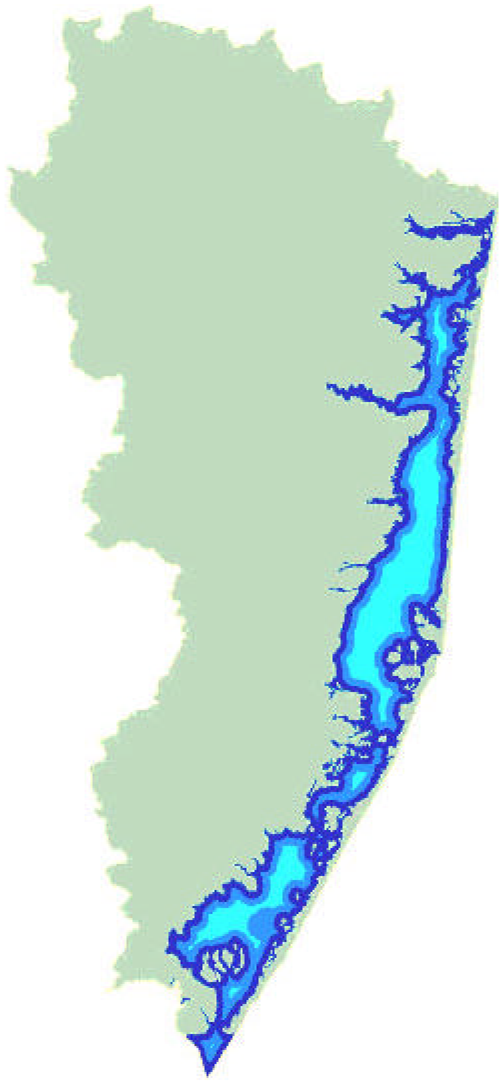
A Build-out Analysis of the Barnegat Bay Watershed



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Introduction

As part of the National Estuary Program, the Barnegat Bay region has been the focus of an ambitious scientific characterization and data synthesis process. This effort has recently culminated in the development a Comprehensive Conservation and Management Plan (CCMP) for the bay and its watershed (Barnegat Bay Estuary Program, 2000a). The goal of the CCMP is to balance the competing demands of human uses of the region while promoting the long term sustainability of the bay and its diverse natural resources. In implementing the CCMP and targeting conservation efforts, a prospective look at future development patterns was deemed necessary. In response, we have completed a build-out analysis of the watershed. A build-out analysis maps the expected location of future development and estimates the number of new dwelling units when all land available for development is developed at the highest intensities possible. However, a build-out analysis does not project when build-out will occur. A build-out analysis is useful in long-term planning efforts as a way to understand the potential future growth. The goal of this Barnegat Bay watershed build-out study is to provide information to local decision-makers on the scope and magnitude of future development patterns based on several different scenarios of zoning and land use management policies.

In this study, we use the number of dwelling units, population, and percent of impervious surface cover as ways to quantify the amount of development possible at build-out. The number of dwelling units and population are indicators of residential water demand, while impervious surface is an indicator of non-point source pollution. By understanding the potential changes of these indicators, we can better identify actions needed to protect the resource in the Barnegat Bay.

Methods to Create Build-out Scenarios

We created the build-out model using a Geographic Information System. This is a computer based tool used to manage, manipulate, and analyze digital data. The approach allowed us to create a spatially explicit model so we could examine potential changes in specific areas of the watershed.

The first step in creating the build-out model was identifying land that is available for development. Already developed areas, permanently protected open space, and land that is undevelopable for environmental reasons (e.g., consists of wetlands or adjacent buffer lands) were excluded from this category. The remaining land in the watershed was deemed available for development (Figure 1). The next step was to identify the type of development that could occur on the available land. Municipal zoning

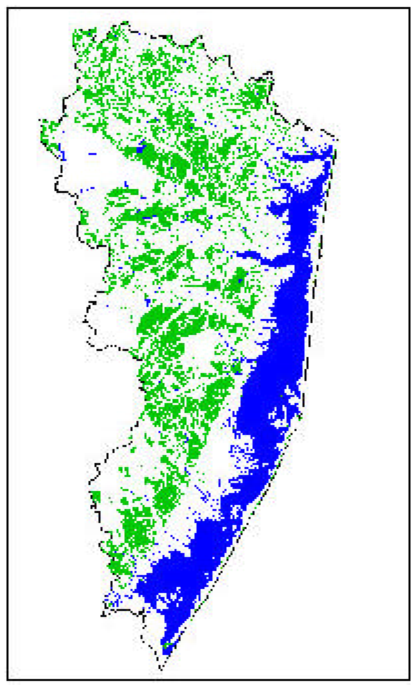

Figure 1. Land available for development.

regulation and the Pinelands Comprehensive Management Plan were used to determine potential future land uses. Sewer service areas were included in the analysis, as lower development densities are often required in places that do not have sewer service. Once the potential land uses of the developable areas were determined, we were able to map potential land uses at build-out.

Three build-out scenarios were considered:

1. Baseline: This is based on current regulations, with down zoning to 3.2 ac outside sewer service areas. We believe this is the most likely prediction of future build-out. The 3.2 acre figure was derived as an average of the existing zoning regulations for non-sewered areas in the Pinelands Reserve and other Ocean County municipalities.

2. No down zoning: This scenarios is based on current regulations but with no down zoning outside sewer service areas.

3. Century Plan Implemented: This scenarios is based on current regulations with down zoning outside sewer service areas to 3.2 ac. Under this scenario, the tracts of land the Trust for Public Land identified in the Century Plan (Blanchard, 1997; Blanchard and Herpetological Associates, 1995) as important to protect as open space are removed from future development.

Indicators Used to Determine Potential Impacts of Build-out

<u>Dwelling Unit and Population Increase</u>

The population living in the watershed will increase as more areas in the watershed are developed. A growing population can negatively impact the regions water resources as a larger population requires a larger supply of freshwater. At present, increase in water demand has lowered the aquifers under the watershed, leading to saltwater intrusion from the Barnegat Bay in certain locations (Barnegat Bay Estuary Program, 2000b). This salt water intrusion threatens the freshwater supply, while potentially negatively impacting the watershed's biological resources. If the population continues to increase, the demand for potable freshwater could exceed the sustainable supply. Thus, it is important to understand the potential size of the population at build-out.

To estimate the increase in population in the watershed we began by estimating the number of new dwelling units. For each patch of land available for development, the number of new dwelling units was calculated by determining the number of units that could be built on that patch based on the minimum lot size requirements for the area as specified in the existing zoning maps. As new development requires public infrastructure (roads, new schools, etc.) we used the 80-20 rule of thumb to calculate the number of new dwelling units. This rule of thumb states that generally 80 percent the of land will be used for residential homesites, while the remaining 20 percent is reserved for infrastructure (e.g., roads).

Once the predicted number of potential new dwelling units was determined, we multiplied new dwelling unit by the average number of people per dwelling unit based on 1990 census data for Ocean County. The resulting number is the predicted population growth at build-out. Adding the predicted new growth to the existing numbers, we then estimated the potential number of total dwelling units and population of the watershed at build-out.

As a means of validating the above build-out modeling methods, we compared predicted vs. observed results for our baseline year of 1995. The predicted number of dwelling units was approximately 16% greater than the observed number in 1995. The over prediction can be explained several ways. First, development does not always occur at maximum density as zoned, which is assumed in the build-out model. In many cases residential lots are larger than the zoned minimum lot size. The second major factor may be the 1995 digital mapped land use/land cover (LULC) data (NJDEP, 2000). The LULC data set was used to map existing development and these data are not mapped on an ownership parcel basis. Areas mapped as developable do not necessarily represent a complete parcel, or may be composed of several partial parcels that have been placed into one contiguous tract that meets the development criteria. Because of the data limitations and unpredictable nature of residential development, the number of new dwelling units is given as a range. The initial model prediction of new dwelling units represents the high end and adjusted prediction (down-weighted by 16%) represents the low end of the range of possible new dwelling units in the watershed.

<u>Impervious Surface</u>

Dominated by sandy soils, the upland and wetland systems of Barnegat Bay's watershed (known locally as the Pinelands) act as a single hydrologic unit. Human development readily impacts the region's surface waters, associated wetlands (Morgan and Good,1988; Zampella, 1994) and groundwater aquifers (Vowinkel and Siwiec, 1991). Previous work in the Mullica River basin, under similar Pinelands conditions, revealed a gradient of increasing pH, specific conductance, and nutrients that paralleled a watershed-disturbance gradient of increasing developed and agricultural land-use intensity and wastewater flow (Zampella 1994; Dow and Zampella 2000). This same general pattern of decreasing water quality with increasing watershed development is also evident in the Barnegat Bay watershed (Hunchak-Kariouk et al., 2001). This degraded water quality, in turn, has also impacted the ecological structure and function of the region's freshwater aquatic and wetland communities (Morgan and Philipp 1986; Ehrenfeld and Schneider 1991; Zampella and Laidig, 1997; Zampella and Bunnell, 1998). Continuing downstream, Barnegat Bay is on the receiving end of this nutrient enriched runoff and has experienced negative impacts associated with eutrophication (Kennish et al., 1984; Seitzinger and Styles, 1999). Thus, there is a close connection between the forcing factors of human-mediated watershed disturbance and the resulting impacts to downstream freshwater and estuarine systems.

Impervious surface is an important environmental indicator of the intensity of human land use and closely correlates with water quality degradation and altered runoff patterns in urban and urbanizing areas (Novotny and Chesters, 1981; Brown, 1988; Driver and Troutman, 1989; Ferguson and Suckling, 1990; Arnold and Gibbons, 1996; Charbeneau and Barrett, 1998). Impervious surface refers to roads, sidewalks, roofs, patios, and other surfaces that water can not penetrate. The percent of impervious surface cover is a good indicator of the amount of non-point source pollution. As non-point source pollution is a leading cause of water quality degradation, understanding potential increases is important for understanding impacts on water quality. Areas that are more intensely developed tend to have a larger percentage of impervious surface cover, contributing more non-point source pollution to the water in the watershed. In compiling data from a number of watersheds, Arnold and Gibbons (1996) developed a set of impact thresholds: 1) < 10% impervious surface cover can be considered non-impacted; 2) between 10-30% cover can be considered impacted; and 3) > 30% cover is generally considered degraded. While these thresholds should not be considered 'hard and fast' breakpoints, they do provide a useful guide in evaluating the comparative risk of water degradation on a watershed scale.

To estimate the percent impervious surface in the watershed at build-out, we used the New Jersey's Department of Environmental Protection's impervious surface estimates from the 1995 digital mapped LULC data (NJDEP, 2000). Build-out impervious surface values were determined by assigning the average values of areas with similar zoning classes that were already developed in 1995. Impervious surface information was then summarized at the catchment level. Summarizing the data by catchments, which average 9 sq. miles, allowed us to identify localized areas where the amount of non-point source pollution is potential quite high.

Results From Build-out Analysis

In 1995, 25 percent of the watershed was urban land, while 27 percent is available for development (Table 1). The remaining land is either permanently protected open space or unavailable for development for environmental reasons (e.g., wetlands). It is

Table 1. Existing Urban and Land Available for Development.

Sub-watershed	Total Acres	% Urban	% Developable
Metedeconk River	22,064	41	27
Toms River	15,425	19	41
Union Branch	16,111	16	22
Kettle Creek	4,433	50	26
Silver Bay	8,504	66	17
Wrangle Brook/ Jakes Branch	12,552	30	32
Potters Creek	2,359	36	16
Cedar Creek	14,064	7	27
Stouts Creek	1,955	22	5
Forked River	6,525	15	32
Oyster Creek	10,060	16	28
Mill Creek/ Westecunk Creek	19,026	14	24
Tuckerton Creek	8,316	18	24
TOTAL	**171,606**	**25**	**27**

important to remember that not all land available for development can be converted to urban land uses. Some of the land, particularly in the Pinelands Management Area, is limited to rural land uses. Areas designated for low density residential development or agriculture are not urban but they are built-out based on land use regulations.

Dwelling Unit and Population Increase

In 1995, the model estimates 246,817 dwelling units in the Barnegat Bay Watershed. At build-out 73,087 to 84,985 potential new dwelling units are predicted. Based on regulations they would be built-out at a density of 1.2 to 1.4 dwelling units per acre.

Table 2 Predicted number of dwelling units and population.

Scenario	Dwelling Units	Population	% Increase
1995	246,817	626,914	-
Baseline build-out scenario	319,904 - 331,802	812,556 - 842,777	30 - 34
Build-out, no down zoning scenario	338,236 - 353,118	859,119 - 896,920	37 - 43
Century Plan scenario	308,359 - 318,377	783,231 - 808,678	25 - 29

The potential new development is associated with a estimated total population of between 812,556 and 842,777 people (these figures represent year-round residents and do not take into account part-time summer residents and visitors). This is an increase of 30 to 34 percent over the baseline year of 1995. If the Century Plan land is removed from possible development through preservation as public open space, then predictions are reduced to a potential 25 to 29 percent increase. However, if there is no down zoning outside sewer service areas, then as much as a 37 to 43 percent increase in dwelling units and population could occur.

Impervious Surface

In 1986, the watershed land area consisted of approximately seven percent impervious surface cover. In 1995, the percent impervious surface cover increases to approximately eight percent. Thirty-two percent of the catchments were above the 10 percent impervious surface threshold identified by previous studies to be the point where water quality begins to be impacted (Arnold and Gibbons, 1996). In 1995, no catchments were above 30 percent impervious surface threshold that can be considered degraded (Arnold and Gibbons, 1996). At build-out, the model predicts impervious surface will rise to 12 percent, with 46 percent of the catchments over 10 percent. Figure 2 clearly illustrates how the existing and future development is concentrated in the northern third of the bay's watershed. The total percent impervious surface cover is predicted at 13 percent if there is no down zoning and 12 percent if the Century Plan land is removed from development. Fifty-seven percent of the catchments are above the 10 percent threshold in the no down zoning scenario, while only 42 percent are predicted as above the 10 percent threshold in the Century Plan scenario. Five percent of the catchments are predicted as above the 30 percent threshold in all three buildout scenarios. Examining the amount of change within each catchment, the baseline scenario has fewer catchments covering more than 10 percent of the land with impervious surface than the no down zoning scenarios (Table 3).

Table 3. Percent of additional land covered by impervious surface, by catchment .

Percent Increase	1986 to 1995	1995 to Build-out (Baseline)	1995 to Build-out (no down zoning)	1995 to Build-out (Century Plan Removed)
No Change	35*	14	12	16
1 - 5	40	40	36	44
6 – 10	1	17	20	13
11 – 15	0	2	5	2
16 - 20	0	2	2	0
21 - 25	0	1	1	1

* Three catchments reduced the estimated amount of impervious surface by 1 percent from 1986 to 1995.

One advantage of this GIS-based modeling technique is the ability to highlight areas of greatest potential change, allowing greater targeting of planning or mitigation efforts to the locations that need them the most. Four of the five catchments that will cover an additional 10 percent of the land with impervious surface in the baseline scenario are contiguous to each other. This hot spot of potential impervious surface increase straddles the Toms River, Union Branch, and Kettle Creek Sub-watersheds. These catchments represent the area of greatest changes in all scenarios, with the alternative scenarios differing by only one or two percent. The other catchment predicted to have an additional 10 percent of its land under impervious surface is located along the Barnegat Bay shoreline in the Oyster Creek sub-watershed. Only eight percent of land was covered by impervious surface in 1995 while 20 percent is predicted to be impervious at build-out. A substantial area of land in this catchment is targeted for protection as open space by the Century Plan. If the land is purchased as open space as proposed, the impervious surface is predicted to increase to only 10 percent of the total catchment land. This type of spatial analysis underscore the advantage of this GIS-based approach to evaluate site-specific scenarios.

Summary and Recommendations

We completed a build-out analysis of the Barnegat Bay Watershed to gain a better understanding of the potential future growth in the watershed. The potential number of dwelling units, residential population, and amount of impervious surface were estimated at build-out under several different scenarios. The build-out model estimates that the number of dwelling units and population could increase 30 to 34 percent in the baseline scenario. An additional four percent of the land area, up from eight percent, in the watershed is predicted to be covered by impervious surface at build-out; this represents an increase in impervious surface cover of 50 percent. Approximately 50 percent of the

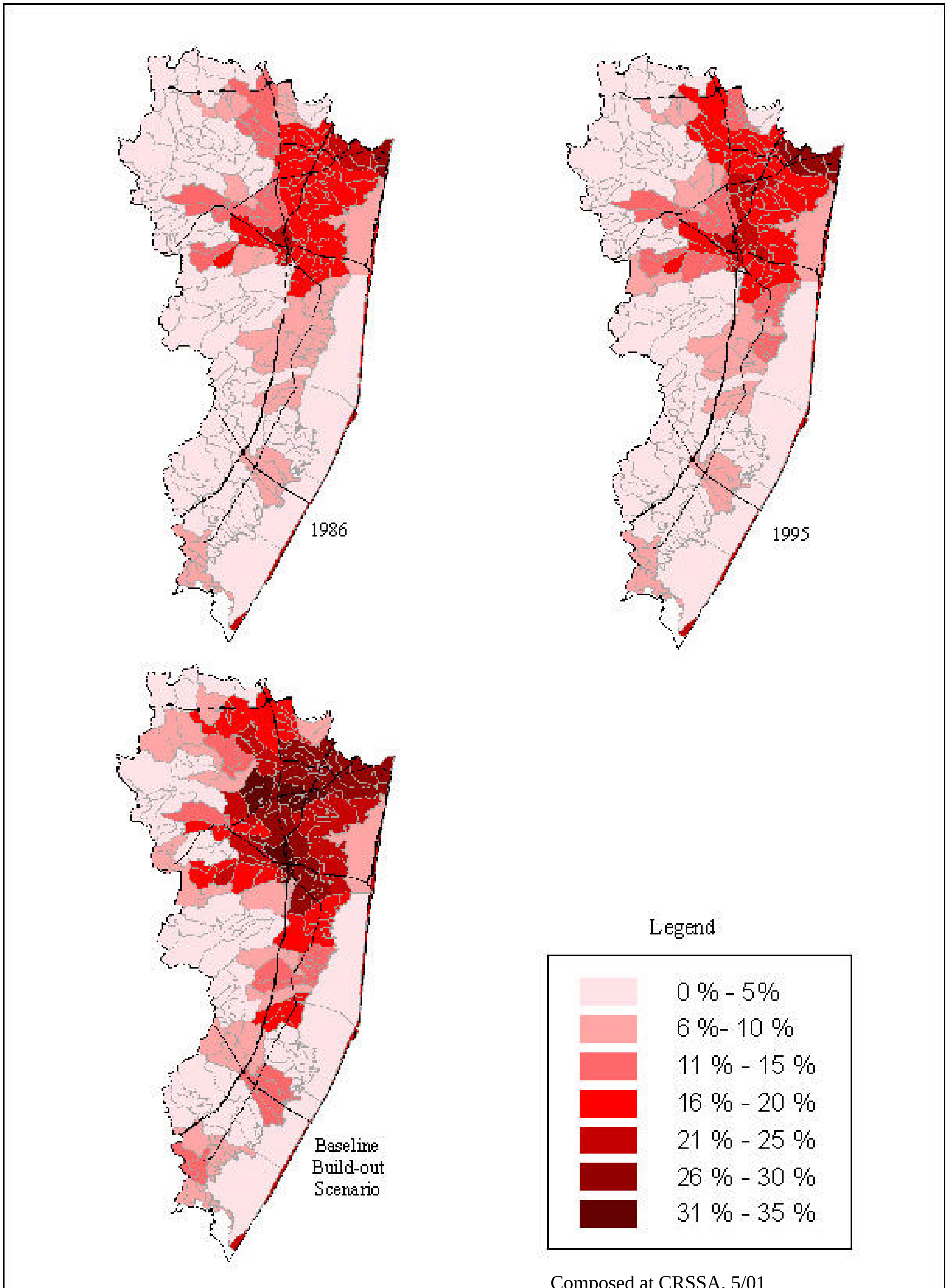

Figure 2. Percent Impervious Surface.

catchments will have more than 10 percent impervious surface cover, suggesting that water quality will be impacted. Unfortunately estuarine and watershed-related science is not sufficiently advanced to allow us to definitively predict how much the water quality will decrease and what the precise impacts will be on Barnegat Bay proper. Whereas we may know enough to predict a general trend towards increasing eutrophication, we are unsure of the exact details. Previous experience in other eutrophic water bodies suggests that we should be prepared for unexpected surprises.

While protecting open space in the Barnegat Bay watershed is important, the results of the Century Plan build-out scenario suggest that this approach alone is not sufficient to ensure protection of water resources. Under the Century Plan scenario, approximately 89,000 acres of open space would be purchased, reducing the overall amount of developable land by 32 percent. However, as these open space tracts are generally zoned as low density residential, their removal from development reduces the total number of dwelling units by only 11,500 or 16 percent and only minimally reduces the overall impervious surface cover. These results suggest several important points: 1) aggressive purchase of open space as outlined in the Century Plan will still allow considerable room for additional growth in the Barnegat Bay watershed; and 2) to protect the bay's water resources, the adverse impacts of this additional development should be mitigated.

Although the exact amount of additional development may vary based on the amount of land protected as open space, zoning and other regulations, and socioeconomic factors, the build-out analysis indicates that significant additional development will occur in the watershed. This build-out analysis reinforces the idea that comprehensive watershed scale planning is needed to address future development impacts. The Barnegat Bay Comprehensive Conservation and Management Plan identifies a number of actions that new and existing residents can adopt to help protect the water quality and supply. For example, new construction should minimize the amount of impervious surface and maximize the amount of undisturbed native vegetation cover to promote water infiltration. Low impact lawn/garden care techniques should be promoted to reduce nutrient inputs in runoff and conserve water supply. Riparian buffers should be retained and in many places restored to help filter runoff and inhibit soil erosion. Storm water management systems need proper design and maintenance to effectively reduce storm peak flows and associated nonpoint source pollution. These types of activities, along with a number of other recommendations, are outlined in the CCMP.

It is our hope that this build-out analysis can be used to highlight 'hotspots' of future change and thereby aid in local planning and management decision making. Rather than generic best management practices, using GIS-based decision support modeling techniques we can more readily and effectively customize recommendations to address the specific circumstances of individual sites. For example, watershed managers could target high risk locations for mitigation actions such as riparian buffer restoration in a more cost effective manner. Only by incorporating both watershed, municipal, and site level actions will we meet the Estuary Program's goals of protecting the public water supply and maintaining and restoring ecological conditions in the Barnegat Bay.

GIS Data Availability

The GIS data (in an ArcView .shp file format) used to develop the build-out analysis as well as the resulting scenario outputs will be made available for free download at the following web site: http://www.crssa.rutgers.edu/projects/runj/bbay.html.

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Dave McKeon and staff at Ocean County Planning offered insight and aided in the data gathering process. Scott Hagg and Steve Lennartz provided valuable assistance during the digitizing and analysis phases. Funding was provided by the US EPA through the Barnegat Bay National Estuary Program.

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