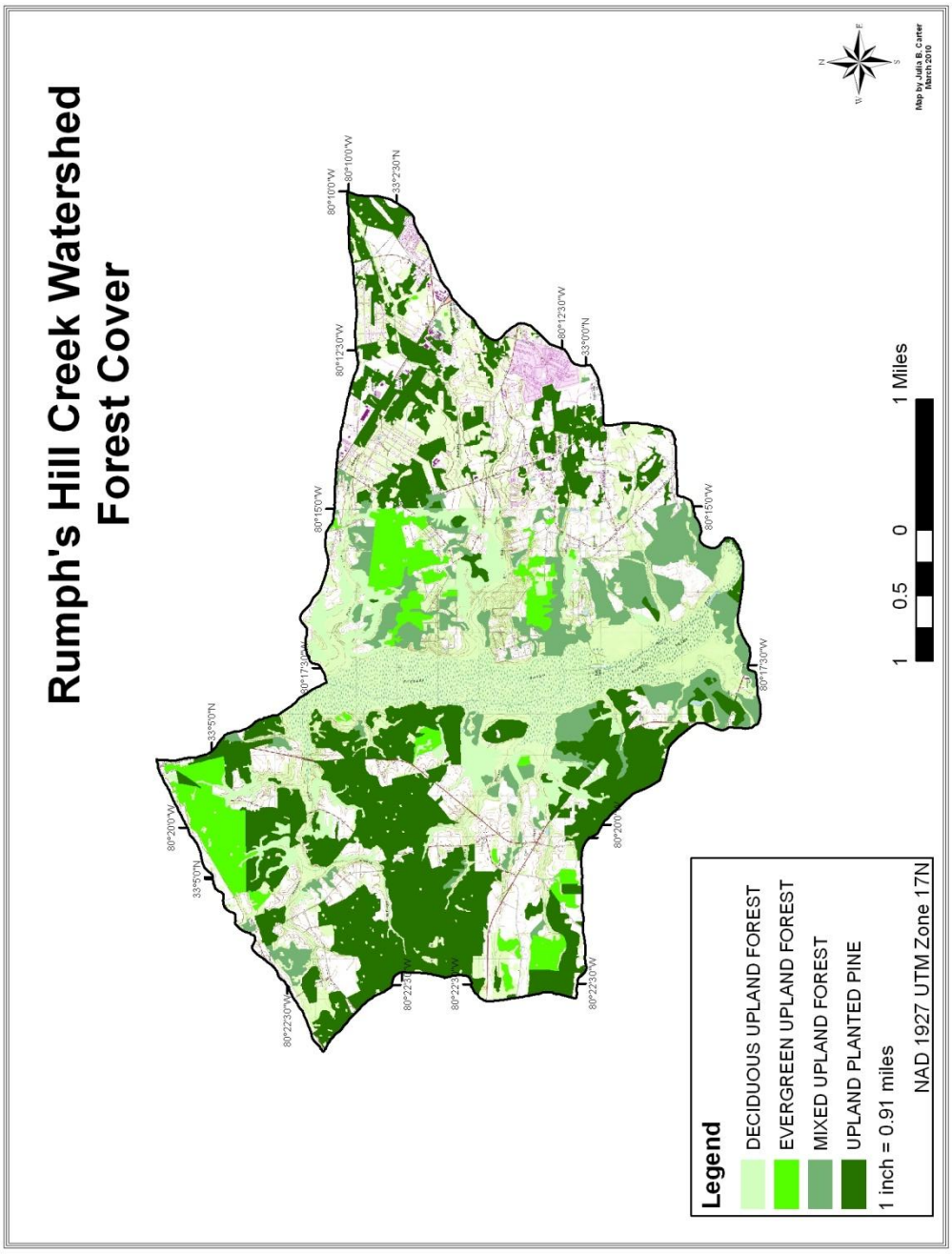


Figure 93. Rumph's Hill Creek watershed agricultural land

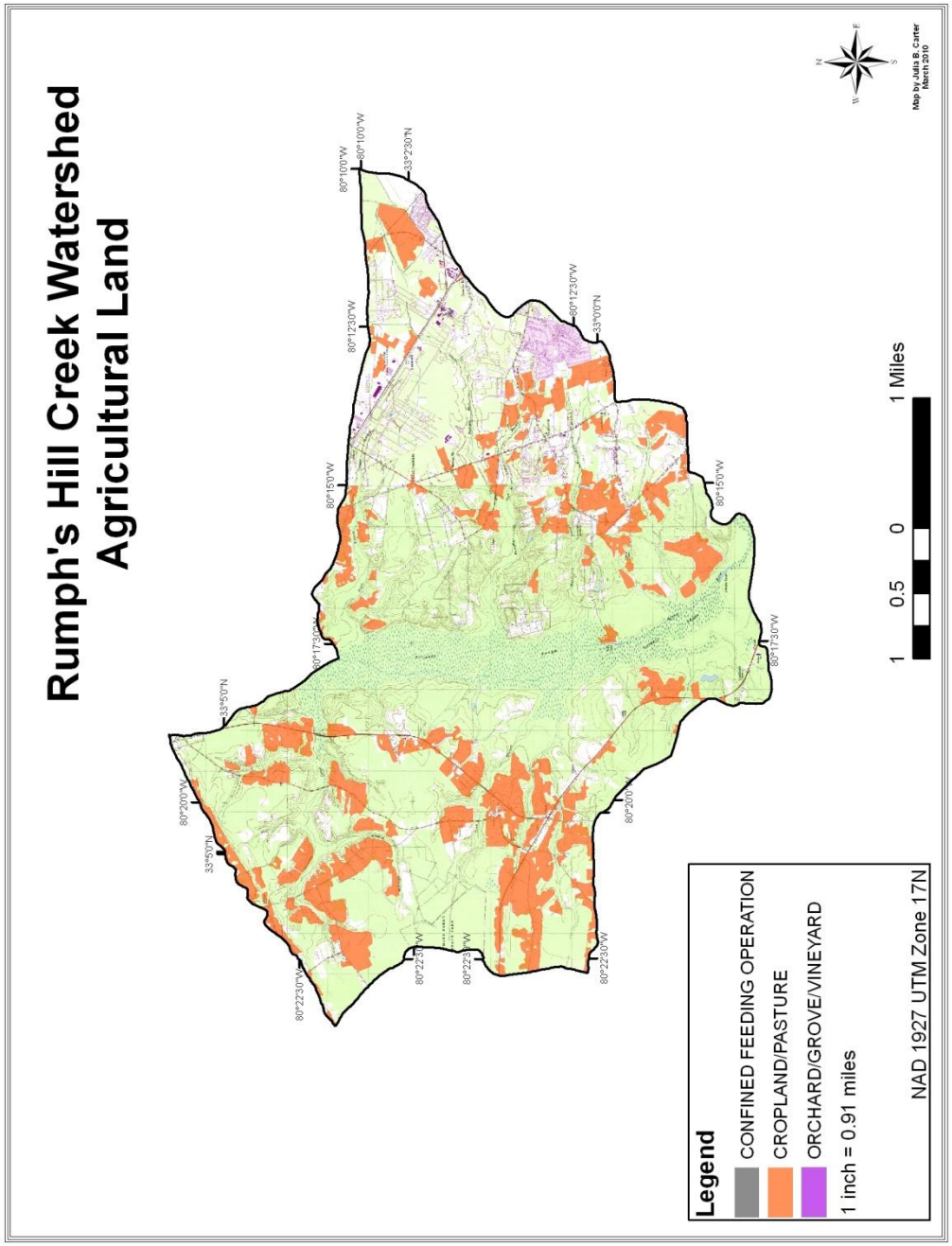


Figure 94. Rumph's Hill Creek watershed developed land

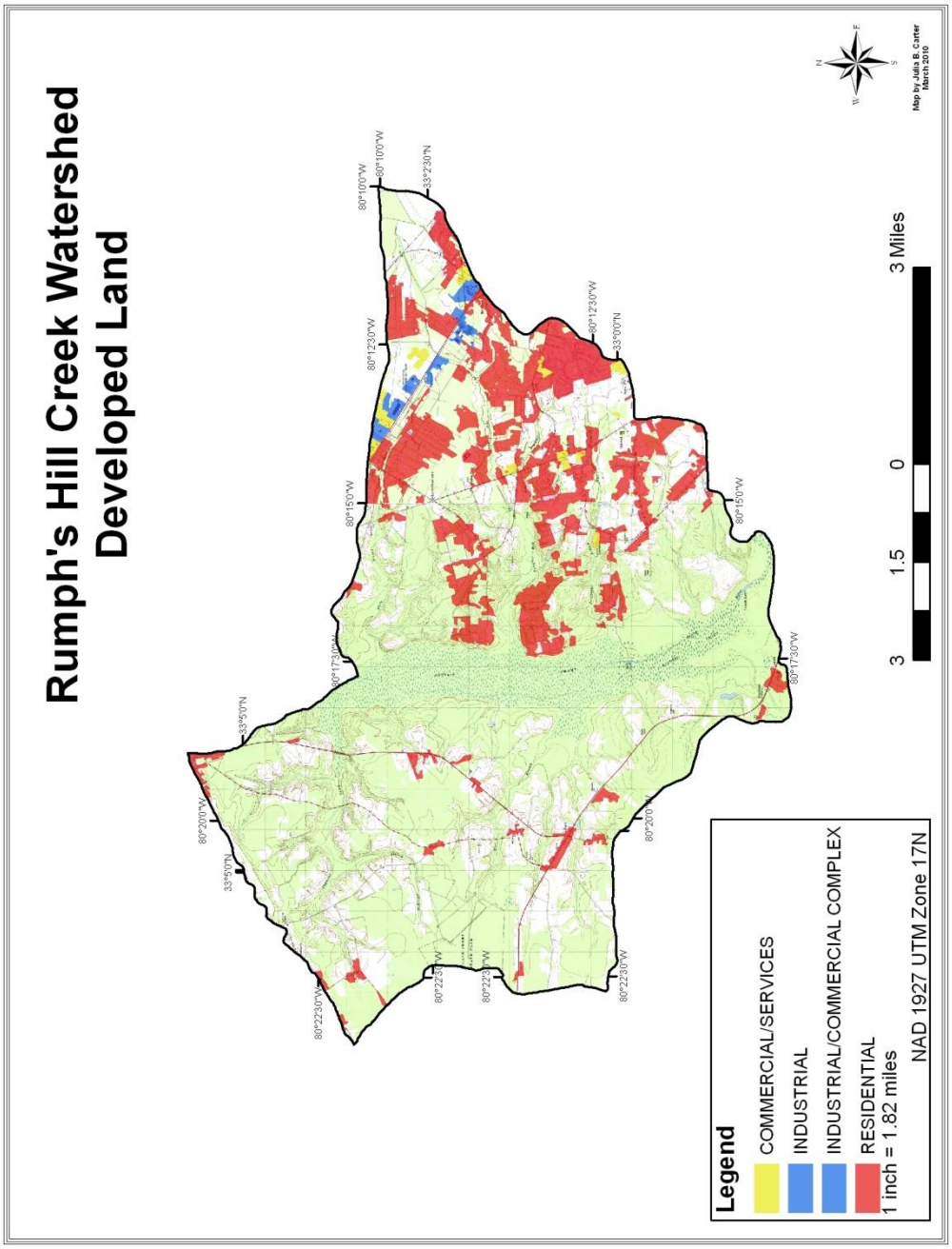


Figure 95. Rumph's Hill Creek watershed impervious surfaces, and sewer and water systems

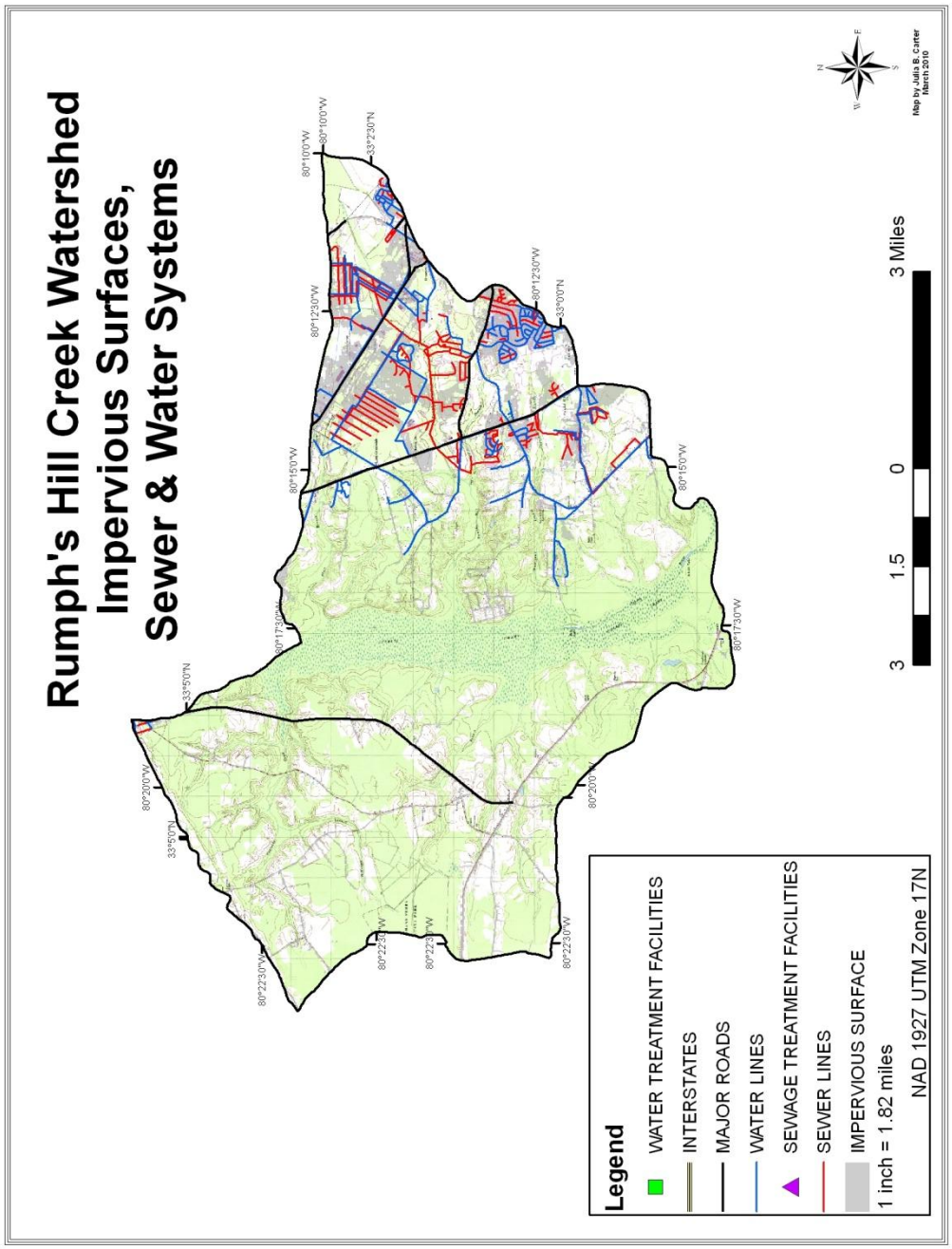
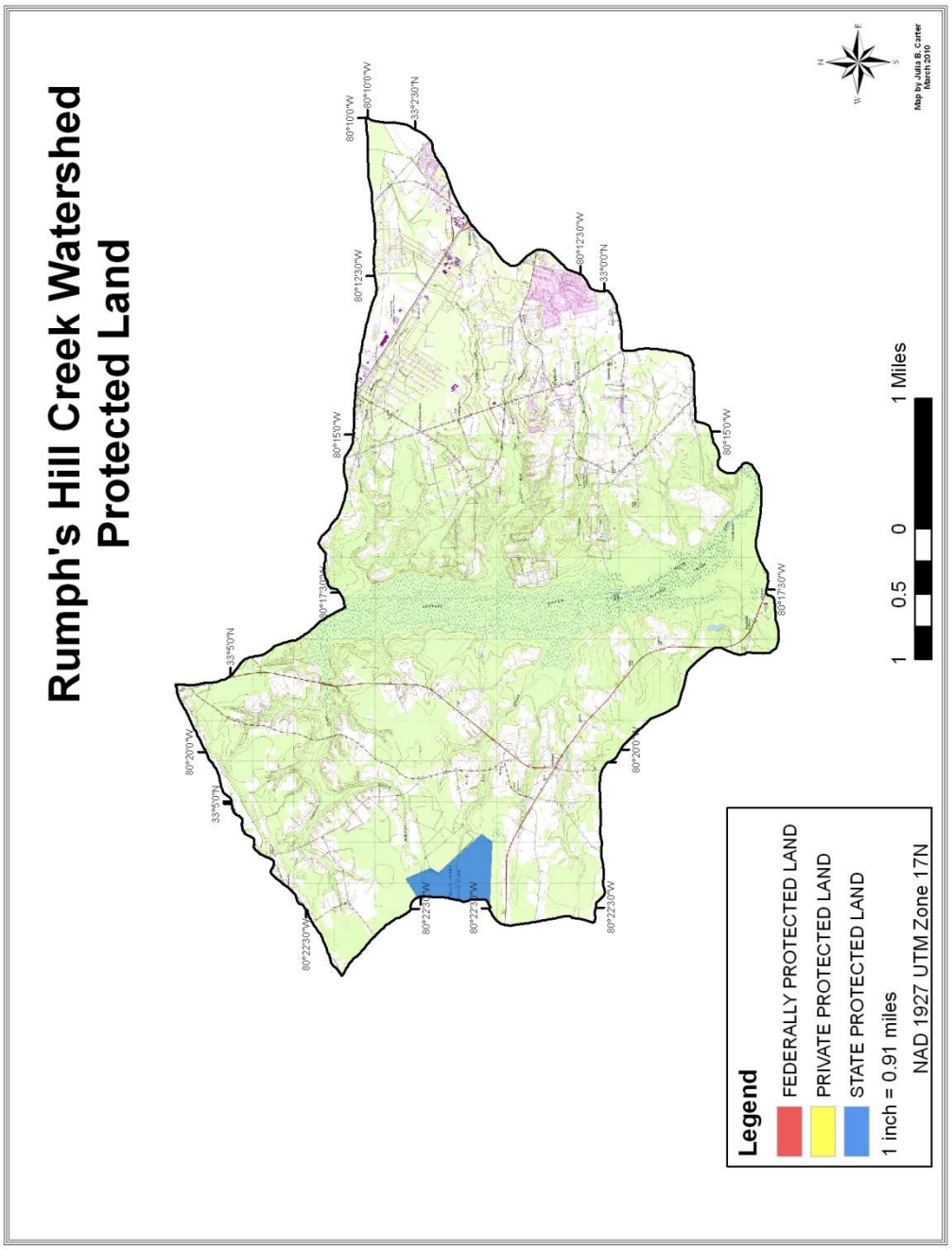


Figure 96. Rumph's Hill Creek watershed protected land



5.0 Discussion

In the Tricounty area natural land cover in the form of forested land, forested wetlands, non-forested wetlands, bays, and estuaries account for a total of 1428946.74 acres or 70% of the Tricounty area. Forested land includes evergreen upland forest, deciduous upland forest, mixed upland forest and upland planted pine. Land that has been developed, including commercial, industrial, residential, and agricultural (cropland/pasture and orchards/vineyards) accounts for 307,680.28 acres or 15% of the Tricounty area. Table 1 shows a list of the land-uses for the Tricounty area along with their area and percent of total area. Chart 1 depicts these numbers in a pie chart format; the total area for natural areas is greater than that for developed land-uses. The two largest land-uses are upland planted pine with an area of 544,329.04 acres (26.65% of the total area) and forested wetlands with an area of 385,941.94 acres (18.89% of the total area). The two largest developments of land are agricultural cropland and pasture with an area of 163,712.62 acres (8.01% of total area) and residential development with an area of 102,874.57 acres (5.04% of total area). It is important to note that confined feeding locations (0.03% of total area), orchard/vineyard (0.07% of total area), industrial (0.09% of total area), and industrial/commercial complex (0.09% of total area) represented very small percentages of the total area. 'Other' in Table 1 and Chart 1 refers to the land-uses within the NWI that were not used in this study. These land-uses include bare exposed rock, beaches, dry salt flats, herbaceous rangeland, mines/quarries/pits, mixed barren land, mixed rangeland, mixed urban, open water, other urban, sandy area, shrub/brush rangeland, transitional areas, transportation utilities, and upland.

As discussed above, the natural areas within the Tricounty area are greater than those of the developed areas. Figure 4 shows the water coverage for the area, while Figure 5 shows the forest coverage; the developed areas consist of the negative areas in both of Figure 4 and 5, which show how much of the Tricounty is covered in undeveloped areas. Forested wetlands near rivers and streams and wetlands in the upper parts of drainage basins function as improvements to water quality because they act as buffers and filters for pollutants before entering waterways (Mallin et al. 2001; Tiner 2005). However, the land-use in the upper basins of the Tricounty are covered in cropland/pasture (Figure 6) and cropland/pasture accounts for 8.01% of the total area. Agricultural uses are associated with pesticides, herbicides and other potential contaminants. There is a concentrated amount of agricultural land in the northwestern section of Dorchester County. These contaminants can make their way through other watersheds via surface and groundwater. Though plants can act as a buffer, Tiner (2005) points out how wetlands adjacent to farmland and urban development can become oversaturated by the overloading of pollutants after several years. The continuation of coastal development and consequent conversion of natural vegetation to impervious surfaces will only increase stormwater run-off and the loading of various pollutants into coastal waters (Holland et al. 2004; Mallin et al. 2001).

The number one cause of impaired waters in the United States is stormwater run-off, accounting for 60-70% of water pollution (Randolph 2004). Stormwater run-off increases as the percentage in impervious surfaces increase. Figure 7 shows the impervious cover for the Tricounty region, which is associated with commercial,

residential and industrial land-uses (Figure 6). At the Tricounty level, Figures 6, 8 and 9 depicts the same developmental trend that is encountered with the impervious surface map (Figure 7). These figures show the contrast of development inside and outside of the urbanized area foot print; commercial, industrial and residential development (Figure 6), sewage treatment plants and sewer lines (Figure 8) and water lines, water wells, and water treatment facilities (Figure 9) are all highly concentrated within the urbanized area footprint, whereas outside of this area, these items are scattered. Figure 12 shows the population by census block and the concentration of those living within the urbanized area, which aligns with the other Tricounty maps depicting a higher concentration of development within the urbanized footprint. In contrast, and not surprisingly considering the large area of impervious surfaces, Figure 10 shows the absence of protected land within the urbanized area. The majority of protected land is found around the Francis Marion National Forest in Berkeley and Charleston Counties, and the coastal island north of Isle of Palms: Bull Island, Capers Island, and the Cape Romain National Wildlife Refuge. No part of the Francis Marion National Forest falls in the watersheds within the urbanized area. There are other small pockets of privately protected areas scattered across the three counties where individuals have developed land easements.

Similarly, the individual watersheds (Figures 19-96) show the same urbanized trends: the commercial, residential and industrial areas, the impervious surfaces and the sewer and water systems are all in urbanized areas with protected land in the 'negative space' created and in some instances there is no protected land in the 'negative space.' The two exceptions to this trend are the Stono River AIW watershed and the Foster Creek

watershed. The Stono River AIW watershed (Figures 35-40) was the only watershed that contained septic tank data. The other watersheds within Charleston County with septic tank data do not fall within the urbanized area boundary. Septic tanks, however, are not linked with urban development, whereas sewer lines and treatment facilities are linked with urban and suburban developments (Young & Thackston 1999). The Stono River AIW watershed is bisected by the Stono River, leaving the western shore as a rural part of the county (Johns Island) and the eastern shore as part of the urbanized area (West of the Ashley). The eastern half of Foster Creek watershed (Figures 70-74) is dominated by commercial land use, largely the U.S. Naval Weapons Station.

The Tricounty has a large percentage of water features. Mallin et al. (2001) suggests that coastal development and replacement of natural vegetation with impervious surfaces will increase stormwater run-off and the loading of pollutants into coastal waters. The SC DHEC 2008 303(d) list includes heavy metals, nutrients, dissolved oxygen, turbidity and fecal coliform as the pollutants impairing the Tricounty watersheds. Some watersheds are impaired with a single contaminant, while others are impaired with multiple contaminants (Figure 13). All of the Charleston County watersheds (35), with the exception of five are impaired at some level. Whereas Berkeley County contains 20 watersheds out of 42 that are not impaired and Dorchester contains 11 watersheds out of 31 that are not impaired. Within the urbanized area, the only watershed that is not impaired is Rumph's Hill Creek watershed (Figures 91-96).

Fecal coliform bacteria is one of the primary contaminants affecting the watersheds in the Tricounty region. Figure 14 shows the amount of watersheds (33) that are impaired with fecal coliform, which greatly outnumbers the amount of watersheds impaired with other contaminants.

Potential sources of fecal coliform bacteria include both wild and domestic animal waste. Mallin et al. (2001) point out that with increased population is the increase of biological waste from both humans and their pets. Figure 6 shows a large portion of land development as residential, which accounts for 5.04% of the total area (Table 1). With each home, there is not only a form of sewer system (septic or sewer lines), but there is a possibility of a pet. In a recent study evaluating fecal coliform and land use relationships, Kelsey et al. (2004) suggested public education programs, 'poop-n-scoop' campaigns, and ordinances to reduce the fecal pollution in coastal waters caused by pet waste. In coastal areas, fecal bacteria negatively affect shellfish harvesting, the odor of waterways, and the use of recreational areas, which can all be addressed with prolific educational programs that target all age ranges.

Turbidity and fecal coliform bacteria pollutants are also associated with agricultural land uses. In rural areas, agriculture can cause disturbances to soil, which runs off into streams and creates turbidity and bacterial pollution (Mallin et al. 2001). Johns Island, Wadmalaw Island, and Edisto Island and beach are all areas with higher concentrations of both agricultural land (Figure 5) and turbidity impaired waters (Figure

16). All nine watersheds impaired for turbidity fall within Charleston County; two of these watersheds share a border with Dorchester County.

Another pollutant of concern that acts as impairment to Tricounty watersheds is a lack of dissolved oxygen; Figure 15 indicates the 18 watersheds that are impaired. Dissolved oxygen is a bio-indicator, pointing out waterways of concern as fish kills and pungent odors increase. Phytoplankton (small free floating plants) populations increase as nutrients are available in greater proportion. Potential sources of nutrients include fertilizer and animal wastes. Algal blooms increase organic material that falls to the bottom of estuaries and is fed on by microorganisms that consume the oxygen which leads to dramatic decreases in oxygen concentrations (Pomeroy & Cai 2006). Therefore excess nutrients from agriculture, leaking septic tanks, suburban residential run-off and golf courses can be potential sources of low dissolvved oxygen in estuaries (Pomeroy & Cai 2006). Figure 15 shows that the watersheds impaired by dissolved oxygen are closest to the urbanized development, with the exception of the four watersheds at the northernmost corner of Dorchester County. The four watersheds in the northern quadrant of Dorchester County that are impaired for dissolved oxygen are also areas with a high concentration of cropland and pasture. The watersheds closest to the urbanized area that are impaired with dissolved oxygen may be influenced by run-off from suburban areas (fertilizer from lawns), sewer system run-off or absorption, and recreational land-use in the form of multiple golf courses, parks, and other open spaces.

Closely linked to dissolved oxygen in the effects of eutrophication are the nutrients nitrogen and phosphorous. Figure 17 depicts the four watersheds impaired with nutrient overload, three of which are impaired for ammonia nitrogen and one of which is impaired with phosphorous and chlorophyll A. Nitrogen, phosphorous and dissolved oxygen are linked in the decomposition process that occurs when organic material from runoff is accumulated in water bodies. When an estuary receives an overloading of nutrients such as nitrogen and phosphorous, photosynthesis increases to match this overload and as the organic matter decomposes, oxygen levels decrease (Pomeroy & Cai 2006). Randolph (2004) calls this eutrophication process 'cultural,' in that the natural process of eutrophication happens over a course of centuries, allowing cycles to progress 'normally,' however the overloading of nutrients accelerates the process to occur within decades due to anthropogenic causes. Potential sources of nitrogen and phosphorous in stormwater run-off are fertilizers, decomposed leaves and mulch, and human and animal waste. The increase in population growth and coastal development points to an increase in nutrient overloading from stormwater run-off (McKellar & Bratvold 2006). McKellar and Bratvold (2006) cite commercial and residential development as causes of nutrient loads in nonpoint source run-off. The watersheds impaired with nutrients are not only within the urbanized area, but they are also all within Charleston County and located either directly adjacent to waterways or have waterways incorporated within the watershed boundaries making it easier for nutrients to make their way into water bodies.

Eight of 23 watersheds are impaired with copper and all of these watersheds are found on the Atlantic coast within Charleston County (Figure 17). The 15 watersheds

impaired with mercury are found throughout the Tricounty but are concentrated in Berkeley County. Industrial land-use is a potential source of heavy metals. Figure 6 shows industrial locations for the Tricounty area to be spread out, but mainly found in the northern 2/3 of the combined Tricounty area, mostly occurring in Berkeley and Dorchester counties, with Charleston County industrial locations only on the Charleston peninsula. Though the NWI land-use maps include data from 1989, the heavy metal contaminants will stay in watersheds over long periods of time (Kleppel et al. 2006), meaning the data from 1989 is still relevant. They remain in local sediment and continue to cycle and accumulate in the food chain (Lee & Maruya 2006). The watersheds impaired with mercury, though spread out, are concentrated around Lake Moultrie and the headwaters of the Cooper River, which is not only a concern for the directly impaired watersheds but all watersheds downstream. The few industry locations that are found in Berkeley County are in the watersheds impaired for mercury. These watersheds do not fall within the urbanized area footprint, but are of concern due to the large bodies of water that contain aquatic life and are recreational areas, in addition to the impact of run-off further downstream.

The Cape Romain National Wildlife Refuge falls within both the Bull Island and Cape Romain watersheds, neither of which falls within the boundaries of the urbanized area. However, they are both watersheds that are impaired for three or more contaminants, yet this area is federally protected therefore the arguments above for contaminants within urbanized and developed areas may not hold true for these watersheds. The Bull Island watershed is impaired for fecal coliform, dissolved oxygen,

turbidity and copper. The Cape Romain watershed is impaired for fecal coliform, turbidity and copper.

Future Work

Through analysis of data, future research and programming possibilities were discovered. The 1989 NWI data that was used was the best available data, however, it would be prudent to conduct a study to update the land-use data that could be used in future comparison studies to show the results of population growth through commercial, residential and industrial development, especially given the recent rapid population growth in many areas of the Tricounty. Future research could also include inquiries on the watersheds outside of the urbanized area that are impaired for three or more contaminants, such as the Bull Island and Cape Romain watersheds that house the Cape Romain National Wildlife Refuge. These studies could help in best management practices (BMPs) for regulating NPS and stormwater run-off.

Further studies into the possible links between fecal coliform bacteria and pet waste in highly residential and urban areas could help bridge the information gap for both the local communities and local officials. How many dogs are in each neighborhood? What is the proximity of the neighborhood to a waterway? These are all questions that could be addressed in future studies into domestic and wildlife waste contaminants.

The social data that was collected independently of this internship could shed light onto the environmental perceptions of local communities and home owners and will aid in characterizing the region for a complete study that involves both physical and

social aspects. This combination of the two will make for a more robust study and platform for education programming.

6.0 Conclusions

The goal of this internship was to develop a physical characterization of the Charleston-North Charleston urbanized area for watershed outreach programming guidance in support of the Ashley Cooper Stormwater Education Consortium (ACSEC). The ACSEC will use the social information gathered independently of the project to compliment the physical characterizations created within this internship. A GIS database was created for organizing, recording and analyzing physical and social data, and GIS layers were acquired, rectified and projected as they represent the landscape features of the region. The data gathered will serve as baseline data for future studies and will help to target pollutants, potential sources, land-uses, specific watersheds, and audiences, which will aid in implementing educational programs.

Holland et al. (2004) wrote, "Through education and community involvement, a conservation ethic may be fostered that encourages the permanent protection of lands for the services they provide." The use of GIS and this database allows the ACSEC to identify areas of concern and target specific audiences for educational programming. Public education and outreach and public involvement are key components in addressing stormwater run-off pollution, as defined by the Environmental Protection Agency's (EPA) Phase II program. It is important to not only educate the public about

environmental concerns that in turn affect the individuals in these communities, but to also encourage participation in the efforts to reach community-wide environmental goals.

7.0 Literature Cited

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8.0 Appendices

Appendix A. List of layers used in this project.

Layer	Description (if needed)	Source
usgs_marsh	Marsh in Berkeley County	Berkeley County
usgs_water	Water in Berkeley County	Berkeley County
usgs_streams	Streams in Berkeley County	Berkeley County
Calhoun_west_inlets	Stormwater drain inlets on Calhoun Street	City of Charleston
Coc_easements	Stormwater easements for City of Charleston	City of Charleston
Coc_marsh	Marsh in City of Charleston	City of Charleston
Coc_ponds	Ponds in City of Charleston	City of Charleston
Coc_inlets	Stormwater drain inlets in City of	City of Charleston

	Charleston	
Coc_streets	Streets in City of Charleston	City of Charleston
Coc_water	Water in City of Charleston	City of Charleston
berk_parcels	Berkeley County parcel data	College of Charleston
dorch_subdivision	Subdivisions in Dorchester County	College of Charleston
arc	Roads/streets in Charleston County	College of Charleston
bldg_29401_29403	Buildings for zip codes 29401 & 29403 (peninsula)	College of Charleston
school_dist	School Districts	College of Charleston
Buildings	Charleston County buildings	College of Charleston
charleston_high_marsh_e		College of Charleston
charleston_low_marsh_e		College of Charleston
drainage_class	Drainage – Charleston peninsula	College of Charleston
mp_parcels	Parcel data for Mt. Pleasant	College of Charleston
parcel_29401_29403	Parcel data for zip codes 29401 & 29403 (peninsula)	College of Charleston
major_h20	S.C. major waterways	College of Charleston
sc_major_rds	S.C. major roads	College of Charleston
sc_cities		College of Charleston
sc_coastal_county2	S.C. Coastal County outlines	College of Charleston
hydro_24k	Detailed rivers & streams for SC	College of Charleston

hydro_100k	Rivers & streams for SC	College of Charleston
mainstem	Main rivers for SC	College of Charleston
sc_basin	S.C. Basins	College of Charleston
sc_drain_basins	S.C. drainage basins	College of Charleston
sc_huc12		College of Charleston
sc_huc10		College of Charleston
sc_huc8		College of Charleston
sc_huc6		College of Charleston
hydroline	S.C. major waterways	College of Charleston
clipd_schools	School point data_clipped to unknown	College of Charleston
tri_coun_zip4	Tricounty zip codes & 2004 Population	College of Charleston
sc_zipcodes	S.C. zip codes	College of Charleston
sc_watersheds	S.C. watersheds	College of Charleston
sewlines	S.C. sewage lines	ESRI
counties	S.C. Counties	ESRI
urban_sc	S.C. urban centers	ESRI
waterlines	S.C. waterlines	ESRI
Interstates	S.C. Interstates	ESRI
rail_trks	S.C. railroad tracks	ESRI
watwells	S.C. water wells	ESRI
cities_dtl	U.S. cities	ESRI

airportp	U.S. airports	ESRI
areacode	U.S. area codes	ESRI
counties	U.S. counties	ESRI
dtl_st	Detailed U.S. states & territories	ESRI
dtl_wat	Detailed waterways in U.S.	ESRI
fedlandp	All federal lands in U.S.	ESRI
ggolf	U.S. golf courses	ESRI
hydroln	U.S. rivers	ESRI
hydropoly	U.S. waters (polygon)	ESRI
lakes	U.S. lakes	ESRI
lalndmrk	U.S. landmarks	ESRI
park_dtl	U.S. parks – detailed polygon	ESRI
placeply	U.S. subdivisions, classifies between cities & towns within states	ESRI
recareas	U.S. Recreational areas	ESRI
tracts	U.S. census tracts	ESRI
urban	U.S. urban centers	ESRI
zip_poly	U.S. zip codes	ESRI
hzschool_tric	Tricounty schools	Hazus
hazus_sc	State of S.C.	Hazus
ms4	SMS4s	Jason McMasters
shellfish_harvest_areas		Jason McMasters

ab_fick_complete	Septic tanks near Abbapoola & Fickling Creeks, Johns Island	Jason McMasters
aw_mc_ml	Septic tanks in McClellanville, Awendaw, & Moore's Landing	Jason McMasters
c_b_complete	Septic tanks near Church & Bohicket Creeks, Johns Island	Jason McMasters
edisto_complete	Septic tanks near Edisto River, Edisto	Jason McMasters
russ_creek_complete	Septic tanks near Russell Creek, Edisto	Jason McMasters
toog_complete	Septic tanks near Toogoodoo River, Edisto	Jason McMasters
log_bridge_complete	Septic tanks near Log Bridge Creek, Johns Island	Jason McMasters
stono_complete	Septic tanks near Stono River, Johns Island	Jason McMasters
chas_parcels	Septic tanks in Charleston County near Wando River	Jason McMasters
berk_parcels	Septic tanks in Berkeley County near Wando River	Jason McMasters
Approved_TMDL_sheds	Approved TMDL watersheds, SC	SC DHEC
Approved_TMDL_sites	For SC	SC DHEC
DHEC_303D_08	303(d) List Assessed sations 2008, SC	SC DHEC
swaste	Solid waste landfills, SC	SC DHEC
ust	Underground Storage tanks, SC	SC DHEC

tsd	Hazardous waste – treatment, storage & disposal	SC DHEC
NWI divisions within each County	National Wetlands Inventory (NWI)	SC DNR
imperv_surf	Impervious Surfaces for the U.S.	The Nature Conservancy
sc_FEDERAL_protected_Mar5_2009	Federally protected areas in S.C.	The Nature Conservancy
sc_PRIVATE_protectedMar24_2009	Private protected areas in S.C. (names wiped)	The Nature Conservancy
sc_STATE_protected_Aug7_2008	State protected areas in S.C.	The Nature Conservancy
blocks	Census blocks for S.C.	TIGER/Line
tl_2009_45_unsd	School Districts	TIGER/Line
tl_2008_45015_addr	Berkeley County address ranges	TIGER/Line
tl_2008_45015_areawater	Berkeley County area hydrography	TIGER/Line
tl_2008_45015_cousub00	Berkeley County subdivisions	TIGER/Line
tl_2008_45015_edges	Berkeley County transportation, inland waters, & boundaries	TIGER/Line
tl_2008_45015_facesah	Berkeley County topological faces – area hydrography	TIGER/Line
tl_2008_45015_facesal	Berk. Co. Topological faces – area landmark	TIGER/Line
tl_2008_45015_tabblock00	Berk. Co. Census block	TIGER/Line
tl_2008_45015_tract	Berk. Co. Census tract	TIGER/Line

00		
tl_2008_45019_addr	Charleston County address ranges	TIGER/Line
tl_2008_45019_areawater	Charleston County area hydrography	TIGER/Line
tl_2008_45019_cousub00	Charleston County subdivisions	TIGER/Line
tl_2008_45019_facesah	Chas. Co.Topological faces – area hydrography	TIGER/Line
tl_2008_45019_facesal	Chas. Co. Topological faces – area landmark	TIGER/Line
tl_2008_45019_tabblock00	Chas. Co. Census block	TIGER/Line
tl_2008_45019_tract00	Chas. Co. Census tract	TIGER/Line
tl_2008_45019_vtd00	Chas. Co. voting district	TIGER/Line
tl_2008_45035_addr	Dorchester County address range	TIGER/Line
tl_2008_45035_areawater	Dorch. Co. area hydrography	TIGER/Line
tl_2008_45035_cousub00	Dorch. Co. subdivisions	TIGER/Line
tl_2008_45035_edges	Dorch. Co. transportation, inland waters, & boundaries	TIGER/Line
tl_2008_45035_facesah	Dorch. Co. topological faces – area hydrography	TIGER/Line
tl_2008_45035_facesal	Dorch. Co. topological faces – area landmark	TIGER/Line

tl_2008_45035_tabblock00	Dorch. Co. Census block	TIGER/Line
tl_2008_45035_tract00	Dorch Co. Census tract	TIGER/Line
ua99_d00	Urbanized area	U.S. Census Bureau

Appendix B. Field-based Survey Questions.

Part I – Landscape

1. Do you have a yard at your residence? Yes/No

2. Would you characterize your home location as: Rural/Suburban/Urban

3. How big is your yard? Less than .25 acre/.25-.5 acre/.5-.75 acre/1-3 acres/over 3 acres

4. What % of your landscape (estimate) is grassed lawn? Less than 25% / 25-50% / 50-75% / Over 75%

5. How often do you fertilize every year? Never/ Once/ Two or three times/ more than three times a year/ when it looks like it needs it

6. How do you determine what type and how much fertilizer to use? Label on bag/ Friends, neighbors, or relative's advice/ Lawn care company does it/ Based on soil test and/or Extension Service information/ Home Center or Lawn Store advice/ Other:_____

7. Have you ever had a soil test done for your yard? Yes/No

7a) If yes, how long ago? Less than 1 year/ 1-2 years/ 3-4 years/ more than 5 years ago

8. Do you compost at home? Yes/No

8a) If yes, what do you compost? (circle all that apply) Yard trimmings/ Leaves/ Food wastes/ Manure/ Sawdust/ Paper/ Other:_____

8b) If not, what do you do with your yard waste? Put in trash/ County picks up separately/ Burn/ Mulch/ Other:_____

9. Do you use pesticides on your lawn? Never/ Sometimes/ Regularly/ All the time

9a) If yes, what types? (circle all that apply) Herbicides/ Insecticides/ Fungicides/ Other

9b) If you use pesticides, is it normally a result of: dealing with a problem/ preventing a problem

10. How do you determine what type and how much pesticide to use? Label on bag/ Friends, neighbors, or relatives advice/ Lawn care company does it/ Based on extension Service recommendations/ Home center or lawn store advice/
Other:_____

11. Have you ever heard of native species plants? Yes/No

11a) If YES, do you use them in your home landscape? Yes/No

11b) Why or why not?

12. Have you ever heard of rain gardens? Yes/No

12a) If YES, did you install one at your home? Yes/No

12b) Why or Why not?

13. Have you ever heard of rain barrels? Yes/No

13a) If YES, did you install one at your home? Yes/No

13b) Why or why not?

Part II – Water

14. Do you think what people do on land affects bodies of water? Yes/No/Don't know

15. Have you heard of the term, "watershed"? Yes/No

16. Do you know what a watershed is? Yes/No

17. Do you think that most storm water runoff is treated? Yes/No/Don't know

18. Do you think urban areas/ cities cause more water pollution than industries? Yes/No/Don't know

19. Do you think shrubs and trees protect water quality? Yes/No/Don't know

20. Do you think pesticides and fertilizers are sources of pollution in water bodies? Yes/No/Don't know

21. Do you think pet waste is a source of pollution in water bodies? Yes/No/Don't know

22. Do you own a dog? Yes/No

22a) If YES, do you pick up and dispose of their waste? Yes/No/Sometimes

22b) If not, why?_____

22c) If not, would you be more likely to pick up pet waste if: more convenient/ ordinance required/ neighbor complaints/ better methods

23. Do you think faulty septic systems cause pollution to water bodies? Yes/No/Don't know

24. Is your home served by a septic system? Yes/No/Don't know

24a) If YES, when was the last time it was inspected (years)? Less than a year/ 1-2 years/ 3-5 years/ 6 or more years

25. Do you think household chemicals (paints/paint thinners, cleaners, pesticides) are sources of pollution in water bodies? Yes/No/Don't know

26. How do you dispose of household chemical containers? Put them in trash/ Pour down the drain/ Pour on the ground/ Pour n a ditch/ Pour down storm drain/ Use them until finished/ Take to landfills hazardous waste disposal