

**Assessment of Land Use Change and Riparian Zone Status in
the Barnegat Bay and Little Egg Harbor Watershed:
1995-2002-2006**



Intact forested riparian zone along the upper reaches of the Forked River.

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Executive Summary

The Barnegat Bay/Little Egg Harbor (BB/LEH) estuary is suffering from eutrophication issues due to nutrient, most importantly nitrogen, loading from both atmospheric as well as watershed sources (Kennish et al, 2007). Urban and agricultural land uses can be an important source of nitrogen loading. As part of our ongoing monitoring efforts, the Grant F. Walton Center for Remote Sensing & Spatial Analysis, with funding provided by the Barnegat Bay National Estuary Program, undertook to map and assess recent land use change in the Barnegat Bay-Little Egg Harbor watershed. Our updated mapping reveals that urban land use increased from approximately 25% in 1995 to approximately 30% of the BB/LEH watershed in 2006. Including all altered land uses (i.e., agriculture and barren lands) puts the percentage of altered land in the BB-LEH watershed at over 33% in 2006. The BB/LEH estuary system is continuing to experience a significant conversion of forested and wetland habitats to urban land cover and thereby exacerbating nutrient loading to the BB-LEH estuary.

The riparian zone is defined as those areas that are adjacent or hydrologically connected to the surface water network (e.g., streams, rivers, lakes or reservoirs). Riparian zones may constitute the immediate upland buffer to a stream as well as areas that may be more physically distant but are hydrologically connected through groundwater flow (e.g., hydric soils or wetlands that are in close proximity to a stream). Protected riparian buffer zones adjacent to water bodies and streams, where human development and agriculture is excluded or minimized is advocated as a “best management practice” to reduce the impact of human developed land uses on adjacent aquatic ecosystems and downstream water quality. As outlined in Action Item 6.1 of the Barnegat Bay Estuary Program Comprehensive Conservation and Management Plan (Barnegat Bay Estuary Program, 2000), “a re-examination of the current condition of riparian buffers and strategic measures to ensure their protection are vital to meeting the goals of water quality and habitat protection within the Barnegat Bay watershed.” The objective of this study was to address this action item.

This assessment shows that development of riparian buffer zones continues with a total 1,920 acres of riparian habitat converted to urban areas between 1995 and 2006. The sub-basins draining to the northern portion of BB/LEH estuary (i.e., the Metedeconk, Beaver Dam, Kettle Creek and Silver Bay sub-basins) have riparian zones that are significantly compromised with > 20% riparian zones in altered land use. We have identified approximately 1,300 acres of barren land and 677 acres of agricultural land within the mapped riparian zones that could serve as potential targets for revegetation and restoration. Over 600 acres or approximately one third of the area identified above as of potentially restorable land is located in the highest priority sub-basins that have the highest percentage of altered riparian zones. Additional work is needed to translate the results of this assessment to refine and prioritize a site-level portfolio of possible restoration targets.

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Introduction

The Barnegat Bay/Little Egg Harbor (BB/LEH) estuary has experienced a number of environmental issues suggesting that this estuarine system is suffering from eutrophication issues due to nutrient, most importantly nitrogen, loading (Kennish et al., 2007). These indications include

- A seventy six percent loss of hard clam stock in Little Egg Harbor between 1986 and 2001 (Celestino et al., 2003);
- Recurring blooms of the algae species *Aureococcus anophagefferens* from 2001 to 2003 (Gastrich et al., 2003);
- Increasing amounts of macro algae covering seagrass habitat (Kennish et al., 2006); and,
- Loss of sixty to eighty percent of seagrass biomass from 2004 to 2006 (Kennish et al., 2006).

While substantial amounts of nitrogen originate from direct atmospheric deposition and groundwater discharge, the majority of the load is from surface water inflow from the BB/LEH watershed (Kennish et al., 2007; Hunchak-Kariouk and Nicholson, 2001). Zampella et al. (2006) found as the percentage of altered land increased in Barnegat Bay watersheds, that nitrite plus nitrate concentration of surface waters measured at stream monitoring sites increased. As of 1995 the Barnegat Bay watershed contained 25% altered land while a further 27% percent of the landscape remains potentially developable in the future given current land use zoning (Lathrop and Conway, 2005). It is clear that nutrient loading from urban and agricultural and land uses in the BB/LEH watershed represents a major contributor of nitrogen to the bay system and that it may be expected to continue to increase into the foreseeable future.

One partial remedy for BB/LEH's eutrophication issues is a major reduction in the export of nitrogen from BB/LEH's watershed. Protected buffer zones adjacent to water bodies and streams, often referred to as riparian zones, where human development and agriculture is excluded or minimized is a "best management practice" often advocated as a means to reduce the impact of human developed land uses on adjacent aquatic ecosystems and downstream water quality (NJDEP, 1999; NRC, 2002; Mayer et al. 2005). However, previous work by Lathrop and Bognar (2001) has shown that a significant portion of the BB/LEH's riparian buffer zones were compromised by altered land uses. Some of the more developed watersheds had upwards of 50% of the riparian buffer zone (defined as a 90m buffer zone around all freshwater streams and rivers) in altered land use. This report updates this previous work and discusses the results of a study conducted by the Grant F. Walton Center for Remote Sensing & Spatial Analysis of Rutgers University to map land use change in the BB/LEH watershed between the years of 1995, 2002 to 2006 and assess the present status of the BB/LEH's riparian areas.

Background on the Role of Riparian Areas

The riparian zone is defined as those areas that are adjacent or hydrologically connected to the surface water network (e.g., streams, rivers, lakes or reservoirs). Riparian zones may constitute the immediate upland buffer to a stream as well as areas that may be more physically distant but are hydrologically connected through groundwater flow (e.g., hydric soils or wetlands that are in close proximity to a stream). The Barnegat Bay watershed is located in the Pinelands of New Jersey's Outer Coastal Plain and sits atop the Kirkwood-Cohansey aquifer system. This unconfined aquifer system exerts a critical influence on the hydrology of the Barnegat Bay drainage system with a majority of the runoff moving through the shallow groundwater system, rather than overland sheet flow (Modica et al., 1998; Hunchak-Kariouk and Nicholson, 2001). Rhodehamel (1979) estimated that groundwater discharge accounts for approximately 90% of annual stream discharge in undeveloped Pinelands watersheds. Depending on site-specific conditions of geology and seasonal water table, this shallow groundwater system may discharge directly to the stream and/or the adjacent riparian zone (Johnsson and Barringer, 1993).

Where the groundwater table is at or near the surface, the riparian zone soils and vegetation is effective in removing nutrients from the discharging groundwater (Peterjohn and Correll, 1984; Kauffman et al., 2001). Mayer et al. (2005) in their review of the current science found that while nitrogen removal effectiveness varied, riparian buffers were effective at removing large proportions of the nitrogen found flowing through riparian ecosystems. They found that wider buffers were more effective than narrow buffers with 90% removal efficiencies occurring in buffers of 112 m wide. The critical nutrient nitrogen is attenuated through plant uptake, microbial immobilization and denitrification, and soil storage (NRC, 2002), reducing the impacts of downstream eutrophication. The conversion of biologically available nitrite and nitrate into the much more biologically inert nitrogen gas, known as denitrification, is mediated by heterotrophic bacteria in the oxygen poor conditions of saturated wetland soils. Vegetation in riparian zones help to trap sediment particulates carried in surface runoff before they reach the stream and are transported to downstream rivers and eventually coastal estuaries (Correll, 1996; Lowrance et al. 1997). Riparian zones are also critically important during periods of high rainfall providing stability to stream banks through vegetation and plant roots, and slowing down the amount of water running into streams and river from adjacent upland areas (Welsch, 1991). Streamside vegetation also helps to shade the stream lowering water temperatures.

Through all of the above mentioned reasons riparian zones in some form of natural vegetation provide valuable ecological services by helping to ameliorate the effects of upland land use alteration by reducing the export of sediments, pollutants, and nutrients to downstream water bodies. Excluding conflicting human land use activities as well as maintaining streamside riparian areas in natural vegetation are widely advocated as a best management practice for maintaining the quality of water resources in adjacent stream systems as well as to downstream coastal estuaries (Welsch, 1991; NJDEP, 1999; NRC, 2002). In addition, riparian buffers in natural vegetation provides vital habitat for both

upland and wetland-dependent wildlife and plant species and serve as movement corridors connecting the upland watershed and the downstream estuary.

Objectives

The specific objectives of this study are to:

- map and assess developed land use change for the years 1995, 2002 and 2006;
- map BB/LEH riparian zones based on hydric soils, wetlands and floodplains, as well as a simple 300 foot buffer from all rivers and streams;
- determine the percentage of the riparian zones in altered land use as of 2002 and 2006;
- assess the trends in riparian zone alteration and map areas of greatest change at a sub-watershed scale;
- identify those sub-watersheds and riparian corridors that should be priority targets for restoration.

Methods

Mapping Land Use Change

Altered land use was defined as all urban, agriculture and barren land uses as determined using the New Jersey Department of Environmental Protection (NJDEP) land use/land cover dataset for 1995 and 2002. The 2006 land use/land cover dataset was created at the Center for Remote Sensing and Spatial Analysis, Rutgers University. 2006 leaf-on natural color digital orthophotographic images acquired by the USDA-FSA Aerial Photography Field Office at a scale of 1:40,000 (1-meter resolution pixels) provided the basis for the 2006 land use mapping. The 2006 imagery was visually interpreted on screen, 2002 land use mapped data displayed as a graphic overlay and areas that have experienced land use change between 2002 and 2006 were digitized. Not all land use changes were noted but rather those that went from natural vegetation to some form of altered human land use.

All of the datasets were converted to raster 10 meter cell resolution within the Universal Transverse Mercator projection system using the North American Datum of 1983. The change in land use for the entire BB/LEH watershed area between 1995, 2002, and 2006 was examined.

Defining the riparian zone:

Riparian zones in the study area were mapped based on the hydrologic properties of land cover and soil, as well as probability of inundation. The individual Geographic Information Systems (GIS) thematic maps or coverages were extracted as described below. The components were then combined to create a composite coverage to map the extent of the riparian area. Two different riparian zone GIS coverages were produced: 1) the “full” riparian area based on hydric soils, wetlands and floodplains, hereafter referred to as the riparian zone; and 2) a simple 300 foot buffer from all rivers and streams,

hereafter referred to as the 300 foot buffer zone. This last analysis is more comparable to the approach employed by Lathrop and Bognar (2001) where a 90m (295 foot) buffer out from both sides of all mapped streams and rivers. Salt Marsh, open estuary, and barrier island areas were excluded from all of this analysis as the focus is on upstream riparian zones (Figure 1).

The following existing digital GIS data sets were used to map the individual possible parameters:

A. Flood prone areas

1. NJDEP *floodprone*

- a) "USGS Documented Floodprone Area"
- b) "Undocumented Floodprone Area"

Source: NJDEP *floodprone* coverage (derived from USGS 100-year floodplain coverage). NJDEP GIS CD-ROM Series 1, Bureau of Geographic Information and Analysis (CD-ROM date: January 1, 1996)

The flood-prone areas have been delineated through the use of readily available information on past floods rather than from detailed surveys and inspections. In general, the delineated areas are for natural conditions and do not take into consideration the possible effects of existing or proposed flood control structures except where those effects could be evaluated. Flood areas have been identified for: (1) urban areas where the upstream drainage basin exceeds 25 square miles, (2) rural areas in humid regions where the upstream drainage basin exceeds 100 square miles, (3) rural areas where in semiarid regions where the upstream drainage basin exceeds 250 square miles, and (4) smaller drainage basins, depending on topography and potential use of the flood plains.

2. FEMA *Q3 flood* coverage – 100-year floodplain.

- a) "Flood Insurance Risk Zone A" - Areas subject to inundation by the 1-percent-annual-chance flood event. Because detailed hydraulic analyses have not been performed, no base flood elevation or depths are shown. Mandatory flood insurance purchase requirements apply.
- b) "Flood Insurance Risk Zone AE" - Areas subject to inundation by the 1-percent-annual-chance flood event determined by detailed methods. Base flood elevations are shown within these zones. Mandatory flood insurance purchase requirements apply.

Source: FEMA Q3 digital flood data. Disc 18 – New Jersey, Puerto Rico, Virgin Islands. (CD-ROM date: September 1996).

The digital Q3 Flood Data are designed to serve FEMA's needs for disaster response activities, National Flood Insurance Program activities, risk assessment, and floodplain management. The data are expected to be used for a variety of planning applications including broad-based review for floodplain

management, land-use planning, commercial siting analysis, insurance target marketing, natural resource/environmental analyses, and real estate development and targeting.

B. Riparian Soils – based on the Natural Resources Conservation Service (NRCS) *SSURGO* digital soils coverage

1. Hydric soil: partial and full hydric classified soils; as defined in the *SSURGO* HYDCOMP (Hydric component information) soil attribute table.
2. Seasonal depth to high water table less than or equal to 18 inches: as defined in the *SSURGO* HYDCOMP (Hydric component information) soil attribute table.
3. Alluvial soils: soils of alluvial origin as defined through personal communication with Chris Smith of the NJ office of Natural Resources Conservation Service; includes all soils taxonomically classified as fluvents, udifluvents, or fluvaquents.

Source: Natural Resources Conservation Service (NRCS) Soil Survey Geographic (*SSURGO*) produced by the National Cartography and Geospatial Center, U.S. Department of Agriculture, Natural Resources Conservation Service, P.O. Box 6567, Fort Worth, Texas 76115. Downloaded from USDA NRCS Soil Data Mart, URL <http://soildatamart.nrcs.usda.gov/>.

The map extent for Soil Survey Geographic (*SSURGO*) data sets is “soil survey area.” This may consist of a county, multiple counties, or parts of multiple counties in any given area. *SSURGO* data sets comprise geographic and attribute data, as well as metadata.

Hydric soils were extracted for areas available in *SSURGO* format using the Hydric Class Presence field, [hydclsprs], in the *muaggatt* table. This field shows “(an) indication of the proportion of the map unit, expressed as a class, that is ‘hydric,’ based on the hydric classification of individual map unit components.”¹ Features with [hydclsprs] values of “All hydric” or “Partially hydric” were extracted for riparian area delineation.

Soils with a depth to high water table (DWT) of less than or equal to 18 inches were extracted using the Water Table Depth – Annual – Minimum Field, [wtdepanmin], in the *muaggatt* table. This is defined as “the shallowest depth to a wet soil layer (water table) at any time during the year expressed as centimeters from the soil surface, for components whose composition in the map unit is equal to or exceeds 15%”¹ All features with a [wtdepanmin] value less than or equal to 45.7 cm (approximately 18 inches) were extracted.

For all counties represented in the SSURGO data, alluvial soils were extracted using the Taxonomic Class Field, [taxclname], in the *component* table. This is defined as “a concatenation of the Soil Taxonomy subgroup and family for a soil (long name).”¹ All features that included the fragment “fluv” in the [taxclname] field were extracted to capture fluvents, udifluvents, and fluvaquents as prescribed by NRCS soil scientist, Chris Smith. Alluvial soils were extracted from the ITU data using the [TAXCLASS] field. Features including the following [TAXCLASS] values were extracted: EAQFLMO, IOCDYFL, and IOCEUFL.

C. **Wetlands** – NJDEP 2002 *Land cover*

All wetlands (including *Agricultural Wetlands - Modified*) within 33 feet* of a stream are considered to be hydrologically connected to that stream. They are, therefore, included in the riparian area. All 2002 mapped streams were used for proximity. Some of these mapped stream segments (e.g., drainage ditches) may not be directly connected to the larger stream-river network through mapped surface connections (although there may be unmapped piped connections).

*The 33 foot threshold was used as this distance represents the National Mapping Accuracy Standard for the possible inaccuracy in the spatial location of a mapped feature.

D. **Stream Buffer** – NJDEP 2002 Hydro data

All 2002 mapped streams were included in the analysis. Some of these mapped stream segments (e.g., drainage ditches) may not be directly connected to the larger stream-river network (although, there may be unmapped piped connections). Streams were buffered by 300 feet on either side of the stream bank or centerline where no stream bank data exist (Figure 2).

Original Data Sources:

- 2006 LU data, “CRSSA 2006 Barnegat Bay watershed land use change data”, Center for Remote Sensing & Spatial Analysis, Rutgers University, based on interpretation and mapping of 2006 color aerial photography
- 2002 LU/LC data, “NJDEP 2002 Land Use/Land Cover for New Jersey by Watershed Management Area (WMA)”, New Jersey Department of Environmental Protection, <http://www.state.nj.us/dep/gis/lulc02cshp.html>
- 2002 hydrography data, “NJDEP 2002 Streams for New Jersey” New Jersey Department of Environmental Protection, <http://www.state.nj.us/dep/gis/hydro02shp.html>

- 2002 roads data, “NJDOT 2003 New Jersey Roadway Network”: New Jersey Department of Transportation.
<http://www.state.nj.us/transportation/gis/map.shtm>
- Natural Resources Conservation Service (NRCS) SSURGO soils data
<http://www.ncgc.nrcs.usda.gov/products/datasets/ssurgo/>
- NJDEP *floodprone* coverage (derived from USGS 100-year floodplain coverage). NJDEP GIS CD-ROM Series 1, Bureau of Geographic Information and Analysis (CD-ROM date: January 1, 1996)
- Huc14 watersheds, “NJDEP 14 Digit Hydrologic Unit Code delineations for New Jersey (DEPHUC14)”: New Jersey Department of Environmental Protection, on-line linkage:
<http://www.state.nj.us/dep/gis/digidownload/zips/statewide/dephuc14.zip>

Assessing riparian zone land use alteration

Riparian Areas were binned into sub-basins using the USGS hydrologic unit code GIS data set. These sub-basins were merged to represent major basins which entered the BB/LEH estuary system at single spatial positions. This was done to highlight sub-basins which have highly altered riparian areas (urban + barren + agriculture) and to identify which sub-basins have experienced the largest percent change from natural (forest and wetland) riparian zones to altered riparian zones over the study period. Note that some the BB/LEH watershed was excluded as not representing riparian zones contiguous to a major BB/LEH tributary.

Results and Discussion

Altered land within the larger watershed

The land use/land cover as of 2006 is displayed in Figure 3. The land use analysis within the entire watershed shows an increase of 11,127 acres of urban area between 1995 and 2002 (Table 1a & Figure 3). This equates to a rate of change of 1,590 acres per year between the years of 1995 and 2002. This trend continued, albeit at a slower pace between 2002 and 2006 with an increase of 4,368 acres of urban land, equating to a rate of change of 1,092 acres per year of new urban land. The percent of the watershed (excluding water) that is mapped as urban land use increased from 25.1% in 1995 to 28.4% in 2002 to 29.8% in 2006. Note that these percentage amounts are somewhat different than the percent developed land cover amounts quoted in Lathrop and Bognar (2001) or the 2005 State of the Bay Report (Barnegat Bay National Estuary Program, 2005). The difference between the land use and land cover amounts are due to differenced in definitions and the mapping techniques employed.

Forested land cover declined by 9,241 acres during the 1995 to 2002 time period and 4,753 acres during the 2002 to 2006 time period for a total decline of approximately 13,994 acres (Table 1a). Examination of the from-to category transitions shows that the decline of forest land cover (approximately 13,278 acres) is largely attributable to clearing and development of new urban land (Table 1b). Over 1,000 acres of wetland were also subject to urban land conversion during this same 1995 to 2000 time period (Table 1b). Table 1b also shows that barren land areas have transitioned into forest, while other forest areas have been converted to barren (i.e., through surface mining activities of transitional to future development) for a net loss of 970 acres.

It should be noted that there are differences in the land cover mapping imagery and methodologies employed in the three different time periods: 1995, 2002, 2006. These differences in methods result in a small but unquantified differences in the areal coverages of the different land cover categories. In other words, a very small percentage of the time period to time period differences are artifacts of the mapping process, rather than real on-the-ground change. However, the overall trends are unequivocal: increasing urban land; decreasing forest, agriculture and wetlands.

Altered land in Riparian Zones between 1995, 2002, and 2006

Riparian areas within the BB/LEH estuary experienced moderate change in altered land use over the 1995, 2002 to 2006 study periods (Table 2a). Between 1995 and 2002 a total of 625 acres were converted from riparian forested land and 373 acres were converted from wetland areas to some form of human altered land use. In total 1,290 acres of riparian habitat were converted to urban areas between 1995 and 2002. This represents roughly 1 percent of the total riparian areas for the entire watershed for this 7 year period or approximately 184 acres per year. Between 2002 and 2006 a further 425 acres of forested areas and 205 acres of wetland habitat (or a total of 630 acres) were converted to some form of altered land use. This represents a slight decrease in the rate of conversion of natural riparian habitat between 1995-2002 and 2002-2006 from 184 to 158 acres per year. Urban land accounted for a majority of the altered land use change in both time periods (Table 2b).

The percentage of the riparian zone in altered land use (urban, agriculture and barren land) in 2006 was determined for the twelve major basins in the BB-LEH watershed (Table 3). The percentage of altered land ranged from a low of 4% in the Cedar Creek basin to a high of 50 percent altered in Kettle Creek. Generally the northern part of the watershed had a larger percentage of altered riparian habitat *vis a vis* the southern part of the watershed (Figure 4). On a percentage change basis, the Tuckerton Creek, Beaverdam Creek and Metedeconk River basins showed the greatest change with between 3 and 4% increase in altered riparian land over the 1995 to 2006 time period (Table 3). While the Toms River watershed had the greatest absolute change with approximately 425 acres altered, due to its larger size, the percent change was lower. Cedar Creek actually had a decrease in altered riparian habitat as areas classified as barren in 1995 were reclassified as forest areas in 2002.

Altered land in the 300 foot Buffer Zone

The land use analysis within the 300 foot river/stream/lake buffer zone closely mirrors the riparian zone analysis above. Approximately, 122 acres of wetland and 465 acres of forested land (for a total of 587 acres) were converted to human altered land use between 1995 and 2002 (Table 4). These trends were continued at a slower pace into the 2002-2006 time period with a conversion of 61 acres of wetland habitat and 309 acres of forested habitat (for a total of 370 acres). Urban land accounted for a majority of the altered land use change in both time periods. This 300 foot stream buffer analysis is more comparable to the approach employed by Lathrop and Bognar (2001) where a 90m (295 foot) buffer out from both sides of all mapped streams and rivers, though in this case only the upland portions of the watershed were assessed (i.e., sub-basin areas that drained primarily the bay's wetland fringe or barrier islands were excluded).

Identifying potential restoration targets

Existing agricultural and barren lands within riparian zones were identified as potential targets for revegetation and the restoration of beneficial ecological functions. Approximately, 1,294 acres of barren land and 677 acres of agricultural land within the riparian zones were identified in 2006 (Table 2) (Figure 5). Further examination of the most highly developed sub-basins draining the northern portion of the Barnegat Bay watershed (i.e., the Metedeconk, Beaver Dam, Kettle Creek, and Silver Bay sub-basins), reveals that there are approximately 371 acres of agricultural land and 264 acres of barren land that could be restored in these high priority sub-basins.

Summary and Policy Recommendations

Our updated mapping of 2006 land use reveals that the BB/LEH estuary system is continuing to experience a significant conversion of forested and wetland habitats to urban land cover. Urban land use area increased by over 18% from approximately 25% (87,757 acres) in 1995 to approximately 30% (103,746 acres) of the BB/LEH watershed in 2006. Including all altered land uses (i.e. agriculture and barren lands) puts the percentage of altered land in the BB-LEH watershed at over 33% in 2006. The rate of conversion of forest, farm and wetland to urban land use has slowed from approximately 1,590 acres per year between 1995 and 2002 to 1,092 acres per year between 2002 and 2006. According to urban buildout modeling based on current zoning laws undertaken by Conway and Lathrop (2005), the BB-LEH watershed could reach significantly higher levels of urbanization to over 50% of the watershed at a future date.

The continued urbanization of the BB/LEH watershed puts greater importance on the ecosystem services provided by intact riparian zones in natural vegetation rather than in altered land uses. As outlined in Action Item 6.1 of the Barnegat Bay Estuary Program Comprehensive Conservation and Management Plan (Barnegat Bay Estuary Program, 2000), "a re-examination of the current condition of riparian buffers and strategic measures to ensure their protection are vital to meeting the goals of water quality and habitat protection within the Barnegat Bay watershed." Our assessment shows that

development of riparian buffer zones continues (for example, see Figure 6) with a total 1,920 acres of riparian habitat converted to urban areas between 1995 and 2006. The sub-basins draining to the northern portion of BB/LEH estuary (i.e., the Metedeconk, Beaver Dam, Kettle Creek and Silver Bay sub-basins) have riparian zones that are significantly compromised with > 20% riparian zones in altered land use. The future ecological health of the downstream estuary system increasingly relies on the ability of upstream riparian zones to ameliorate a continually urbanizing watershed.

To halt if not reverse this trend, future development of riparian zones should be severely curtailed and riparian zones that have already impacted should be considered for some level of restoration where feasible. Intact riparian zones that are presently in forest or wetland vegetation (for example, see Figure 7) should receive high priority in conservation planning and open space preservation. To help reduce the input of nitrogen to the downstream estuary, restoration of select riparian areas adjacent to areas of intensive agriculture, managed lawns and other residential/commercial development (i.e., sources of nitrogen) would potentially have the greatest impact. However, due to the existing development and land use pattern (for example, see Figure 8), such a program will require education and working one-on-one with the multitude of private land owners. Another approach is to identify larger tracts of land that are not presently developed and that could be targeted for re-vegetation and restoration. Along these lines, we have identified approximately 1,300 acres of barren land and 677 acres of agricultural land within the riparian zones that could serve as restoration targets. Over 600 acres or approximately one third of the area identified above as of potentially restorable land is located in the highest priority sub-basins that have the highest percentage of altered riparian zones. A more detailed map of possible restoration sites is located online at <http://crssa.rutgers.edu/projects/coastal/riparian/>. Additional work is needed to translate the results of this assessment to refine and prioritize a site-level portfolio of possible restoration targets.

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Tables

Table 1a. Entire Study area compared with land use land cover from 1995, 2002, and 2006 total area was slightly different between years due to the fact water was excluded from the analysis .

| Type | 1995 acres | 2002 acres | 2006 acres | Net change 95-02 | Annual Net change 95-02 | Net Change 02-06 | Annual Net Change 02-06 |
|--------------------|---------------|------------|---------------|------------------------|----------------------------------|------------------------|----------------------------------|
| Urban | 87,757 | 99,308 | 103,746 | +11,551 | +1,650 | +4,438 | +1,109 |
| Agriculture | 5,302 | 4,576 | 4,205 | -726 | -104 | -371 | -93 |
| Barren | 9,199 | 8,935 | 9,034 | -264 | -38 | 99 | 25 |
| Forest | 156,827 | 147,401 | 142,579 | -9,425 | -1,346 | -4,822 | -1,206 |
| Wetland | 90,165 | 89,325 | 89,048 | -841 | -120 | -277 | -69 |
| Water | 158,727 | 158,432 | 159,365 | -295 | -42 | +933 | +233 |

Table 1b. Transition Table for Entire Study area between 1995 and 2006.

| | | 2006 Land Cover | | | | |
|--------------------------------|-------------|------------------------|-------------|--------|---------|---------|
| | | Urban | Agriculture | Barren | Forest | Wetland |
| 1995 Land Cover | Urban | 86,606 | 102 | 151 | 569 | 19 |
| | Agriculture | 215 | 950 | 43 | 110 | 2 |
| | Barren | 1,761 | 25 | 5,647 | 1,201 | 202 |
| | Forest | 13,278 | 246 | 2,171 | 140,535 | 64 |
| | Wetland | 1,012 | 32 | 179 | 51 | 88,594 |

Table 2a. Riparian Zones compared with land use land cover from 1995, 2002, and 2006 total Riparian area was slightly different between years due to the fact water was excluded from the analysis .

| Type | 1995 acres | 2002 acres | 2006 acres | Net change 95-02 | Annual Net change 95-02 | Net Change 02-06 | Annual Net Change 02-06 |
|-------------|------------|------------|------------|------------------|-------------------------|------------------|-------------------------|
| Urban | 11,587 | 12,877 | 13,239 | +1,290 | +184 | +362 | +91 |
| Agriculture | 781 | 712 | 677 | -69 | -10 | -35 | -9 |
| Barren | 1,406 | 1,263 | 1,294 | -143 | -20 | 31 | 8 |
| Forest | 30,711 | 30,086 | 29,661 | -625 | -89 | -425 | -106 |
| Wetland | 53,330 | 52,957 | 52,752 | -373 | -53 | -205 | -51 |

Table 2b. Transition Table for Riparian Areas between 1995 and 2006.

| | | 2006 Land Cover | | | | |
|------------------------|-------------|------------------------|-------------|------------|--------|---------|
| | | Urban | Agriculture | Barren | Forest | Wetland |
| 1995 Land Cover | Urban | 11,329 | 9 | 16 | 130 | 9 |
| | Agriculture | 100 | 615 | 22 | 32 | 2 |
| | Barren | 177 | 2 | 903 | 246 | 1 |
| | Forest | 1,097 | 26 | 228 | 29,228 | 30 |
| | Wetland | 524 | 26 | 86 | 21 | 52,594 |
| | | | | | | |

Table 3. Riparian Zones percent altered and percent change between 1995 and 2006 by sub-watershed (arranged north to south).

| Basin Name | Percent of Riparian Zone in Altered Land Use (urban + barren + agriculture) 2006 | Acres of Riparian zone converted to altered land use: 1995-2006 (percent of total riparian areas) |
|-------------------|---|--|
| Beaver Dam | 27% | 346 (3%) |
| Toms River | 13% | 425 (1%) |
| Metedeconk River | 24% | 348 (3%) |
| Kettle Creek | 50% | 13 (<1%) |
| Silver Bay | 27% | 22 (2%) |
| Cedar Creek | 4% | -22 (>-1%) |
| Forked River | 12% | 27 (<1%) |
| Oyster Creek | 4% | 5 (<1%) |
| Mill Creek | 15% | 15 (<1%) |
| Cedar Run | 6% | 12 (1%) |
| Westecunk Creek | 4% | 6 (<1%) |
| Tuckerton Creek | 15% | 61 (4%) |

Table 4. Stream buffer 300 feet zones compared with land use land cover from 1995, 2002, and 2006.

| Type | 1995 acres | 2002 acres | 2006 acres | Net change 95-02 | Annual Net change 95-02 | Net Change 02-06 | Annual Net Change 02-06 |
|-------------|------------|------------|------------|------------------|-------------------------|------------------|-------------------------|
| Urban | 6,596 | 7,362 | 7,583 | +766 | +109 | +221 | +55 |
| Agriculture | 533 | 468 | 429 | -65 | -9 | -39 | -10 |
| Barren | 540 | 488 | 491 | -52 | -7 | 3 | 1 |
| Forest | 20,379 | 19,914 | 19,605 | -465 | -66 | -309 | -77 |
| Wetland | 30,203 | 30,081 | 30,020 | -122 | -17 | -61 | -15 |

Riparian Zones of the Barnegat Bay Watershed

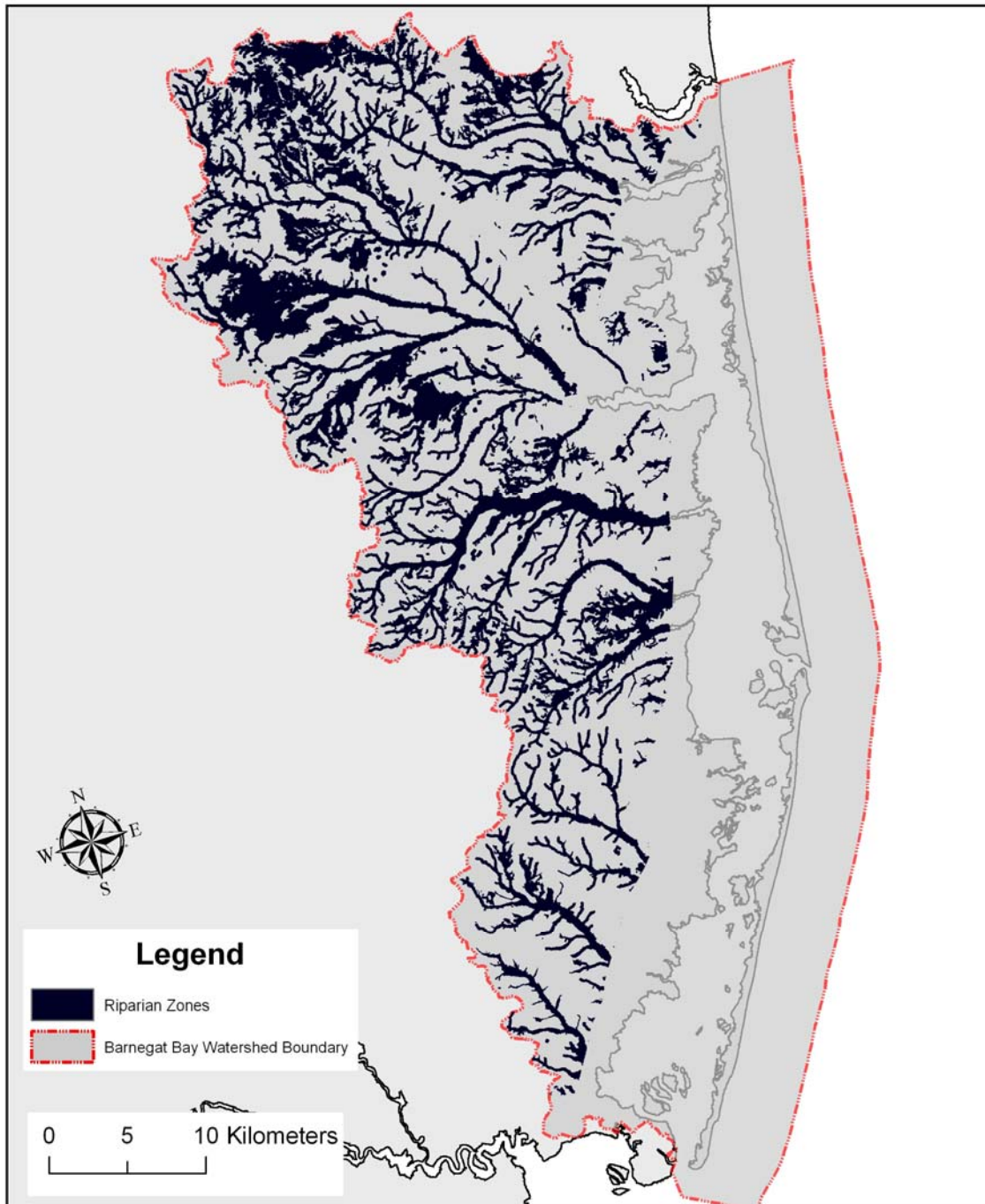


Figure 1. Map of watershed riparian zones along the freshwater tributaries to Barnegat Bay-Little Egg Harbor.

300 foot stream buffers in the Barnegat Bay Watershed

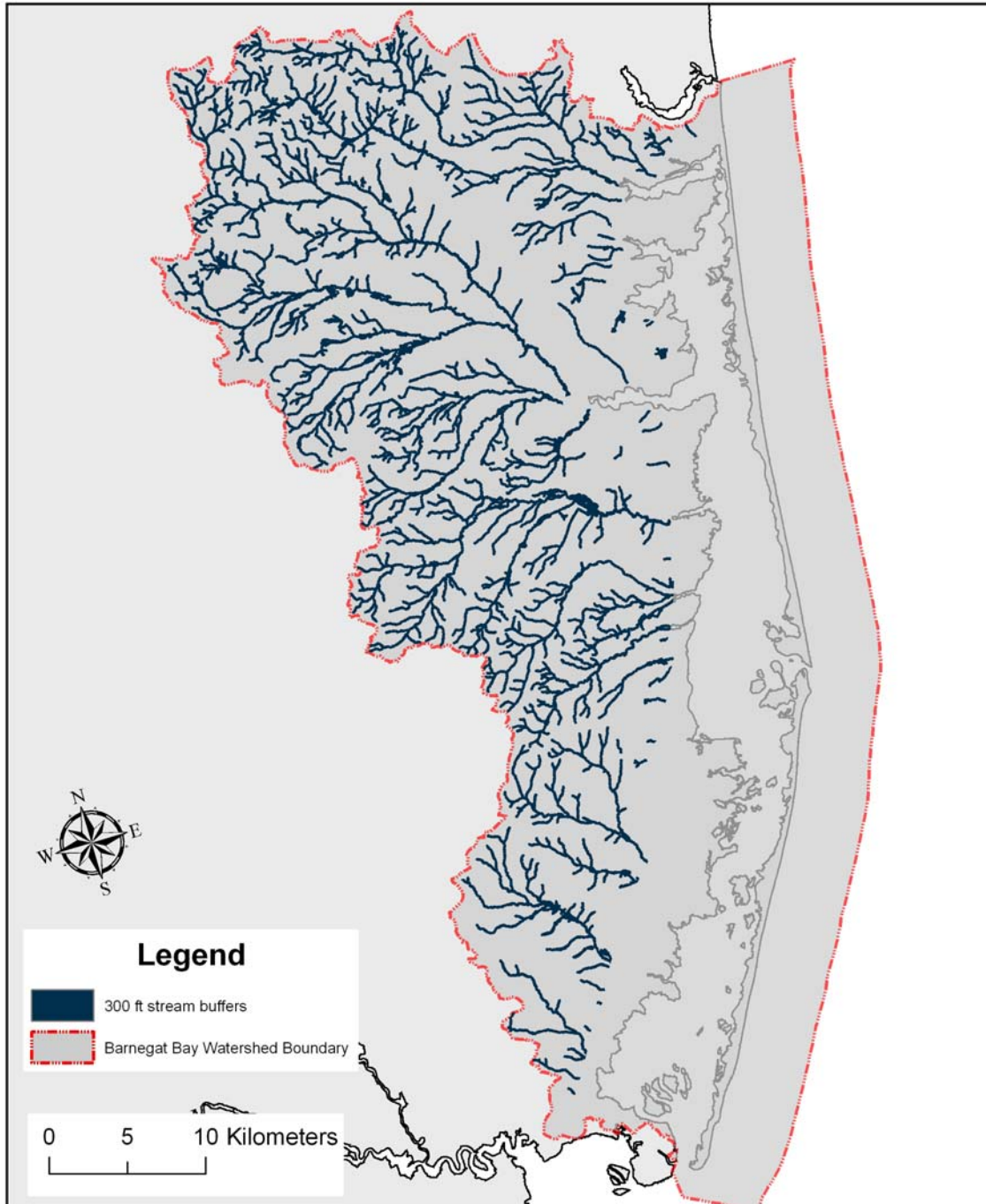


Figure 2. Map of 300 foot buffer zones along the freshwater tributaries to Barnegat Bay-Little Egg Harbor.

2006 Land Cover for the Barnegat Bay Watershed

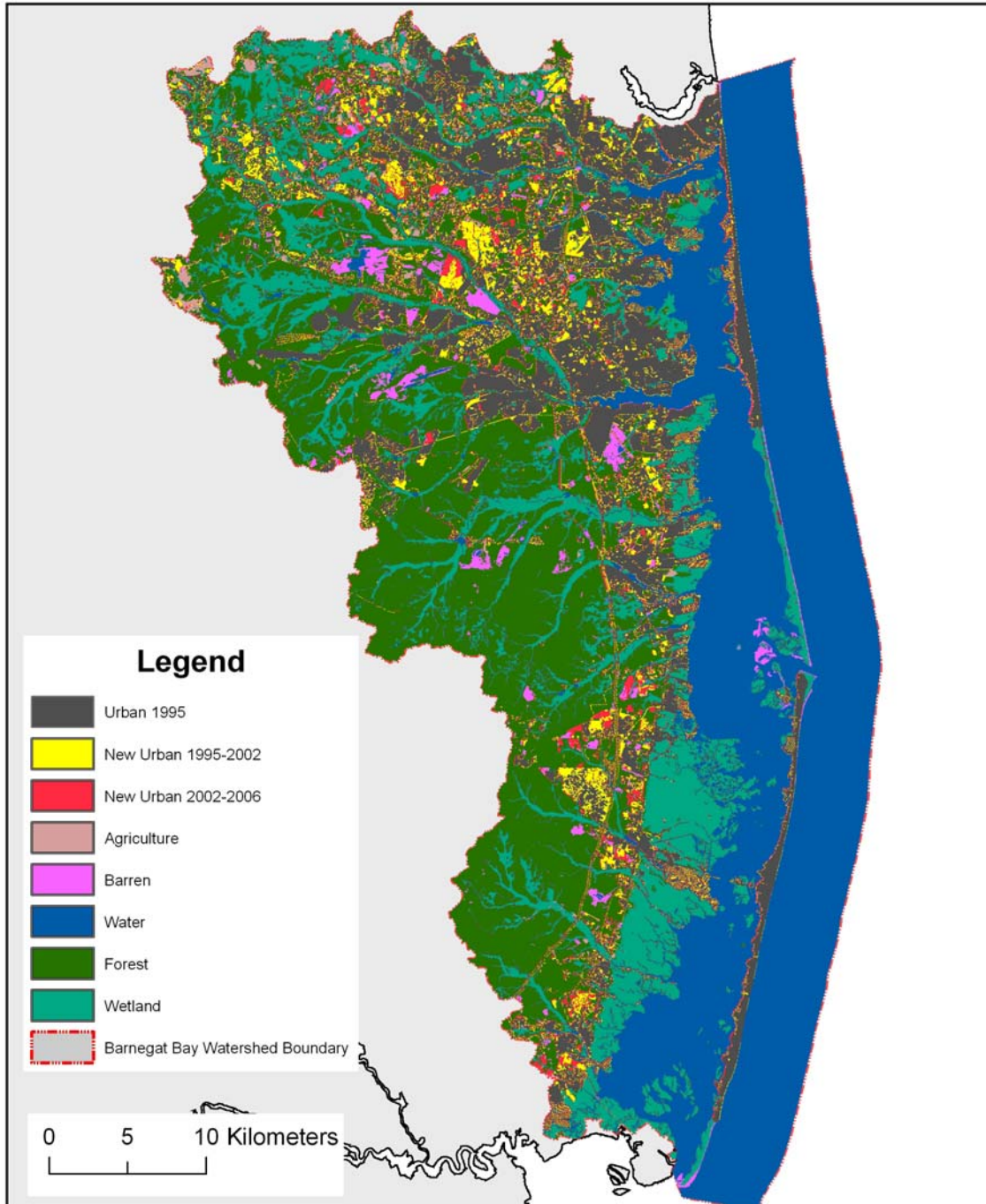


Figure 3. Map of the Barnegat Bay – Little Egg Harbor watershed land use/land cover and highlighting new urban development between the years 1995 - 2002 and 2002-2006.

Percent Altered Riparian Zones

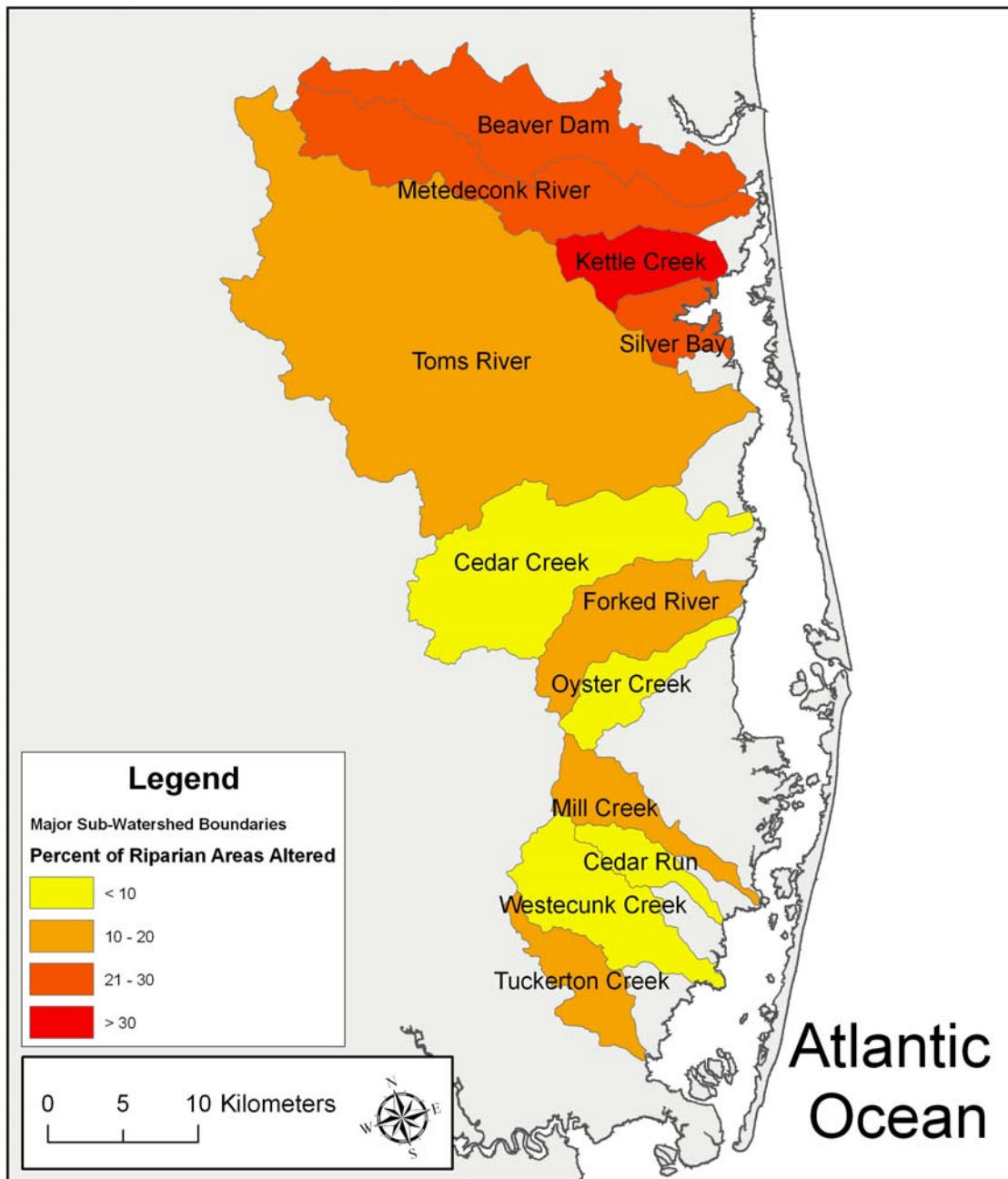


Figure 4. Percent of riparian zones in altered land use by major sub-watershed in the Barnegat Bay-Little Egg harbor watershed. Note that some sub-basins that drain primarily the BB-LEH's wetland fringe (i.e., did not include substantial amounts of upland watershed) were excluded, e.g., Potter's and Stout's Creeks and a portion of the Oyster Creek drainage, as well as the barrier islands.

Barren and Agricultural land overlaid with Riparian Zones

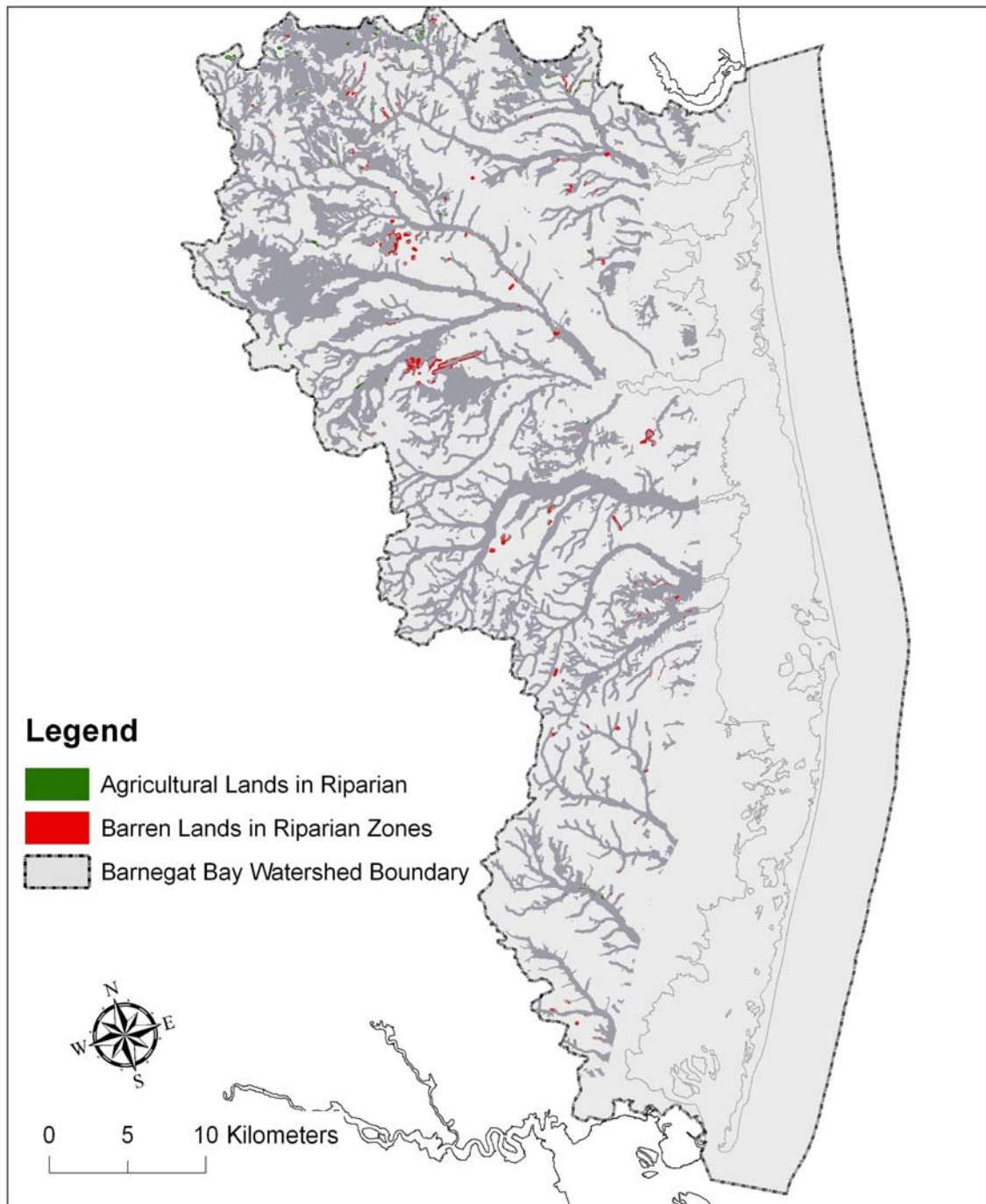


Figure 5. Map showing location of possible restoration targets (in red), i.e., where there is presently unvegetated barren land within riparian zones (in gray).



Figure 6.
Example of new urban development in the riparian buffer zone adjacent to the Long Swamp Creek. Photo 2007.



Figure 7.
Example of forested riparian buffer in the headwaters of Long Swamp Creek.
Photo 2007.



Figure 8.
Example of urban residential development in the riparian buffer zone adjacent to the Long Swamp Creek. Photo 2007.