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The opinions expressed herein are solely those of the authors and do not necessarily represent the official opinion of the Environmental Protection Agency.

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CHAPTER 3
NEW JERSEY

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SUMMARY

Sea level is rising 12–16 inches per century (3–4 millimeters per year) along the coast of New Jersey. Ocean beaches are eroding, prompting beach nourishment projects along most of the developed New Jersey Shore. Along the shores of Delaware Bay, beaches and marshes are eroding, and aging dikes are increasingly vulnerable. Along the bay side of Long Beach Island, high tides now flood some streets that were dry when the roads were originally paved. All of these effects could become more widespread if rising global temperatures cause the rate of sea level rise to accelerate The Intergovernmental Panel on Climate Change, for example, estimates that by the end of the next century, sea level is likely to be rising 0 to 3 inches per decade more rapidly than today (excluding the possible impacts of increased ice discharges from the Greenland and Antarctic ice sheets).

The state has a policy of nourishing ocean shores. But for most coastal areas, including the bay sides of most barrier islands, there is no explicit plan for the fate of most low-lying coastal lands as sea level rises. Environmental planners do not know whether to assume that the coastal wetlands will be lost or simply migrate inland. Those who plan coastal infrastructure do not know whether to assume that a given area will be submerged by rising waters or protected from the sea. And even in developed areas that will presumably be protected, public works departments do not know whether to assume that the land surfaces will gradually be elevated or that the area will be protected with a dike.

This report develops maps that distinguish shores that are likely to be protected from the sea from those areas that are likely to be submerged, assuming current coastal policies, development trends, and shore protection practices. Our purpose is primarily to promote the dialogue necessary to decide where people will yield the right of way to the inland migration of wetlands and beaches, and where we will hold back the sea. A key step in evaluating whether new policies are needed is to evaluate what would happen under current policies. The maps in this report represent neither a recommendation nor an unconditional forecast of what will happen, but simply the likelihood that shores would be protected if current trends continue.

We obtained the land use and planning data for the state's coastal zone, and consulted with planners representing the 11 coastal counties along the Delaware River, Delaware Bay, Atlantic Ocean, and Raritan Bay, and the Meadowlands Commission on how to best interpret the data given existing statutes, regulations, and policies. We also conferred briefly with planners from 3 of the coastal counties in Northern New Jersey, and Monmouth County obtained input from boroughs and townships. The result is a statewide series of maps that uses existing data, filtered through the county governments who coordinate land use planning activities.

By "shore protection" we mean activities that prevent dry land from converting to either wetland or water. Activities that protect coastal wetlands from eroding or being submerged were outside the scope of this study. This study does not analyze the timing of possible shore protection; it simply examines whether land would be protected once it became threatened. Nor do we analyze whether shore protection is likely to be a transitional response or sustained indefinitely.

The maps divide the dry land close to sea level into four categories of shore protection:

- shore protection almost certain (brown);
- shore protection likely (red);
- shore protection unlikely (blue); and
- no shore protection, i.e., protection is prohibited by existing policies (light green).

For reasons related to data quality, our study area includes lands within about 17–18 feet (about 5 meters) above the tides. (We did not project the fates of secured federal installations but depicted them in red so that they stand out.)

One can also view these maps as representing three shore protection scenarios. For example, in an "enhanced wetland migration" scenario, only the areas depicted in brown would be protected; but in an "enhanced shore protection" scenario, only the areas depicted in light green would be submerged. Thus the prospects for shore protection are best understood in the areas shown in brown and light green; those shown in red and blue are most amenable to coastal planning. "Expected shore protection" is an intermediate scenario in which the areas depicted in brown and red are protected, and those shown in blue and light green are submerged.

Results

Map 3-1 shows our assessment of the likelihood of shore protection for the coastal zone of New Jersey, and adjacent areas of New York, Pennsylvania, and Delaware. Table 3-1 quantifies the area of land within approximately 3 feet (1 meter) above the tides for each of the shore protection categories by county. Table 3-2 quantifies the length of shoreline along the Atlantic Ocean, Delaware Estuary, and back barrier bays by likelihood of shore protection.

New Jersey has a well-established policy in favor of shore protection along the developed ocean shores. As a result, shore protection is almost certain along 80 percent of the state's 137-mile (220-km) ocean coast. The only major exceptions are the 11-mile (17-km) Island Beach State Park–where shore protection is likely–and the 9-mile (14-km) Forsythe National Wildlife Refuge, which extends from the southern portion of Long Beach Island to the northern portion of Brigantine Island.

Along the mainland shores behind the barrier islands, by contrast, wetlands are likely to have room to migrate inland in most areas. Approximately 85 percent (30 square miles) of the dry land within 3 feet above the tides is likely or certain to be protected; but 23 square miles (61 square kilometers) of nontidal wetlands also lie within 3 feet above the tides. Planners generally expect these lands to remain off-limits to development, creating the potential for conversion from nontidal to tidal wetlands. Thus, tidal wetlands would continue to be found in most areas that have them today. Nevertheless, because the area for possible wetland migration is a small fraction of the more than 2,000 square miles (nearly 5,500 square kilometers) of tidal wetlands currently found along the Atlantic Coast, this area would lose 85–90 percent of the tidal wetlands if wetlands prove to be unable to keep pace with rising sea level, regardless of policies regarding wetland migration.

Along Raritan Bay and its tributaries, by contrast, the prospects for tidal wetlands are more sensitive to governmental policies. The area currently has 23 square miles of tidal wetlands, but only 1.4 square miles of nontidal wetlands. Because 95 percent of the land within 3 feet above the tides is likely to be protected, only 0.5 to 1.9 square miles of land would be available for new wetland creation. Nevertheless, the Meadowlands include 6.2 miles (16 square kilometers) of land (shore protection likely) that might be allowed to flood if wetland protection became a priority.

The Delaware Estuary has a long history of shore protection. With the large tide range, it had extensive marshes that could be "reclaimed" as agricultural lands by constructing dikes and simple drainage systems. Several dikes were constructed along the Delaware River when New Jersey was still a Dutch colony. By 1866, 20,000 acres of marshes had been reclaimed from the New Jersey side of Delaware Bay and converted to farmland, mostly in Salem and Cumberland counties. Since the turn of the 20th century, however, these land reclamation efforts have been reversed, and formerly diked lands have been converted to marsh. (Dikes still protect some populated areas, however, such as the "Gibbstown Levee" in Gloucester County.)

The momentum of these environmental restoration efforts has extended inland: The state plan of New Jersey discourages development along most of the undeveloped areas south of the Delaware Memorial Bridge. Above the bridge, however, most of the shore is developed and shores are likely to be protected. Development has been removed from all but a few bayfront communities in Cumberland County as part of an environmental restoration program. Most of the tidal wetlands along the bay shore of Cape May County transition to nontidal wetlands, generally within wildlife management areas. Thus, shore protection is likely or certain along 10–15 percent of New Jersey's 104-mile (169-km) Delaware Bay shore, but more than two thirds of its Delaware River shore.

Conclusions

1. *The prospects for shore protection appear to be largely established along 86 percent of the 137-mile Atlantic Ocean coast.*
   - High property values and dense development make shore protection almost certain along 108 miles (175 km) of shore.
   - Conservation policies preclude shore protection along approximately 10 miles of shore owned by the U.S. Fish and Wildlife Service.

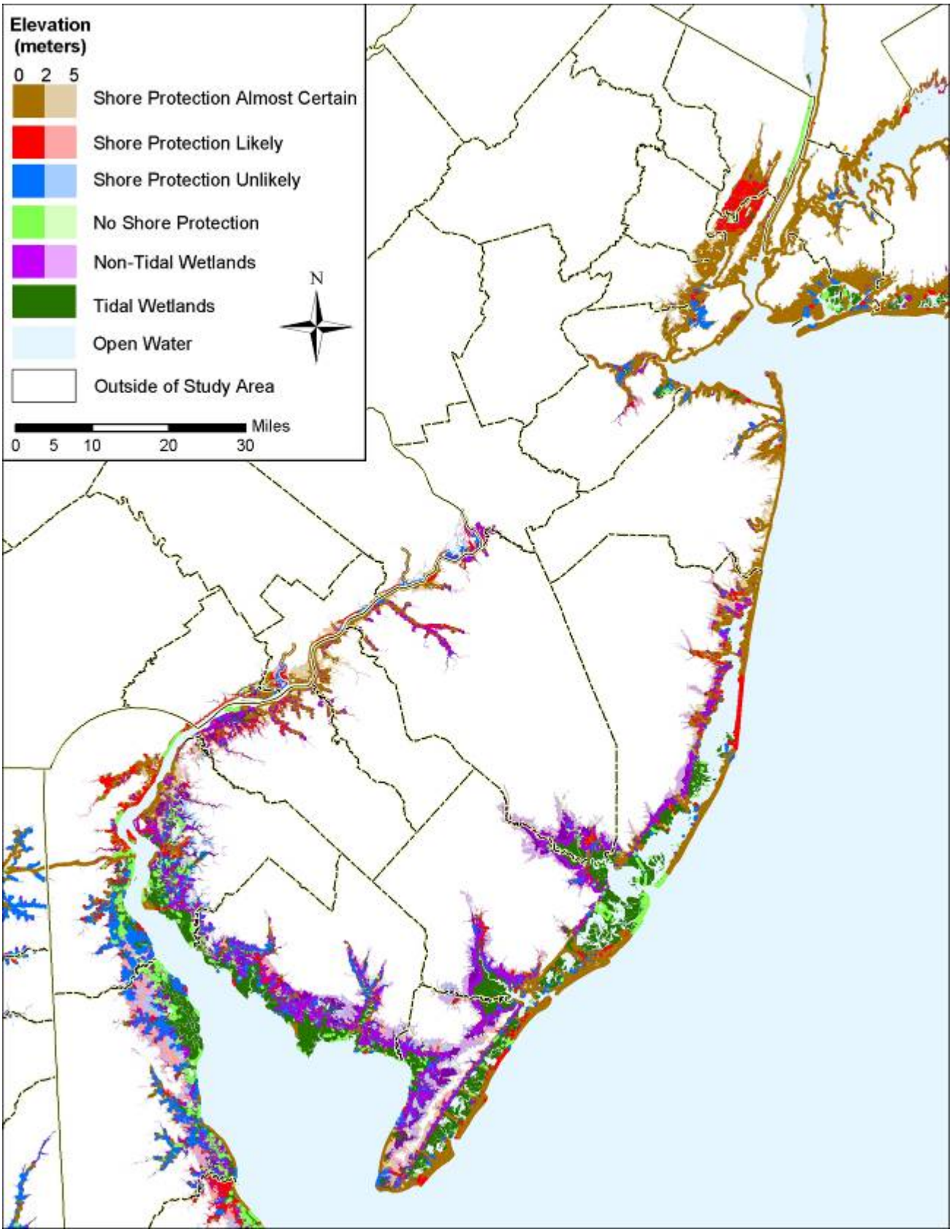
2. *Shore protection is still uncertain along about 14 percent of the Atlantic Coast.*
   - Cape May County includes 6 miles of military lands and lightly developed barrier beaches where shore protection is likely but not certain.
   - Continued shore protection is likely—but not certain—at Island Beach State Park.
   - Wide beaches account for about 2 miles of shoreline. Although shore protection is unlikely, the land behind beaches is almost certain to be protected if the beaches erode.

3 Along the barrier bays of New Jersey, most dry land is likely or certain to be developed, but nontidal wetlands may provide an opportunity for the landward migration of tidal marshes.
   - Of the 37 square miles of dry land within 3 feet above the tides along the Atlantic Coast of New Jersey, 30 square miles are likely or certain to be protected.
   - Approximately 2.1 square miles are within conservation areas, and another 2.9 square miles are in areas where development is unlikely. Thus, the area of dry land that is likely to be available for wetland migration is small compared with the 202 square miles of tidal wetlands.
   - Approximately 60 square miles of nontidal wetlands, however, may also be available for the creation of new tidal wetlands. (The extent to which land that is dry today might convert to nontidal wetlands as sea level rises is outside the scope of this report.)

4. Along the Delaware Estuary below the Walt Whitman Bridge, the prospects for shore protection are less certain than along the ocean. These lands include approximately 16.3 square miles of dry land within about 3 feet (1 meter) above the tides.
   - Only 36 percent of the dry land within 1 meter above the tides along the Delaware estuary in Cape May, Cumberland, Salem, and Gloucester Counties along the Delaware shore is

developed enough for planners to view shore protection as almost certain, and 15 percent of the land is within conservation areas.

- Shore protection is likely on about 17 percent of the dry land within about 3 feet (1 meter) above the tides; but it may not be too late to design land use plans that could accommodate both development and wetland migration.
- In the other 9.7 square miles, development and shore protection seem unlikely today; but land owners may choose to protect these lands in the future.



Map 3-1. The Likelihood of Shore Protection: Statewide Results of this Study. For each shore protection category, the darker shades represent lands that are either less than 6.6 feet (2 meters) above spring high water, or within 1,000 feet of the shore. The lighter shades show the rest of the study area. This map is based on data published between 1999 and 2004, and site-specific changes suggested by planners in 2002 and 2003.

Table 3-1.
Area of Land within 3.3 feet (1 meter) above Spring High Water by Likelihood of Shore Protection (square miles)

County	Likelihood of Shore Protection				Nontidal Wetlands	Total[1]	Elevation Error[2] (inches)	Tidal Wetlands
	Almost Certain	Likely	Unlikely	No Protection				
North Jersey								
Bergen	5.6	3.0	0.0	0.1	0.3	9.2	25	5.8
Essex	3.4	0.0	0.0	0.0	0.0	3.4	26	0.1
Hudson	6.2	3.0	0.0	0.0	0.1	9.3	26	4.6
Union	3.9	0.0	0.0	0.0	0.1	4.0	28	0.9
Middlesex	4.4	0.2	0.2	0.1	0.7	5.7	34	8.4
Monmouth	2.7	0.1	0.0	0.0	0.2	3.2	8	3.0
Passaic	0.0	0.0	0.0	0.0	0.0	0.1		0.0
Total	**26.2**	**6.2**	**0.3**	**0.2**	**1.4**	**34.8**		**22.8**
Atlantic Coast								
Monmouth	2.6	0.0	0.0	0.0	0.5	3.3	8	1.7
Ocean	9.5	1.4	0.6	0.4	6.6	19.2	8	48.2
Burlington	0.2	0.3	0.2	0.4	5.5	6.6	25	14.4
Atlantic	5.0	1.0	1.1	1.0	9.0	17.4	11	78.8
Cape May	8.9	1.1	1.0	0.2	1.9	13.5	10	59.1
Total	**26.3**	**3.9**	**2.9**	**2.1**	**23.4**	**60.0**		**202.2**
Delaware Estuary								
Cape May	0.9	0.5	1.6	0.5	12.0	15.5	19	18.6
Cumberland	1.8	2.0	3.4	1.3	12.4	20.9	20	82.1
Salem	5.8	1.2	4.2	3.1	11.7	26.1	19	42.5
Gloucester	2.9	1.8	0.5	0.0	4.9	10.2	25	6.9
Camden	2.1	0.0	0.0	0.0	0.2	2.3	49	0.6
Burlington	2.2	0.2	0.0	0.0	0.3	2.8	46	2.1
Total[3]	**15.7**	**5.6**	**9.7**	**4.9**	**41.6**	**77.8**		**152.9**
New Jersey	**68.2**	**15.7**	**12.9**	**7.2**	**66.4**	**172.5**		**377.8**

1. Total Land includes the five categories listed plus land for which no data were available
2. This table is based on the area of map polygons within 3.3 feet (1 meter) above the tides. Although the area of the polygons can be tabulated very precisely, the 3.3-ft (1-m) elevation estimate is subject to the accuracy limits of the underlying elevation data. The elevation error column displays the accuracy limits (root mean square error) of the data used to identify the 1-m elevation contour.
3. Excludes Mercer County

See Table B-2 in Appendix B for details.

Table 3-2. Shoreline Length by Major Water Body and Likelihood of Shore Protection (miles)

County	Likelihood of Shore Protection				Nontidal Wetlands	Totals
	Almost Certain	Likely	Unlikely	No Protection		
Atlantic Ocean	108	17	2	10	0	137
Atlantic	13	0	0	6	0	19
Cape May	31	6	0.5	1	0	38.5
Monmouth	29	0.2	0	0	0	29.2
Ocean	35	11	1	3	0	50
Back Barrier Bays	198	55	28	24	115	420
Atlantic	45	10	11	13	37	116
Cape May	45	18	10	4	38	115
Monmouth	35	1	2	0	0.6	38.6
Ocean	73	27	5	6	39	150
Delaware Bay	10	2	11	12	69	104
Cape May	8	0.6	6	2	22	38.6
Cumberland	2	2	5	8	42	59
Salem	<0.1	0	0	2	5	7
Delaware River	59	6	3	5	30	103
Burlington	19	3	0.4	0	6	28.4
Camden	12	0	0	0	3	15
Gloucester	9	1	0.8	<0.1	11	21.8
Mercer	4	0.5	0	<0.1	2	6.5
Salem	16	2	2	4	8	32
Raritan Bay/ Arthur Kill/ Hudson River	49	0.1	0.8	11	1	61.9
Bergen	4	0	0	11	0.6	15.6
Hudson	12	0	0	0	0.2	12.2
Middlesex	16	0	0.3	0	0.2	16.5
Monmouth	7	0.1	0.5	0	<0.1	7.6
Union	10	0	0	0	0.2	10.2
State Total [1]	**1166**	**315**	**275**	**235**	**919**	**2909**

[1] Includes the shoreline of tributaries to the major water bodies.

INTRODUCTION

With more than 400 miles of shoreline along New York Harbor, Raritan Bay, the Atlantic Ocean, and the Delaware River and Bay (and an additional 2,500 miles along back barriers and tributaries to these major water bodies), rising sea level threatens the coast of New Jersey from the east, the south, and the west.

Approximately 61 square miles of dry land would be inundated by the tides if sea level were to rise 2 feet (Table 3-3), unless shore protection measures were taken to hold back the sea. Figure 3-1 shows the lands within 20 feet (6 meters) above spring high water.[1] As sea level rises, the lowest lands will be eroded or inundated by the tides, unless the state or private property owners take measures to hold back the sea

Purpose of this Study

This study develops maps that distinguish the areas likely to be protected[2] as the sea rises from the areas where shores are expected to retreat naturally, either because the cost of holding back the sea is greater than the value of the land or because there is a current policy of allowing the shoreline to retreat. This report is part of a national effort by the U.S. Environmental Protection Agency (EPA) to encourage the long-term thinking required to deal with the impacts of sea level rise. Maps illustrating the areas that might ultimately be submerged convey a sense of what is at stake, but they also leave people with the impression that submergence is beyond their control. Maps that illustrate alternative visions of the future may promote a more constructive dialogue.

For each state, EPA is evaluating potential state and local responses to sea level rise, with a focus on maps showing the likelihood that lands will be protected from erosion and inundation as the sea rises. These maps are intended for two very different audiences:

State and local planners and others concerned about long-term consequences. Whether one is trying to ensure that a town survives, that wetlands and beaches are able to migrate inland[3], or some mix of both, the most cost-effective means of preparing for sea level rise often require implementation several decades before developed areas are threatened.[4] For the last 25 years, EPA has attempted to accelerate the process by which coastal governments and private organizations plan for sea level rise.[5]

[1]See box on "Reference Elevations and Sea Level Rise" for an explanation of spring high water and sea level rise.

[2]For purposes of this study, “protect” generally means some form of human intervention that prevents dry land from being inundated or eroded. The most common measures include beach nourishment and elevating of land with fill, rock revetments, bulkheads, and dikes.

[3]In some areas, wetlands may accrete sufficient sediment to vertically increase elevation and thus avoid inundation. For further information on the potential for wetland accretion, see Reed, D.J., D.A. Bishara, D.R. Cahoon, J. Donnelly, M. Kearney, A.S. Kolker, L.L. Leonard, R.A. Orson, and J.C. Stevenson, 2008, Site-Specific Scenarios for Wetlands Accretion as Sea Level Rises in the Mid-Atlantic Region, in J.G. Titus and L. Strange (eds.), *Background Documents Supporting Climate Change Science Program Synthesis and Assessment Product 4.1: Coastal Elevations and Sensitivity to Sea Level Rise*, EPA 430R07004, Washington, DC: U.S. EPA.

[4]Titus, J.G., 1998, “Rising seas, coastal erosion and the takings clause: How to save wetlands and beaches without hurting property owners,” *Maryland Law Review* 57:1279-1399.

[5]EPA began helping coastal communities prepare for an acceleration of sea level rise in 1982, long before the agency developed a policy for reducing greenhouse gases. See, e.g., EPA, 1983, *Projecting Future Sea Level Rise*,. See also the report of EPA's 1983 Sea Level Rise Conference: *Greenhouse Effect and Sea Level Rise: A Challenge for this Generation*, M.C. Barth and J.G. Titus, editors, Van Nostrand Reinhold, New York.

Preparing for sea level rise requires society to decide which areas will be elevated or protected with dikes and which areas will be abandoned to the sea. A key step toward such a decision is the baseline analysis of what will happen given current policies and trends. This report provides that baseline analysis.

National and international policy makers. National and international policies regarding the possible need to reduce greenhouse gas emissions require assessments of the possible impacts of sea level rise. Such assessments depend to a large degree on the extent to which local coastal area governments will permit or undertake shore protection efforts.[6] Moreover, the United Nations Framework Convention on Climate Change, signed by President Bush in 1992, commits the United States to taking appropriate measures to adapt to the consequences of global warming.

Caveats

This report has two fundamental limitations. First, it is literally a "first approximation" of the likelihood of shore protection. Like most first-of-a-kind studies, our effort includes methodological judgments that may later prove ill-advised. We examine the implications of current trends in coastal development and coastal management policies. We have attempted to account for uncertainty by dividing our study area into lands where shore protection is almost certain, likely, unlikely, and precluded by current policies. But many important factors cannot be foreseen—and in many cases the only available data are several years old. Therefore, we often relied on planners to fill in the gaps by telling us about recent and expected development. But what is expected now may be different from what was expected when we visited the planners. As new information emerges, assessments of the likelihood of shore protection will change.

Second, this study is not even intended to address all of the issues that some people think about when they hear the term "shore protection." Our intention is to distinguish those lands where a natural retreat would occur from those areas where people will at least attempt to hold back the sea. Our maps are *not* intended to identify

- the vulnerability of particular lands (we simply evaluate whether lands would be protected *if and when* they are threatened);
- options for protecting existing wetlands (we analyze protection only of dry land);
- which areas will receive government funded shore protection;
- whether people will hold back the sea forever, which would depend on cost factors and scientific uncertainties outside the scope of this analysis[7]; and
- whether hard structures, soft engineering, or some hybrid of the two approaches is likely in areas that will be protected, or the environmental impacts of shoreline armoring.

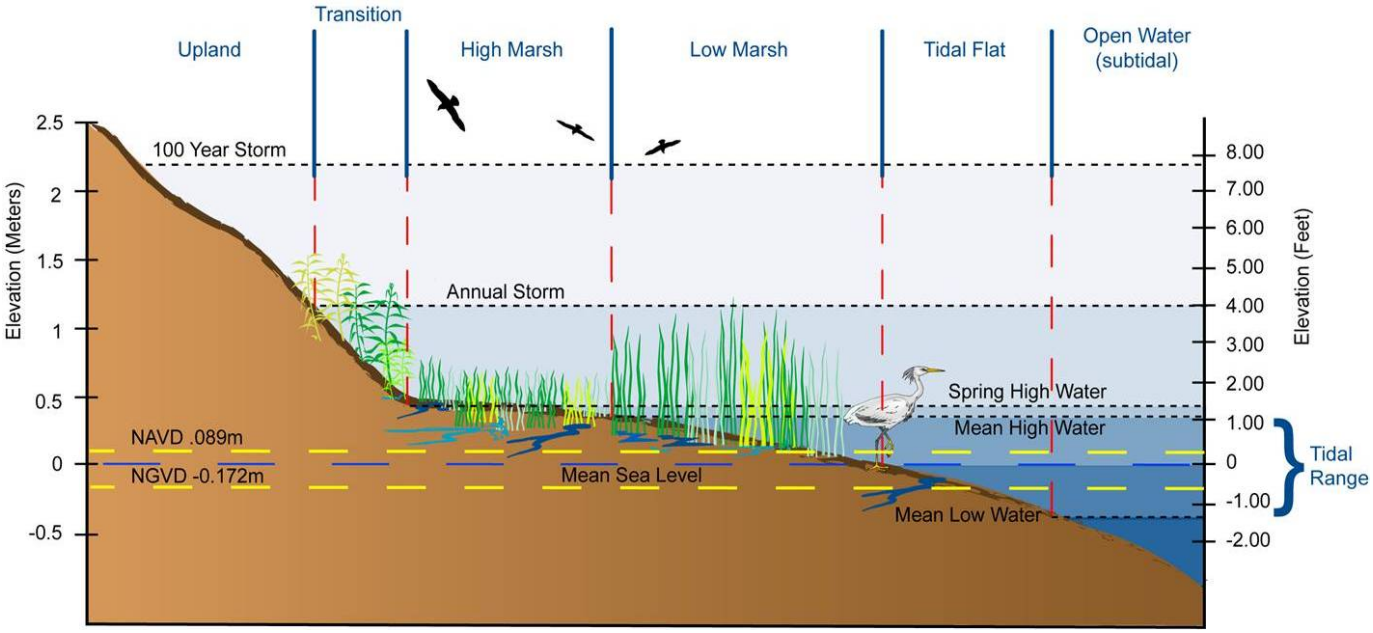
[6]Titus, J.G., et al., 1991, "Greenhouse effect and sea level rise: The cost of holding back the sea," *Coastal Management*, 19:171–204; and Yohe, G., 1990, "The cost of not holding back the sea: Toward a national sample of economic vulnerability," *Coastal Management* 18:403–431.

[7]For example, the sea could rise 10–20 feet over several centuries if one of the world's ice sheets were to melt. See, e.g., IPCC, 2001, *Climate Change Science 2001*, Cambridge University Press, New York and London.

BOX 1: TIDES, SEA LEVEL, AND REFERENCE ELEVATIONS

Tides are caused by the gravitational attraction of the moon and sun on the ocean water. Most places have two high and low tides every day, corresponding to the rotation of the earth. The daily tide range varies over the course of the lunar month. *Mean high water* and *mean low water* are the average elevations of the daily high and low tides. During full and new moons, the gravitational pull of the moon and the sun are in alignment, which causes the tide range to be 15–25 percent more than average. The averages of the full and new moon high and low tides are known as *spring high water* and *spring low water*. In addition to the astronomic tides, water levels fluctuate owing to winds, atmospheric pressure, ocean current, and—in inland areas—river flow, rainfall, and evaporation. Daily tide ranges in the mid-Atlantic are as great as 8 feet in parts of the Delaware River and less than an inch in some of the sounds of North Carolina.

In coastal areas with tidal marshes, the high marsh is generally found between mean high water and spring high water; low marsh is found from slightly below mean sea level up to spring high water. In bays with small (e.g. 6 inch) tide ranges, however, winds and seasonal runoff can cause water level fluctuations more important than the tides. These areas are known as "*irregularly flooded*". In some locations, such as upper Albemarle Sound in North Carolina, the astronomic tide range is essentially zero, and all wetlands are irregularly flooded. Freshwater wetlands in such areas are often classified as "nontidal wetlands" because there is no tide; but unlike most nontidal areas, the flooding—and risk of wetland loss—is still controlled by sea level. Wetlands whose hydrology is essentially that of nontidal wetlands, but lie at sea level along an estuary with a very small tide range, are called *nanotidal wetlands*.



The term *sea level* refers to the average level of tidal waters, generally measured over a 19-year period. The 19-year cycle is necessary to smooth out variations in water levels caused by seasonal weather fluctuations and the 18.6-year cycle in the moon's orbit. The sea level measured at a particular tide gauge is often referred to as local mean sea level (LMSL).

Tide gauges measure the water level relative to the land, and thus include changes in the elevation of the ocean surface and movements of the land. For clarity, scientists often use two different terms:

- *Global sea level rise* is the worldwide increase in the volume of the world's oceans that occurs as a result of thermal expansion and melting ice caps and glaciers.
- *Relative sea level rise* refers to the change in sea level relative to the elevation of the land, which includes both global sea level rise and land subsidence.

In this report, the term "sea level rise" means "relative sea level rise."

Land elevations are measured relative to either water levels or a fixed benchmark. Most topographic maps use one of two fixed reference elevations. USGS topographic maps measure elevations relative to the National Geodetic Vertical Datum of 1929 (NGVD29), which was approximate sea level in 1929 at the major coastal cities. New maps and high-resolution data measure elevations relative to the North American Vertical Datum of 1988 (NAVD88). This report measures elevations relative to spring high water (for 2000), which indicates how much the sea must rise before the land is inundated by the tides.

TABLE 3-3. AREA OF LAND VULNERABLE TO SEA LEVEL RISE IN NEW JERSEY (SQUARE MILES)[a]

Jurisdiction[b]	Vulnerable land[c]	Tidal wetlands	Elevation[d] 0-2 feet Dry land	0-2 feet Nontidal Wetlands	0-4 feet Dry land	0-4 feet Nontidal Wetlands	0-8 feet Dry land	0-8 feet Nontidal Wetlands
Salem	61.0	42.5	9.3	9.2	17.5	13.2	32.4	18.9
Cape May	95.0	77.8	7.9	9.3	18.8	16.5	37.1	28.4
Cumberland	[e]	82.1	[e]	[e]	10.2	14.9	20.1	25.0
Ocean	57.4	48.2	5.4	3.8	17.1	8.1	33.0	14.9
Hudson	[e]	4.6	[e]	[e]	11.3	0.1	18.7	0.2
Bergen	[e]	5.8	[e]	[e]	10.8	0.4	16.9	0.6
Atlantic	89.1	78.8	4.1	6.3	11.0	10.6	21.3	19.0
Monmouth	8.5	4.7	3.4	0.4	7.7	0.8	16.7	1.4
Middlesex	[e]	8.4	[e]	[e]	[e]	[e]	11.5	1.5
Gloucester	[e]	6.9	[e]	[e]	6.4	6.0	12.4	9.9
Burlington	22.3	16.5	2.2	3.6	4.4	7.1	9.0	13.1
Union	[e]	0.9	[e]	[e]	4.8	0.1	8.5	0.2
Essex	[e]	0.1	[e]	[e]	[e]	[e]	7.4	0.0
Camden	[e]	0.6	[e]	[e]	2.6	0.2	5.2	0.5
Passaic[f]	0.1	0.0	0.1	0.0	0.1	0.0	0.3	0.0
Ellis Island	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Mercer	[e]	0.7	[e]	[e]	[e]	[e]	0.1	0.0
Statewide totals	**474**	**379**	**61**	**45**	**133**	**79**	**251**	**133**

[a] J.G. Titus and J. Wang. 2008. Maps of Lands Close to Sea Level along the Middle Atlantic Coast of the United States: An Elevation Data Set to Use While Waiting for LIDAR. Background Document supporting Climate Change Science Program Synthesis and Assessment Product 4.1

[b] Jurisdictions ranked by amount of dry land within 2 feet above the ebb and flow of the tides.

[c] The area of tidal wetlands plus the area of land within 2 feet above spring high water.

[d] Elevations relative to spring high water, that is, the average highest tide during full moons and new moons. Therefore, the land within 2 feet of spring high water is the area that would be tidally flooded if the sea rises 2 feet.

[e] Value omitted because the topographic information Titus and Wang used for this jurisdiction had poor vertical resolution.

[f] Not included in this study.

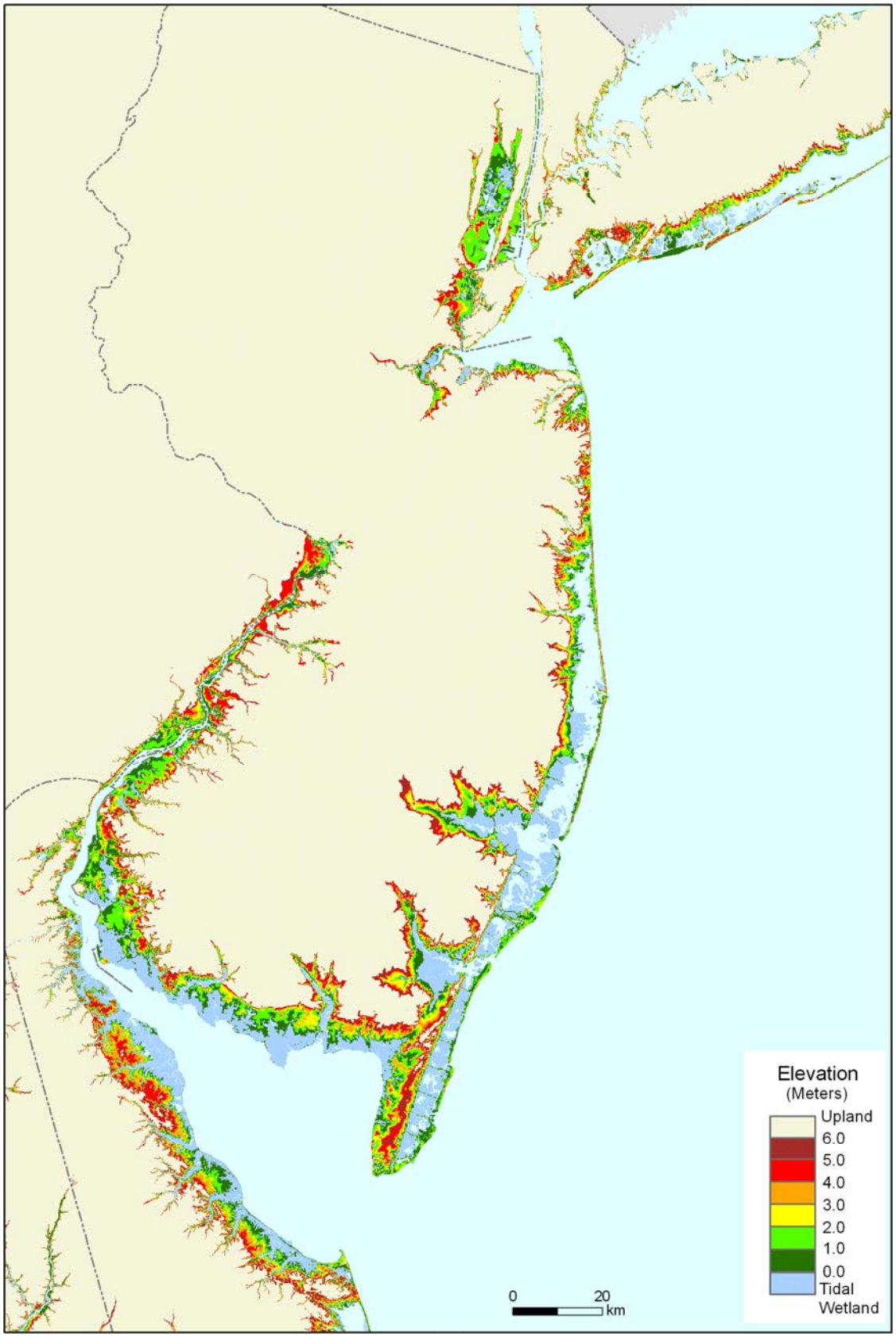


Figure 3-1. Lands Vulnerable to Sea Level Rise. Source: Titus and Wang (2008; see Table 3-3 for full reference). Elevations are relative to spring high water. Because the map has a contour interval of 1 meter (3.28 feet), we have not converted the legend from metric to the English units used in the text of this report.

How to Read this Report

This chapter is one of eight state-specific chapters in Volume 1. Each of the eight chapters was written and reviewed as a stand- alone document, because the authors assumed that many readers are interested in the analysis of only a single state. To assist readers interested in more than one state, each chapter (except the short chapter on the District of Columbia) is organized in a similar fashion, including a summary of likely responses, introduction, methods, relevant state policies, county-specific policies and responses, result appendices, and other appendices as needed.

Some subsections appear verbatim in each chapter, including the subsections on purpose, caveats, and the text box on tides and reference elevations. Subsections on map scale and use of experts have text that is nearly verbatim, except for changes that reflect state-to-state differences. The methods sections reflect differences in available data for each state, but the study area subsection is nearly the same from state to state.

This chapter has separate sections in which we describe:

- methods by which we assess the likely responses to sea level rise;
- state policies that affect the management of coastal lands; and
- county policies and land use trends that affect the management of coastal lands, and anticipated sea level rise responses.

At the end of this chapter, we provide detailed quantitative results in three appendices:

(A) best estimates of the length of shoreline by likelihood of shore protection;

(B) best estimates of the area of land at various elevations by likelihood of shore protection; and

(C) uncertainty ranges of the amount of land at various elevations by likelihood of shore protection.

Because the quantitative results were developed after this study was complete, they are not integrated into the text of this report, other than the summary.

The last two appendices describe:

(D) the complete list of data sources, and

(E) a summary of the New Jersey State Plan Goals and Strategies.

METHODS

This assessment involved three distinct phases, all of which relied heavily on the interpretations of local officials regarding land use and shore protection policies. Table 3-4 lists the local officials who provided input to this study. The pilot phase[8] developed preliminary maps for the counties along the Atlantic Ocean and Delaware Bay. During the second phase, we revised the classifications and approach and extended the analysis to include the counties along Delaware River and the Raritan Bay watershed. The final phase included review by the state and local government (stakeholder review).

Readers primarily interested in understanding our results should review the subsections on "Study Area" and "Phase 2: Revised Maps." Those who are interested in fully understanding the methods and limitations of this effort should read all of the subsections in this Methods section, which address:

- scope of the study area;
- methods used during the pilot phase;
- methods used during the second phase;
- our approach for gathering updated information and to confirm the content of the maps and report; and
- the appropriate scale for viewing the resulting maps.

Study Area

Because efforts to improve elevation maps were taking place as this study was conducted, and elevation data will continue to improve when funds become available for LIDAR, we deliberately picked an overly broad geographic area for our assessment. This large study area is not meant to suggest that sea level rise would inundate the entire area studied. One can always "mask out" lands that are too high to be affected by sea level rise as the data improve [9]; it would be more problematic if subsequent improvements in elevation data were to show that we omitted areas that are vulnerable.

Therefore, our general approach was to use either the 20-ft or 5-m contour to define the study area, depending on the maps being used. In this study, the USGS 100,000 scale maps were employed, and their lowest contour is the 5-m contour.

Hence we started out focusing on the land below the 5-m NGVD contour.[10] As the study progressed, however, it became evident that the Coastal Area Facility Review Act (CAFRA) boundary might also be appropriate. Therefore, for the part of the state within CAFRA jurisdiction, we are able to display results for the CAFRA area.

[8]The pilot effort was conducted by Michael Craghan based on scenario definitions, study areas, and overall assumptions provided by EPA.

[9]For example, the quantitative results reported in Appendix B estimate the land area within 1 meter above the tides.

[10]Until recently, most topographic maps provided contours that measured elevation above the National Geodetic Vertical Datum of 1929. That datum represented mean sea level for the tidal epoch that included 1929, at approximately 20 stations around the United States. The mean water level varied at other locations relative to NGVD, and inland tidal waters are often 3–6 inches above mean sea level from water draining toward the ocean through these rivers and bays. Because sea level has been rising, mean sea level is above NGVD29 almost everywhere along the U.S. Atlantic Coast.

TABLE 3-4. LOCAL OFFICIALS WHO PROVIDED INPUT TO THIS STUDY

State, County, or Region	Contact	Office
Statewide	Mark Mauriello, land use regulation director	NJDEP Bureau of Coastal Regulation
Statewide	Bernard Moore, administrator	NJDEP Engineering and Construction
Bergen	Peter Kortright III, assistant director, Open Space Trust Fund	Department of Planning and Economic Development, Bergen County
Meadowlands	Sarah Sundell, senior project engineer	New Jersey Meadowlands Commission
Essex	David Boyd, director of planning	Essex County Transportation, Department of Finance and Administration, Hudson County
Hudson	John Lane	
Monmouth	Linda Brennen, P.P., A.I.C.P., supervisor, Environmental Planning Section Edward Sampson, supervisor, Long Range Planning Section Robert W. Clark, P.P., director	Monmouth County Planning Board
Monmouth	Gerald J. Freda, P.E., borough engineer	Borough of Keyport
Ocean	David McKeon, P.P., assistant planning director	Ocean County Department of Planning
Atlantic	John E. Peterson, P.P., supervising planner Brian M. Walters, principal planner	Atlantic County Department of Regional Planning and Development
Cape May	James J. Smith, P.P., A.I.C.P, planning director	Cape May County Department of Planning
Cumberland	Robert Brewer, P.P., assistant planning director Stephen Kehs, department director Michael D. Reeves, director	Cumberland County Planning and Development
Salem	Ron Rukenstein, planning director Charlie Munyon, principal planner	Salem County Planning Board
Gloucester	Rick Westergaard, principal planner Charles Romick, P.P., A.I.C.P., planning director	Gloucester County Public Works Department, Planning Division
Camden	Doug Griffith Curt Noe	Camden County Department of Public Works, Division of Planning
Burlington	Mark Remsa, regional planning coordinator	Burlington County Economic Development and Regional Planning

Phase 1: Pilot Phase

New Jersey was the first state assessed in this nationwide effort,[11] and hence the initial phase served as a pilot for the entire project. Initially, we considered three alternative scenarios of shore protection:

Enhanced Protection Scenario (Scenario 1)—Protection of all areas that can be protected under existing state and local policies. It may bear little relation to what is practical and feasible.

Expected Protection Scenario (Scenario 2)—This scenario reflects an assessment of current as well as anticipated behavior (e.g., future development patterns) (whether consistent with current policy or not). It assumes "practical" implementation of regulations and local planners' expectations. As such, it represents an assessment of the areas that are likely (or certain) to be protected from erosion, flooding, and inundation.

Enhanced Wetland Migration (Scenario 3)—This scenario is based on an assessment of alternative policies that would provide greater protection to natural resources (e.g., wetlands) or

[11]EPA's initial work assignment authorized studies for Rhode Island/Massachusetts, New Jersey, and North Carolina. The North Carolina assessment proceeded only a few months after the New Jersey study; but (aside from Currituck County) it was initially based on the assessment of state officials, and did not consult with the county officials or use GIS data until after planning studies for several states had been undertaken.

culturally significant resources (e.g., unique coastal populations or archeological sites). This scenario was meant to be a "reality check" on the expected protection scenario. For example, if the expected protection scenario showed that planners expected virtually an entire county to require shore protection, the logical question arises: Are there any areas where it might be feasible to allow wetlands to migrate inland, such as areas that have not yet been developed? Some lands are almost certain to be protected even if policy makers decide to promote landward migration of wetland; but areas where development is likely but not certain might be plausible candidates for a landward migration.

Alternative Illustration of Results

In the pilot phase, we used state policies combined with the judgments of county planners to specify maps for the three scenarios. We had little trouble specifying the "enhanced shore protection" and "expected shore protection" scenarios. However, some planners found it difficult to distinguish the lands where shore protection is expected regardless of environmental policy from those lands that might plausibly be available for wetland migration. Moreover, we found it difficult to define this scenario at times. Similarly, colleagues working on this project in other states found it difficult to identify areas where planners considered wetland migration to be economically or politically feasible.

Given the confusion, we modified the scenario definitions after the completion of the initial discussions with planning staff: *Enhanced wetland migration now identifies only the areas that are almost certain to be protected.* This new definition largely serves the same function; we merely change the emphasis. Lands that are likely (but not certain) to be protected are better candidates for wetland migration than lands that are almost certain to be protected. The reasons why shore protection is less than certain may have nothing to do with wetland policy, but for most purposes that does not matter. Along the ocean coast, protection may be less than certain because of moderate population densities or high costs of shore protection. Although such lands may not be suitable candidates for wetland migration, it seemed just as useful to distinguish those lands from the high density lands where shore protection is almost certain, as doing so along estuaries.

When viewing the initial study maps (which were separate maps for each scenario), it was also difficult to compare and contrast the scenarios for specific areas. As a result, we developed an approach for translating the scenarios into a single map in a way that takes the independent scenarios and combines the information into a cumulative summary. The translation between scenarios and the likelihood of shore protection is illustrated in Table 3-5. The resulting map combines the scenario information into a continuum of the likelihood of protection divided into four map colors depicted with the following scheme:

Brown: Almost certain to be protected (i.e., protected under all scenarios).

Red: Likely (but not certain) to be protected (i.e., protected under Scenarios 1 and 2 but not the enhanced wetland migration Scenario 3).

Blue: Protection unlikely (i.e., protected under the enhanced shore protection Scenario 1 but not protected under Scenarios 2 or 3).

Light Green: No shore protection under any scenario, that is, lands that are managed for a conservation objective that would be incompatible with shore protection.

Although our maps are based on a continuation of current policies, we were also mindful of the possible implications of changing priorities. If the costs or environmental consequences of shore protection led society to deliberately reduce shore protection compared with what one might expect given current policies, then (ignoring site-specific environmental and shore protection cost issues) the light green, blue, and red identify those areas where retreat would be feasible as a matter of land use planning. If development and/or land values increase beyond what is currently expected, the brown, red, and blue areas might all be protected.

Outside the study area, we also show wetlands using dark green and sometimes purple (for nontidal wetlands). We differentiate tidal and nontidal wetlands because the effects of sea level rise are potentially very different. We differentiate nontidal wetlands from dry land because this report evaluated only whether dry land would be protected.[12]

Mapping the Baseline Plan for Sea Level Rise

We first created maps for the counties along the Atlantic Ocean and Delaware Bay, based on a review of state policies (discussed below). We then visited the offices of each county and obtained county planner suggestions. Because of a high degree of awareness of the implications of the fundamental choice between shore protection and retreat, the planners were generally able to translate existing land use policies into the probable implications for long-term shore protection. We modified the maps accordingly.

Let us first examine how the initial maps were created.

Areas Likely to Be Protected [13]

State plan and centers. The initial maps assumed that lands in state plan planning areas (PAs) 1, 2, and 3 are likely to be protected, as well as all centers in other planning areas.

Lands in PAs 1–3 have, by virtue of their planning area designation, been found to be not particularly environmentally sensitive, and to be suitable for development. Lands located within centers may be environmentally sensitive, but the state plan recognizes development as a reality. (See Appendix E for an explanation of planning areas and centers.)

We concede that we made a conceptual leap from "suitable for development" to "likely to be protected" but it seemed to be a logical path, given the fact that developed areas are rarely abandoned.[14]

Our initial maps of Scenario 1 did not include all developed areas: Although most of PAs 4 and 5 are undeveloped and not part of a center, there are exceptions—particularly in the coastal zone. These exceptions have sometimes been a source of conflict between state and local governments. Leaving those areas out of Scenario 1 did not constitute a judgment that those areas will not be protected, it was simply an outcome of the data and the initial methods, which focused solely on the state's policy. (Subsequent revisions assume protection for most of those areas.)

Other areas. We made a number of adjustments to the initial maps based on common sense, and our many decades of experience in this state.[15] Some areas of high economic importance will be protected, even if just to sustain their contribution to society. Commercial ports and other major employers fall into that category. A few types of public facilities are in areas that might be susceptible to sea level rise, and based on their importance, it is believed that they will be protected. Places such as sewage treatment plants, Coast Guard or marine police stations, and hospitals are examples of this type.

Some specific transportation links have been identified as likely to be protected. Examples include causeways and bridges that link barrier islands to the mainland and to each other, and major highways like the Garden State Parkway, Atlantic City Expressway, and State Highways 9 and 47. In many cases, the commercial strips

[12]Shore protection designed to protect dry land does not necessarily have the same impact on nontidal wetlands. Erosion control structures designed to prevent homes from eroding into the sea may also protect adjacent nontidal wetlands. Efforts to elevate land with fill to keep it dry would not necessarily be applied to nontidal wetlands. Some nontidal wetlands in developed areas may be filled for development.

[13]The pilot study did not differentiate between "likely" (red) and "certain" (brown) to be protected. Elsewhere, "shore protection likely" tends to refer to areas that are likely—but not certain—to be protected; in this discussion, it refers to all lands that are likely to be protected (red and brown).

[14]Any author-injected subjectivity from this phase would be mitigated by multiple opportunities for counties to modify these site-specific assumptions.

[15]In addition to the lead author's long-term residence in New Jersey, the project manager has spent one month every year along the New Jersey shore for the last several decades. Again, any author-injected subjectivity from this phase would be mitigated by multiple opportunities for counties to modify these site-specific assumptions.

Table 3-5
Relationship between Shore Protection Scenarios and Likelihood of Shore Protection

Shore Protection Scenario		Likelihood of Shore Protection[5]			
Scenario Name	Short Name	Shore protection almost certain (brown)	Shore Protection likely (red) [6]	Shore Protection unlikely (blue)	No shore protection (light green)[7]
Enhanced Shore Protection	Scenario 1[1]	●	●	●	○
Expected Shore Protection	Scenario 2[2]	●	●	○	○
Enhanced Wetland Migration	Scenario 3[3]	●	○	○	○
Retreat	No Shore Protection [4]	○	○	○	○

Key:
● = Lands are protected
○ = Lands available for wetland migration

Notes:
1. The original definition of this scenario was: Areas that can be protected under current policies.
2. The original definition of this scenario was: Areas that are probably going to be protected.
3. The original definition of this scenario was: Same as scenario 2, but *subtract* areas that might be allowed to become submerged if wetland migration were to become a major priority for coastal zone management.
4. The initial study did not specifically identify a "No Shore Protection" scenario. This additional scenario, however, can be simply considered as the land that would not be protected under any of the other scenarios.
5. We use the term "likelihood" as convenient shorthand. The classifications did not result from a formal assessment of probabilities. In the early rounds of many state-specific efforts, the groupings were based on shore-protection scenarios. We later reclassified the categories based on the differences between scenarios, and noticed that the differences roughly corresponded to different likelihood of shore protection.
6. This study did not attempt to characterize military lands outside of urban areas. To avoid having to define an additional map color, the maps depict these lands as red. *The GIS analysts assisting study authors, however, mostly neglected this distinction in creating GIS data sets; so most of the summary statistics include rural military lands with "shore protection likely."*
7. This term reflects a compromise between various considerations. The original draft maps presented to stakeholders used a variety of terms in different states, including "protection illegal," "protection contrary to public policy." None of those terms was precisely accurate, and stakeholders indicated that all of them could be misleading under some circumstances. Also "shore protection very unlikely," "protection extremely unlikely," "protection will not occur", and "protection…precluded by current policies."

along those roads would be protected as well as the road.

Some historical or cultural features are also likely to be protected. Places like Convention Hall in Asbury Park, Officers Row at Sandy Hook, and historic districts such as in Tuckerton, Cape May, and Ocean Grove are in this category. The Route 9 corridor was also identified in one meeting as being of such cultural and historic importance that it would not be permitted to be lost. The Oyster Creek nuclear facility is also in this category.

Areas Unlikely to Be Protected

State plan environmentally sensitive planning areas. The state plan calls for open space preservation and limits on development in PAs 4 and 5. The initial maps assumed that if development is to be concentrated in centers and the other planning areas, then portions of PAs 4 and 5 not in centers probably would not be actively defended as sea level rises.

Parklands (state, county, local). Areas that are incorporated into parks are thought to be unlikely to be protected. Much of the parkland in the coastal zone is for wildlife habitat or public access to the water. Therefore, the initial maps assumed that parks within PAs 4 and 5 will not be protected from sea level rise, even if they are within centers. In PAs 1, 2, and 3, protecting urban parks may be necessary to properly protect the surrounding areas.

The exceptions to this guideline were Island Beach State Park and Sandy Hook. These areas are so heavily used, or of critical importance to the current state of the environment, that their present functions seem likely to be maintained. Doing so might involve a hybrid of protection and natural migration.

Isolated places. Development that is so small scale that it is effectively isolated from other built areas will face a much higher hurdle to earn government protection. In general, areas that consist of just a few houses will lose out to more populous places in the competition for shore protection funds. Moreover, protecting an isolated area has a higher protection cost per structure. Finally, some of these isolated developments are inholdings within conservation areas, and as such the properties are already coveted by refuge managers. Although the desirability of a home in a pristine isolated area may result in high property values, our initial maps assumed that such areas would not be protected. These areas were rarely in centers or PAs 1, 2, or 3 anyway, so this reasoning should be construed as an additional reason for expecting such areas to be abandoned rather than a sole basis for abandonment.

Initial County Meetings

After developing these initial maps, we visited the planning offices of the counties along the Atlantic Ocean and Delaware Bay. County-specific insights from those meetings are discussed in the separate sections discussing these counties. To a large extent, these meetings were used to better identify the site-specific modifications mentioned in the subsection on other areas, above. But the most important contribution was the identification of areas that the state plan finds unsuitable for development but which are, in reality, either developed or likely to be developed. Ultimately, land use is a local responsibility—generally at the borough and township level. But the counties are very aware of what is happening in the boroughs and townships. *Whenever a local official provided site-specific reasons for changing a map designation, we deferred to the local official's judgment.*

Phase 2: Revised Maps

The maps from the pilot effort required revisions for three reasons: First, the initial study considered only the CAFRA counties—but the New Jersey coastal zone also includes three counties along the Delaware River and five counties in Northern New Jersey that are potentially vulnerable to sea level rise. Once EPA decided to develop sea level rise planning maps for Pennsylvania and New York, it would have been anomalous to exclude New Jersey counties across the

Delaware and Hudson rivers from those states—especially because most of the lowest land is on the New Jersey side of those rivers.

Second, the pilot effort did not successfully distinguish those areas that are almost certain to be protected from the areas that will probably be protected. Finally, the initial effort did not adequately distinguish conservation areas where shore protection is precluded from privately owned lands where protection seems unlikely today.

Atlantic and Delaware Bay Counties (CAFRA Counties)

We started out by developing an initial set of revised maps, based on available data and the new study classifications. Table 3-6 summarizes our data sources. Our primary task was to develop a more realistic enhanced wetland migration scenario by distinguishing the lands that are almost certain to be protected from the lands that are likely but not certain to be protected. We treated all land that was either in a center or PA 1 as almost certain to be protected. Within PAs 2 and 3,[16] if the state's land use data said that the land was already developed,[17] we treated it as certain to be protected as well. Those areas would be protected even in an enhanced wetland migration scenario; we assumed that other lands would not be protected in such a scenario. Thus, the lands where protection is expected, but which would not be protected in the enhanced wetland migration scenario, are designated as "shore protection likely." That is, the lands our maps depict in red are those areas that were not part of a center and either (a) were within PA 2 or 3 and not yet developed or (b) were not within PA 1, 2, or 3, but had been designated as likely to be protected by the counties during the pilot effort.

In most cases, those areas that had been added during the pilot effort were places that were already developed but had been left out of the boundaries for centers or fringe developing areas—often over the opposition of local government. Therefore, we extended that principle by obtaining land use data[18] and assuming that all developed areas are likely to be protected (if not otherwise defined as almost certain to be protected).[19] The underlying rationale for our assumptions is that developed areas are rarely if ever abandoned to the sea in New Jersey. Those areas that are either in a center or PA 1 have state acceptance for intense development, which would tend to make state maintenance of infrastructure and state-sponsored coastal protection almost certain. Those areas that are already developed in PAs 2 and 3 also have state acceptance for future development; and the existing development usually implies an economic basis to expect protection. By contrast, areas that are neither developed nor in the state PA 1, 2, or 3 (or in a center) would have less support from the state, and, as a result, development is uncertain and state support for protection unlikely.[20] In between

[16]Defined as suburban and fringe planning areas, respectively.

[17]We used the classification "urban" for this purpose.

[18]We delineate these developed lands using land use/land cover data. For the purpose of this study, we define developed lands as including industrial areas, residential developments of high or single-unit/medium density, commercial and service areas, and other urban built-up lands.

[19]This discussion oversimplifies the process of how we got to that point. Phase 2 originally did not supplement the lands identified as protected in the pilot effort with all developed lands for the CAFRA counties; i.e., the maps assumed that developed areas in PAs 4 and 5 were unlikely to be protected unless they were part of a designated center. This assumption did not result from discussions with local government. Rather, in the case of CAFRA counties, Phase 2 primarily involved dividing lands protected in Phase 1 between red and brown; we neglected to revisit whether Phase 1 had truly included all the lands that are likely to be protected. By contrast, the assessment of the Delaware River counties started with Phase 2, by which time we knew to ask the counties whether existing development was likely to be protected. During stakeholder review, some CAFRA counties asked for site-specific map changes to protect developed areas. Nevertheless, after the stakeholder review meetings, the EPA project manager noticed the large number of developed areas that the maps showed as unlikely to be protected, and consulted with the counties, all of which indicated that all developed areas are likely to be protected.

[20]Compare this approach to the approach taken in the companion studies of Maryland, Virginia, and Delaware. In those areas, developed areas are viewed as

are developed portions of PAs 4 and 5 where there is an economic basis for protection, and undeveloped portions of PAs 2 and 3 where state policy provides a basis for expecting eventual development and shore protection.

We distinguished areas where protection is legally permissible (blue) from conservation areas where protection is probably precluded (light green) using two types of data:

(1) The state plan has distinct classifications for parklands. Most of the park planning areas are rural, but some are ballfields or other small recreational parks in urban areas. The park planning areas do not include all conservation lands, but

(2) We obtained "open space" data from the New Jersey Department of Environmental Protection (NJDEP; see Table 3-4). Most of this open space consists of state-owned conservation lands within the rural and environmentally sensitive PAs 4 and 5, but it also includes small recreation-oriented parks (e.g., trails).

Our draft set of maps showed all park and open space lands as light green—regardless of planning area and whether the pilot effort treated them as likely to be protected. This approach and the expanded conservation data layer expanded the light green in the maps compared with the land not protected under any scenario in the pilot effort, for two reasons: Within PAs 4 and 5, public and privately owned conservation areas as well as any publicly owned parks that were omitted from the parks planning areas would now show up as a conservation land. Second, numerous ballfields and small parks in PAs 1–3 show up. Most of these parks would presumably be protected along with adjacent lands, but in a few cases preserving natural functions might be more important than keeping the land dry. It was at least conceivable that a community might elevate homes and adjacent yards but allow an open space area to gradually convert to wetlands. We then scrutinized all of these parks and changed recreational parks and historic sites back to protection likely. We also relied on county reviewers to change those parks as needed.

We sent the initial revised maps to NJ DEP for review and revisited the coastal county planning offices,[21] with a focus on our distinctions between *almost certain* and *likely* to be protected. As we explain below in the county-specific discussions, most of the changes made shore protection more likely.

almost certain to be protected, while growth areas that have not yet been developed are likely to be protected. Both approaches assume that developed areas in planned growth regions will be protected, but in New Jersey protection is less certain for developed areas outside of designated planning areas, whereas in the other states protection is less certain for areas that have not yet been developed. In both cases, local officials had the opportunity to change the classifications, so the final results are not as different as the variation in approach might seem to imply.
Nevertheless, the distinction is not totally without justification: In New Jersey, the planning areas are based in part on environmental sensitivity, which has an effect on the feasibility of shore protection. Therefore, it is reasonable for the planning area to have a greater impact on the likelihood of shore protection than in other states. Moreover, the dense populations and high property values in the coastal zone imply that all areas in PAs 1, 2, and 3—as well as the centers—will eventually be much more densely populated than (noncenter) lands within PAs 4 and 5, which makes current development density less important than planning area designation. In the less densely developed areas of the other states, by contrast, some of the undeveloped areas slated for growth may not be developed for a few decades, which increases the feasibility of possible plans to preserve wetlands in those areas.

[21]Michael Craghan revisited these counties.

TABLE 3-6. SUMMARY OF GIS DATA APPLIED IN STUDY[a]

Data Name	Application in Study	Source/Scale/Year Published
2002 state plan	Recreational parks, planning areas 1 through 5, and military lands within full study area; The Meadowlands in Bergen County	New Jersey Office of State Planning/ 1:24,000/ 2002
State open spaces	State-owned and protected open spaces and recreation areas within full study area	New Jersey Department of Environmental Protection, Green Acres Program/ 1:12,000/ 1999
Federal open spaces	Federally owned and protected open spaces and recreation areas within full study area	New Jersey Department of Environmental Protection, Green Acres Program/ 1:24,000/ 1999
Conservation lands	Conservation easements and parcels owned by New Jersey land trusts within full study area	New Jersey Conservation Foundation/ 1:100,000/ 1999
Nonprofit conservation lands	Conservation easements and parcels owned by nonprofit organizations within full study area	New Jersey Department of Environmental Protection/ 1:100,000/ 1999
Pinelands Commission	Preservation area district, military and federal installation areas, regional growth areas, Pineland towns, Pineland villages, and rural development areas within the state designated Pinelands area	New Jersey Department of Environmental Protection/ 1:24,000/ 2003
1995 land use/land cover	Transportation structures and developed lands[b] within planning areas 2 and 3 in Atlantic Ocean counties and within planning areas 4 and 5 in Delaware River; transportation structures and developed lands[b] within Pineland regional growth areas, Pineland towns, Pineland villages, and Pineland rural development areas; major barrier beaches and barrier roads in Cape May, Atlantic, Burlington, and Ocean counties	New Jersey Department of Environmental Protection/ 1:40,000/ 1995
State Planning Center	Planning centers within the full study area	New Jersey Department of Environmental Protection/ 1:24,000/ 2002
CAFRA II	CAFRA boundaries and coastal centers within full study area	New Jersey Department of Environmental Protection/ 1:12,000/ 1999
Salem County: urban areas	Commercial, development, high density residential, industry, and institutional zones within Salem County	Salem County Zoning/ 1:24,000/ 2001
Salem County: open spaces	Open spaces, farmland preservation areas, and natural heritage sites.	Salem County/ 1:24,000/ 2004
Salem County: state plan	Planning areas 1 through 5 and recreational parks	Salem County/ 1:24,000/ 2004
ESRI	Major roads in full study area	ESRI/ 1:50,000/ 2002
Wetlands	Wetlands in full study area	New Jersey Department of Environmental Protection/ 1:40,000/ 1986

[a]Appendix D provides additional detail on each data source.
[b]Developed lands include residential, commercial, industrial, and institutional lands.
[c]Developed lands were identified by the following Anderson classification codes: 1000 (urban land), 1100 (residential), 1200 (commercial and services), 1211 (military reservations), 1300 (industrial), 1400 (transportation/communications/utilities), 1500 (industrial and commercial complexes), 1600 (mixed urban or built-up land), 1700 (other urban or built-up land), 1800 (recreational land), and 1804 (athletic fields – schools).

Delaware River Counties

We started out by visiting the county planning offices in Burlington, Camden, and Gloucester counties with drafts of the pilot effort for the coastal counties but no proposed planning maps for those counties. Those visits provide the basis for much of the discussions in the county-specific sections.

In each case, the planners endorsed the decision rules we applied in the Atlantic and Delaware Bay counties, with a few modifications. Except for parks and conservation lands, the general rule is that land in PA 1, 2, or 3 and centers in PAs 4 and 5 are almost certain to be protected (brown). All other developed areas (according to state land use data[22]) are likely to be protected (red). Protection is unlikely (blue) for undeveloped land in PAs 4 and 5 that is not designated as a park or conservation land.

As with the CAFRA counties, the underlying rationale is that developed areas are rarely if ever abandoned to the sea in New Jersey. Nevertheless, lightly developed areas may not always justify shore protection. Those areas that are either in a center or in PA 1, 2, or 3 have state acceptance for development, which would tend to make future development as well as state maintenance of infrastructure and state sponsored coastal protection more likely. By contrast, developed areas that are not in PA 1, 2, or 3 or in a center would have less support and, as a result, shore protection is less certain.[23]

Our default rule for Delaware River counties seems more protective than the general rule for CAFRA counties, where undeveloped PA-2 and PA-3 lands are assumed likely (but not certain) to be protected. There is less difference than meets the eye, for two reasons: First, the undeveloped PA-2 and PA-3 lands near the Delaware River are relatively small areas that would generally be protected along with protecting areas that are already developed; and the CAFRA counties made numerous changes to the maps to reflect near-certain development and protection of undeveloped PA-2 and PA-3 areas.

We distinguished areas where protection is unlikely from conservation areas where protection is probably precluded based on the state planning area data. As with the CAFRA counties, parks and open space lands were generally treated as conservation lands that will not be protected. However, parks that were adjacent to a PA 1–3 area (or a center) were generally depicted as red (likely), on the assumption that they would be protected along with the adjacent lands. Nevertheless, lands included in the open space data layer (which excludes most recreational parks) were treated as conservation lands even if they were adjacent to a center or PA 1–3 land.

North Jersey and Raritan Bay Counties

We devoted fewer resources to these counties than elsewhere in New Jersey because the high population densities make shore protection very likely. We developed initial maps based on the state plan and discussions with state officials, using the decision rules discussed above. We then contacted the counties and the Meadowlands Commission to determine whether changes were warranted.

Phase 3: Stakeholder Review

As a final check on the maps, we sent the January 2003 draft of this report along with the revised maps to each of the counties. Doing so was important because even though we dutifully followed the decision rules and otherwise depicted the protected areas as suggested during previous meetings, textual adherence to GIS decision rules is no substitute for comparing a map to reality. This final round of telephone conversations produced written comments from several

[22]We delineate these developed lands using land use/land cover data. For the purpose of this study, we define developed lands as including industrial areas, residential developments of high or single-unit/medium density, commercial and service areas, and other urban built-up lands.

[23]See note 20 (comparing variations in method between this study and companion studies of Maryland, Virginia, and Delaware).

counties and identified additional areas for probable shore protection.

Most of the map changes from this final round of comments involved relatively minor site-specific changes. In a few cases, however, we noticed a pattern in the changes and redefined county-wide or state-wide GIS decision rules based on that pattern.[24] We also took one last look at the maps and fixed errors that the stakeholders had not noticed.[25]

Map Scale

Because our maps are based on decision rules and previously published data, the horizontal resolution at which one should reasonably display our maps is limited by the precision of the input data.

Most of the input data for this study were created at a scale of 1:24,000 or 1:40,000. The land use data were generally at a scale of 1:40,000. The state plan, local planning data, and some federal lands data were at a scale of 1:24,000. Conservation lands data, by contrast, generally appeared to be 1:100,000. In general, the conservation lands data are used to identify "no protection" and the other data were used to distinguish shore protection certain, likely, and unlikely. Thus, at first glance one might be inclined to consider the "no protection" polygons to have less precision than other map boundaries. However, we made numerous site-specific corrections to the lands within the other three categories as a result of the stakeholder review. Those corrections were mostly made using the land use (1:40,000 scale) data, but some involved "heads up" digitizing of features with a precision worse than 1:100,000. Therefore, we recommend that none of our maps be produced at a scale better than 1:100,000.

The quality of our input data is not the primary uncertainty associated with our map boundaries.

Future development and shore protection are very uncertain. Thus, the scales we suggest are simply our advice regarding the maximum scale at which one ought to display the maps for a given location rather than our assessment of the accuracy of what will actually transpire in the decades ahead.

Use of Experts

This study is a hybrid between a pure data-driven assessment and an expert panel assessment. Like most assessments of shore protection, we start with the premise that (under current policies) lands will be protected if the cost of protection is less than the value of the resources being protected, except for where specific policies dictate otherwise. But estimating the costs and benefits of shore protection at every location would have been infeasible—and possibly involve wasted efforts for areas where the question is not close.

Instead, we adopted a simpler model: First, we identify areas where conservation lands preclude shore protection, areas that

[24] Counties pointed to several parks in developed areas that are likely to be protected, and did not specifically identify any parks where retreat is likely in the midst of an area where lands are otherwise being protected. The counties did not comment on every park in the data set, but whenever we asked about a park, they indicated that protection was likely if not certain. Therefore, we revised the maps in all counties by showing parks and open space lands within PA 1 as almost certain to be protected and parks and open space lands within PAs 2 and 3 as likely to be protected, unless the county had specifically indicated otherwise.

[25] Most problems resulted from one of two erroneous decision rules. First, the maps had incorrectly assumed that developed areas in PAs 4–5 that were not part of centers were unlikely to be protected. (See discussion under Phase 2 and footnote 19.) Second, Phases 1 and 2 of this study had overlooked the fact that PAs 1–5 do not apply in the Pinelands. We erroneously treated any land that was not PA 1–3 as if it was PA 4 or 5. The EPA project manager noticed that New Gretna and Mays Landing did not show up on the draft maps. He originally thought it was a problem with the land use data, but in reality it had resulted from the combination of the two erroneous decision rules, both of which have been corrected. See the discussion of Burlington County for additional details. In addition, an incorrect ordering of some layers of data showed no protection for some industrial areas near Liberty Park.

governments have decided to revert to nature for flood mitigation or environmental reasons, and areas that are so densely developed that no one seriously doubts the likelihood of shore protection (given current policies). Second, along estuaries we assume that residential, commercial, and other developed lands will be protected and that undeveloped lands will not be protected.[26] We rely on local planners to help us correctly use land use, planning, and zoning data—and to apply current land use policies—to identify current and project future development. Third, along ocean coasts, our premise is that current shore-protection policies generally have defined the areas where beach nourishment is almost certain, and that shore protection is likely in other areas that reach high densities. All of these aspects of the study are essentially data-driven, using a very simple model of the areas where shores are protected.

Nevertheless, we had to rely on local planners to provide facts or opinions in those cases in which the necessary data are unavailable, out of date, or provide an ambiguous result requiring a human tie-breaker. Most of the map changes provided by local planners involved cases where our data showed no development, but planners were aware of recent or imminent development. But in a small number of cases, planners reviewed our initial results, made a policy-based conjecture, and requested a map change. Judgment-based map designations constitute a very small percentage of the land depicted in the maps in this study.

We hope that the way we document our results does not leave researchers with the impression that our estimates of the likelihood of shore protection are simply the opinions of planners on a subject over which they lack expertise. We rely on planners to help us identify current and future land use and identify policies related to development and shore protection—matters that fall within their responsibility. Given expected development, the favorable or unfavorable economics of shore protection—not planner opinions—generally determine our results.

For most readers, these distinctions may be of little interest. For brevity, the report often says “planners expect shore protection” at a specific location, when a more precise exposition of our analysis might say “planners provided us with data on existing land use data and/or master plans. These data, along with site-specific planner knowledge, imply a level of development that would more than justify shore protection if current policies and economic trends continue. Therefore, planners expect shore protection.

[26]The cost of shore protection along estuaries is small compared to property values in developed areas—and homes are rarely given up to retreating estuarine shores except for where policies prohibit shore protection.

STATE POLICIES

State policy regarding coastal hazard responses is very clear on one point. Former Governor Whitman promised coastal communities that "there will be no forced retreat," and that the government would not force people to leave the shoreline. That policy does not necessarily mean that there will always be government help (e.g., state-sponsored shore protection, permits for private actions, guarantees of insurance availability, and maintenance of bridges, highways, and causeways) for shore protection. Nevertheless, although subsequent administrations have not expressed this view so succinctly, they have not withdrawn the policy either. If fact, the primary debate in New Jersey tends to be the level of public access required before a community is eligible to receive protection, not the need for publicly funded shore protection itself.

Tourism is one of the largest segments of the New Jersey economy. A large portion of this contribution is directly related to tourism at the state's beaches. Beach tourism is cited as a compelling reason to fund shore protection measures; beach nourishment has been touted as investment in a tourism infrastructure.

In New Jersey, beach nourishment is the preferred method for reversing beach erosion and protecting oceanfront land from coastal storms. Numerous projects have been implemented along the New Jersey Shore, and they are likely to continue into the foreseeable future. The entire Monmouth County shoreline either has been recently filled or will be in construction soon. Continued renourishment is also planned over the next 50 years. Beach nourishment has been undertaken or desired in every coastal county, including the Delaware Bay shore and Delaware River counties. Historically, some form of beach nourishment has been undertaken along much of the developed portion of Island Beach, near Barnegat Inlet, on nearly all of Long Beach Island, at Atlantic City and Ocean City, in Avalon, in Stone Harbor, at the end of the Cape May peninsula, and on Raritan Bay shores.

Based on the state's policies, property owners will not be forced away from the coastline through state actions. Beach nourishment is likely everywhere on the ocean shoreline that budgets allow. Areas that contribute to tourism will also almost certainly be protected. At least that is how most observers see the situation today. If a catastrophic storm caused substantial beach erosion and property damage during a period of state budget deficits, it might be economically infeasible to reclaim all the land lost to oceanside erosion. A severe storm might also cause new land to be created on the baysides of some barrier islands, through the geological overwash process. Nevertheless, permanent changes to the shoreline along the densely developed portions of the New Jersey shore would probably be confined to a very small number of unusually vulnerable areas and, in any event, would probably be too small to be noticeable at the scale intended for the maps produced by this study. Therefore, the assumption that these shores will be protected in their entirety is a generally accurate assumption; but occasional small-scale exceptions may occur.

Rules for Coastal Zone Management (N.J.A.C. 7:7E)

The Coastal Area Facility Review Act (CAFRA) seeks to control the development of the coastal area to improve the economic position of inhabitants while also preserving ecologically sensitive areas.[27] This law regulates development activities within the coastal area and requires a permit for most residential, commercial, or industrial development; excavation; grading; and shore protection structures.

[27] See http://www.state.nj.us/dep/landuse/njsa/13_19.pdf.

The corresponding rules for coastal zone management (CZM) were originally adopted in September 1978 and amended many times over the years. Unfortunately, the rules for CZM are not clear demarcations of state policy. Although it is possible to read between the lines and find discouraged uses, the regulations do not explicitly prohibit any activities. Some actions are unregulated, whereas other actions may be permitted if certain conditions are satisfied.

Some direction is discernible in the rules for CZM. Technically, any activity can earn a permit. Governing principles, the rules for wetland areas, and policies for engineering uses, however, provide a sense of how the state would like to see coastal areas evolve. Below, we review the eight components of the state's CZM goals originally developed in 1978, and the key elements of rules and policies for wetlands and coastal engineering.

Coastal Decision-Making Principles

1. Protect and enhance the coastal environment.
2. Concentrate rather than disperse the pattern of coastal residential, commercial, industrial, and resort development; encourage the preservation of open space; and ensure the availability of suitable waterfront areas for water dependent activities.
3. Employ a method for decision making that allows each coastal location to be evaluated in terms of both the advantages and the disadvantages it offers for development.
4. Protect the health, safety, and welfare of people who reside, work, and visit the coastal zone.
5. Promote public access to the waterfront through protection and creation of meaningful access points and linear walkways and at least one waterfront park in each waterfront municipality.
6. Maintain active port and industrial facilities, and provide for necessary expansion in adjacent sites.
7. Maintain and upgrade existing energy facilities and site additional energy facilities determined to be needed by the New Jersey State Energy Master Management Plan in a manner consistent with the rules of this Coastal Management Program.
8. Encourage residential, commercial, and recreational mixed-use redevelopment of the developed waterfront.

Wetlands N.J.A.C. 7:7E –3.27

"Development in wetlands defined under the Freshwater Wetlands Protection Act of 1987 is prohibited unless the development is found to be acceptable under the Freshwater Wetlands Protection Act Rules."

"Development of all kinds in all other wetlands not defined [under the Freshwater Wetlands Protection Act of 1987] is prohibited unless the Department can find that the proposed development meets the following four conditions:

> 1. Requires water access or is water oriented as a central purpose of the basic function of the activity....;
>
> 2. Has no prudent or feasible alternative on a non-wetland site;
>
> 3. Will result in minimum feasible alteration or impairment of natural tidal circulation (or natural circulation in the case of non-tidal wetlands);
>
> 4. Will result in minimum feasible alteration or impairment of natural contour or the natural vegetation of the wetlands."

Coastal Engineering N.J.A.C. 7:7E –7.11

"Non-structural solutions to shoreline erosion problems are preferred over structural solutions. Vegetative shore protection measures have been proven effective, and are preferred at shoreline sites in which they are feasible.... The infeasibility and impracticability of a non-structural solution must be demonstrated before structural solutions may be deemed acceptable."

"Beach nourishment projects, such as non-structural shore protection measures, are

encouraged...” subject to design and public access requirements.

“The construction of new shore protection structures or expansion or fortification of existing shore protection structures... is acceptable only if it meets [specific] conditions”

“Maintenance or reconstruction of an existing bulkhead is conditionally acceptable....”

Waterfront Development Law

The Waterfront Development Law was passed in 1914 to avoid the disruption of navigation channels, marinas, moorings, other existing uses, and the environment. Today, property owners must obtain a Waterfront Development permit to develop on land adjacent to a tidal waterway. Under this law, the NJDEP reviews all permit requests for construction and reconstruction of coastal structures (including shoreline armoring), excavation, and filling.[28]

State Plan

The state plan is an advisory land-use planning tool first developed in 1992 that aims to channel growth into urban areas and other places with sufficient infrastructure to accommodate development. Although local municipalities are not required to participate in this planning process, the state infrastructure financing process provides a financial incentive. Regions and municipalities can also designate areas as “centers” to classify the area for future growth.

The state plan calls for concentration of development in growth planning areas (1 and 2) and centers. Land adjacent to PAs 1 and 2 areas may be characterized as PA 3 (fringe planning area) and may experience significant development in the future. Preservation of open space appears to be achievable in those environmentally sensitive areas (5, 4B) that were realistically designated and in rural planning areas (4).[29]

[28]See http://www.state.nj.us/dep/landuse/coast/coast.html.
[29]In 2000, the state also incorporated the state plan concepts in the regulatory framework of the CZM rules. See Appendix E for more information on the goals and strategies of the state plan.

Discussions with State Officials

We contacted two NJDEP officials during this investigation: Mark Mauriello, Bureau of Coastal Regulation, in his Trenton office and Bernard Moore, Engineering and Construction, by telephone.

NJDEP Bureau of Coastal Regulation

Mark Mauriello, Land Use Regulation director, NJDEP

Mr. Mauriello commented on state policies, including the former governor’s “No Retreat” statement. The NJDEP does not want to force people from the barrier islands. The CAFRA legislation unequivocally gives people the right to rebuild homes that are damaged in a storm. The state can, however, adopt other ways to deal with coastal hazards besides removing people from the shoreline. Setbacks and voluntary acquisitions can be used to protect people from risk. Other measures the state is looking at include encouraging the elevation of homes to protect them from flooding.

In terms of permitting, coastal wetland alterations are effectively off limits; docks or public utilities are about all that would be allowed in wetlands. Bulkhead permit requests would be reviewed case by case. The state is trying to move away from “vertical structures” for shore protection and is looking to use hazard setbacks and the CAFRA regulations to address erosion.

NJDEP Engineering and Construction

Bernard Moore, administrator, Engineering and Construction, NJDEP

If the state continues with its beach nourishment program, the ocean shoreline can handle the entire sea level rise projected for the next 100 years. The state is not, however, planning any projects for the estuarine environments. Mr. Moore recognized that sea level changes could generate substantial problems, including wetland loss and encroachment onto highways and into built areas.

Mr. Moore suggested some measures that would have to be undertaken to deal with sea level

changes in the back bays (such as raising bulkheads and installing flap valves on drainage systems). Pumping systems might be necessary in some places. Other possible projects include raising highways such as the Garden State Parkway (which would necessitate large-scale filling of wetlands) or building tidal gates such as from Sea Bright to Highlands. He indicated that large-scale projects like the tide gates are not likely to be undertaken.

In summary, he believed that the state is able to handle a modest amount of sea level change on the ocean shoreline. Currently, no plans exist for state-sponsored shore protection projects in back bay environments.

Other State Factors

A study of coastal zone management practices to deal with sea level rise in New Jersey is complicated by several factors. Some are unique to New Jersey, such as the Blue Acres program; others are also encountered in other coastal states.

Federal Funding for Shore Protection

The availability of federal funds for shore protection measures is one of the most important variables in sea level rise protection planning. Decreases to the federal coastal engineering budget or to the federal contribution of the cost-sharing formula would have a severe impact on the size and scope of shore protection measures in New Jersey. Decreases to the amount of money available for engineering projects will force the state to allocate money in a different fashion, and may result in some areas being unable to attract any funding.

Blue Acres

The Blue Acres program commenced in 1994 following the strong storms in the early part of that decade. The program applies a two-pronged approach to mitigate future storm damage. Forty percent of the program's $15 million funding is dedicated to open space preservation in coastal areas to protect it from development—as of 1998, all these funds had been committed to projects. The remainder of the Blue Acres program is oriented to buying property from willing sellers who are at some risk from coastal storms or chronic erosion.[30] The impact of the Blue Acres program on land use in coastal areas is also unclear. To date, Blue Acres' funds have not been used for buyouts.

The long-term implications of this program are unclear. If contiguous homeowners apply for and receive Blue Acres money to abandon risky areas, then that will alter the exposure to damage and allow governments to reallocate coastal protection money. On the other hand, homeowners along the whole coast of New Jersey may receive buyouts after storm damages. Although potentially equitable, that scenario will have a very different consequence for CZM.

Municipal Land Use Regulation

New Jersey is a home-rule state, and land use decisions are made at the municipal level. County governments have (for practical purposes) no land use regulatory power in New Jersey. The state becomes involved only when adverse environmental impacts are presumable (e.g., wetlands or waterfront development). Local governments decide whether residential developments or shopping malls are approved. Predicting the decisions of hundreds of local planning boards made up of transient membership is impossible and beyond the scope of this project. The fact that the state has some purview over land use in waterfront areas, wetlands, wetland transition area, and the CAFRA zone, however, may curtail some of the autonomy of local planning boards in coastal areas.

Private Resources

Private resources have enabled several shore protection projects or land uses that would not have otherwise been undertaken. Oceanfront bulkheads have been installed by private homeowners in places that may have been low priorities for state action. In other instances financial security has permitted some to escape flood insurance problems or to overcome obstacles of the Coastal Barrier Resource Act.

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[30]The state has appropriated $15 million for both post-storm and pre-storm purchases and projects. Personal communication with Mark Mauriello, NJDEP. Also see www.state.nj.us/dep/greenacres/blue.htm, accessed on October 7, 2004.

RESPONSES TO SEA LEVEL RISE

Let us now examine the likely response to sea level rise implied by existing policies, the decision rules discussed in the Methods section, and the site-specific insights provided by county planners. To provide some context, we include information about county policies, demographics, and other relevant information collected in the meetings with county planners. We separate the discussion into three geographic regions: (1) the coastal counties along the Atlantic Ocean and Delaware Bay (2) counties along the Delaware River; and (3) the northern counties in the New York metropolitan area.

ATLANTIC COAST AND DELAWARE BAY COUNTIES

Meetings with coastal county planning representatives were initially conducted in 1999. Meetings with planners were held in Salem, Cumberland, Cape May, Atlantic, Ocean, and Monmouth counties. Follow-up discussions were conducted in January and February 2002. These counties have approximately 240 miles of open water shoreline on Delaware Bay, the Atlantic Ocean, and Raritan Bay. The tributaries and back bays have more than 1,000 miles of shoreline. We briefly examine each of these counties, starting with Monmouth County at the north end of the Jersey Shore, then working our way south to Cape May and then up Delaware Bay.

Table 3-7 summarizes the general approach we employed to map the protection likelihood. Site-specific differences are noted in the individual county discussions.

Middlesex County

Middlesex County has mostly natural shores along Raritan Bay, with substantial dunes. To a large extent, public roads, bike paths, and parks are immediately inland of the beach, with residential development farther inland. Those areas are almost certain to be protected, with beach nourishment the likely method. Above Perth Amboy, along Arthur Kill, one finds a mixture of armored shores and beaches, with dense development inland of the shore. (See Photos 3-1 through 3-5.)

Baseline Plan for Sea Level Rise

Given a combination of budget limitations and the likelihood that all developed lands would be protected, Craghan initially mapped this county based on his own judgment, and did not contact the local governments. In the draft maps, our only departure from the general decision rule concerned three landfills along the Raritan River, which are outside of the protected planning areas and centers. Nevertheless, the environmental implications of allowing landfills to erode can be substantial. Therefore, we classified these areas as likely to be protected. With this change, the map showed 85–90 percent of the shore as almost certain to be protected, with the remaining areas evenly divided between the other three categories.

Map 3-2 shows the areas likely to be protected. The page that follows the map provides a more detailed legend that defines each of the symbols used in the county-specific maps included in this report.

Stakeholder Review

The County agreed with our general assumptions, and found that most of its coastal zone was correctly depicted in the maps. Nevertheless, the environmental planner suggested three changes[31]:

Change the conservation lands along the South River from light green to red. Those conservation areas represented the well fields for the Perth Amboy/Runyon and Duhernal water systems. Shore protection is likely but not certain, because saltwater is likely but not certain to advance upstream if sea level rises enough to

[31]See email from William Kruse, assistant planning director for Environment, Parks, & Comprehensive Planning, Middlesex County, to Jim Titus, December 1, 2004 (responding to email from Titus, November 30, 2004, with attached map [summarizing conversation that morning on suggested map changes]). The conversation originally contemplated certain protection of the closed portion of an open land fill, but on reflection it would seem at least possible that if wetland migration were required somewhere in the county, those landfills might be sites for future wetland mitigation.

TABLE 3-7. GENERAL APPROACH FOR MAPPING ANTICIPATED SEA LEVEL RISE RESPONSE: ATLANTIC OCEAN, DELAWARE BAY, AND RARITAN BAY (MONMOUTH, OCEAN, BURLINGTON, ATLANTIC, CAPE MAY, CUMBERLAND, AND MIDDLESEX COUNTIES)[a]

Land Area	Protection Likelihood				Source
	No protection	Unlikely	Likely	Certain	
Site-specific exceptions to general rule[b]	Varies				Varies
Open spaces[c] within planning area 1[d]				✓	State plan, state open spaces, federal open spaces, and conservation lands
Open spaces[c] within planning area 2 or 3[d]			✓		
Remaining open spaces[c]	✓				
The Pinelands[e]: Preservation Area District	✓				
The Pinelands[e]: military and federal installation areas			[f]		
The Pinelands[e]: developed lands[e] within regional growth areas, Pineland towns, Pineland villages, and rural development areas				✓	Pinelands Commission and 1995 land use/land cover
The Pinelands[e]: remaining lands within regional growth areas, Pinelands towns, Pinelands villages, and rural development areas			✓		
Planning centers				✓	State planning centers
Developed lands[g] in planning areas 2 and 3				✓	
Monmouth and Middlesex counties: developed lands in planning areas 4 and 5				✓	State plan and 1995 land use/land cover
Developed lands[g] in planning areas 4 and 5[h]			✓		
Planning area 1				✓	State plan
Planning areas 2 and 3, and other lands identified as likely to be protected in initial phase of study[i]			✓		State plan, original planning study
Remaining public and private lands		✓			State plan

[a]Where land areas overlap, classifications higher in the table take precedence.
[b]See text of report for site-specific exceptions to the general mapping method.
[c]Open spaces include state open spaces, federal open spaces, conservation easements, land trusts, greenways, wildlife preserves, and national parks.
[d]The original drafts had treated parks as unlikely to be protected. Comments made by planners during stakeholder review indicated that parks in developed areas are likely to be protected.
[e]We defined "The Pinelands" as lands within the state designated pinelands area. Areas within the Pinelands National Reserve but outside the state designated pinelands area are not included in this category.
[f]Based on the nationwide approach of this study for secured installations, the maps depict these areas as red. The data we distribute assigns the code "military" rather than "protection likely."
[g]We used New Jersey land use/land cover to identify developed lands (transportation structures and residential, commercial, industrial, and institutional lands).
[h]The draft treated undeveloped areas as unlikely to be developed. This general rule was added as a result of the stakeholder review.
[i]See text of report for explanation of the initial study.

Photos 1–3. Views from the Raritan Yacht Club, Perth Amboy. On the other side of Arthur Kill, natural sandy beaches dominate the shores of Staten Island (Photos 1–2). Armored shores are more common, by contrast, on the New Jersey side (Photo 3) (August 2003).

Photos 4–5. Woodbridge Township Public Launch. Sand and clay shore along Arthur Kills, near Pumping Station 2 (August 2003).

inundate these areas. Currently, portions of these areas are nontidal freshwater wetlands, and conversion to tidal freshwater wetlands would not harm the aquifer protection function of these conservation lands. Conversion to salt marsh, by contrast, would contaminate the aquifer, and even occasional tidal flooding from saltwater could cause problems. Nevertheless, protection is not certain because by the time this area is threatened with sea level rise, saltwater intrusion through the ground might be so great that protecting this recharge area from inundation would not protect the wells. Therefore we changed these areas from light green to red.

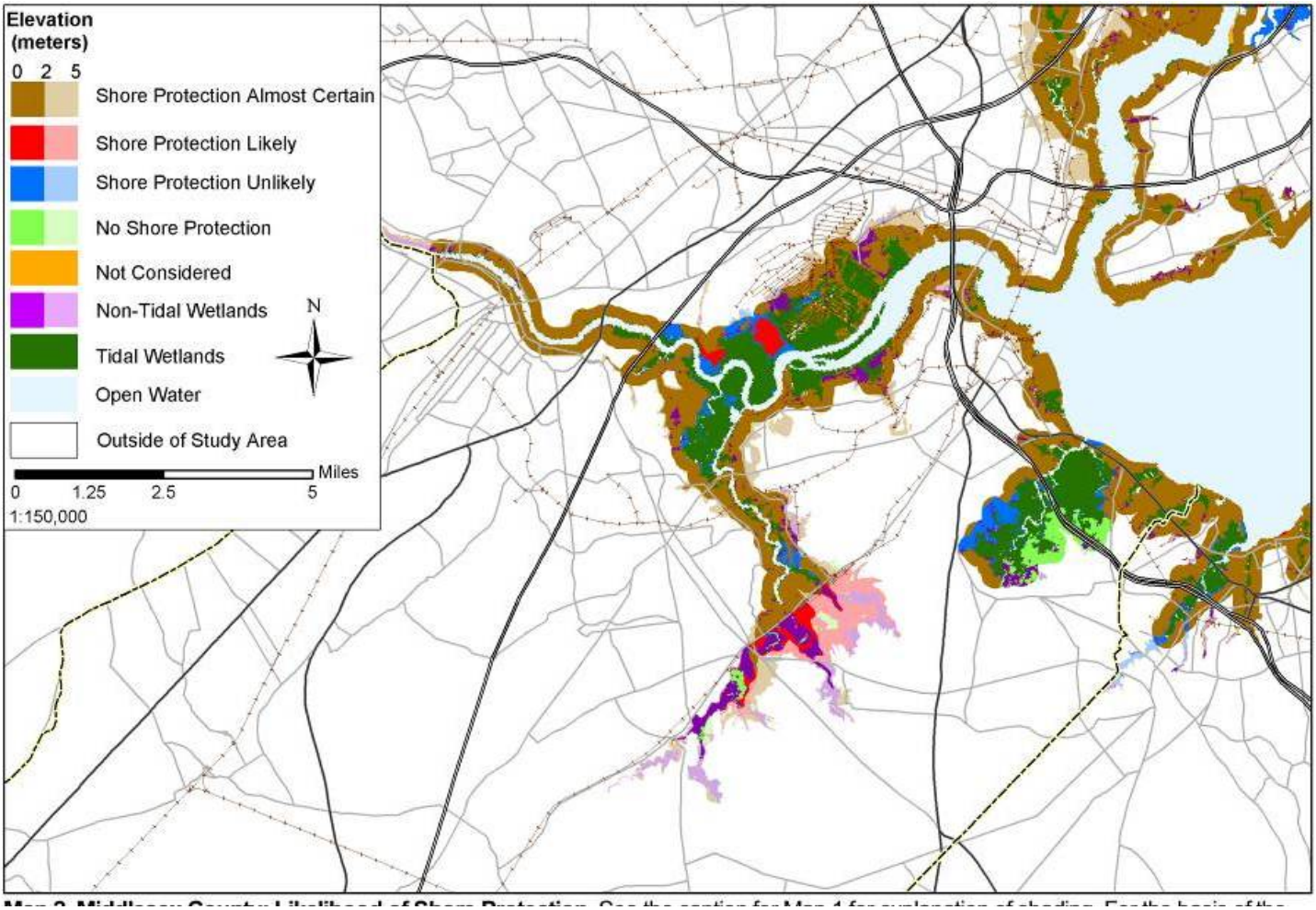
Change the middle of the three landfills from red to brown. This area included the former Kinbuc chemical waste landfill, now a Superfund site, with substantial quantities of oily wastes, including PCBs. There could be substantial risks from allowing this site to become flooded. The polygon also includes the adjacent Edison Municipal Landfill. The extent to which Kinbuc chemicals may have migrated to Edison is unknown, but given its proximity to the Superfund site, it is reasonable to assume that it is almost certain to be protected as well.

Change dry land within the old Raritan Arsenal grounds from blue to red. The developable dry land is likely to be developed.[32]

In addition to these changes, the County corroborated several aspects of the map:

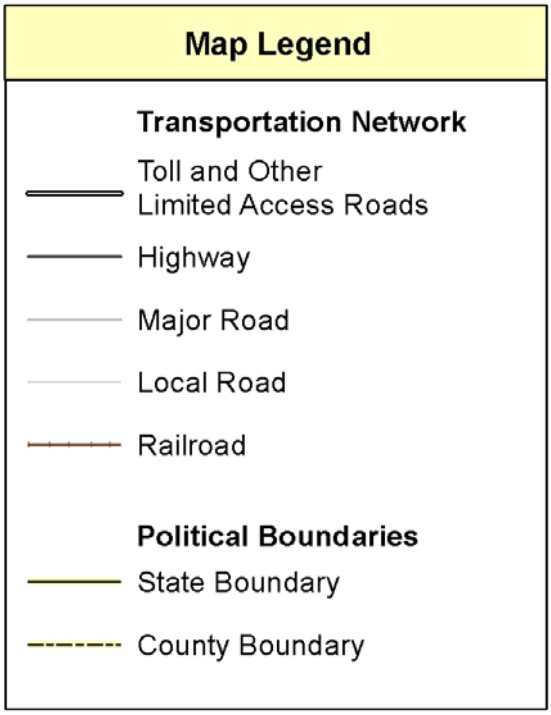
- Parks along the shore, in general, will be protected.
- Just west of where the Garden State Parkway crosses the Raritan River, the maps correctly show wetlands with roads running through the marsh.
- The many small blue polygons represent areas that are not likely to become developed. These areas are generally environmentally sensitive and likely to be buffers of dry land adjacent to wetlands, or wetlands that show up as dry land with the data set we used.

[32]"The Raritan Arsenal closed years ago. The land was sold to developers [who] created the Raritan Center office and industrial park. The center's owners have developed most of the upland parts of their holdings. They continue to work with the NJDEP, EPA and the Corps of Engineers to determine the remaining areas that are suitable for development and whether or not mitigation is possible to assemble large enough areas for new development. A new roadway extension (Riverside Drive) is proposed for construction through this area. At such time that the road alignment is settled and developable lands identified, it is expected that Raritan Center will expand into this area." William Kruse, December 1, 2004, email to Jim Titus.



Map 3-2. Middlesex County: Likelihood of Shore Protection. For each shore protection category, the darker shades represent lands that are either less than 6.6 feet (2 meters) above spring high water or within 1,000 feet of the shore. The lighter shades show the rest of the study area. For the basis of the shore protection categories in adjacent states, see the companion study of New York. This map is based on data published between 1999 and 2001. Although the map also reflects site-specific changes suggested by planners in 2002 and 2003, the intended use of this map is to convey countywide prospects for shore protection, not to predict the fate of specific neighborhoods. Changes in the policies and trends we considered—or factors that we did not consider—may lead actual shore protection to deviate from the likelihoods depicted in this map.

The detailed legend for this and the other county-specific maps is on the next page.



Map 3-2 (continued). Middlesex County: Likelihood of Shore Protection. This legend defines the meaning for the transportation and political boundaries used in the county-specific maps.

Monmouth County

Monmouth County is the northernmost county along New Jersey's ocean coast. It is also in the part of New Jersey's Atlantic Coast closest to New York City and metropolitan North Jersey, and its coastal region is very highly developed. Of the four open-ocean counties, Monmouth County is also at a much higher elevation than the spit and barrier island coasts to the south. The county also has both sandy shores and tidal wetlands along Raritan Bay (see Photos 3-6 through 3-10), Sandy Hook Bay, and numerous small bays and creeks.

The regulated coastal zone in Monmouth tends to be narrow, and is mostly developed; the large wetlands found in the southern estuaries do not exist in this county. The county has a long history of coastal protection activities. The shoreline is heavily armored with groins and jetties at two inlets. A seawall runs from the City of Long Branch north to Sandy Hook, portions of which were originally built almost 100 years ago. Although the seawall was set back from the shore, by 1980 the shore had eroded up to the seawall, leaving little if any beach. In spite of the importance of beaches, dismantling the seawall was out of the question because it protected the primary coastal highway.

For a time, some coastal geologists, alarmed that this experience might be replicated elsewhere, coined the term "NewJerseyization" to indicate the replacement of ocean beaches with hard structures. Although the phrase was less-than-complimentary, it helped to create a statewide consensus against hard structures in favor of beach nourishment, and also prompted North and South Carolina to enact erosion-based setback laws. More recently, the beaches have been entirely restored through various beach nourishment projects. (See Photos 3-11and 3-12.)

Discussions. Our assumptions regarding the County's response to sea level rise are based on conversations with Linda Brennen, P.P., A.I.C.P., supervisor, Environmental Planning Section; Edward Sampson, supervisor, Long Range Planning Section; Robert W. Clark P.P., director, Monmouth County Planning Board, and Gerald J. Freda, P.E., borough engineer, Borough of Keyport.

State Plan. Nearly the entire CAFRA zone in Monmouth has been classified as PA 1 (i.e., a metropolitan planning area). Patches of PA 5 (the environmentally sensitive planning area) include wetlands on the Raritan bayshore and Navesink River shoreline, and bay islands in the Shrewsbury estuary. The Monmouth Beach, Sea Bright, Sandy Hook spit complex is also PA 5.

The planners did not express any objections to the state's planning area designations. It was felt that the plan was consistent with what the County wanted. A fully developed bay island in the Shark River estuary will be changed from PA 5 to PA 1. Some of the PA 5 in the county referred to historically significant areas and not to the environmentally sensitive appellation. (See specific instances below.)

Economics. Economic activity at the coast is dominated by beach tourism. Tourism is also being pursued as a possible jump start to redevelopment in Long Branch and in bayshore communities. Beach access is generally good, although Loch Arbour, Deal, Monmouth Beach, and Sea Bright lack parking. Nearly all the beaches are municipally owned. Sandy Hook is part of a national park, and Seven Presidents Park in Long Branch is run by Monmouth County.

Other tourism related industries in Monmouth County include commercial and recreational fishing. Brielle, Belmar, and communities along the Shrewsbury River and Raritan Bay host recreational fishing fleets. There is also commercial fishing at Belford on Raritan Bay.

Cultural Features. Prominent cultural features at the beach include the Convention Hall and Carousel building in Asbury Park, the community of Ocean Grove (which is on the National Register), and historical sites at Sandy Hook.

Photos 6–10. Port Monmouth and Vicinity. Photo 6 shows groins and dunes along the sandy beach at Bayshore Waterfront Park, along Raritan Bay. Sandy Hook is visible in the distance from Photo 7, taken from the same location. The other photos show (8) wetlands along the eastern edge of Port Monmouth, and a marina (9) and a dike (10) along the Pews Creek tidal marsh (August 2003).

Photos 11–12. Sea Bright, New Jersey. A decade ago, there was no beach between the seawall and the ocean, but beach nourishment projects have restored the recreational use of the shore (August 2003).

Other Considerations. The County Planning Board seeks to maintain public access to the beaches and discourages development that negatively affects scenic vistas and contributes to beach erosion. They also recognize that the coastline is subject to the forces of nature and is not a fixed boundary that must be maintained. However, because of existing economic investment, current zoning, and identification of these areas as PA 1, all currently developed areas along the coast will certainly be protected.

Transportation links may be at some risk from sea level changes. Route 36 currently floods in a number of places during storms: portions of the road along Raritan Bay feeder streams flood, and the area through Monmouth Beach and Sea Bright is at risk from Shrewsbury River flooding. In some places the Garden State Parkway's elevation is low as the parkway passes through coastal marshes. In addition, the North Jersey Coast Line railroad is also at some risk from rising water. It passes through numerous coastal salt marshes and crosses open water in several places, including Raritan Bay and the Manasquan River. Ferry links from the Raritan Bay shore to Manhattan might also be vulnerable to access limitations and terminal problems.

Shore protection has a long history in Monmouth County. Numerous groins and jetties exist along the two inlets. Bulkheading is ubiquitous along the estuarine shores and portions of Sandy Hook Bay. The infamous seawall runs from Long Branch north into Sandy Hook. An ongoing beach nourishment project runs from the Manasquan Inlet to Sandy Hook, which started in the 1990s and has a project duration of 50 years. Relatively little of the Raritan Bay shore has been armored, and beach nourishment has been employed in some cases. (See Photos 3-13 through 3-16.)

The Borough of Keyport is one example of a town that has been actively preparing for sea level rise. Recent activities include waterfront redevelopment initiatives, a proposed bulkhead improvement project, and a proposed realignment of American Legion Drive, which runs near the downtown business district. In addition, they are part of the Army Corps of Engineers "Erosion and Storm Drainage Reduction" feasibility study, which includes protection measures for the town's shoreline.

The U.S. Navy has an ammunition loading facility in Sandy Hook Bay that will probably be protected from rising seas. Other government

Photos 13–16. Estuarine shores in Monmouth County. Marshes and mudflats along Troutman's Creek (13), bulkheads separating marsh from nearby homes on the bayside of Monmouth Beach (14), wetlands with homes in the background visible from Shorelands Park, and (15) a recreational beach along Sandy Hook Bay at Atlantic Highlands, with Sandy Hook in the background (August 2003).

facilities include Coast Guard stations at Sandy Hook and at Shark River.

Some drinking water reservoirs might be at risk. Swimming River and the Manasquan River estuary might be affected by migrating salt fronts in the rivers.

Baseline Plan for Sea Level Rise

This county's long experience with shore protection gives it both the confidence that it can hold back the sea as necessary and the humility to understand that care must be taken to ensure that the results are desirable. Beach nourishment is almost certain to continue for the foreseeable future along the Atlantic Coast. Beach nourishment is also likely to be employed increasingly along Raritan Bay if shore erosion accelerates. Most of the developed areas along Sandy Hook Bay are already armored; and the back bays are gradually being armored as well.

Map 3-3 shows the areas likely to be protected, based on the assumptions enumerated in the methods section and site-specific changes suggested by county planners. Almost the entire coastal zone is developed and part of PA 1, 2, or 3, or a center. Nevertheless, during the second visit to the planning office,[33] a number of changes were requested, which are reflected in the final maps:

Change Bayfront Water Park from light green to red, because it is a park in a developed area

[33]Michael Craghan made this visit during winter 2001–2002 as part of Phase 2.

and will be protected in the course of protecting nearby areas.[34]

Change the U.S. Naval Weapons Station Earle near Port Monmouth to almost certain to be protected.[35]

Change the Atlantic Highlands Pier to almost certainly protected.

Change Sandy Hook to almost certain to be protected. There have been numerous beachfill and seawall projects as well as bulkheads and other shoreline armoring projects here. The Park Service is currently planning to build a sand bypass system to shore up the narrow section of the spit. Although Sandy Hook is part of the National Park System,[36] it has historic areas, a National Marine Fisheries Service Laboratory, and an active Coast Guard base.

Monmouth Beach will be protected.[37]

Seven Presidents Park will certainly be protected; it is in the middle of the Monmouth County beachfill project and has been nourished in the past.

The southern shore of the Shrewsbury River is certain to be protected—it was given the PA-5 designation because of the historical character of the area, not for environmental reasons.

Wall township is certain to be protected.

Stakeholder Review

The staff of the Planning Board reviewed the reports and maps for consistency with the *Monmouth County Growth Management Guide: Goals, Objectives, and Policies*. Their primary comment was that all developed areas should be shown as "protection almost certain."[38] The County marked the specific areas of concern on a map.[39] The final result was that very few areas are depicted in blue.

Monmouth County also distributed the report to 36 boroughs and townships for comment. Only the Borough of Keyport replied, emphasizing that Keyport's ongoing shore protection efforts help demonstrate that this community will be protected.[40]

[34]This and a number of other parks showed up as light green because of our approach of assuming that all park and open space lands would not be protected and then asking the counties to identify those instances where parks would be protected.

[35]As a practical matter, most of this base is in the highlands and more than 40 feet above sea level. A very small portion might be vulnerable to sea level rise. As a general rule, this project generally colors secured federal installations as red to acknowledge uncertainty and the fact that federal military intentions are outside the scope of expertise for county planners and state environmental officials. However, in an area where the surrounding land is all certain to be protected, the county planners may have more confidence, and to depict the installations as less likely to be protected would be misleading.

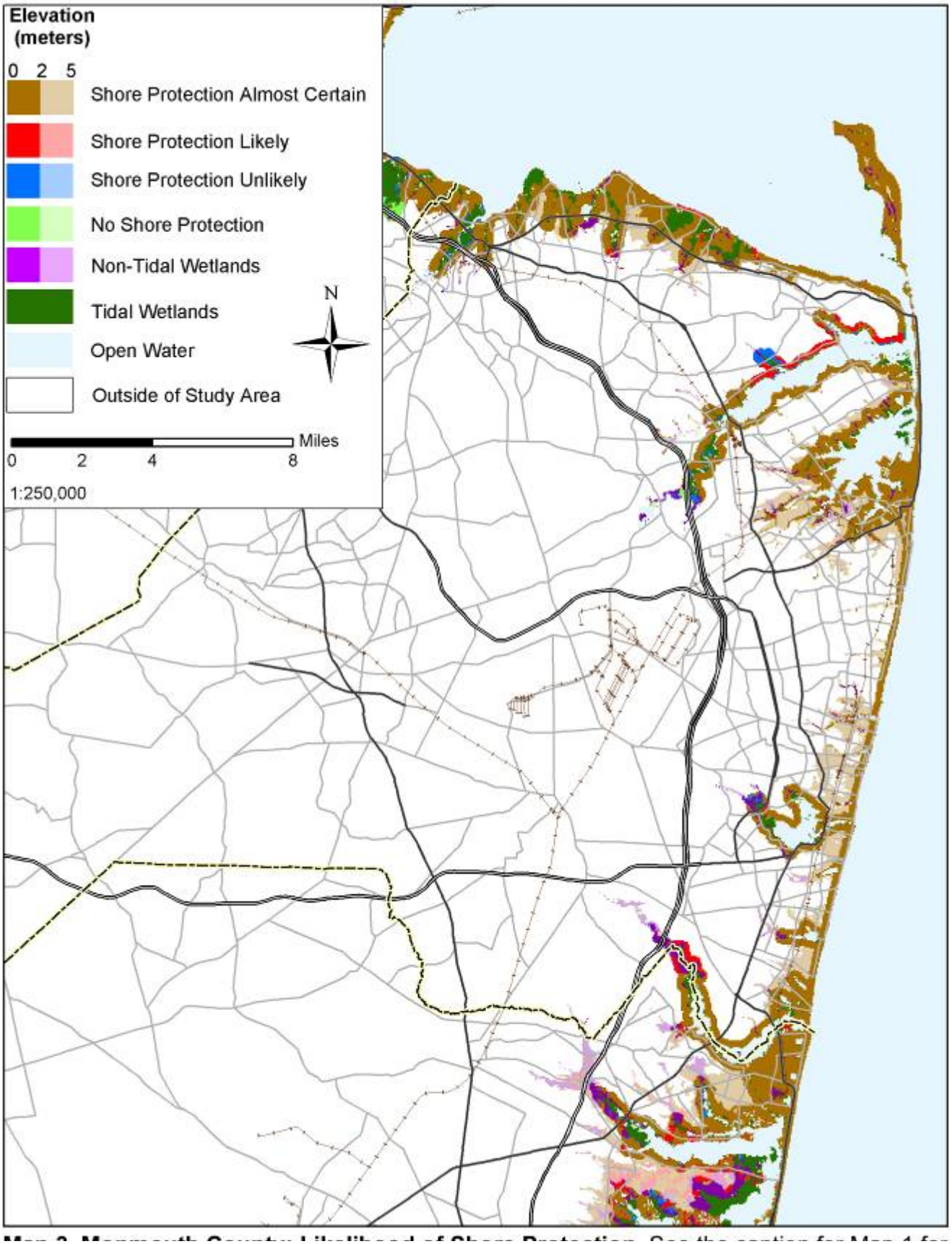
[36]Ordinarily, the National Park Service prefers to allow natural processes to work their will, and this project depicts most of these lands as light green.

[37]Like most barrier island communities, Monmouth Beach was classified as PA 5. Although the community has a central business district, expensive homes, and a post office, the state did not classify it as a center and our mechanical application of the decision rule led to the admittedly unreasonable projection of Monmouth Beach possibly not being protected while neighboring communities like Sea Bright were protected.

[38]Craghan's meetings with staff had resulted in numerous site-specific changes, but Craghan continued to operate within the original paradigm in which (a) PAs 1–3 were red or brown and PAs 4–5 were blue, unless (b) the locality stated otherwise. By the time of the stakeholder review, the "exceptions had swallowed the rule"; i.e., the locality had stated otherwise more often than not. The stakeholder review led us to recognize that our general rule was inappropriate, so we changed the rule to indicate that all developed areas were almost certain to be protected in Monmouth County.

[39]Robert W. Clark, PP, director, Monmouth County Planning Board, letter to Jennifer Kassakian, December 16, 2002.

[40]Gerald J Freda, PE, borough engineer, Borough of Keyport, letter to Judity L. Poling, borough clerk/administrator, Borough of Keyport, October 25, 2002 (forwarded to Robert W. Clark by Judity Poling, October 28, 2002 [attachment to December 16, 2002, letter from Robert W. Clark to Jennifer Kassakina]).



Map 3-3. Monmouth County: Likelihood of Shore Protection. For additional details, see the legend and caption accompanying Map 3-2.

Ocean County

Background

Ocean County has an open ocean shoreline that mostly comprises a barrier spit (Island Beach) extending south from Bay Head and another coastal barrier known as Long Beach Island. There is also an extensive estuarine shoreline along Barnegat Bay and its tributaries. The low sides of Long Beach Island flood regularly at high tide during wet periods and during extended periods of strong easterly or northeasterly winds, especially in the fall. (See Photos 3-17 through 3-20.)

Other areas at risk from sea level changes include Point Pleasant Beach on the oceanfront and other communities along the Manasquan River, Little Egg Harbor, and Great Bay estuaries.

Ocean County has undergone tremendous population growth recently, and has developed a strong tourism oriented economy. A tremendous amount of conservation activity is ongoing in Barnegat Bay and the other estuaries. Much of the bay shore has been protected in the Forsythe National Wildlife Refuge and Island Beach State Park, as well as in local and county parks and state wildlife management areas.

Discussions. Our assumptions regarding the County's response to sea level rise are based on conversations with David McKeon, P.P., assistant planning director, Ocean County Department of Planning

State Plan. The mainland portion of Ocean County north of Barnegat Inlet is nearly all PA 2, and there is a spot of PA 3 around Waretown.

Photos 17–20. Long Beach Island. (17) Typical flooding during high tide at Ship Bottom (Labor Day, 2003). (18) Bulkheads along the shore at Brant Beach, with High Island in the background. The beach in the foreground is part of Brant Beach Yacht Club—aside from parks and yacht clubs, bay beaches are rare. (19) An old cottage being elevated and (20) the ocean shore at Brant Beach (February 2005).

The undeveloped wetlands on the western side of Barnegat Bay are in PA 5. The barrier spit north of Barnegat Inlet is in PA 5 from Bay Head to the Seaside area but is classified as a coastal center. The southern half of the spit is Island Beach State Park. A fair amount of northern Ocean County is in designated centers.

South of Barnegat Inlet the planning areas are divided by geography. The inland boundary of our study area roughly divides the lower, environmentally sensitive PA 5 from the PA 2 and 4 areas on the mainland. PA 2 is located to the north, and PA 4 trails south from the Route 72 area down to Great Bay. Long Beach Island is designated PA 5 except in the national wildlife refuge at its southern tip. The entire developed portion of Long Beach Island is in a center. Centers also include the mainland in the Tuckerton area, and in the Stafford area where Route 72, Route 9, and the Garden State Parkway come together. The small islands in Barnegat Bay and Little Egg Harbor—many of which have lands several feet above spring high water—are generally PA 5.

The main contention Ocean County has historically had with the state plan is that the highly developed barrier areas no longer fit the definition of environmentally sensitive and should not be classified as PA5. The County has suggested a new "Coastal Town" designation as an alternative.

Economics. Barrier island communities produce substantial tourism revenue for not only the county but also the entire state. Protecting the barrier island infrastructure is considered vital to the economy. Some towns are very active in attracting tourism, others are more low key. Overall, a significant variety of tourism opportunities and revenue sources is available throughout the county.

Major employers in the county are not in danger from sea level changes. Commercial fishing ports in Point Pleasant Beach and Barnegat Light, however, would probably require some protection as sea level rises.

The Route 9 corridor is one of the highly developed commercial areas of the county. Growth is not permitted in much of the Pinelands area, so development pressure within the corridor will continue.

The county has some sewage treatment plants that might be vulnerable to an increased sea level. They will almost certainly be protected.

Cultural Features. Development in Ocean County has historically focused along the Route 9 corridor, which runs north–south through the county. Vulnerable areas along Route 9 will be protected at all costs. Historical and commercial centers are located along this road.

The Tuckerton Seaport could be an important cultural center and tourism draw in the future. The Tuckerton area is also important as a center in that part of the county.

Barnegat Lighthouse (built in 1857) is located at the northern end of Long Beach Island. Across Barnegat Inlet, a former U.S. Lifesaving Service building is located in Island Beach State Park. These facilities will be protected.

Other Considerations. A great deal of uncertainty centers on the Forked River nuclear power plant. The plant was recently purchased by another utility, but is currently scheduled for decommissioning in 2007. Even with decommissioning, the site may be a storehouse for radioactive waste for many years.

Point Pleasant Hospital is directly on the Manasquan River Estuary—although it too has an uncertain future and there are rumors of its closure. The site is likely to be occupied by some other use if its health care role is ended.

Some minor work has been done to mitigate coastal flooding in various municipalities. For example, the state sealed a breach at Island Beach State Park near Barnegat Inlet. Local governments are looking for soft solutions like dunes wherever possible, but rip-rap is still used for protection in areas where infrastructure is highly threatened. In addition, the foot of the Route 72 bridge in Ship Bottom is currently vulnerable to flooding and is likely to be raised in the near future. The bridge is the only evacuation route off Long Beach Island.

Ultimately they feel that land already developed will be protected, unless something catastrophic

happens. “We’re pretty certain that there’s such a level of development that it won’t be abandoned,” said Mr. McKeon.

Baseline Plan for Sea Level Rise

The developed portions of Ocean County’s shore along the Atlantic Ocean will almost certainly be protected with beach nourishment for the foreseeable future. The commitment to hold the line against the sea is so great that Long Beach Township and Harvey Cedars have spent their own money to haul in truckloads of sand from the mainland as they wait for their turn for federal/state beach nourishment projects, which have been focused on the northern part of the Jersey Shore. The baysides of the seashore communities are mostly bulkheaded, and that bulkheading is likely to continue for the foreseeable future. Most of the communities on Long Beach Island have signed the EPA-drafted sea level rise partnership agreements. Those plans recognize that the low baysides are vulnerable to flooding and will have to be elevated over time.

Map 3-4 shows the areas likely to be protected, based on the assumptions enumerated in the methods section and site-specific changes suggested by county planners. In the developed northern part of the county, virtually all the dry land will be protected. If coastal wetlands there are unable to keep pace with rising sea level, most of the natural shores along Barnegat Bay will be along Island Beach State Park. Below Barnegat Inlet, by contrast, natural shores along the mainland are likely to persist for the foreseeable future, because the sea would have to rise several feet before US-9 was threatened with tidal inundation. Near the bridge-causeway to Long Beach Island, Beach Haven West (to the south) and Mud City (to the north) will almost certainly be protected. The extensive finger canals through Beach Haven West—as well as a number of other “dredge and fill” canal estate developments—imply that filling the land has been cost-effective in the past; it will surely be cost-effective in the future. On the east end of the bridge-causeway lies the Island of Cedar Bonnet, part of Stafford Township. Although it is not classified as a center, the high property values and the fact that the causeway must be protected imply that this island will almost certainly be protected.

A few inholdings in the Forsythe Wildlife Refuge are more likely to be abandoned. Along West Creek Dock Road and Cedar Run Dock Road numerous small homes are being replaced with more substantial structures. Because these developments are mostly along a single street, they may be too small to warrant state assistance for shore protection. Moreover, because they are inholdings within the wildlife refuge, there is some chance that at some point the U.S. Fish and Wildlife Service will acquire a rolling easement or perhaps pay to relocate the homes—especially if a severe storm were to destroy the infrastructure there. Nevertheless, a home in the middle of a wildlife refuge with a dock and navigable water appeals to many people, who would have substantial incentive to use their own funds to elevate their land surface. Therefore, these small inholdings must be considered as likely to be protected under current policies—although their location along West Creek and Cedar Run would make them good candidates for relocation if the current policies were modified.[41]

During the second visit to the planning office, a number of minor changes were requested, which are reflected in the final maps. In several cases, relatively dense developments were omitted from both the state plan and the land use data we employed. The requested changes are as follows:

Change Pelican Island (on the bridge to Seaside) from blue to brown. This island is fully developed and is sure to be protected.

Add High Bar Harbor/Loveladies Harbor (west of Barnegat Light on Long Beach Island) and depict as brown. The state plan and land use data are erroneous for omitting this dredge-and-fill community. It is certain to be protected.

Change two small areas in Brick Township (between the Metedeconk River and Kettle

[41]This discussion logically follows from the existence of development outside the developed planning areas. Because early versions showed this area as not protected, the EPA project manager discussed it specifically with the county planner during a phone conversation in October 2003.

***Creek) from blue to brown*:** Mandalay Park (Seaweed Point) and the area at the end of Cherry Quay Road. These areas are developed, which was overlooked by the land use data.[42]

Change three other small areas in Brick Township (between the Metedeconk River and Kettle creek) from blue to red.[43]

Change some areas of red near Point Pleasant Beach to brown. We were not sure why those areas were not part of a center. The County pointed out that if the whole area around it will be protected, this area will be protected as well—and it is already developed anyway.

Fix the southern tip of Long Beach Island. The ocean side is high ground and should be depicted a light green, given that it is a wildlife refuge.

Change Island Beach State Park from blue to red. It will probably be protected on the ocean side, given the substantial beach and road facilities.

Remove all blue near Mystic Island in Little Egg Harbor Township. The revised map showed a blue area near the development. In reality, the entire area is either wetland or developed and certain to be protected.[44]

In Lacey Township change the light green area to blue, because it is a wildlife management game farm. It is unlikely to be protected, but it could be protected because it is not a conservation area.

Stakeholder Review

The County directly edited the text of the report, which we imported verbatim.[45] The County's

[42]Initially, we failed to implement this suggestion and some draft maps treated it as unprotected. The county planners actually raised questions about five areas, suggesting that those areas might be developed but that it was difficult to discern from the 11 × 17 scale map of the county we provided. Craghan inspected those areas after the meeting and determined that three of the areas are undeveloped, but that two are developed. Because those two areas are at the end of a long road through the wetlands, he concluded that they would probably not be protected, and the IEc authors prepared maps based on that judgment. Later, the EPA project manager disagreed, for the following reasons: First, the County had successfully spotted an error in our application of our own procedure, and protecting this area is consistent with our decision rules. Second, we generally defer to counties. Third, we had no analysis supporting the notion that these areas could not be protected: If it were cost-effective to fill the marshes to build a road to begin with, it would be cost-effective to elevate the road—even if it is done at the expense of private property owners; and waterfront property along Barnegat Bay is generally very valuable—especially finger canal estates, which provide water access for almost every property owner. Upon reflection, the IEc authors agreed with the EPA project manager that it had been an error to disregard the County's suggestions.

[43]We initially failed to implement this suggestion for reasons similar to the two areas discussed in the preceding footnote. The EPA project manager argued these areas should be red, for the following reasons: First, the Ocean County planner was indicating that he expected the area to be developed when he told Craghan that he thought it had been developed. Second, this peninsula is a highly desirable place to live, given the proximity both to the ocean and to Barnegat Bay. As a result, the pressure to develop them is great. Brick Township rather than the State of New Jersey has primary land use authority. Third, the fact that this area is surrounded by subdivisions makes it unsuitable for agriculture, so if all permits for development were denied, landowners might file successful takings claims; thus, state land use regulations are more likely to prevent environmentally harmful development, not all development. Such restrictions might reduce density or otherwise limit the cost-benefit ratio of shore protection, but because those areas are between developed area that will be protected, with marsh on one or two sides, shore protection would not be prohibitively costly. Upon reflection, the IEc authors agreed with the EPA project manager that a consistent application of our approach favored making a change to the map in response to the County's comments. The possibility that the land might not be developed—or might be developed in a fashion allowing for wetland migration—is indicated by designating this area as probably protected.

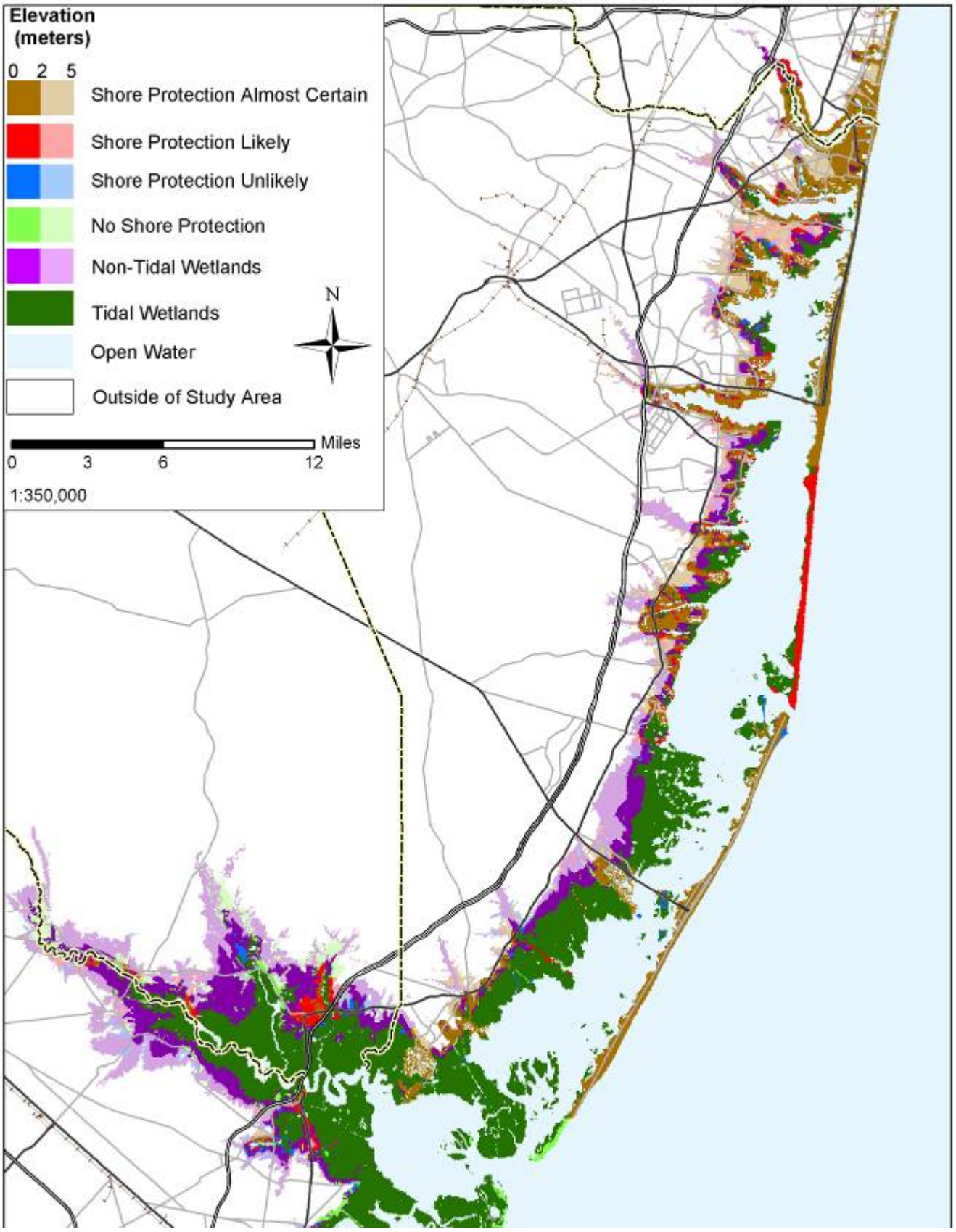
[44]This comment points to a difficult methodological question regarding data management: What to do when communities keep telling us to show an area as developed and protected, while the wetlands data we overlay keep saying that it is wetlands. Eventually, the data should reflect the reality. However, for the most part, wetlands data have far more precise boundaries than the land use and planning data; hence the best way to proceed is generally to maintain a database showing whether an area will be protected assuming that it is not wetland, and then display or calculate results using the best available wetlands data set. Our current intention is to keep some sort of layer with possible wetland data errors we know about so that we do not get the same comment each time we redo a map. That approach is clearly only a partial solution.

[45]David J. McKeon, assistant director, Ocean County Planning Department, email to Jennifer Kassakian, August 9, 2002.

written comments made no suggested changes, but in a telephone conversation with the EPA project manager, the County indicated that all developed areas are likely, if not certain, to be protected.[46] We also specifically discussed West Creek Dock Road as an example. The County indicated that there is some possibility that some inholder may one day sell their land to the wildlife refuge, and thus that protection likely is an appropriate designation for this area.[47]

[46]See September 30, 2003, email from Jim Titus to Jennifer Kassakian, with copy to David McKeon of Ocean County, summarizing conversation. "I spoke with Dave McKeon about the sea level planning maps. He said that all developed areas should be shown as likely to be protected. He also put his previous comments within that context. You may recall that he had expressed concern that the map not be used for matters not appropriate for the scale. Today, he told me that one of the main reasons for that concern was that the maps might show an area as unlikely to be protected, and someone who lives there would be annoyed that the map showed their home as unlikely to be protected. The County understands that the data may not pick up every last house—but the County does not intend for the maps to show any developed area as unlikely to be protected. To the extent that the County has qualms about the map, the primary concern is that the scale or imperfections in data might cause us to inadvertently show a developed area as not likely to be protected."

[47]David J. McKeon, assistant director, Ocean County Planning Department. Telephone conversation with Jim Titus, September 30, 2003.



Map 3-4. Ocean County: Likelihood of Shore Protection. For additional details, see the legend and caption accompanying Map 3-2.

Burlington County (Coastal)

Background

Although Burlington County has no open water on the Atlantic Ocean or Delaware Bay, it has two widely separated portions that might be at risk from sea level changes: the western border along the Delaware River and the southeastern portion along Mullica River Great Bay and its tributaries. Because the county is predominantly located along the Delaware River, meeting notes for this county are included in the Delaware River Counties section of this report. (See Photos 3-21 and 3-22.)

Photos 21-22 Burlington County. Shoreline armoring (21), homes, Spartina, and Phragmites (22) along the Mullica River

State Plan. The coastal portion of the county that is in the CAFRA area is in PA 5; there is a tiny (19-acre) center in Bass River Township where a county road, U.S. 9, and the Garden State Parkway intersect. The rest of the southeast portion of the county is in Pinelands protected area zoning.[48] Aside from the town of New Gretna, this area is sparsely developed.

Other Considerations. The Garden State Parkway traverses low-lying marsh in the relatively undeveloped portion of the county. We found a general consensus that the parkway will be protected. The highway department has not decided whether such protection would be best accomplished by maintaining a causeway across open water or by replacing the roadway with bridges, or by some combination of the two. A small region consisting of wetlands exists in and near the Great Bay National Estuarine Research Reserve.

Baseline Plan for Sea Level Rise

The coastal portion of Burlington County along the Mullica River is included in Map 3-5, of Atlantic County. New Gretna is the primary area that must be protected. Aside from that town, very little of the eastern part of the county is almost certain to be protected; but much of the

[48]Unfortunately, during Phase 2 we forgot that Phase 1 had analyzed only the CAFRA areas, and erroneously treated all of the Pinelands as PA 5, the default category.

dry land is likely to be protected. This expectation is based on our general analysis of the Pinelands Management Area data, which identify existing towns and villages as well as development zones. Our final maps assume that New Gretna and other existing development within designated villages, towns, and development areas are almost certain to be protected and that undeveloped land within designated villages, towns, and development areas is likely to be protected.

Regrettably, we did not use the Pinelands data until the end of the study. No one noticed that our various draft maps treated New Gretna as unlikely to be protected until the EPA project manager was conducting his final review during a vacation at nearby Long Beach Island.[49] The decision rules we applied to the Pinelands categories are analogous to the approach applied to PAs 1–5, but it is possible (but unlikely) that local officials would see the situation differently had they been offered an opportunity to reflect on these assumptions.

Atlantic County

Background

The Atlantic County coast is dominated by barrier islands and back-bay estuaries. The coastal zone also extends from Great Egg Harbor into the county along the Great Egg Harbor River, and from Great Bay along the south side of the Mullica River. The majority of the mainland development is relatively high and is in a corridor along the shore parallel to Route 9.

Atlantic City dominates the coastal zone of Atlantic County. Development along Absecon Island includes Margate and Ventnor in addition to Atlantic City. Brigantine Island, to the north of Atlantic City, is partially developed with the City of Brigantine.

Most of the marshes in the back bays are protected in national wildlife refuge or state wildlife management areas. Several access causeways cross the salt marshes to link the developed barriers to the mainland. Some of these causeways have histories of flooding during storms.

Discussions. Our assumptions regarding the County's response to sea level rise are based on conversations with John E. Peterson, P.P., supervising planner, and Brian M. Walters, principal planner, Atlantic County Department of Regional Planning & Development.

State Plan. The planning boundary between the mainland and the coastal portion of Atlantic County closely matches the study area boundary. The CAFRA line is another planning region boundary but it is located farther inland. Most of the land within the study area is assigned to PAs 4 and 5. The glaring exception is Absecon Island; the developed portions of Longport, Margate, Ventnor, and Atlantic City are in PA 1. The City of Atlantic City is also an urban CAFRA center. Another exception is Egg Harbor Township, which is a small community to the east of the Black Horse Pike (U.S. 40) access road to Atlantic City; it is a center in PA 5. The developed portion of Brigantine Island is also a center in PA 5. Other miscellaneous centers encroach into small parts of PAs 4 and 5, but are largely in PAs 2 and 3. Finally, a significant portion of the land potentially vulnerable to sea level rise is along the Mullica River, whose head of tide is in Mays Landing.

Economics. Shore access and coastal protection for Atlantic City and its accesses are assured. Longport, Margate, and Ventnor are also likely to be protected. Marina and recreational fishing activity is ongoing in Somers Point and

[49]This oversight resulted from several factors. First, Craghan's Phase 1 analysis considered only the CAFRA area. Second, he omitted visiting Burlington County, most of whose coastal zone is far to the west along the Delaware River. Third, Jennifer Kassakian's analysis of three Delaware River counties considered only land along the Delaware River, and when she met with Burlington County she focused exclusively on the Delaware River. Fourth, during the draft map preparation, we identified only developed lands located within PAs 1 through 5. Because the New Gretna area is located within the Pineland Management Area (PA 10), we mistakenly excluded this development. Finally, when seeking stakeholder review from Burlington County, Kassakian did not specifically ask the County to focus on the Atlantic portion of the county; and hence the County evidently focused only on the Delaware River portion, which had been the subject of all previous discussions.

Brigantine. A commercial fishing port is located in the marina district of Atlantic City.

Brigantine and Atlantic City have no beach access problems. Longport was mentioned as discouraging access by having no parking—they were also said to have no beach.

Cultural Features. There are historic districts in Ventnor, Margate, and Longport. Lucy the Elephant is also in Margate. Historic sites in Atlantic City include Gardner's Basin, the Absecon lighthouse (1857), and Atlantic City Convention Hall. All of these either are sufficiently elevated to not be affected by sea level rise or are in PA 1 and will be protected.

Other Considerations. The main consideration is access to the barrier islands. Black Horse Pike, U.S. 30, and Longport Blvd. flood regularly and have been raised in places. Margate Causeway and Somers Point/Longport Blvd. both serve as evacuation routes from the towns of Margate and Longport, respectively, and they will certainly be protected, as will other evacuation route connectors. There is also some flooding in Margate/Ventnor/Longport and the bayside of Atlantic City. Given the value of this land, Atlantic City will be protected.

A number of other sites are designated for certain protection. These include Atlantic City High School, the Atlantic City Public Works building, the Regional Treatment Plant, and an existing casino development.

There has been a fair amount of beach replenishment in Atlantic City. Brigantine has a bulkhead and has also done beach replenishment. Longport has a bulkhead around most of the town, and it was thought that Ventnor did also.

Baseline Plan for Sea Level Rise

As with most of the New Jersey shore, the barrier islands of Atlantic County are certain to be protected. The value of the land, structures, and infrastructure in Atlantic City is so great that it would be protected under almost any conceivable scenario. Unlike other parts of the Jersey Shore, however, it is not a foregone conclusion that Atlantic City will rely completely on the gradual elevation of land and structures. The city currently has an underground storm water retention system, along with check valves. As sea level rises, that system may be retrofitted with pumping systems.

Map 3-5 shows the areas likely to be protected, based on the assumptions enumerated in the methods section and site-specific changes suggested by county planners. Although the barrier islands will be protected, and the mainland along the back barrier bays is mostly developed, wetlands may be able to migrate inland along the Great Egg Harbor River, whose shores are mostly undeveloped, other than in the area of Thompsontown, Cataba, Belcoville, and Mays Landing. Similarly, along the Mullica River, most land is undeveloped and not in an area slated for development under the state plan, although the community of Sweetwater might be protected.

Most of the changes that Atlantic County suggested in response to the revised maps concerned map discrepancies having to do with how wetlands data match development data. The golf course on Brigantine, for example, originally showed up as partly wetland with the dataset we were using. As with other counties, the revised maps included map discrepancies that we knew about and planned to fix in the final version—but we neglected to provide the counties with explanations and hence probably wasted some of their time as they pointed out problems that we were planning to correct. Nevertheless, the County did have a few substantive changes to the map:

Change the Smithville area along the US-9 corridor from blue to red.

Depict the evacuation routes from Margate/Ventnor/Longport the same way that the other major routes from Atlantic City are depicted. They will certainly be protected.

Stakeholder Review

When we sent the draft report to Atlantic County as part of the stakeholder review, the County

asked us to change several more areas from blue to brown[50]:

- Atlantic City High School.
- Casino development along North Owens Avenue north of NJ-87 near Absecon Channel.
- The regional water treatment plant, just north of Venice Park.
- The Atlantic City public works building just to the southeast Atlantic City High School.
- The Seaview Harbor development just across the bridge from of Margate on NJ-152, and the development just south of the intersection of Stern Drive and Longport-Sommers Point Boulevard (NJ-152) south of Steelman.[51]
- All evacuation routes are certain to be protected.[52]

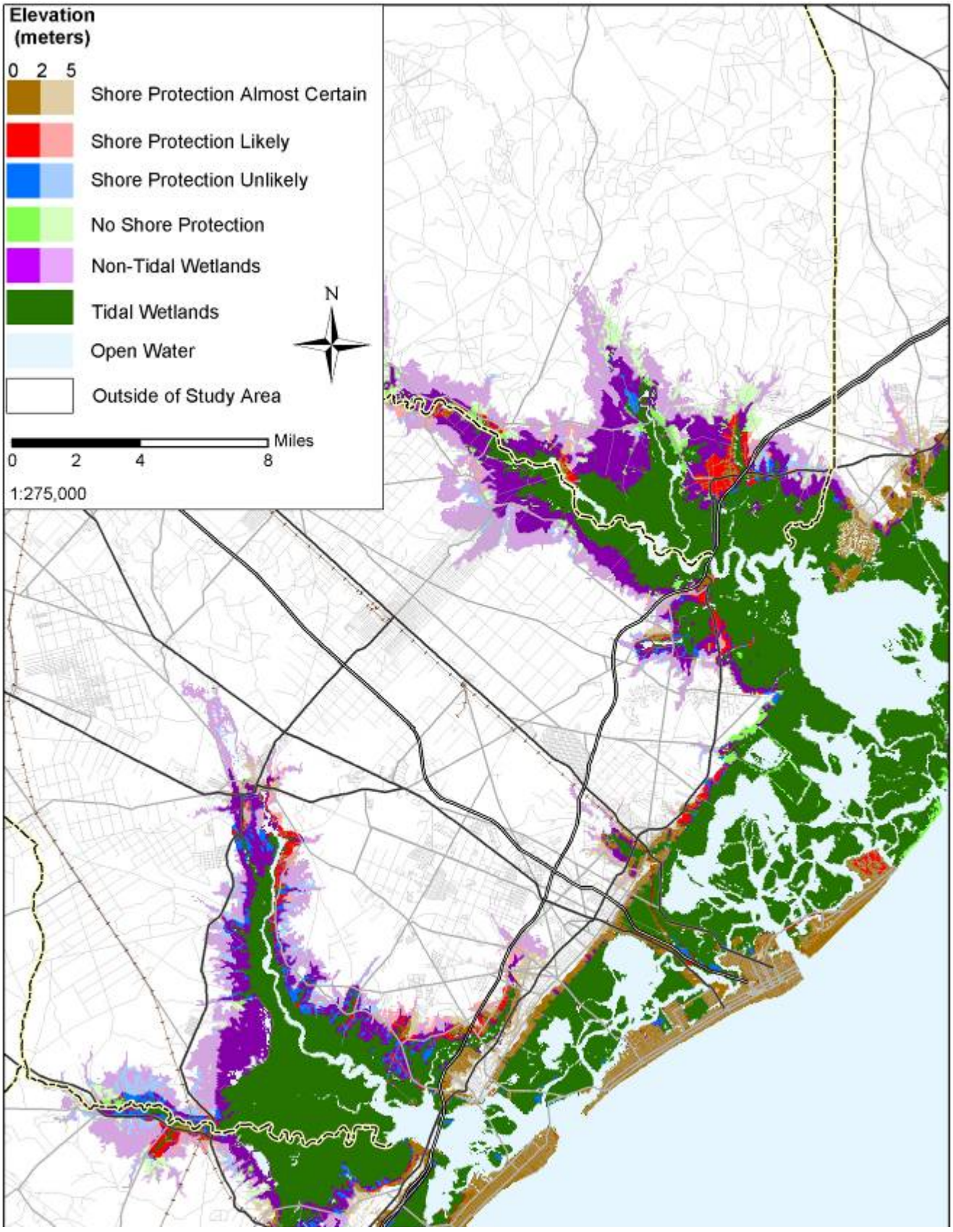
During the final review of the maps, the EPA project manager noticed that the maps had treated all land within the Pinelands—including Mays Landing—as unlikely to be protected. We revised the maps to treat developed and undeveloped lands within Mays Landing and other designated villages, towns, and development areas as almost certain and likely to be protected, respectively.[53]

[50]Letter from Brian Walters, principal planner, Atlantic County, to Jennifer Kassakian, August 14, 2002, along with annotated stakeholder review map.

[51]They are both small dredge-and-fill developments on large marsh islands. As such, they were classified as PA 5; and because they are isolated, they are not part of centers. Nevertheless, they are certain to be protected: they are along the primary evacuation route for southwestern Absecon Island, which is certain to be protected as long as Absecon Island exists. With the road certain to be protected, property owners need only be concerned with the costs of elevating their own land and structures, which is small compared with the value of this coastal property.

[52]These maps are designed to depict land that will be protected, not infrastructure. Therefore, roads that pass through unprotected areas are shown as protected only when (a) officials suggest that the roads would be causeways rather than low bridges and (b) the roadways are wide enough to show up given the scale of the map.

[53]See Burlington County discussion for a further explanation of this issue.



Map 3-5. Ocean County: Likelihood of Shore Protection. For additional details, see the legend and caption accompanying Map 3-2.

Cape May County

Background

Cape May is the southernmost of the open-ocean counties. It is a peninsula with the Atlantic Ocean and a series of shallow water bays and sounds on its eastern side and Delaware Bay to its west. The county is fairly low-lying. However, a slightly higher core runs along the center of the peninsula. Most of the nonbarrier island development is in this core.

The barrier islands of Cape May are well developed and include noted resorts such as Ocean City and the Wildwoods. Other barrier island communities are Sea Isle City, Avalon, and Stone Harbor. The historic communities of Cape May City and Cape May Point are found at the southern end of the county.

Discussions. Our assumptions regarding the County's response to sea level rise are based on conversations with James J. Smith, P.P., A.I.C.P., planning director, Cape May County Department of Planning.

State Plan. In the state plan, all the developed barrier islands were designated PL 5 areas. The NJDEP, however, also designated these areas as state "coastal centers" to facilitate the implementation of the state plan. Whale Beach and Strathmere are examples of ocean front development that were not named centers.

On the Delaware Bay shoreline, Villas, Town Bank, and Del Haven were designated as coastal centers. The other Cape May centers are small areas that are inland from open water, or they are in the development core of PAs 1, 2, and 3 that forms the backbone of Cape May.

Cape May had a few issues with the plan. They felt that more of the Route 9 corridor should be in PA 2, but it technically cannot be, because PA 2 is required to adjoin PA 1. They did not like the zoning of barrier islands to PA 5 with a center overlay; PA 5 was thought to be inappropriate.

Economics. Most of the county's major employers (Burdette-Tomlin Hospital, the Crest Haven complex) are in the higher core of the county; each is in PA 3, and the hospital is also in a center. The power plant by Great Egg Harbor is the main source of electricity for the county; it is in PA 2.

Seasonal beach tourism is the dominant economic activity in Cape May County. All of the developed barrier beach areas are in centers, with the exception of Strathmere/Whale Beach. Strathmere has no sewer system; Whale Beach currently is inundated when there are high waves. This area is not likely to receive substantial protection from sea level rise; it may receive modest shore protection (dune building, sandbagging), but that is probably the limit.

Cultural Features. Ocean City was one of the first beach resorts in the country, and is still a very popular family beach destination. Cape May City is a National Historic Landmark city, and is also a popular tourism destination. However, most of the county's historical and cultural features are in its core along Route 9 in the elevated portion of the county.

The Cape May Point lighthouse (built in 1859) is in PA 5 in Cape May State Park. Given the lighthouse's inclusion on the state and national registers of historic places and its proximity to the Cape May Point center, it may also be protected or moved. Hereford Inlet lighthouse (built in 1874) is also on the National Register.

Other Considerations. Flooding problems in West Wildwood have earned it the alternative name "Wet Wildwood." The county also has a problem with saltwater infiltration into the drinking water supply. Cape May City recently constructed a desalinization plant. Flooding during storms has also been a problem. Mitigation is being pursued: there is a flood siren in Wildwood, towns are starting to look at things like higher minimum floor elevations, and the exit lane on Wildwood Boulevard is higher than Route 1.

Mr. Smith is less concerned about the possibility of land loss than the consequences of shore protection: "I don't see retreat. I see the Sea

Bright experience."[54] Smith indicated that a big storm with drastic changes might lead to some abandonment. However, that is not what is being planned. The Ocean City/Longport bridge is going to be rebuilt at a substantial cost. Tourism is too much of an economic force to walk away from. Beach access is not a problem—beach use is encouraged.

Besides tourism, transportation infrastructure is also likely to earn parts of the county some protection from modest sea level changes. Garden State Parkway is a backbone for the county, although the southern end of it resembles a local highway: it has traffic lights and intersections. The Delaware Bay ferry connects New Jersey with Lewes, Delaware. If the ferry link is preserved, then it is logical to suspect that the parkway connection will also be protected.

Baseline Plan for Sea Level Rise

Cape May County's barrier islands will mostly be protected, given the heavy development. Erosion associated with the Cape May canal has required shore protection in the past. The developed shore along Delaware Bay is gradually being armored already. Nevertheless, the county has some potential for wetland migration, along various wildlife management areas at the northern end of its shoreline along Delaware Bay.

Map 3-6 shows the areas likely to be protected, based on the assumptions enumerated in the methods section and site-specific changes suggested by county planners. During the second visit to the planning office, a number of minor changes were requested, which are reflected in the final maps[55]:

Strathmere/Whale Beach should be depicted in red, if not brown. The decision rules should have shown this area as red, but problems with the data caused the revised maps to show part of it as undeveloped (blue). Thus the planners' comments picked up an error in data interpretation. The extreme vulnerability and absence of infrastructure make protection less likely than most of the barrier islands in the county.[56]

Avalon Manor should be blue, even though it is developed and hence the decision rules would suggest red.

The sand pit at the south end of Stone Harbor should be shown as blue, given the high costs of protecting a hole in the ground from the sea.

Change the portion of Lower Township on the barrier island next to Wildwood, and the Schekllenger's Landing Area, from red to brown. These areas were not defined as centers because the township refused to participate in the state planning process. It is just as developed as adjacent areas shown in brown and just as likely to be protected.

Fix the Cape May Coast Guard Station. Draft maps erroneously depicted this area as a combination of wetlands (dark green), red, and blue. The portion southwest of the jetties to Cape May Harbor has substantial facilities and would unavoidably be protected by projects to protect Cape May (change to brown). The portion of this installation northeast of the jetties is sparsely developed and was changed to red in accordance

[54]Indeed, a facility owned by the Catholic Church just west of the town of Cape May has been armored in response to the erosion caused by the Cape May Canal and the jetties protecting its entrance.

[55]Michael Craghan visited county offices as part of Phase 2 during January–February 2002. These concerns were reiterated during a conversation between Jim Titus and Jim Smith. See email from Titus to Jennifer Kassakian, with a copy to James Smith of Cape May County, October 2, 2003, summarizing that conversation between Titus and Smith: "Note also: Jim Smith noticed a number of other small changes needed in the map. His concerns essentially seemed to be echoing the previous issues I had noticed in my quality control. I am copying him on those comments—he said he will let me know if his concerns diverge from what I had written. We specifically discussed the Coast Guard station, the wetland area being protected, and the small neighborhood to the right of Rt 47 before the bridge to Wildwood. All of those areas should be shown as certain to be protected—and the latter neighborhood is considered to be part of Wildwood for these purposes."

[56]We remind the reader that our general decision rule was to start with the assumption that parks and open space are either forms of conservation lands where nature will take its course or recreational lands that will probably be protected. As with our other decision rules, this is a starting point, not an ending point. Some parks will almost certainly be protected, such as ballfields within an urban area. Some areas managed for conservation purposes might be protected, in which case the color blue is most appropriate.

with our general approach for secured installations.

Cape May Meadows[57] will be protected. This critical freshwater ecosystem is immediately behind the dunes, which have eroded severely as a result of the jetties protecting the entrance to the Cape May Canal. In this unusual case, environmental considerations have prompted shore protection efforts. This area will almost certainly be protected for the foreseeable future. Therefore, we must change this area from "no protection" to "protection almost certain."

Change Marmora Wildlife Management Area from light green to blue. Although wildlife management areas generally allow natural processes to work their way, this area is landward of Garden State Parkway. One cannot reasonably say that there is a policy to relocate Garden State Parkway. Most likely, even if the parkway is protected, conservation areas will be allowed to flood; hence this area is colored blue.

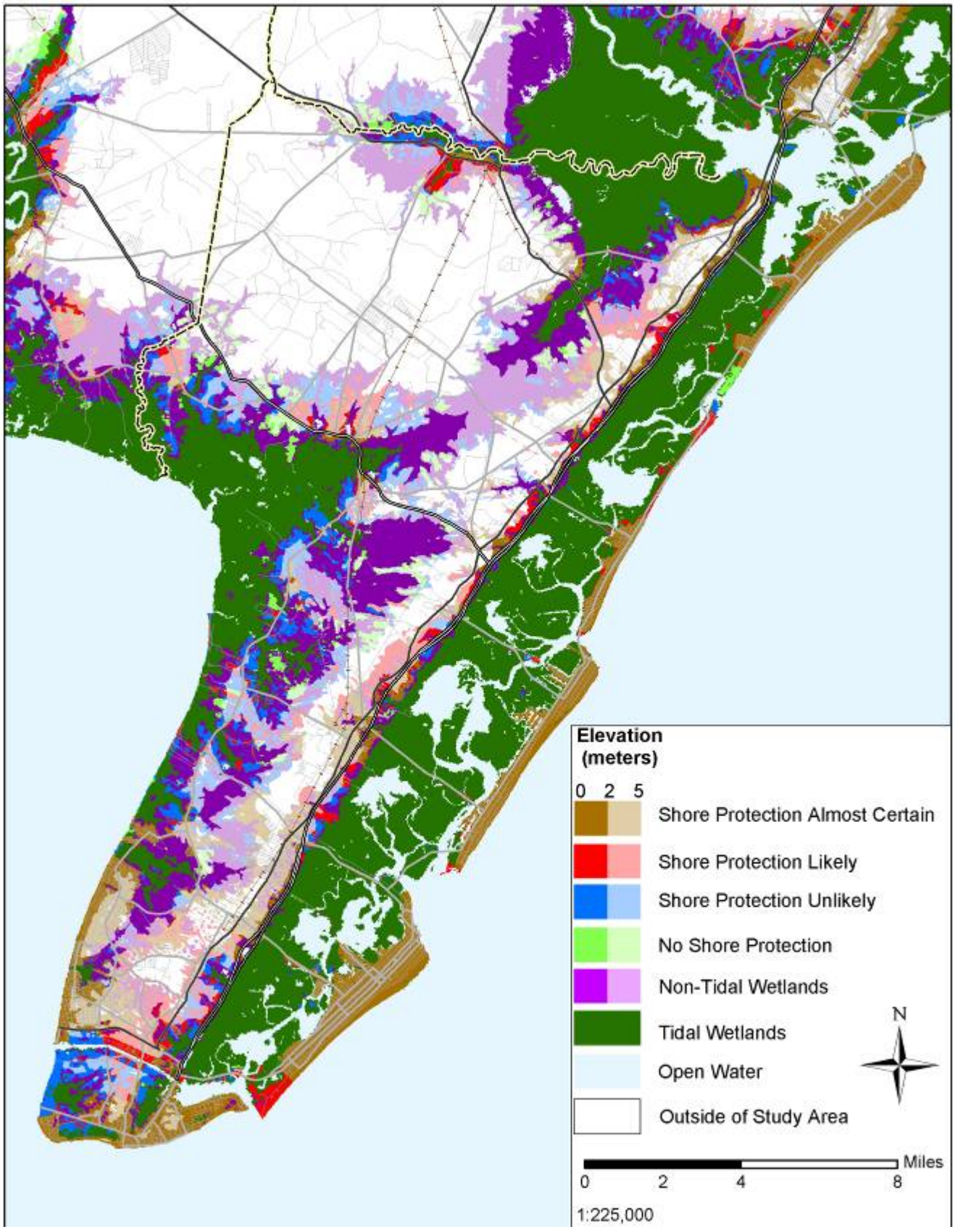
Stakeholder Review

We sent the draft report to the County, whose planning director stated that all comments had been addressed and that he agreed with the maps.[58] In a subsequent telephone conversation, he told the EPA project manager that we should assume that all developed land is at least likely to be protected.[59]

[57]The Meadows are within Cape May Point State Park and The Nature Conservancy's Cape May Migratory Bird Refuge.

[58]James Smith, telephone conversation with Jennifer Kassakian, July 31, 2002.

[59]See email from Jim Titus to Jennifer Kassakian, with a copy to James Smith of Cape May County, October 2, 2003, summarizing conversation between Titus and Smith:
I spoke with Jim Smith on the issue of non-PA 1-3 developed areas. He said that all developed areas will probably be protected, whether or not they are in a center or PA 1-3. In some cases, developed areas were left out of the planning areas and centers due to an oversight or old data. Moreover, the County spent considerable effort getting the state to classify the barrier islands as centers. The fact that other developed areas were not moved into a center or a PA 1-3 does not reflect a judgment that those areas need not be protected--the County simply felt that they could "agree to disagree" with the state for some of those mainland areas, whereas it was essential to get the state to recognize the barriers as centers….
…My understanding of our conversation is that he believes that the entirety of the barrier island with Sea Isle City will be protected, and would not agree with the assertion that some small pockets of land, shown in blue in the attached picture, will neither be developed nor protected--other than wetlands. Moreover, he stated that the entirety of the barrier islands (including mainland areas along the ocean) will be protected, so any areas depicted in blue would have to be changed to red.



Map 3-6. Cape May County: Likelihood of Shore Protection. For additional details, see the legend and caption accompanying Map 3-2.

Cumberland County

Cumberland County has no open-ocean coast, but has an extensive shoreline along the open waters of Delaware Bay. Most of its shore is coastal wetlands. Small sandy beaches are intermittently scattered along the shore, as are a few small, water-oriented communities. Virtually the county's entire low-lying shoreline is at risk from sea level change, although there is very little development in harm's way. The county's population is very stable, and much of its shoreline is in protected wetlands.

There are two urban areas near the head of tide: Bridgeton, on the Cohansey River, and farther east, Millville, on the Maurice River. Most of these communities are high enough to escape the probable impacts of rising seas.

Background

Discussions. Our assumptions regarding the County's response to sea level rise are based on conversations with Robert Brewer, P.P., assistant planning director; and Stephen Kehs, department director, Cumberland County Department of Planning and Development.

State Plan. Nearly all of the coastal zone is in PA 4 or 5. Almost all the county's land within the study area is in PA 5. The Bridgeton and Millville areas are the major exceptions. These urban areas have sections in the CAFRA zone that are in the study area and in PAs 1 and 2.

Cumberland County has several centers in the CAFRA zone. The only center on the open water of Delaware Bay is Fortescue. There is a string of centers along County Road 553: Port Norris, Dividing Creek, Newport, Cedarville, and Fairton. These centers are near the study area boundary (near the 16-ft contour) and are 2–4 miles inland across the salt marshes. Leesburg is similarly situated on the east side of the Maurice River; Greenwich is to the west of the Cohansey River.

At the time of our discussion, Cumberland disagreed with portions of the proposed CAFRA coastal center designations. A number of centers that Cumberland County had proposed were not accepted in the state's recommendation. Small bay communities such as Sea Breeze, Money Island, and Gandys Beach had not been given center designations.[60] Other communities that were designated as centers, such as Delmont, Greenwich, and Dorchester/Leesburg, were given much smaller boundaries than what Cumberland preferred.

Economic. Very little development is located within portions of the county at risk from sea level rise. Port Norris has some seafood processing and fishing activities. There is a steel plant (defunct) at Dorchester/Leesburg. Fortescue bills itself as "The Weakfish Capital of the World."

Cultural Features. The lighthouse (built in 1849) at East Point and the Dorchester/Leesburg area were described as "very authentic South Jersey towns." The Greenwich Tea Burning Monument is at risk from sea level changes. The Bivalve area is also rich in Cumberland County heritage. The schooner *Meerwald* (New Jersey's official tall ship) is moored there, and the area was an important oyster industry district. Rutgers University's Haskin Shellfish laboratories are also located there.

Other Considerations. There are some recreation considerations: a boat ramp and a small beach are a "source of local pride" at East Point; Port Elizabeth has a boat ramp and recreational fishing.

The county has had some experience with rising seas. Moore's Beach and Thompson's Beach have been abandoned because it was too costly to maintain roads. They could not get permits to raise the roads because the side slope would go into wetlands. In a portion of Greenwich there is tidal flooding every day, and the state would not give permission to repair a dike in the area.

There will be a strong concerted effort to save Port Norris, Dorchester/Leesburg, and Fortescue as viable communities. "If it means putting in bulkheading, jetties, etc. we'll take that route."[61]

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[60]By the time of the second round, Sea Breeze and Gandy's Beach did show up as a center.

[61]Robert Brewer, Cumberland County planner, during initial discussion.

Money Island, Gandys Beach, Shellpile, Bivalve, and Sea Breeze are also certain to be protected.

Something is likely to be done to save County Road 553 and State Route 47, which are major transportation arteries. Additionally, all roadways that access the aforementioned communities will certainly be protected. Weggel et al.[62] estimated the cost of protecting the entirety of the Dividing Creek area at several tens of millions of dollars.

Historically, thousands of acres of salt marsh were diked and converted to agricultural lands. Much of this land has since been abandoned and reverted back to salt marsh. However, there are several hundred acres of farmland, primarily in the town of Lawrence Township, that continue to be operated as very productive, large-scale farm operations. The County identifies these lands as likely to be protected.

Baseline Plan for Sea Level Rise

Sea level rise has very different ramifications for Cumberland County than for other parts of New Jersey. Most of the coastal zone is wetlands, and most dry land is undeveloped and unlikely to be developed. Unlike many areas, however, the lack of development does not automatically imply that land will not be protected, at least for a time. The reclamation of salt marsh for agricultural purposes has taken place in this county for more than 200 years. For the most part, dikes were constructed along the shore to prevent marshes from being flooded by the tides, with tidal gates that drained the lands at low tide.

Over the last few decades, many of those dikes have been dismantled. Sea level rise of 1–2 feet over the last few centuries, combined with the subsidence caused by draining wetlands, implies that lands that were once at approximately the elevation of high tide are now barely above low tide, making drainage difficult. Some of these "poulders" have failed during storms, often with adverse effects on horseshoe crabs. Others have been purchased by conservation programs seeking to restore wetlands, most notably PSE&G in its efforts to offset possible environmental effects of a nuclear power plant.

Although the trend is for dike removal, the fact that diked farms have been part of the landscape for centuries leads one to the logical inference that dikes may be used to hold back a rising sea. In fact, dikes may be more effective at protecting currently arable dry land than protecting former marsh, because the subsidence (if any) induced by shore protection is less with dry land than with salt marsh reclamation. (In addition, if lands are not protected, subsidence may be induced by soil salinization.)

Nevertheless, the recent trend has been for a gradual retreat from the shore. Several small settlements along Delaware Bay are gradually being abandoned, and there are no plans for development of new communities along the bay. The majority of dry land along Delaware Bay is part of a conservation area. Finally, because the county has relatively little coastal development, it is strongly committed to retaining the coastal communities that have not become part of a conservation program.

During our second visit to the county offices, we showed the initial revisions to the County. At first, the County suggested relatively minor revisions.[63] We discussed the issue of diked

[62]Weggel, J.R., S. Brown, J. C. Escajadillo, P. Breen, and E.L. Doheny, 1989, The Cost of Defending Developed Shorelines Along Sheltered Water of the United States from a Two Meter Rise in Mean Sea Level by the Potential Effects of Global Climate Change on the United States. Report to Congress. Appendix B: Sea Level Rise. EPA 230-05-89-052. U.S. Environmental Protection Agency, Washington, D.C.

[63]First, like most counties, planning staff found the various mismatches between data sets to be quite distracting. We should have provided a list of known mismatches and simply explained that we found it more efficient to fix them later. Second, two changes were needed for Greenwich: (a) we showed wetlands based on NWI data for areas north of Market Lane; that area is developed and should be shown as certainly protected; (b) the blue areas north and northwest of the brown area will probably be protected as well. During that second meeting, the County also emphasized the need to protect Fortescue, inasmuch as that community is the only full-fledged community remaining on Delaware Bay.
Based on Craghan's observations rather than the County's suggestions, we had already changed Sea Breeze and Gandy's Beach from brown to red. These isolated settlements along Delaware Bay are similar to settlements that have recently been taken over by conservation projects, and may be too small to realistically warrant protection from a rising Delaware Bay.

farmland, but given the recent trends toward removing these dikes, we assumed that those lands were likely to all become part of a conservation project or wetland restoration effort, and colored those areas blue. The stakeholder review maps, however, treat these lands as more likely to be protected. The County indicated that the existing diked farmland in Lawrence Township will almost certainly be protected. For other farmland, the County indicated that those lands will probably be protected. Moreover, we are reminded that the purpose of the color red in these maps was originally to define possible conservation opportunities for wetland migration, and therefore, red would be the appropriate color even if we were correct in assuming that those wetlands are likely targets for conservation effort.[64]

Map 3-7 shows the likelihood of protection, based on the assumptions enumerated in the methods section and site-specific changes suggested by county planners. All roadways accessing viable communities will be protected. Farmland in Lawrence Township is also likely to be protected.

Stakeholder Review

Both the planning director[65] and the supervising planner[66] for Cumberland County examined the maps during the stakeholder review. At first, the County was concerned that a few developing areas might not be included, but after reviewing a larger-scale map, the County was satisfied with how the land was depicted.[67] Subsequently, the County indicated that existing developed areas should be shown as likely to be protected.[68]

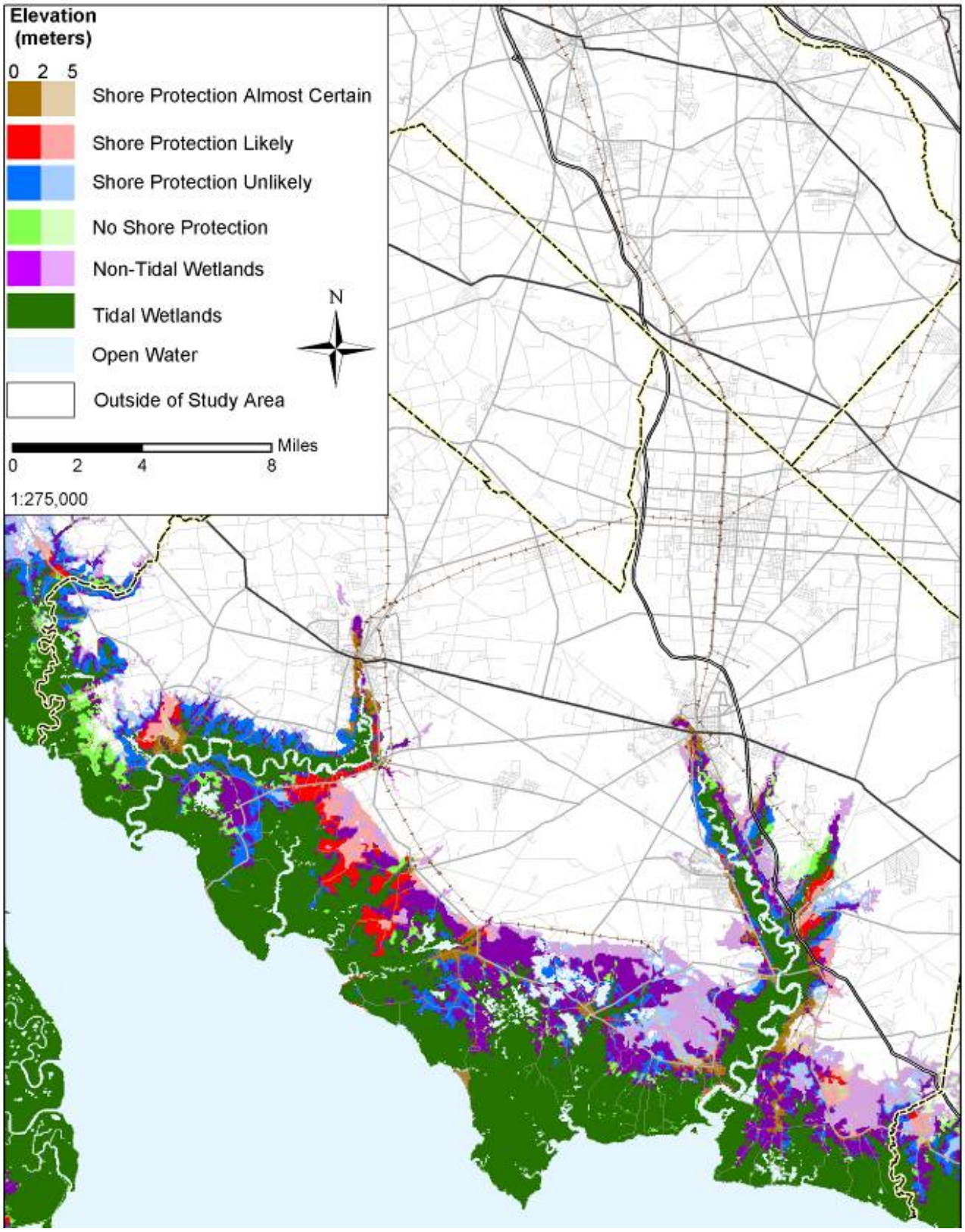
[64] See Delaware Bay text box for additional information on the tidal dikes.

[65] Stephen Kehs, director, Cumberland County Department of Planning and Development. Phone conversation with Jennifer Kassakian, July 31, 2002.

[66] Bob Brewer, supervising planner, Cumberland County Department of Planning and Development. Phone conversation with Jennifer Kassakian, August 5, 2002.

[67] From an August 23, 2002, email: Bob Brewer. Email to Jennifer Kassakian, 8/5/2002: "The maps appear to include all the existing developed areas, which are the areas we are most concerned about, as reasonably likely or almost certain for protection. This includes Seabreeze, Gandy's Beach, Money Island, Fortescue, Shellpile and Bivalve as shown for protection. However the roadways accessing these communities are not mapped. Perhaps the scale is too small but how are they accommodated in this project?" The road issue has arisen with many jurisdictions. Our goal is to show land protection, and hence roads are only shown as protected land if the jurisdiction expects that it would maintain a causeway through the marsh, rather than a bridge.

[68] Email from Rob Brewer to Jim Titus, September 17, 2003: "Thanks for bringing this to my attention. The developed areas in PA 4 & 5 (yellow) should be shown as probably protected (red). They may be centers in the future, particularly Fairton."



Map 3-7. Cumberland County: Likelihood of Shore Protection. For additional details, see the legend and caption accompanying Map 3-2.

BOX 2 Delaware Bay Dikes

The Delaware Bay coast offers many lessons for how rural or lightly developed shorelines may be affected by sea level rise. Along the Delaware River, dikes were constructed, starting in colonial times and continuing into the 20th century, to allow for agriculture. They were built by meadow companies[a] that were essentially cooperative ventures of benefiting farmers. Dikes had to cover a large areal extent to be effective, they had impacts on neighboring lands, they were expensive, and the berms needed constant maintenance,[a] so cooperatives were the only effective way to accomplish land reclamation. The dikes had typical heights of 37 feet above the marsh, some guidance was for 18 inches above the highest flood level,[a] and dikes were set back out of the reach of strong currents and storm waves. Diking would cause the protected areas to dry out, consolidate, and settle, leaving them lower. Farming depended on excluding the tides but keeping the land high enough to drain.

By the middle of the 20th century, farming and diking were in decline because of economic forces and conservation efforts to preserve marshes.[a] When there were economic benefits to be had, action was once warranted, and for many decades dikes were an effective way of excluding the tides from extensive lands. However, the dikes, which had always been in need of constant maintenance, were not intended to deal with sea level rise, and by the late 20th century relative sea level had increased 13 feet since their construction.

Over the last century, development has occurred in some places that were protected by dikes. Simultaneously the meadow companies have disintegrated as economic forces and modern agriculture impacted their business. Before the mid-20th century, environmental regulations were not constraints, although that has markedly changed. Permits to build or work in wetlands are impossible or difficult to get. These trends have left a few small communities at risk from deteriorating, unmaintained dikes.

At the start of the 21st century, the protection from these old, unmaintained dikes has become unaffordable to the communities, and the protection from inundation they may have once offered is also becoming less effective. Earthen structures that were built two centuries ago are maintenance problems, and they probably never provided protection against high magnitude storms or a hurricane in Delaware Bay; further, sea level rise and subsidence have made flooding a progressively higher risk. There have been appeals for the state to repair and maintain these facilities to protect houses from floods, but New Jersey has not exhibited much interest. In 2001, the state wrote a letter referring the problem back to the nonfunctioning private meadow companies that own the structures.[b] Local interests have also appealed to FEMA and USACE for funds and assistance, but the dikes were not federally constructed and they are in private ownership.[c] In an exception, the USACE has been involved with the Gibbstown/Repaupo Levee (see the Gloucester County section of this document). In addition, FEMA has provided a predisaster mitigation planning grant to a hazards planning group made up of Cumberland, Salem, Camden, and Gloucester counties. The work has not yet begun (October 2007), but because of the known risk from some structures, looking into the dikes will specifically be one part of the comprehensive planning process. An important step will be to develop an accurate inventory because (reflecting their

origin in private companies) the full number and location of these features is not presently known.[c] The map included here illustrates the approximate location of tidal dikes; however, this does not represent an exhaustive inventory of dikes. Information on the location of these known dikes was not used when creating the likelihood of shore protection maps. As shown from this map, many of the known dikes correspond to developed areas shown as almost certain to be protected (in particular, see Gloucester and northern Salem County). In the southern portion of Salem County as well as Cumberland and Cape May counties, however, these levees are located within areas that this study identified as unlikely to be protected. Although these shore protection structures currently exist, their presence is more indicative of past efforts to manage the land for agricultural and salt hay production rather than active planning to protect the land into the future.

In recent times, there have been instances where levees that protected large areas were let go and reestablished as much smaller systems around developed areas. In another notable instance of dike breaching, in some places PSEG restored functioning salt marshes on former salt hay farming sites as a way of mitigating environmental damages from its Salem power plant.[d] Consolidating protected zones, buying at-risk properties from willing sellers, repairing damaged levees, restoring wetlands environments, and taking no action are all strategies for coping with deteriorating dikes that have been employed and that will continue to be policy options.

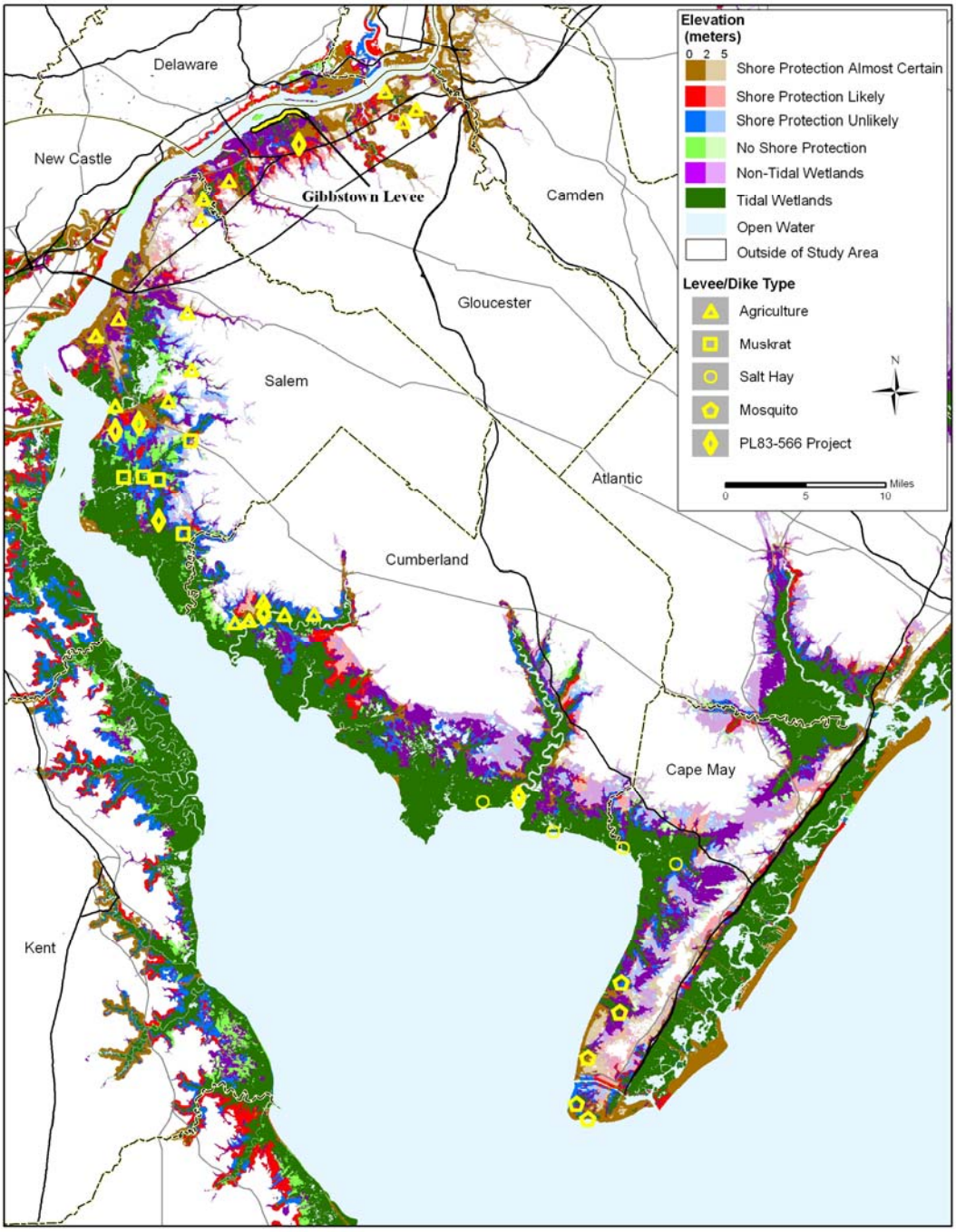
Some important lessons for the 21st century are the following: (1) diking can be effective if the structures are properly maintained, (2) diking is an expensive proposition and requires collective action, (3) unforeseen changes in economic forces may lead to abandonment, (4) changing environmental standards may limit future action, (5) people presume a level of safety behind structures that may be unwarranted, especially as time goes by, and (6) sea level will continue to rise.

[a]Sebold, K. R., 1992, From Marsh to Farm: The Landscape Transformation of Coastal New Jersey. U.S. Department of the Interior, National Park Service. Available from: http://www.nps.gov/history/history/online_books/nj3/.

[b]DiMuzio, K.A., 2006, A New Orleans Style Flood: Could It Happen Here? New Jersey Municipalities, February 2006, published by N.J. State League of Municipalities. Available from: http://njslom.org/featart0206.html.

[c]Delaware Estuary Levee Organization (DELO). Available from: http://www.sjrcd.org/delo/.

[d]PSEG Estuary Enhancement Program. Available from: http://www.pseg.com/environment/estuary/overview.jsp



LOCATION OF LEVEES AND DIKES IN COMPARISON TO THE LIKELIHOOD OF SHORE PROTECTION: The yellow symbols identify the approximate location of known dikes. Because no formal inventory of dikes has been conducted, the map may not include all dikes in the region depicted. The symbols identify dikes constructed for different purposes: keeping land dry enough for agriculture; creating lands suitable for a crop of marsh grasses such as salt hay, controlling mosquito population by draining wetlands, and preventing flooding through projects authorized under the Watershed Protection and Flood Prevention Act (Public Law 83-566). The purpose of a "Muskrat" dike may be for agriculture, salt hay, flood control, or mosquito control, but also includes devices to prevent muskrats from damaging the levee.

SOURCE: Digitized based on an electronic copy (published on the web site of the Delaware Estuary Levee Organization)[c] of a paper map compiled from various sources, including the U.S. Department of Agriculture and the Public Service Enterprise Group, to help PSE&G plan wetland mitigation projects.

Salem County

Background

Salem is the most inland of the coastal counties covered by CAFRA. As a result, it is also probably the least coastal in character. The coastal citizens are very conscious of being on the river—unlike Cumberland County, which was described as more ocean-like. The state included only a portion of Salem County in the CAFRA region.

Shoreline erosion is a problem along the bay. There is also a concentration of heavy industry and manufacturing on the riverfront. Much of the shoreline is wetlands in wildlife management areas, a national wildlife refuge, and a state park; there are wetlands around the Salem nuclear power plant facility as well.

The main concentration of people in the coastal zone is in the historic city of Salem. In the area outside the CAFRA region, development exists along the Delaware River north and south of the New Jersey Turnpike/Delaware Memorial Bridge.

Discussions. Our assumptions regarding the County's response to sea level rise are based on conversations with Michael D. Reeves, director, and Charlie Munyon, principal planner, Salem County Planning Board.

State Plan. The non-CAFRA area of Salem's waterfront is classified as PAs 1 and 3. Most of the county's coastal area is classified as PAs 4 and 5. There are some slivers of PA 1 that represent portions of Pennsville near the CAFRA border. There are some centers in the CAFRA zone: a portion of Elsinboro on the Delaware River; Sinnickson's Landing on the Salem River; and some lands near and in the City of Salem. Small centers are also located several miles inland but still in the coastal zone. It was expressed during the discussion that the state planning area designations were reasonable.

Economic. As is typical of areas where rivers transition into estuaries, there is a fair amount of heavy industry along the Salem County waterfront. A nuclear power station, a cogeneration facility, and industrial and chemical plants can be found on the Delaware and Salem rivers. There are also cargo loading and port facilities.

The use of the waterfront is primarily commercial/industrial. Recreational areas are limited to Fort Mott State Park. The county was said to be "not as much a resort as say Cumberland." There are some marinas north of Salem City on Route 49.

Cultural Features. All of Salem City was cited as a cultural area that might be worthy of some protection. Ft. Mott, Finn's Point lighthouse, and the historic Finn's Point National Cemetery were also mentioned. All of the other cultural features were said to be in centers.

Other Considerations. Salem County's waterfront is dominated by the nuclear power facility. It is on the water to make use of the coolant supply. The plant is isolated from the mainland by extensive marshes, and it is constructed on a section of land called "Artificial Island," which speaks to its origins. The possibility of continued use, contaminated areas, or on-site storage of radioactive waste probably earns this facility protection from encroaching seas.

Some coastal engineering work has been performed in the county. Route 49 going north from Salem City was raised in the early 1990s. There is a bulkhead along the river in Pennsville. Elsinboro wants the Army Corps of Engineers to repair erosion that they attribute to dredging of the Salem River.

Aside from the already protected environmentally sensitive areas, there is little threat to the county from sea level changes. The planners felt that the bluffs along the river offered some level of protection in the northern part of the county, and that communities such as Pennsville are certain to be protected. (See Photos 3-23 through 3-25).

Photos 23–25. Salem County. Retirees fishing at low tide at Church Landing in Pennsville. The watermark suggests that the entire beach was submerged during the previous highs submerged during some high tides (23). The Delaware Memorial Bridge is in the background. Shoreline armoring and pumping stations around Penn's Beach (24, 25). (March 2003).

Baseline Plan for Sea Level Rise

As with the other CAFRA counties, based on the original pilot study, we showed all land in PAs 1–3, as well as the centers, as likely or almost certain to be protected. Because of a reorganization, Craghan was unable to get the County's attention during Phase 2. Therefore, the stakeholder review maps followed the general rule without any of the county-specific changes that had modified maps from the other counties.

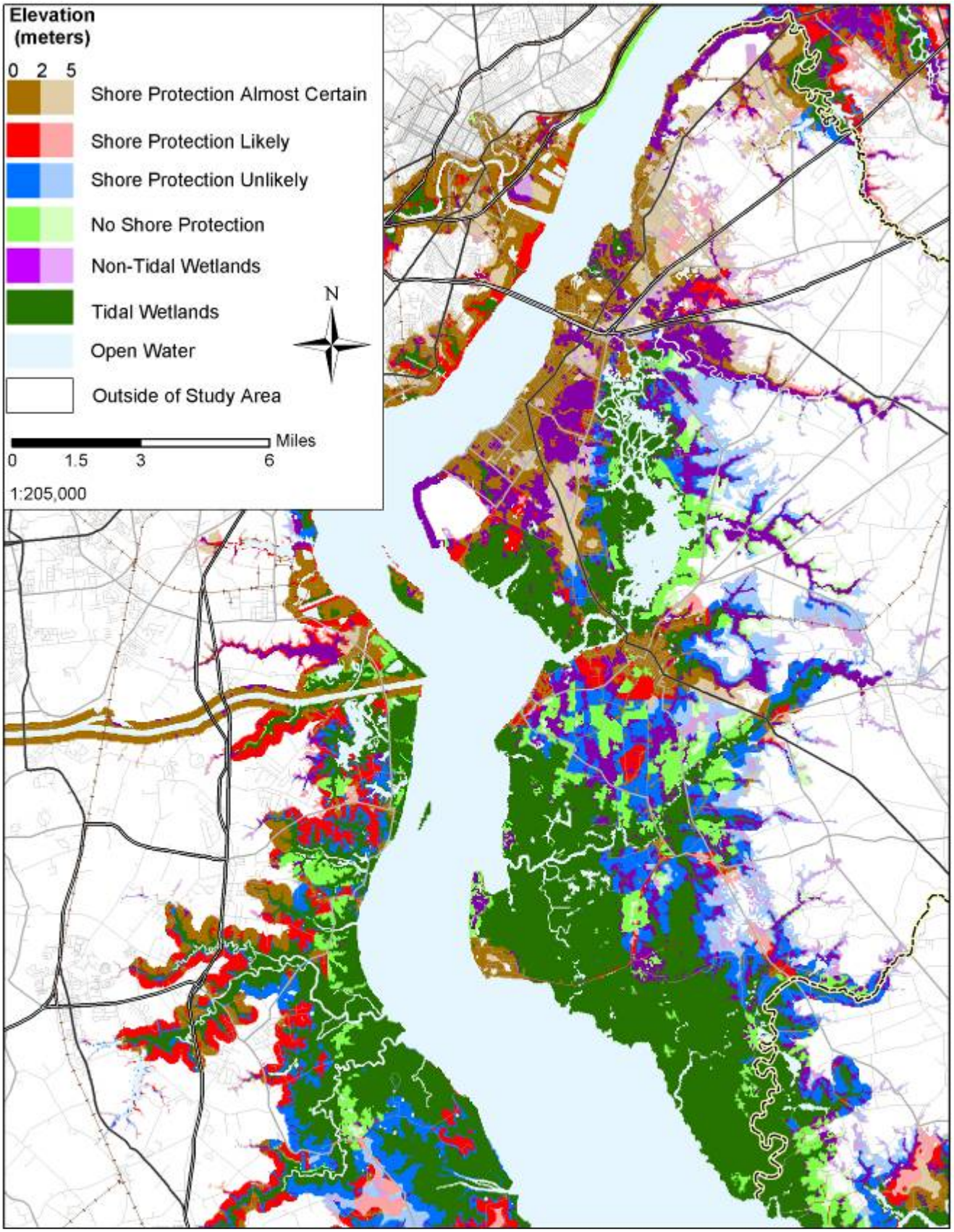
Stakeholder Review

The absence of county input during Phase 2 made a serious review for Phase 3 most important. Therefore, the EPA project manager visited the planning director at the county offices in Salem.[69] The planning director indicated that his staff recalled the previous phases of the study. He also indicated that the maps should assume that all centers and land in PAs 1–3 should be mapped as almost certain to be protected, and that other developed areas are likely to be protected. Finally, he had his staff provide us with the county data, and suggested that final versions of the map include township boundaries.

The net effect of the Salem County changes was to use the same generic assumptions that we were already using for the other counties along the Delaware River.

Map 3-8 shows the likelihood of protection, based on the assumptions enumerated in the methods section and site-specific changes suggested by county planners.

[69]Meeting between Ron Rukenstein, planning director for Salem County, and Jim Titus in Salem, September 3, 2003.



Map 3-8. Salem County: Likelihood of Shore Protection. For additional details, see the legend and caption accompanying Map 3-2.

DELAWARE RIVER COUNTIES

Gloucester, Camden, and Burlington counties do not fall within New Jersey's CAFRA zone and are therefore subject to slightly different rules and regulations than other waterfront counties in New Jersey. Outside the CAFRA zone, the Waterfront Development Law controls development along tidal waterways. Although the law was written as a basis for regulating and protecting commerce and navigational development (e.g., wharves, channels, and piers), it is now used as a policy for the environmental protection of waterfront areas. Based on this law, property owners must obtain a permit from NJDEP to construct, reconstruct, alter, or expand structures; excavate; or fill land within the land area adjacent to the tidal waterway.[70] Below, we summarize information from meetings held in 2001 with representatives from each of the three counties located along the tidal portion of the Delaware River. [71]

Table 3-8 illustrates the general approach we employed to map long-term shore protection for the counties adjacent to the Delaware River. Site-specific differences are examined in the individual county discussions. The primary difference between the approach that we employed for this area—compared with the CAFRA area—was that along the river, our default assumption was that developed areas in PAs 2 and 3 are almost certain (brown) rather than likely (red) to be protected. As a practical matter, however, the final results are not very different because site-specific corrections to the maps by CAFRA county staff had converted much of the developed PA 2 and 3 lands to protection almost certain (brown) anyway.

Gloucester County

Background

Gloucester County is adjacent to the tidal portion of the Delaware River and therefore subject to the Waterfront Development Law. The riverfront is mostly wetlands and industrial development. Farther inland, lands are heavy residential development and then extensive agricultural lands.

Discussions. Our assumptions regarding the County's response to sea level rise are based on conversations with: Rick Westergaard, principal planner; and Charles Romick, A.I.C.P, P.P., planning director, Gloucester County Public Works Department, Planning Division.

State Plan. When developing the state planning areas, the state worked closely with Gloucester County. As a result, the County is comfortable with the designations; however, they feel it is important to recognize that planning areas and development patterns are not directly correlated. For example, the state does not intend for PA 3 "fringe" areas to be heavily developed, but many fringe areas in the county are experiencing significant development. Therefore, PAs 1, 2, and 3 are already or soon may be developed and will therefore also be protected. Lands within

[70]The Waterfront Development Law of 1914 regulates activities up to the high water mark. In non-CAFRA regions, the law's jurisdiction also extends from the mean high water line to the first paved public road, railroad or surveyable property line. The zone extends at least 100 feet, but no more than 500 feet, inland from the tidal water body. Source: http://www.state.nj.us/dep/landuse/coast/coast.html on the Waterfront Development Law N.J.S.A 12:5-3s.

[71]A portion of Salem County is outside the CAFRA zone (i.e., north of the Kilcohook National Wildlife Refuge); however, the county is considered in the coastal county section of this report. Additionally, the southern portion of Mercer County is adjacent to the tidal portion of the Delaware River. Because virtually all of this area is either wetland or the heavily developed Trenton area, we rely on response scenarios provided by the NJDEP in place of discussions with Mercer County representatives.

TABLE 3-8. GENERAL APPROACH FOR MAPPING ANTICIPATED SEA LEVEL RISE RESPONSE: DELAWARE RIVER COUNTIES (SALEM, GLOUCESTER, CAMDEN, AND BURLINGTON COUNTIES)[a]

Land Area	Protection Likelihood				Source
	No protection	Unlikely	Likely	Certain	
Site-specific exceptions to general rule[b]	Varies				Varies
Salem County: open spaces[3] within planning area 1				✓	Salem County
Salem County: open spaces[3] within planning areas 2 or 3			✓		
Salem County: remaining open spaces[c]	✓				
Salem County: urban areas				✓	Salem County zoning
Open spaces[d] within planning area 1				✓	State plan, state open spaces, federal open spaces, and conservation lands
Open spaces[d] within planning areas 2 or 3			✓		
Remaining open spaces[d]	✓				
Planning centers within planning areas 1, 2, and 3				✓	State planning centers
Planning centers within planning areas 4 and 5			✓		
Developed lands[e] within planning areas 4 and 5			✓		State plan and 1995 land use/land cover
Recreational parks within planning area 1				✓	State plan
Recreational parks within planning areas 2 and 3			✓		
Recreational parks within planning areas 4 and 5		✓			
Planning areas 1, 2, and 3				✓	
Planning areas 4 and 5		✓			

[a] Where land areas overlap, classifications higher in the table take precedence.
[b] See text of report for site-specific exceptions to the general mapping method.
[c] Open spaces in Salem County include open spaces, ecological heritage sites, and farmland preservation lands.
[d] Open spaces include state open spaces, federal open spaces, conservation easements, land trusts, greenways, wildlife preserves, and national parks.
[e] We used New Jersey land use/land cover polygons to identify developed lands (e.g., transportation structures and residential, commercial, industrial, and institutional lands).

PAs 4 and 5 are not likely to be developed further and, with the exception of existing development, are not likely to be protected.

Economics. A significant portion of the land adjacent to the river is industrialized, and much of that is currently undergoing aggressive environmental remediation, including the Mobil refinery at Paulsboro and a Dupont facility at Gibbstown. Many of the industrial facilities have changed ownership a number of times and are in various states of operation or remediation. Sites not currently in operation are likely to be redeveloped in the future. Dikes already protect many sites, and the remaining sites will almost certainly be protected in the future.

Considerable development pressure exists in Gloucester County. Woolwich, Harrison, and East Greenwich are the county's fastest growing municipalities. One significant ongoing project is the Riverwinds residential development in the township of West Deptford, where the land to the south of the borough of National Park is being developed as a residential community.

Parks and Open Space. The Gloucester County Board of Chosen Freeholders actively maintains and seeks to obtain additional lands for public recreational uses. Given the current political atmosphere, parks are likely to be protected to ensure continued public access. The dedication to protecting parks for recreational use, however, could change as new freeholders come into office and preferences and goals change.

The Raccoon Creek Acquisition Project is an ongoing recreational access project in the town of Logan. The Gloucester riverfront on either side of Raccoon Creek was a proposed site for dumping dredged materials; however, the County is fighting this proposal.[72] The County is

[72]This area is a proposed dredging site for 33 million cubic yards of material from a Delaware River dredging project.

currently trying to purchase this land (approximately 1,500 acres) to develop as a recreational facility that might include riding stables, trails, and a marina. This land is likely to be protected because the land has little environmental value—since so much fill has already been dumped there—and because the County expects a public use in the future.

Farther back from the industrial waterfront, Gloucester County is composed of extensive agricultural lands. The County has an aggressive agricultural preservation program that acquires development rights. Once the development rights are acquired, the agricultural lands will not be developed and therefore also not protected from sea level rise.

Other Considerations. Flooding is a significant problem in areas along the Delaware River in Gloucester County. In the 1600s, one company constructed a flood gate known as the "Gibbstown Levee" on Repaupo Creek south of Chester Island under the stipulation that it would maintain the structure. The gate, however, was last rebuilt in the 1920s and renovated in the 1960s. Much of this area is subject to considerable flooding because of the ill repair of this gate. The town attempted to reconstruct the gate, but because the area is riparian, NJDEP has not granted the permits. In addition, the issue of ownership of the gate is an ongoing debate that is delaying any reconstruction planning. In December 1998, $100,000 in federal funding was received to investigate various reconstructive measures,[73] but at present, no local sponsor has agreed to sign the necessary feasibility cost-share agreement. Potential sponsors of a feasibility study of improvements to the levee include the State of New Jersey, Gloucester County, and Greenwich and Logan Townships.[74] Other areas with substantial flooding problems include the mobile home park just south of the Borough of National Park and another area near Lake Martha.

The Gloucester County Utilities Authority, which is located in West Deptford, will certainly be protected from inundation. All other utilities and utility rights of way in the county will also be protected. Saltwater intrusion into aquifers is a major area of concern in the county.[75]

[73]In a discussion of possible projects, the Corps of Engineers states that improvements would be authorized under Section 205 of the Flood Control Act of 1948. The Corps goes on to say: "The Gibbstown Levee runs 4.5 miles along the Delaware River in Logan Township and Greenwich Township in Gloucester County, N.J. It protects the 21-square-mile Repaupo Creek watershed inhabited by approximately 6,700 residents in the townships of East Greenwich, Greenwich, Harrison, Logan, Mantua and Woolwich…. Constructed over 200 years ago, the levee was repaired in many places in 1962 by the Corps of Engineers under Public Law 84-99. In September 1967, the Corps performed a reconnaissance study and recommended the levee be restored to minimize flood potential in the Repaupo Creek watershed from possible failure of the aged and deteriorated Repaupo Creek floodgate and adjacent levee. In November 1969 the Repaupo Meadow Company—the sponsor at that time—notified the Corps of its inability to provide funding and the study was halted in March 1970. In April 1973, the Repaupo Meadow Company formally requested the Corps to reactivate the study, but written assurance of local cooperation was never furnished. In 1976 the study was again terminated. In November 1999, the Corps received funding under PL 84-99 to repair the floodgates at Repaupo Creek. This work, completed in May 2000, includes replacement of the gates and frames, repairs to the deteriorated concrete and adding trash racks on the Delaware River side.
Several meetings were held with Gloucester County, Greenwich Township and Logan Township officials to determine their interest in conducting an updated feasibility study of improvements to the Gibbstown Levee. In December 1998, $100,000 in federal funding was received to consider various combinations of levee raising and nonstructural measures. However, no local sponsor has indicated an intention to sign the necessary cost share agreement (FCSA) to complete the study. Therefore, all study efforts are presently on hold…. [No] Sponsor [has been] None identified at this time. Potential sponsors could include The State of New Jersey, Gloucester County, Greenwich and Logan Townships."

[74]U.S. ACOE, Philadelphia District Projects in New Jersey, http://www.nap.usace.army.mil/cenap-dp/projects/nj_projects.htm.

[75]The Delaware River is generally fresh above the Commodore Barry Bridge. The river recharge aquifers that have been pumped well below sea level. During droughts, however, saltwater advances upstream to Gloucester and even Camden counties, recharging aquifers with saltwater that persists long after the drought ends. Sea level rise tends to exacerbate these tendencies. See, e.g., Hull, C.H.J. and J.G. Titus (eds.), 1987, Greenhouse Effect, Sea Level Rise, and Salinity in the Delaware Estuary, EPA and DRBC. Available on the EPA "Sea Level Rise Reports" web page, www.epa.gov/globalwarming/sealevelrise.

Photos 26–29. The Gibbstown Levee. The water behind the levee to the left appears to be a few meters lower than the Delaware River (26). The Commodore Barry Bridge is in the background. Because drainage is determined by a tide gate (Photo 27), the water levels will be no lower than the low tide level, leaving the lands behind the dike (Photos 28-29) vulnerable to flooding as sea level rises. These areas are already below sea level (March 2003).

Baseline Plan for Sea Level Rise

The sea level has risen more than 3 feet since the Delaware River area was settled, so to a large extent, one can already see the response to sea level rise in Gloucester County. The industrial northeastern half of the county's riverfront is on high ground, generally above the 10-ft (NGVD) contour, and thus more than 5 feet above the tides. Most of the shoreline there is already bulkheaded, to provide the vertical shore that facilitates docking—but the effect is also to stop coastal erosion.

Despite its name, the Gibbstown Levee (Photos 3-26 and 3-27) is, for all practical purposes, a dike that prevents the inundation of the low-lying parts of Greenwich Township and also protects higher parts of the township from flooding. Several square miles are below the 00-ft (NGVD) contour, according to the USGS 7.5 minute quadrangle for the area. Although most of this low area is some form of freshwater wetland, there are also a few homes (Photos 3-28 and 3-29) and a trailer park along "Marsh Dike Road" below the 00-ft contour This dike once served a function similar to the dikes in Cumberland County, preventing tidal inundation and lowering the water table to a level between mean low water and mean sea level. When the "levee" was built more than 300 years ago, the tides were 3 feet lower; hence the combination levee and tide gate were able to keep the water levels low enough to permit cultivation. But rising sea level and land subsidence have left this land so low relative to the tide that most of it can no longer be drained by low tide. Parts of Raccoon Island near the entrance to the

Commodore Barry Bridge, for example, are below mean sea level.

Our approach for identifying land likely to be protected as sea level rises was generally in accord with the County's expectations. The County is certain that the industrial areas would be protected for the foreseeable future.

The nonindustrial area along the river from Gibbstown to Raccoon Creek, protected by the Gibbstown Levee and other dikes, by contrast, is another story. Even if those dikes and their associated tide gates are fortified, the undeveloped lands will gradually be submerged unless pumping facilities are installed, because much of the area is barely above low tide even today. The wetlands will gradually convert to open water ponds.

The County does not foresee pumping facilities sufficient for a daily pumping of all the very low lands protected by those dikes. Rather, the primary effect of the dikes will be to prevent flooding from storm surges and ordinary tides. That is, with a daily tide range of 8 feet, land 4 feet above sea level would be inundated by the tides without the dike; with tide gates opening only at low tide, land about 2 feet below sea level can be drained twice a day for 3 or 4 hours, and land precisely at sea level can be drained for 6 hours twice a day, while not being flooded by the tides.

Such protection would not permanently obviate the need for additional measures, but could delay the need for however long it takes for the sea to rise a few feet.[76] For the isolated settlements along Marsh Dike Road and elsewhere, elevating homes and land surfaces may be cost-effective; although property values are less than along the barrier islands, sources for fill material are closer. Gibbstown, Bridgetown, and other more populated communities could be encircled with a ring dike with a pumping system that drains only the densely developed area; or they too may find it cost-effective to elevate land as the sea rises. But the majority of land behind the dike will probably not be protected.

The dikes will also tend to keep saltwater from invading the freshwater wetlands and ponds behind the dikes. Currently, those areas are rarely salty—but as sea level rises, the saltwater front will gradually migrate upstream.

If the dikes are not maintained, by contrast, the same measures will be required for protecting developed areas—but much sooner. The wetlands behind the dikes would convert to mudflats or open waters rather rapidly.[77]

Map 3-9 depicts the likelihood of protection for the dry land areas as sea level rises. The only way by which the County's expectations differ from the general decision rules for Delaware River are that a recreation facility is planned for the PA 5 area along both sides of Raccoon Creek. This facility will probably be protected.

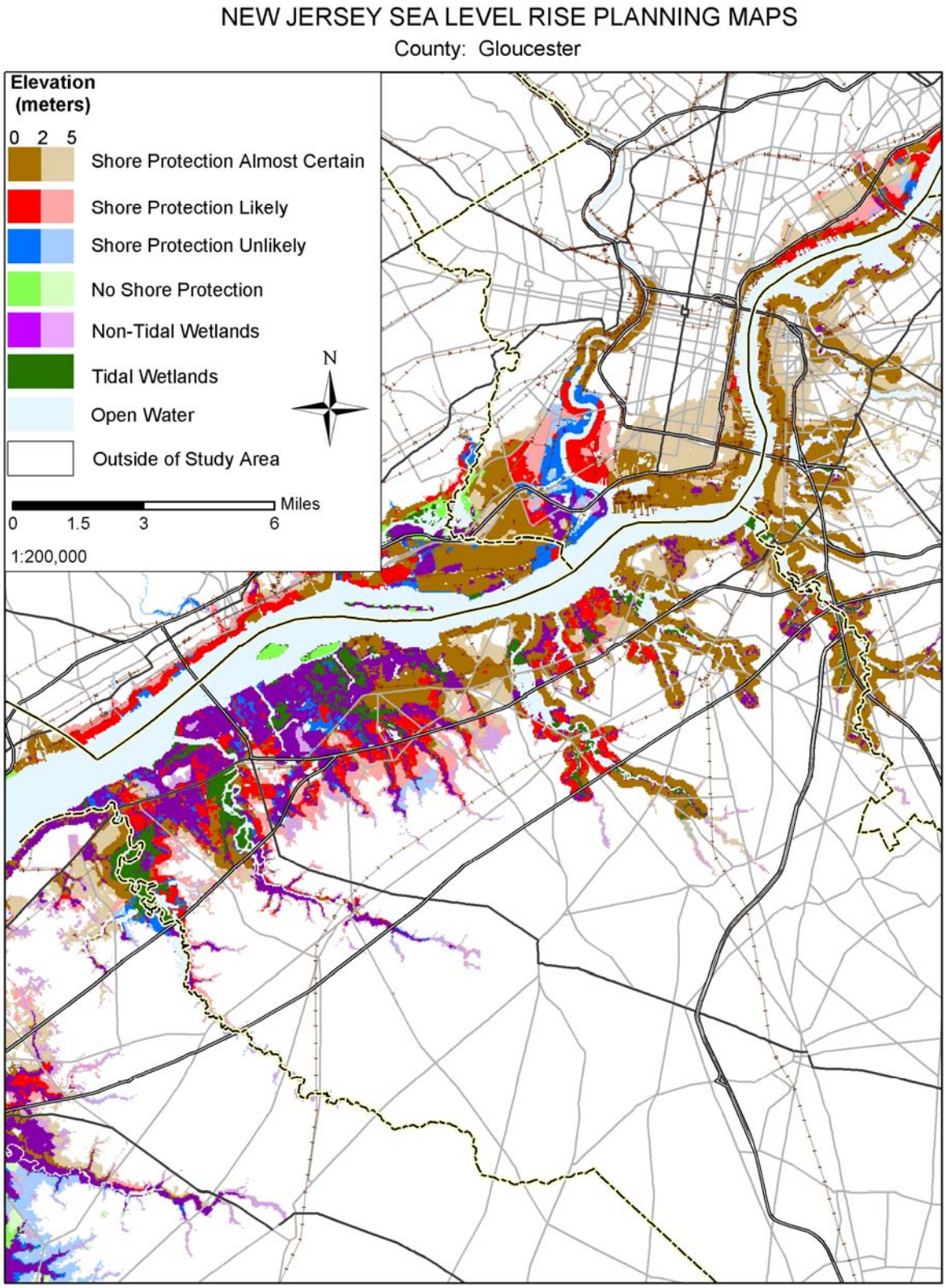
Stakeholder Review

The County indicated that the map accurately portrayed its expectations.[78]

[76]If one looked only at tidal inundation, the dikes delay the need for further measures until the sea rises enough to leave land otherwise flooded by spring high tides unable to drain during low tide. Because it may take some time to drain, that distance would be somewhat less than the full tide range—but more than one-half the tide range, so one might reasonably expect the dike and tide gate to protect against a rise in sea level of about 6 feet. However, developed areas need to drain during storms. If a heavy rain coincides with a high tide, even an area at the high tide elevation would not drain; and lands at mean sea level would be unable to drain approximately half the time.

[77]These wetlands are generally slightly above mean low water, and hence would be exposed for a small part of the day. Such frequent submergence would drown most forms of wetland vegetation, even if saltwater did not kill it. Whether the area then became mudflat or shallow water would depend on sediment transport, the extent to which peat soils oxidized or submerged in response to reactions of the soils with saltwater.

[78]Rick Westergaard, Gloucester County Public Works Department Planning Division, telephone conversations with Jennifer Kassakian, August 1, 2002.



Map 3-9. Gloucester County: Likelihood of Shore Protection. For additional details, see the legend and caption accompanying Map 3-2

Camden County

Camden County is a densely developed and highly industrialized area where open space constitutes less than 10 percent of the total land area. The natural areas of the county lie along the banks of the Delaware River from North Camden to Cramer Hill. The riverfront from Gloucester City to Camden City is heavily industrialized with much of the shoreline already armored.

Background

Discussions. Our assumptions regarding the County's response to sea level rise are based on conversations with Doug Griffith and Curt Noe, Camden County Department of Public Works, Division of Planning.

State Plan/Economics. All lands in Camden County less that 20 feet in elevation are designated PA 1; the County agrees with this designation. This area is highly developed and increasing in density. Redevelopment and revitalization of industrial areas are ongoing. The waterfront was once an area of heavy industry and commerce, but activity has decreased substantially in recent years. Many abandoned piers and structures are targets for redevelopment. These lands will be protected from sea level rise.

The Camden City waterfront from approximately the Tweeter Center to the Ben Franklin Bridge is an active recreational area. Some of the important sites along the waterfront include the Tweeter Center, Children's Garden, New Jersey State Aquarium, and the future site of the *USS New Jersey* Museum. All of these areas will certainly be protected. In addition, the county is experiencing very high demand for more marinas along the river. These active recreational areas will be protected.

Cultural Features. Petty Island lies at the mouth of the Cooper River and to the northeast of the city of Camden. The northeastern half of the island serves as a storage site for oil supply tanks, and the southwestern half of the island is undeveloped and mainly wetlands. Because the remains of several Fulton steamships reside here, the site possesses significant cultural and archeological value.

Parks and Open Space. Less than 10 percent of the land in Camden County is considered open space. The county's open space program is relatively active and is currently working to enhance residents' and visitors' recreational opportunities. In general, with the exception of a few other designated parks, only the stream valleys are left as open space. The Greenway Committee is working to develop a chain of parks that runs up the Cooper River to Camden and will preserve these stream valleys as open space.

The Harrison State Street Landfill in the town of Pennsauken is no longer in use, and the County is hoping to develop it as an active recreational area. Once the site has been sealed, the County may build ballfields, parking lots, and possibly a marina. Consequently, this area is likely to be protected. They are also attempting to procure the waterfront in Gloucester City to be maintained as a public park.

Other Considerations. Several areas within the county experience serious flooding problems. For example, Route 30, which runs near the Cooper River, experiences substantial flooding. The Army Corps of Engineers is currently investigating approaches for alleviating some of these problems. Any protection for the stream valleys would likely be in the form of a sluice or other structure that would regulate the flow of water into the tributaries as opposed to actually hardening the stream banks.

Baseline Plan for Sea Level Rise

Because all lowlands in Camden County are within PA 1, the decision rules of this study would suggest that the entire shore of this county will be protected.[79] That assumption corresponds with the County's thinking: The County is not entertaining any plans to remove shoreline armoring to bring back wetlands and beaches along existing waterfront parks, let alone the heavily developed areas.

[79] A map of Camden County is thus unnecessary, so we do not include one.

As with most urban areas, the key planning issue for sea level rise will be *how* not *whether* to protect the land from rising water levels. Unfortunately, Jennifer Kassakian was unable to reach the planning staff for comments during the stakeholder review.[80]

Burlington County (Delaware River)

Burlington County has seen cycles of both economic growth and decline since its inception in the early 17th century. One of the oldest towns along the river, Burlington City was settled in the 1600s as a port and area of commerce. Most of the towns west of Burlington City were established in the 19th and early 20th centuries. These towns are densely developed, with compact concentrations of people and commerce adjacent to the river. Although most of the county is located along the Delaware River, a portion extends to the Atlantic Ocean. This area is predominately wetlands. (See Burlington County in the section on Atlantic and Delaware Bay counties, above.)

Background

Discussions. Our assumptions regarding the County's response to sea level rise are based on conversations with Mark Remsa, regional planning coordinator, Burlington County Economic Development and Regional Planning.

State Plan. The Burlington County waterfront is densely developed and in many areas heavily industrialized. The lands in our area of study from the western border of the county to just east of Burlington Island are almost exclusively designated as PA 1. Lands farther east along the waterfront are designated PA 2, with the exception of Newbold Island, which is designated PA 3. Some PA 4 lands exist farther inland along the stream valleys. Heavily developed towns within these PAs will all be protected from the impacts of sea level rise.

Economics. Over time, the eastern portion of Burlington County has become more densely developed while the historic riverfront communities have experienced economic decline. Riverfront and Burlington City both have strong downtown areas, and Riverton and Palmyra have viable downtown areas. The town of Beverly is still struggling economically. The County continues to assist in revitalization efforts in these riverfront communities. Because most of the riverfront is already developed, most "new" development will occur on older industrial sites.

Three rehabilitation projects are ongoing or recently completed under Superfund and brownfields programs. The Roebling Steel Mill, located southwest of Newbold Island, is likely to be redeveloped as an area of light industry and a marina. The Cosden Chemical Coatings Factory site in Beverly will most likely remain open space. Plans for the Cinnaminson Landfill site have not yet been determined.

The demand for marinas along the Delaware River is very high. The largest marina complex on the Delaware River is located west of Riverside and is already largely bulkheaded.

Parks and Open Space. Preserving public access to parks is important to the county. Municipalities with parks along the waterfront include Burlington City and Beverly; these parks will almost certainly be protected from sea level rise. Other parks that lie along the Rancocas Creek will also be protected if sufficient funding can be secured. The County is trying to create a greenway of trails along the Rancocas Creek linking a number of waterfront parklands that the County already owns or is attempting to purchase. The town of Palmyra is also interested in establishing a nature center (including buildings) on a dredge spoil site, and consequently that site is also likely to be protected. The County is also looking to preserve some open space within PAs 1 and 2. Even if these lands are set aside for open space, they will be protected from sea level rise.

[80]Her attempts to contact Doug Griffith were as follows:
September 13: Sent package of materials with return address and contact information.
September 24: Left voicemail to see if he got package or had questions.
October 10: Called but no answer. Sent email. Delivery failed.
October 11: Attempted to call main planning number multiple times, but it was busy each time.

Other Considerations. The historic Camden/Amboy rail line runs through Burlington County along the river. The line is still operating as a freight line, but NJ Transit has purchased the right of way and is planning to develop it as a light passenger rail line. One section of this line in the eastern portion of the county's riverfront (from the Roebling site to Bordentown) was placed at the bottom of the bluffs and is therefore at risk from rising water levels. The tracks for this line will undoubtedly be protected.

Burlington County also has four islands located along the Delaware River. From north to south they are Newbold, Burlington, Hawk, and Amico. Newbold Island was a proposed site for a nuclear power plant, but that plan was rejected. There are plans to construct a new power plant just to the east of the island, but it will not be in any way connected to it. County planners doubt that this island will be developed; hence it is depicted in blue. The ownership of Burlington Island is divided between the city and the Board of Island Managers. The town has some interest in developing the island as a golf course, but no official plans have been initiated. It is quite possible that this island will be protected. Hawk Island was at one time an island but became a dumping site for dredge spoils and is now more accurately described as a peninsula. It is unlikely that any measures will be taken to protect this area. Amico Island is a dredge spoil site that mostly consists of parkland, and it is likely to be protected. The island is connected to the banks of the river by a spit of land; this connection will also be maintained to allow access to the park.

Baseline Plan for Sea Level Rise

Map 3-10 depicts our results for the county's Delaware River shore; see Map 3-5 for the eastern portion of the county. Wetlands will probably migrate inland as sea level rises in the eastern part of the county along the Mullica River, but the vast majority of the county's shores along the Delaware River and its tributaries will almost certainly be protected; and almost all of it will probably be protected given current plans and policies.

Within Burlington County, the Conrail tracks (now owned by NJ Transit) will be converted into a NJ Transit light rail line. These tracks will probably be protected.

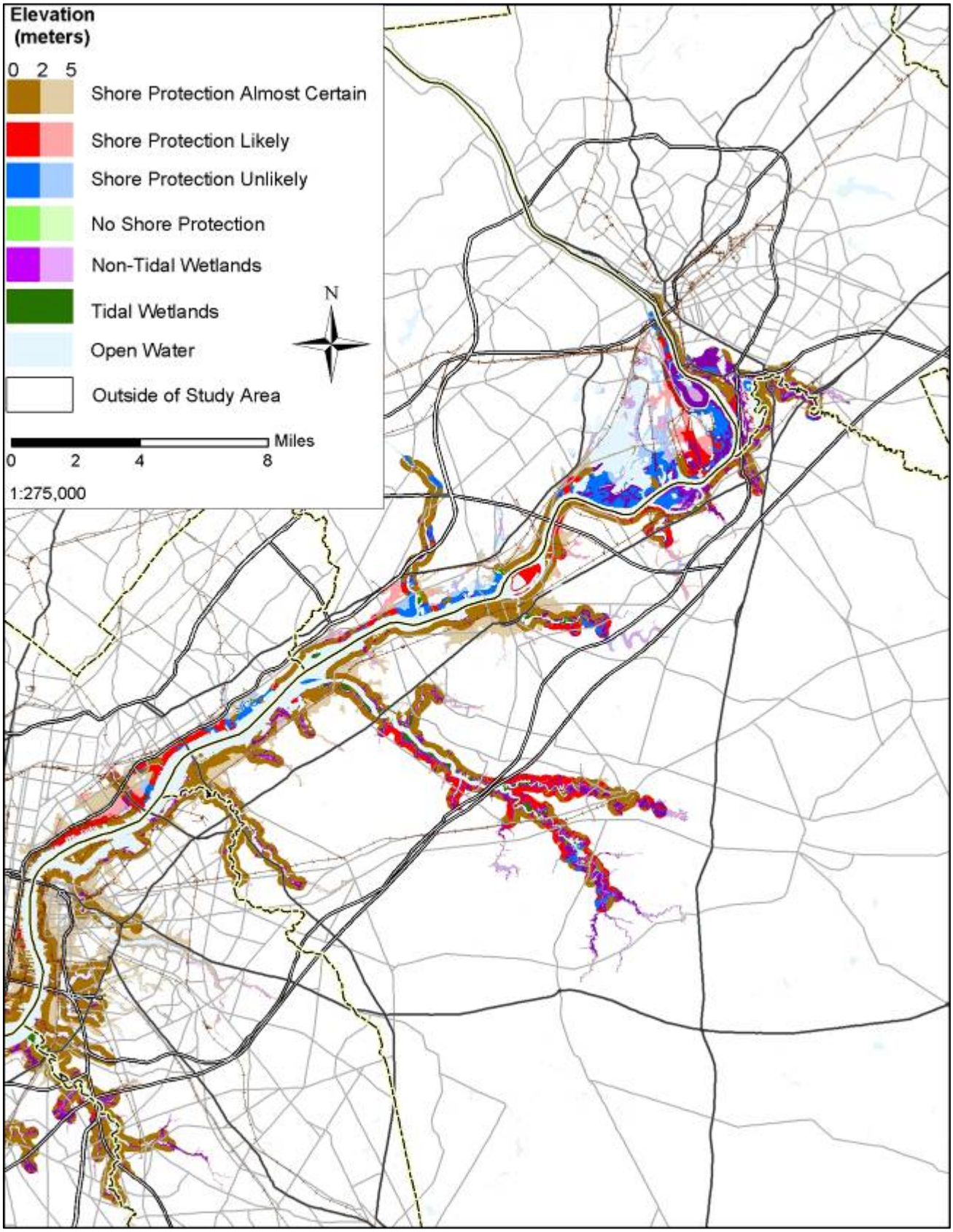
Stakeholder Review

The County had no suggested map changes.[81]

Mercer County

Because of its limited amount of land located along tidal water, we did not meet with Mercer County planners to obtain information on the counties policies and other considerations. However, based upon the decision rules used for the other Delaware River Counties (see Table 3-8), we mapped the likelihood of shore protection for the portion of the county within the study area. The resulting data are included in Map 3-10 (Western Burlington County).

[81]Mark Remsa, telephone conversation with Jennifer Kassakian. August 6, 2002.



Map 3-10. Western Burlington County: Likelihood of Shore Protection. For additional details, see the legend and caption accompanying Map 3-2.

NORTH JERSEY

The coastal area of Urban North Jersey—including Bergen, Essex, Hudson, and Union counties—comprises dense residential, commercial, industrial, and transportation uses. The Hackensack Meadowlands, which contain the Meadowlands Sports Complex, Teterboro Airport, and multiple marshland preservations and other industrial and open space land uses, are also located in this region.[82]

The only area where protection is less than certain would appear to be the currently undeveloped portion of the Hackensack Meadowlands. However, existing development and the development that eventually occurs will almost certainly be protected. Waterfront development along the Hudson River, across from Manhattan, is also at risk from sea level rise. This area will be raised with fill or secured with a sea wall if necessary. The area around the George Washington Bridge and up the river from that point is at a higher elevation and protected by the Palisades.

Even some ecologically sensitive lands will be protected in Bergen County. The Oradell Reservoir is more then 6 miles up the Hackensack River from the Meadowlands, and is more than 18 miles upstream from the open water of Newark Bay. It provides drinking water for northeastern New Jersey, including Bergen and Hudson counties. This area could feasibly be isolated from sea level changes, and almost certainly will be protected if necessary.

[82]Given the densely developed nature of this area, we did not conduct discussions with county planners in these counties during the development of the draft of this report. Instead, we first relied on the state planners' comments to create the initial response maps. Then, we obtained input from county planners—as well as New Jersey Meadowlands Commission planners—to revise the map to reflect local considerations.

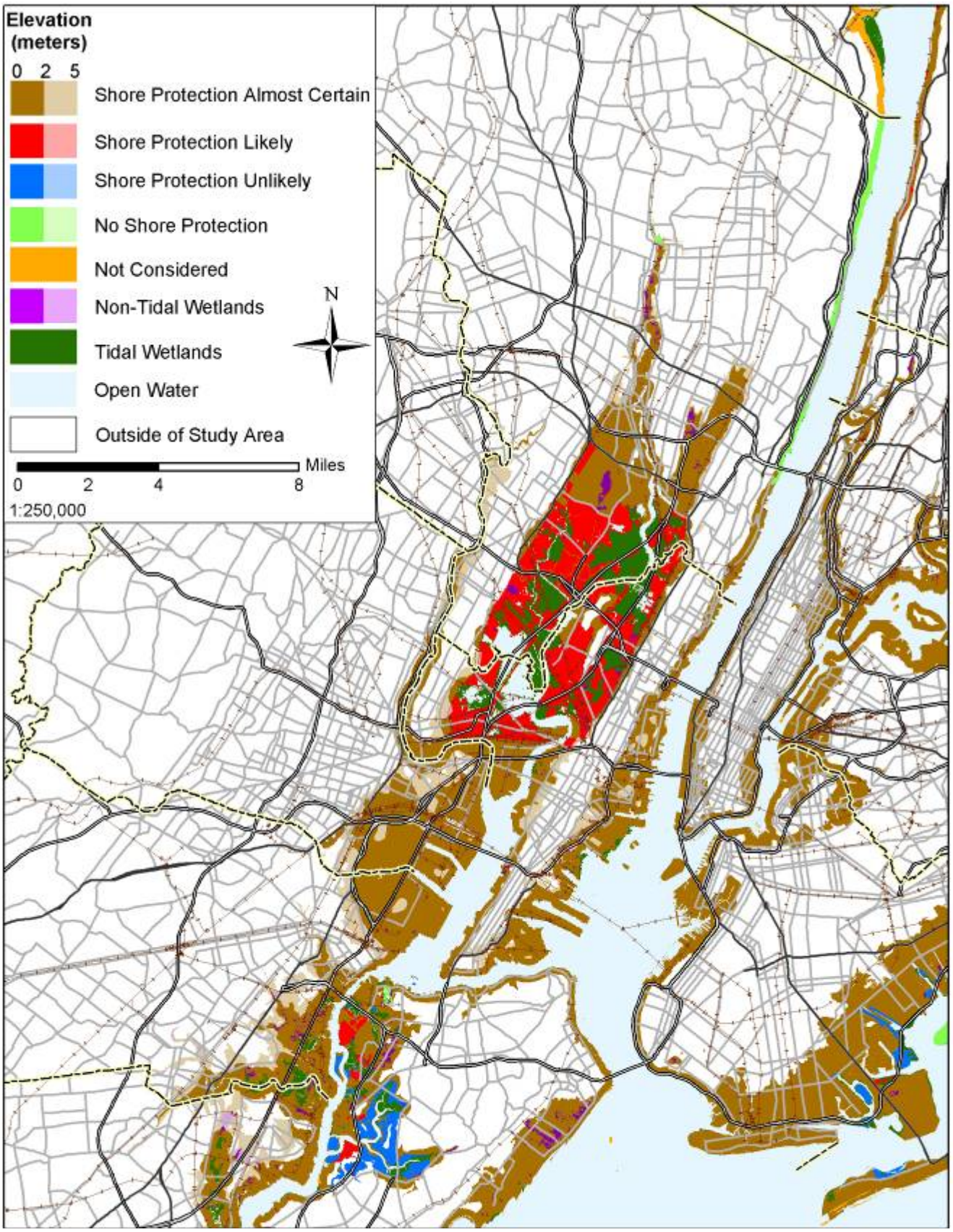
Baseline Plan for Sea Level Rise

Given resource constraints, we devoted less time and energy to this area so that we could devote more time to the counties along the Atlantic Ocean and Delaware Estuary. The need to stabilize shorelines is so apparent for much of this area that for some counties this project is a trivial exercise and was unable to command much attention from planners. Therefore, we sought only one round of comments from the local governments, except for the Meadowlands, where we had two iterations. In a few counties, we had to rely on the state to corroborate the implications of our decision rules. Table 3-9 summarizes our general approach for this area. Table 3-10 summarizes additional information provided by planners reviewing the first draft of this report. Map 3-11 depicts the results of our analysis for North Jersey.

Union County

This densely developed county along Arthur Kills and parts of Newark Bay is largely industrial, although residential neighborhoods are mixed in. (See Photos 3-30 through 3-33) Some tidal beaches remain, however, along Newark Bay and Arthur Kill in urban mixed residential areas. One often sees large chemical tanks standing on ground that would otherwise be marsh. Tremely Point has relatively low ground. All of these areas are virtually certain to be protected. Other responses seem implausible.[83]

[83]No comments were obtained from Union County; Jennifer Kassakian sent materials to Al Faella, head of Division of Planning and Community Development for Union County, and followed up with a single phone call.



Map 3-11. North Jersey: Likelihood of Shore Protection. For additional details, see the legend and caption accompanying Map 3-2.

TABLE 3-9. GENERAL APPROACH FOR MAPPING ANTICIPATED SEA LEVEL RISE RESPONSE: NORTHERN NEW JERSEY AND RARITAN BAY COUNTIES (BERGEN, HUDSON, ESSEX, AND UNION COUNTIES)[a]

Land Area	Protection Likelihood				Source
	No protection	Unlikely	Likely	Certain	
Major highways				✓	ESRI
Key facilities and currently protected areas in the Meadowlands				✓	Planner input
Meadowlands			✓		Planner input implemented using state plan
Military lands			[b]		State plan
Open spaces[c] within planning area 1				✓	State plan, state open spaces, federal open spaces, and conservation lands
Open spaces[c] within planning area 2 or 3			✓		
Remaining open spaces[c]	✓				
Remaining public and private lands				✓	State plan

[a] Where land areas overlap, classifications higher in the table take precedence.

[b] Based on the nationwide approach of this study for secured installations, the maps depict these areas as red. The data we distribute assigns the code "military" rather than "protection likely."

[c] Open spaces include state open spaces, federal open spaces, conservation easements, land trusts, greenways, wildlife preserves, and national parks.

Essex County

Essex County has an even more densely developed coastal zone, and the decision rules of this study imply virtual certainty that the shores will be protected. The County agreed with that assessment.[84]

Hudson and Bergen Counties

Unlike most of North Jersey, these counties have a substantial amount of very low land in an area commonly known as the Meadowlands. The Meadowlands Commission covers the portion of the meadowlands west of US-1/US-9 and east of the NJ Transit Kingland and Pascack lines, south of the Teterbero Airport, and north of the Lower Hacksensack drawbridge. At the northern end, however, the area between Redneck Road and Moonachie Road south to Moonachie Avenue is excluded from the commission's jurisdiction. This area includes some of the lowest developed lands in North Jersey, with the intersection of Moonachie Avenue and Road having an elevation of 5 feet above NGVD, according to the USGS 1:24,000 scale map. As a result, the area floods regularly.

The Meadowlands has its own PA 9, and hence our general decision rules do not apply. Unlike other parts of North Jersey, county staff believe that there is a chance that some dry land areas will not be protected, although protection is likely.[85] The Meadowlands Commission reviewed the

[84]David Boyd, Essex County. Voicemail left with Jennifer Kassakian, September 26, 2002: "If you are only concerned with coastal areas, your maps accurately reflect Essex County's thoughts on what will be protected."

[85]Letter from Sara J. Sundell, staff engineer, Meadowlands Commission to Jennifer Kassakian, December 12, 2002.

maps and reconfirmed our understanding that they view most of the Meadowlands in Bergen County as likely,[86] but not certain, to be protected. The staff annotated the draft maps with several suggestions for changing small areas from red to brown, including, the airport and major facilities, as well as areas that are currently developed.

Hudson County is also dubious about protecting its low-lying areas. In the Sawhill Creek Wildlife Management Area, near the confluence of the Passaic and Hackensack rivers, almost one square mile of dry land is unlikely to be protected. Liberty State Park, by contrast, will almost certainly be protected. Protection is also likely for Ellis Island, which is now recognized to be largely in New Jersey. (See Photos 3-34 and 3-35.)

Photos 34–35. View from the Hudson River near Hoboken. Ellis Island is in the center of Photo 34 with the Statue of Liberty to the left. Because of a historical fluke, both Liberty and Ellis islands are part of New York City even though they lie entirely within New Jersey waters. Because wetlands are part of the waters of New Jersey, the wetlands remained part of New Jersey—even after they were filled to create additional useable land. A recent Supreme Court case recognized that much of Ellis Island is within New Jersey. To the right is the Liberty State Park ferry terminal, which was once the terminus for the New York Central Railroad. Photo 35 shows the Hoboken shoreline.

TABLE 3-10. NORTH JERSEY STAKEHOLDER REVIEW COMMENTS

County[a]	Contact	Comments
Bergen[b]	Peter Kortright III, assistant director, Open Spaces Trust Fund, Department of Planning and Economic Development, Bergen County	Bergen County did not have any specific edits to make but suggested speaking with the NJ Meadowlands Commission and the local municipalities.[2]
Hudson[c]	John Lane, Transportation, Department of Finance and Administration, Hudson County	The combined sewer system that exists in almost all the county's municipalities makes visualizing protection from sea level rise difficult. If a feasible engineering solution became available, however, protection would be a possibility. Additionally, no source currently exists with which to fund these types of activities.
Essex[d]	David Boyd, director of planning, Essex County	County is in agreement with the responses as defined from state-level input.
New Jersey Meadowlands[e]	Sarah Sundell, senior project engineer, New Jersey Meadowlands Commission	Areas not identified in the original maps as certainly protected that should be designated as such include Teterboro Airport, the PSE&G Bergen Generating Station, the NJ Transit Bergen and Main Line railroads, the Amtrak Northeast Corridor, and currently protected lands.

[a] We did not contact planners from Union County.
[b] Peter Kortright, assistant director, Open Space Trust Fund, Bergen County. Letter to Jennifer Kassakian, September 23, 2002. We include comments from the New Jersey Meadowlands Commission in this report; however, a town-by-town review process is not within the scope of the project at this time.
[c] John Lane, Hudson County. Telephone conversation with Jennifer Kassakian, September 27, 2002. Because funding is not a consideration at this point of the study, we continue to show the majority of the densely populated Hudson County waterfront as almost certainly protected.
[d] David Boyd, Essex County. Voicemail left with Jennifer Kassakian, September 26, 2002.
[e] Letter from Sara J. Sundell, staff engineer, Meadowlands Commission to Jennifer Kassakian, December 12, 2002.

Appendix A

LENGTH OF SHORELINES BY LIKELIHOOD OF SHORE PROTECTION

Authors: John Herter, Gaurav Sinha, and Daniel Hudgens

Table of Contents: List and description of tables included in this appendix

Table Name	Description	Table Number
Definitions: Water body categories used in this Appendix	Descriptions of the water body categories used in this Appendix.	A-1
Shoreline length by County	Total shoreline length for each county.	A-2
Shoreline length of primary water bodies	Shoreline length reported for Primary Water Bodies by Water Body Name (aggregated across).	A-3
Shoreline lengths for all bodies of water by county	Shoreline length reported by unique County, Water Body Category, and Water Body Name.	A-4
Military lands	Shoreline length reported by unique County, Water Body Category, and Water Body Name where the shoreline is located within a Military Facility.	A-5
Islands with roads	Shoreline length reported by unique County, Water Body Category, and Water Body Name where the shoreline is located on an island that contains roads.	A-6

Notes

This appendix estimates the lengths of tidal shoreline for each of the categories of shore protection likelihood. By "shoreline" we mean the land immediately adjacent to tidal open water or tidal wetlands. We provide several alternative summaries of our tidal shoreline estimates, including shoreline length by county, type of water body, and major body of water. For information on how we created, categorized, and measured the shoreline, see Appendix 1 of this report.

Table A-1: Definitions: Water body categories used in this Appendix

Water Body Category[1]	Description
Shorelines Along Primary Water Bodies [2]	
Primary Bay	Shoreline located along a major bay such as Chesapeake Bay.
Barrier/Bayside	The side of barrier islands adjacent to the inner coastal bay.
Primary River	The portion of a major river that flows either into the Atlantic Ocean or a Primary Bay where the river is wider than one kilometer. In this case, a major river is subjectively determined but represents the most significant waterways in the region based on relative size (e.g., Potomac River, Delaware River, Nanticoke River, etc.).
Barrier Bay/Mainland	Shoreline that is located along the major county landmass and, at least partially, shielded by a barrier island.
Barrier/Oceanside	The side of barrier islands adjacent to the Atlantic Ocean.
Ocean Front	Land located immediately adjacent to the Ocean. Excludes land located along a barrier island (which is characterized as Barrier/Oceanfront).
Other Types of Shores	
Dredge and Fill	Shoreline characterized by multiple "finger" canals that run from the primary shoreline area inland and provide access to the water for the local community development.
Other/Road	A general term used for land that might not always be considered to be land. In particular, 1) dry land located at the base of causeways leading to barrier islands and 2) docks and piers that extend into the water are included in this category.
Island	A piece of land completely surrounded by water except for a barrier island. Shores along Primary Water Bodies are not included in the "Island" category.
Secondary Bay	Shoreline located along a smaller bay that is further sheltered from the wave action of a major bay or Ocean.
Secondary River	A river that is smaller in relative size than the major rivers identified as Primary River, or where the width of a major river falls below one kilometer.
Tributary[3]	Small tributaries, creeks, and inlets flowing into a Primary Water Body. The water body name reflected in the GIS data is either the actual name of the tributary or the name of the water body into which the tributary flows.

Notes:

1. With the exception of shoreline identified as "Dredge and Fill", all Water Body Categories are mutually exclusive. Dredge and Fill areas are identified separately and are associated with shoreline that would otherwise be identified as Tributary.

2. For the purpose of this study, "Primary Water Body" distinguishes larger water bodies where the more immediate effects of sea level rise are likely to occur. These areas are less protected by land barriers and offer a more favorable environment for the promotion of wave action caused by wind.

3. When categorizing the shoreline, we identify “Unclassified Tributaries” where the water body name reflects the name of the water body into which the tributary flows. For the results presented in this appendix, we combine the “Unclassified Tributaries” within the “Tributary” category and aggregate the shoreline lengths.

Table A-2: Shoreline length by County*

County	Shoreline Length (Kilometers)					
	Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Non-Tidal Wetlands	Totals
Atlantic	179	47	71	84	188	**570**
Bergen	61	85	0	19	9	**174**
Burlington	143	39	19	17	199	**417**
Camden	108	0	0	0	37	**145**
Cape May	207	68	82	34	234	**626**
Cumberland	50	29	127	59	323	**589**
Essex	32	0	0	0	0.1	**32**
Gloucester	114	17	11	11	119	**272**
Hudson	116	60	0	4	4	**185**
Mercer	9	13	6	1	43	**71**
Middlesex	163	2	30	4	17	**216**
Monmouth	239	6	19	0.7	10	**275**
Ocean	348	119	46	48	139	**700**
Salem	71	21	32	95	154	**372**
Union	36	0	0	0	1	**37**
Totals	**1875**	**506**	**442**	**379**	**1478**	**4680**

* Excludes Passaic and Somerset County.

Table A-3: Shoreline length of primary water bodies

Water Body Category	Water Body Name	Shoreline Length (Kilometers)					
		Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Non-Tidal Wetlands	Totals
Barrier Bay/Mainland	Absecon Bay	3	<0.1	0.3	0	0.9	**4**
Barrier/Bayside	Absecon Bay	3	<0.1	1	0	0.4	**5**
Barrier/Bayside	Absecon Channel	9	3	<0.1	0	0	**13**
Barrier/Oceanside	Atlantic Ocean	132	27	3	16	<0.1	**178**
Ocean Front	Atlantic Ocean	43	0	0	0	0	**43**
Barrier Bay/Mainland	Barnegat Bay	26	14	5	2	37	**84**
Barrier/Bayside	Barnegat Bay	44	26	0.7	0	0.1	**70**
Barrier/Bayside	Bonita Tideway Bay	2	0	0	0	0	**2**
Barrier/Bayside	Brigantine Channel	0.3	0	0	4	0.3	**5**
Barrier/Bayside	Broad Creek	0	3	0.2	0	0	**4**
Barrier Bay/Mainland	Cape May Harbor	5	0	<0.1	0	0	**5**
Barrier/Bayside	Cape May Harbor	0.6	2	0	0	0.3	**3**
Primary Bay	Delaware Bay	17	3	18	20	111	**169**
Primary River	Delaware River	96	10	6	7	49	**167**
Barrier Bay/Mainland	Forked River	2	<0.1	0	0	3	**5**
Barrier Bay/Mainland	Grassy Bay	0	0	0	2	1	**3**
Barrier Bay/Mainland	Grassy Sound	0.5	0.4	0.5	0.2	2	**3**
Barrier/Bayside	Grassy Sound	5	0	0	0	0	**5**
Barrier Bay/Mainland	Great Bay	6	0	0.5	0.1	7	**14**
Barrier/Bayside	Great Bay	0.3	<0.1	0	5	0	**5**
Barrier Bay/Mainland	Great Egg Harbor Bay	9	6	14	2	63	**93**
Barrier/Bayside	Great Egg Harbor Bay	8	4	0	0	<0.1	**12**
Barrier Bay/Mainland	Great Sound	0.7	<0.1	0.6	0	7	**8**
Barrier/Bayside	Great Sound	10	<0.1	0.2	0	0	**10**
Barrier/Bayside	Great Thoroghfare	0	0	0	9	0.4	**9**
Barrier Bay/Mainland	Hammock Cove	0	0	0.4	0.8	3	**4**
Primary River	Hudson River	26	0	0	18	1	**45**
Barrier Bay/Mainland	Jarvis Sound	5	0.3	2	0.4	7	**15**
Barrier/Bayside	Jarvis Sound	6	2	0	0	0	**8**
Barrier Bay/Mainland	Jenkins Sound	0.7	0.5	0.5	<0.1	6	**7**
Barrier/Bayside	Jenkins Sound	4	3	0	0	0	**8**
Barrier Bay/Mainland	Lakes Bay	15	0.4	0.5	0	0.2	**16**
Barrier/Bayside	Lakes Bay	7	0.4	2	0	0	**9**
Barrier Bay/Mainland	Little Bay	2	3	3	0	0	**8**
Barrier/Bayside	Little Bay	3	0	0	0	0	**3**

Table A-3: Shoreline length of primary water bodies

Water Body Category	Water Body Name	Shoreline Length (Kilometers)					
		Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Non-Tidal Wetlands	Totals
Barrier Bay/Mainland	Little Egg Harbor	11	0.9	2	0.5	20	**34**
Barrier/Bayside	Little Egg Harbor	19	0.9	0	8	0	**28**
Barrier Bay/Mainland	Ludlam Bay	2	0.2	4	2	9	**17**
Barrier/Bayside	Ludlam Bay	5	12	0.7	2	0.1	**20**
Barrier Bay/Mainland	Manahawkin Bay	2	0	0	0	0	**2**
Barrier/Bayside	Manahawkin Bay	1	0	0	0	0	**1**
Barrier Bay/Mainland	Matedeconk River	0.5	<0.1	0	0	0.2	**0.7**
Barrier/Bayside	Obes Thoroughfare	2	0	0	0	0	**2**
Primary Bay	Raritan Bay	17	0.2	1	0	0.2	**19**
Barrier Bay/Mainland	Reeds Bay	0.8	1	2	0.4	6	**10**
Barrier Bay/Mainland	Richardson Sound	1	0	0	0	4	**5**
Barrier/Bayside	Richardson Sound	6	0.2	<0.1	0	<0.1	**7**
Barrier/Bayside	Sandy Hook Bay	10	0	0	0	0.7	**11**
Barrier Bay/Mainland	Scull Bay	10	0	<0.1	0	0.6	**11**
Barrier/Bayside	Scull Bay	5	0	0	0	0	**5**
Barrier Bay/Mainland	Shrewsbury River	37	1	4	0	0.3	**42**
Barrier/Bayside	Shrewsbury River	9	0.3	0	0	0	**9**
Barrier Bay/Mainland	Silver Bay	3	0.2	0.9	0	0.3	**4**
Barrier/Bayside	Steelman Bay	2	0.2	0	0	0	**2**
Barrier Bay/Mainland	Stites Sound	0.2	0	0	1	2	**4**
Barrier/Bayside	Stites Sound	3	0	0	0	0	**3**
Barrier Bay/Mainland	Toms River	3	1	0	0	0	**4**
Barrier Bay/Mainland	Townsend Sound	0.6	0.2	1	<0.1	5	**7**
Barrier/Bayside	Townsend Sound	5	1	<0.1	0	0	**6**
Barrier/Bayside	Wading Thoroughfare	3	0	0	0	0	**3**
Totals		**648**	**130**	**73**	**100**	**346**	**1299**

Table A-4: Shoreline lengths for all water bodies*

County	Water Body Category	Water Body Name	Shoreline Length (Kilometers)					
			Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Non-Tidal Wetlands	Totals
Atlantic	Barrier Bay/Mainland	Absecon Bay	3	<0.1	0.3	0	0.9	4
Atlantic	Barrier/Bayside	Absecon Bay	3	<0.1	1	0	0.4	5
Atlantic	Island	Absecon Bay	2	0	0	0	0	2
Atlantic	Other	Absecon Bay	6	<0.1	0.8	0.1	0	7
Atlantic	Tributary	Absecon Bay	2	0.8	0.9	0	0.9	5
Atlantic	Barrier/Bayside	Absecon Channel	9	3	<0.1	0	0	13
Atlantic	Dredge and Fill	Absecon Channel	<0.1	0.7	0	0	0	0.8
Atlantic	Barrier/Oceanside	Atlantic Ocean	21	0	0	10	0	32
Atlantic	Barrier/Bayside	Bonita Tideway Bay	2	0	0	0	0	2
Atlantic	Barrier/Bayside	Brigantine Channel	0.3	0	0	4	0.3	5
Atlantic	Island	Brigantine Channel	0	0	0	0.4	0	0.4
Atlantic	Tributary	Brigantine Channel	0	0	0	3	0.1	3
Atlantic	Barrier/Bayside	Broad Creek	0	3	0.2	0	0	4
Atlantic	Barrier Bay/Mainland	Grassy Bay	0	0	0	2	1	3
Atlantic	Other	Grassy Bay	0	0	0	24	<0.1	24
Atlantic	Tributary	Grassy Bay	0	0	0	0.5	3	3
Atlantic	Barrier Bay/Mainland	Great Bay	<0.1	0	0	<0.1	5	5
Atlantic	Barrier/Bayside	Great Bay	0.3	<0.1	0	5	0	5
Atlantic	Island	Great Bay	0	1	2	7	4	13
Atlantic	Other	Great Bay	0	0	0	0.3	0.9	1
Atlantic	Tributary	Great Bay	<0.1	0.2	0	0.5	2	2
Atlantic	Barrier Bay/Mainland	Great Egg Harbor Bay	5	4	9	0.9	42	60
Atlantic	Island	Great Egg Harbor Bay	7	2	6	0.6	6	22
Atlantic	Tributary	Great Egg Harbor Bay	29	16	22	1	57	126
Atlantic	Barrier/Bayside	Great Thoroughfare	0	0	0	9	0.4	9
Atlantic	Island	Great Thoroughfare	0	0	0	3	0.2	4
Atlantic	Tributary	Great Thoroughfare	0	0	0	2	0.2	2
Atlantic	Barrier Bay/Mainland	Hammock Cove	0	0	0.4	0.8	3	4
Atlantic	Other	Hammock Cove	0	0	0	0	0.5	0.5
Atlantic	Barrier Bay/Mainland	Lakes Bay	15	0.4	0.5	0	0.2	16
Atlantic	Barrier/Bayside	Lakes Bay	7	0.4	2	0	0	9
Atlantic	Dredge and Fill	Lakes Bay	2	0	0	0	0	2
Atlantic	Island	Lakes Bay	3	1	0.8	0	0	5
Atlantic	Other	Lakes Bay	0.6	0	<0.1	0	<0.1	0.7
Atlantic	Tributary	Lakes Bay	11	0.1	1	0	<0.1	12
Atlantic	Barrier Bay/Mainland	Little Bay	2	3	3	0	0	8
Atlantic	Barrier/Bayside	Little Bay	3	0	0	0	0	3
Atlantic	Other	Little Bay	3	0.1	0.3	0	0	4
Atlantic	Tributary	Little Bay	1	0	0	0	0	1
Atlantic	Secondary River	Mullica River	3	8	9	8	54	81
Atlantic	Barrier/Bayside	Obes Thoroughfare	2	0	0	0	0	2

Table A-4: Shoreline lengths for all water bodies*

County	Water Body Category	Water Body Name	Shoreline Length (Kilometers)					
			Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Non-Tidal Wetlands	Totals
Atlantic	Barrier Bay/Mainland	Reeds Bay	0.8	1	2	0.4	6	10
Atlantic	Barrier Bay/Mainland	Scull Bay	10	0	<0.1	0	0.6	11
Atlantic	Barrier/Bayside	Scull Bay	5	0	0	0	0	5
Atlantic	Dredge and Fill	Scull Bay	0.7	0	0	0	0	0.7
Atlantic	Island	Scull Bay	14	0.8	10	3	1	29
Atlantic	Other	Scull Bay	0.2	<0.1	0.6	0	0.1	0.9
Atlantic	Barrier/Bayside	Steelman Bay	2	0.2	0	0	0	2
Atlantic	Barrier/Bayside	Wading Thoroughfare	3	0	0	0	0	3
Bergen	Island	Hackensack River	0.7	15	0	0	0.9	17
Bergen	Secondary River	Hackensack River	30	69	0	0.4	4	104
Bergen	Dredge and Fill	Hudson River	1	0	0	0	<0.1	1
Bergen	Primary River	Hudson River	7	0	0	18	1	26
Bergen	Secondary River	Passaic River	22	0	0	0	4	26
Burlington	Island	Delaware River	6	9	6	0	11	32
Burlington	Other	Delaware River	0.5	0	0	0	0	0.5
Burlington	Primary River	Delaware River	31	5	0.7	0	10	46
Burlington	Tributary	Delaware River	53	2	<0.1	<0.1	36	91
Burlington	Secondary River	Mullica River	8	5	8	16	77	115
Burlington	Tributary	Rancocas Creek	44	18	5	0.5	64	133
Camden	Tributary	Big Timber Creek South Branch	37	0	0	0	16	53
Camden	Dredge and Fill	Delaware River	2	0	0	0	0.5	3
Camden	Island	Delaware River	7	0	0	0	0.3	8
Camden	Other	Delaware River	1	0	0	0	0.1	1
Camden	Primary River	Delaware River	19	0	0	0	5	25
Camden	Tributary	Delaware River	42	0	0	0	15	57
Cape May	Barrier/Oceanside	Atlantic Ocean	41	10	0.8	2	0	53
Cape May	Ocean Front	Atlantic Ocean	9	0	0	0	0	9
Cape May	Other	Atlantic Ocean	3	0	0	0	0.2	3
Cape May	Other	Cape Island Creek	5	0.1	4	0.2	5	14
Cape May	Tributary	Cape Island Creek	0.3	0.4	0.9	0	3	5
Cape May	Barrier Bay/Mainland	Cape May Harbor	5	0	<0.1	0	0	5
Cape May	Barrier/Bayside	Cape May Harbor	0.6	2	0	0	0.3	3
Cape May	Island	Delaware Bay	0.1	2	5	7	10	24
Cape May	Primary Bay	Delaware Bay	13	1	9	4	36	63
Cape May	Tributary	Delaware Bay	2	4	15	3	83	107
Cape May	Island	Delaware River	0	0	0	1	0.3	1
Cape May	Barrier Bay/Mainland	Grassy Sound	0.5	0.4	0.5	0.2	2	3
Cape May	Barrier/Bayside	Grassy Sound	5	0	0	0	0	5
Cape May	Barrier Bay/Mainland	Great Egg Harbor Bay	3	2	5	0.7	21	32
Cape May	Barrier/Bayside	Great Egg Harbor Bay	8	4	0	0	<0.1	12

Table A-4: Shoreline lengths for all water bodies*

County	Water Body Category	Water Body Name	Shoreline Length (Kilometers)					
			Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Non-Tidal Wetlands	Totals
Cape May	Dredge and Fill	Great Egg Harbor Bay	2	0	0	0	0	2
Cape May	Island	Great Egg Harbor Bay	5	0.3	5	0.2	4	15
Cape May	Tributary	Great Egg Harbor Bay	2	2	4	0.3	24	32
Cape May	Barrier Bay/Mainland	Great Sound	0.7	<0.1	0.6	0	7	8
Cape May	Barrier/Bayside	Great Sound	10	<0.1	0.2	0	0	10
Cape May	Dredge and Fill	Great Sound	4	0	0	0	0	4
Cape May	Island	Great Sound	12	3	4	0.5	1	21
Cape May	Other	Intercoastal Waterway	2	5	5	0	2	14
Cape May	Barrier Bay/Mainland	Jarvis Sound	5	0.3	2	0.4	7	15
Cape May	Barrier/Bayside	Jarvis Sound	6	2	0	0	0	8
Cape May	Island	Jarvis Sound	8	4	6	1	0.6	20
Cape May	Barrier Bay/Mainland	Jenkins Sound	0.7	0.5	0.5	<0.1	6	7
Cape May	Barrier/Bayside	Jenkins Sound	4	3	0	0	0	8
Cape May	Dredge and Fill	Jenkins Sound	2	0	0	0	0	2
Cape May	Island	Jenkins Sound	9	1	2	1	<0.1	14
Cape May	Barrier Bay/Mainland	Ludlam Bay	2	0.2	4	2	9	17
Cape May	Barrier/Bayside	Ludlam Bay	5	12	0.7	2	0.1	20
Cape May	Dredge and Fill	Ludlam Bay	0	0.2	0	0	0	0.2
Cape May	Island	Ludlam Bay	4	5	3	7	2	20
Cape May	Other	Ludlam Bay	0.4	0	0	0	0	0.4
Cape May	Tributary	Ludlam Bay	0.5	0.7	0.4	<0.1	1	3
Cape May	Barrier Bay/Mainland	Richardson Sound	1	0	0	0	4	5
Cape May	Barrier/Bayside	Richardson Sound	6	0.2	<0.1	0	<0.1	7
Cape May	Island	Richardson Sound	4	0	2	0	0.3	6
Cape May	Barrier Bay/Mainland	Stites Sound	0.2	0	0	1	2	4
Cape May	Barrier/Bayside	Stites Sound	3	0	0	0	0	3
Cape May	Island	Stites Sound	2	0.2	0	2	0	4
Cape May	Barrier Bay/Mainland	Townsend Sound	0.6	0.2	1	<0.1	5	7
Cape May	Barrier/Bayside	Townsend Sound	5	1	<0.1	0	0	6
Cape May	Dredge and Fill	Townsend Sound	1	0	0	0	0	1
Cape May	Island	Townsend Sound	2	2	1	0.2	0	4
Cape May	Other	Townsend Sound	0.3	0	0	0	0	0.3
Cape May	Tributary	Townsend Sound	0.4	0	0	0	0	0.4
Cumberland	Tributary	Cohansey River	9	6	36	3	38	92
Cumberland	Island	Delaware Bay	<0.1	0	0	0.3	0.7	1
Cumberland	Other	Delaware Bay	2	0	0	0.2	<0.1	2
Cumberland	Primary Bay	Delaware Bay	3	2	9	13	67	95
Cumberland	Tributary	Delaware Bay	8	6	31	17	128	191
Cumberland	Island	Delaware River	17	4	19	21	19	80
Cumberland	Other	Delaware River	0	0	0	0	1	1
Cumberland	Tributary	Delaware River	0.1	3	4	0	13	21

Table A-4: Shoreline lengths for all water bodies*

County	Water Body Category	Water Body Name	Shoreline Length (Kilometers)					
			Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Non-Tidal Wetlands	Totals
Cumberland	Island	Maurice River	0	0	0	0.1	0	0.1
Cumberland	Tributary	Maurice River	11	8	27	4	55	105
Essex	Secondary Bay	Newark Bay	12	0	0	0	0	12
Essex	Secondary River	Passaic River	19	0	0	0	0.1	19
Gloucester	Tributary	Big Timber Creek South Branch	21	0.1	0	0	15	36
Gloucester	Island	Delaware River	0	0	1	11	0	13
Gloucester	Primary River	Delaware River	14	2	1	0.1	17	35
Gloucester	Tributary	Delaware River	9	8	8	0	43	69
Gloucester	Tributary	Mantua Creek	28	6	<0.1	0	27	61
Gloucester	Tributary	Woodbury Creek	41	0.5	0	0	17	58
Hudson	Island	Hackensack River	0.9	9	0	0.2	0.7	11
Hudson	Secondary River	Hackensack River	22	50	0	4	3	80
Hudson	Dredge and Fill	Hudson River	4	0	0	0	0	4
Hudson	Primary River	Hudson River	19	0	0	0	0.3	19
Hudson	Tributary	Hudson River	3	0	0	0	0	3
Hudson	Secondary River	Kill Van Kull River	7	0	0	0	0	7
Hudson	Secondary Bay	Newark Bay	12	0	0	0	0.3	13
Hudson	Secondary River	Passaic River	14	1	0	0	0	16
Hudson	Island	Upper New York Bay	3	0	0	0	0	3
Hudson	Secondary Bay	Upper New York Bay	30	0	0	0	0.1	30
Mercer	Primary River	Delaware River	6	0.8	0	0.1	3	10
Mercer	Tributary	Delaware River	3	12	6	0.9	39	61
Middlesex	Secondary River	Arthur Kill River	20	0	0	0	0.2	20
Middlesex	Tributary	Cheesequake Creek	6	0	5	4	1	16
Middlesex	Island	Raritan Bay	2	0	0	0	0	2
Middlesex	Primary Bay	Raritan Bay	5	0	0.5	0	0.1	6
Middlesex	Tributary	Raritan Bay	9	0	<0.1	0	0.8	9
Middlesex	Island	Raritan River	4	0	7	0	1	12
Middlesex	Other	Raritan River	20	0	<0.1	0	0.4	20
Middlesex	Secondary River	Raritan River	85	2	18	0.1	13	118
Middlesex	Island	Spring Creek	0.3	0	0	0	0	0.3
Middlesex	Tributary	Spring Creek	11	0	0	0	0.4	12
Monmouth	Barrier/Oceanside	Atlantic Ocean	18	0.2	0	0	<0.1	18
Monmouth	Ocean Front	Atlantic Ocean	29	0	0	0	0	29
Monmouth	Secondary River	Manasquan River	15	0.4	0	0	3	18
Monmouth	Island	Navesink River	1	0	0	0.2	0	2
Monmouth	Island	Raritan Bay	2	0	0.7	0	0	2
Monmouth	Primary Bay	Raritan Bay	12	0.2	0.7	0	0.1	13
Monmouth	Tributary	Raritan Bay	17	0.1	5	0	0.5	23
Monmouth	Barrier/Bayside	Sandy Hook Bay	10	0	0	0	0.7	11

Table A-4: Shoreline lengths for all water bodies*

County	Water Body Category	Water Body Name	Shoreline Length (Kilometers)					
			Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Non-Tidal Wetlands	Totals
Monmouth	Dredge and Fill	Sandy Hook Bay	0.8	0	0	0	<0.1	0.9
Monmouth	Island	Sandy Hook Bay	2	0	0	0	0	2
Monmouth	Secondary Bay	Sandy Hook Bay	14	2	0	0	0.4	16
Monmouth	Tributary	Sandy Hook Bay	4	0.6	0	0	0.9	5
Monmouth	Secondary River	Shark River	17	0.7	0	0	0.8	19
Monmouth	Barrier Bay/Mainland	Shrewsbury River	37	1	4	0	0.3	42
Monmouth	Barrier/Bayside	Shrewsbury River	9	0.3	0	0	0	9
Monmouth	Dredge and Fill	Shrewsbury River	0.2	0	0	0	0	0.2
Monmouth	Island	Shrewsbury River	0	0	1	0	0.4	1
Monmouth	Secondary Bay	Shrewsbury River	1	0	0	0	0	1
Monmouth	Tributary	Shrewsbury River	50	0	7	0.5	3	61
Ocean	Barrier/Oceanside	Atlantic Ocean	51	17	2	4	0	75
Ocean	Ocean Front	Atlantic Ocean	5	0	0	0	0	5
Ocean	Barrier Bay/Mainland	Barnegat Bay	26	14	5	2	37	84
Ocean	Barrier/Bayside	Barnegat Bay	44	26	0.7	0	0.1	70
Ocean	Dredge and Fill	Barnegat Bay	23	2	1	0.2	0	26
Ocean	Island	Barnegat Bay	6	5	9	4	16	40
Ocean	Other	Barnegat Bay	0.3	0	0	0	0	0.3
Ocean	Tributary	Barnegat Bay	30	15	4	2	27	78
Ocean	Tributary	Beaver Dam Creek	13	4	1	0	2	20
Ocean	Barrier Bay/Mainland	Forked River	2	<0.1	0	0	3	5
Ocean	Tributary	Forked River	8	3	0	0	2	13
Ocean	Barrier Bay/Mainland	Great Bay	6	0	0.5	<0.1	3	9
Ocean	Island	Great Bay	8	0	2	14	3	27
Ocean	Tributary	Great Bay	8	0	0	0	0.5	8
Ocean	Tributary	Kettle Creek	12	2	2	0	5	21
Ocean	Barrier Bay/Mainland	Little Egg Harbor	11	0.9	2	0.5	20	34
Ocean	Barrier/Bayside	Little Egg Harbor	19	0.9	0	8	0	28
Ocean	Dredge and Fill	Little Egg Harbor	2	0	0	0	0	2
Ocean	Island	Little Egg Harbor	0.8	6	8	10	4	29
Ocean	Other	Little Egg Harbor	0	4	0	0.8	0.9	5
Ocean	Tributary	Little Egg Harbor	4	0	<0.1	<0.1	1	6
Ocean	Barrier Bay/Mainland	Manahawkin Bay	2	0	0	0	0	2
Ocean	Barrier/Bayside	Manahawkin Bay	1	0	0	0	0	1
Ocean	Dredge and Fill	Manahawkin Bay	0.7	0	0	0	0	0.7
Ocean	Island	Manahawkin Bay	4	1	5	0	0.1	10
Ocean	Tributary	Manahawkin Bay	3	0	0	0	0	3
Ocean	Secondary River	Manasquan River	13	3	0	0	3	18
Ocean	Barrier Bay/Mainland	Matedeconk River	0.5	<0.1	0	0	0.2	0.7
Ocean	Tributary	Matedeconk River	11	5	3	0.3	5	24
Ocean	Secondary River	Mullica River	4	0	2	1	4	11

Table A-4: Shoreline lengths for all water bodies*

County	Water Body Category	Water Body Name	Shoreline Length (Kilometers)					
			Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Non-Tidal Wetlands	Totals
Ocean	Barrier Bay/Mainland	Silver Bay	3	0.2	0.9	0	0.3	4
Ocean	Tributary	Silver Bay	15	2	0	0	1	17
Ocean	Barrier Bay/Mainland	Toms River	3	1	0	0	0	4
Ocean	Tributary	Toms River	11	6	<0.1	0	0.4	18
Salem	Primary Bay	Delaware Bay	<0.1	0	0	3	7	11
Salem	Island	Delaware River	0	<0.1	1	35	7	43
Salem	Other	Delaware River	0	7	<0.1	1	0	8
Salem	Primary River	Delaware River	25	2	4	7	13	51
Salem	Secondary Bay	Delaware River	5	0.4	0	3	1	9
Salem	Tributary	Delaware River	13	1	17	23	68	123
Salem	Island	Salem River	0.9	0.9	0.9	1	10	14
Salem	Secondary River	Salem River	3	0	0	0	0	3
Salem	Tributary	Salem River	23	9	9	22	47	110
Union	Secondary River	Arthur Kill River	16	0	0	0	0.3	16
Union	Secondary Bay	Newark Bay	9	0	0	0	0	9
Union	Island	Spring Creek	0.2	0	0	0	0	0.2
Union	Tributary	Spring Creek	11	0	0	0	0.8	12
Totals			**1875**	**506**	**442**	**379**	**1478**	**4680**

* Excludes Passaic and Somerset County.

Table A-5: Military lands

County	Water Body Category	Water Body Name	Shoreline Length (Kilometers)			
			Shore Protection Certain	Shore Protection Unspecified[1]	Non-Tidal Wetlands	Totals
Monmouth	Tributary	Sandy Hook Bay	2	0	0.5	2
Totals			**2**	**0**	**0.5**	**2**

Note:
1. The general approach of this study was to not speculate on the intentions of the military, but to avoid an excessive number of map colors. The protection response maps depict unclassified military lands in red, however, the protection response for the shoreline was classified as "Unspecified". Military lands in urban areas were classified as shore protection certain in those cases where county officials indicated that the land would be developed and protected even if the installation were to close.

Table A-6: Islands with roads

County	Water Body Category	Water Body Name	Shoreline Length (Kilometers)					
			Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Non-Tidal Wetlands	Totals
Atlantic	Island	Absecon Bay	2	0	0	0	0	2
Atlantic	Island	Great Bay	0	1	2	1	2	6
Atlantic	Island	Great Egg Harbor Bay	7	2	3	0.6	2	15
Atlantic	Island	Lakes Bay	3	1	0.8	0	0	5
Atlantic	Island	Scull Bay	14	0.8	5	2	0.7	23
Atlantic	Secondary River	Mullica River	0	0.6	1	0.6	3	5
Bergen	Island	Hackensack River	0.6	2	0	0	0.1	3
Burlington	Secondary River	Mullica River	0.3	<0.1	0.2	2	7	9
Cape May	Island	Delaware Bay	0	2	2	1	1	7
Cape May	Island	Great Egg Harbor Bay	5	0.2	2	0.1	2	11
Cape May	Island	Great Sound	12	3	4	0.5	0.5	20
Cape May	Island	Jarvis Sound	8	4	3	0.8	0	15
Cape May	Island	Jenkins Sound	9	1	2	0.2	<0.1	13
Cape May	Island	Ludlam Bay	4	1	2	4	0.2	11
Cape May	Island	Richardson Sound	4	0	1	0	0	5
Cape May	Island	Stites Sound	2	0.2	0	2	0	4
Cape May	Island	Townsend Sound	2	0.8	0.5	0.2	0	3
Cumberland	Island	Delaware Bay	<0.1	0	0	0	0	<0.1
Cumberland	Island	Delaware River	0.9	0	0	0.2	0	1
Hudson	Island	Hackensack River	<0.1	<0.1	0	0	<0.1	0.3
Hudson	Island	Upper New York Bay	2	0	0	0	0	2
Middlesex	Island	Raritan River	0.2	0	0.2	0	0	0.4
Monmouth	Island	Navesink River	1	0	0	0	0	1
Monmouth	Island	Raritan Bay	0.6	0	0.5	0	0	1
Ocean	Island	Barnegat Bay	0.9	3	2	0.6	4	11
Ocean	Island	Great Bay	7	0	2	10	3	22
Ocean	Island	Little Egg Harbor	0.8	2	4	5	0.7	12
Ocean	Island	Manahawkin Bay	4	1	3	0	0.1	8
Totals			**90**	**27**	**41**	**31**	**27**	**215**

Appendix B

AREA OF LAND BY SHORE PROTECTION LIKELIHOOD

(Counties in Same Order as Discussed in the Text)

Authors: James G. Titus, Russ Jones, and Richard Streeter

The following tables were created by overlaying the shore protection planning maps developed in this report, with EPA's 30-meter digital elevation data set.

The EPA data set used the New Jersey Department of Environmental Protection wetlands data to distinguish dry land, nontidal wetlands, tidal wetlands, and open water. The boundaries of that wetlands data set do not perfectly match the boundaries of the land use data used in this report. Some areas that the wetlands data treated as dry land, for example, are wetlands or open water according to the land use data sets. This table treats such lands as "not considered" because our planning study did not estimate shore protection likelihood there. Most of these lands are along the shore and are as likely as not to be wetlands or open water today, even if they were still dry land when the wetlands data were created. The "not considered" category also includes Mercer County because we calculated these statistics before the Mercer County results had been incorporated into our data set. See Appendix 2 of this report for additional details on how these tables were created.

Table B-1. Area of Land by Shore Protection Likelihood

New Jersey

Elevation above Spring High Water (m)		Area (square kilometers)							
Above	Below	Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
0.0	0.5	76.0	19.7	17.5	10.6	3.4	127.2	99.5	226.7
0.5	1.0	100.5	21.0	15.9	8.2	2.3	148.0	72.6	220.5
1.0	1.5	102.9	21.7	15.8	7.7	2.2	150.2	70.9	221.1
1.5	2.0	82.6	18.0	16.0	7.2	1.7	125.5	64.4	189.9
2.0	2.5	66.5	16.3	18.6	7.9	1.2	110.5	43.2	153.7
2.5	3.0	64.7	16.3	18.2	8.0	1.1	108.4	41.0	149.4
3.0	3.5	61.8	16.1	17.7	7.9	0.9	104.5	39.8	144.2
3.5	4.0	58.0	16.0	17.9	7.8	0.7	100.5	36.0	136.5
4.0	4.5	57.0	15.9	17.7	7.8	0.5	98.8	35.5	134.4
4.5	5.0	53.9	15.6	17.5	7.7	0.4	95.1	35.0	130.1
5.0	5.5	43.9	12.6	15.6	7.4	0.5	80.0	30.4	110.4
5.5	6.0	42.7	12.8	16.3	7.9	0.5	80.1	29.7	109.9

Middlesex

Elevation above Spring High Water (m)		Area (hectares)							
Above	Below	Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
0.0	0.5	569.7	30.7	32.0	10.6	4.5	647.4	86.1	733.6
0.5	1.0	569.7	30.7	32.0	10.6	4.5	647.4	86.1	733.6
1.0	1.5	569.7	30.7	32.0	10.6	4.5	647.4	86.1	733.6
1.5	2.0	499.9	39.7	20.2	10.2	3.2	573.2	72.7	645.9
2.0	2.5	443.7	50.8	10.5	9.3	1.8	516.2	56.9	573.1
2.5	3.0	443.7	50.8	10.5	9.3	1.8	516.2	56.9	573.1
3.0	3.5	443.7	50.8	10.5	9.3	1.8	516.2	56.9	573.1
3.5	4.0	443.7	50.8	10.5	9.3	1.8	516.2	56.9	573.1
4.0	4.5	443.7	50.8	10.5	9.3	1.8	516.2	56.9	573.1
4.5	5.0	420.8	33.9	19.4	14.2	1.5	489.7	61.7	551.4
5.0	5.5	306.3	6.8	31.7	20.1	0.4	365.3	64.7	430.0
5.5	6.0	306.3	6.8	31.7	20.1	0.4	365.3	64.7	430.0

Monmouth

Elevation above Spring High Water (m)		Area (hectares)							
Above	Below	Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
0.0	0.5	654.7	14.7	13.1	4.7	45.4	732.5	96.6	829.1
0.5	1.0	739.4	6.2	6.4	0.8	31.0	783.8	70.7	854.5
1.0	1.5	944.6	8.8	5.4	1.4	26.1	986.3	65.8	1052.1
1.5	2.0	1002.8	8.9	5.0	0.9	17.8	1035.4	69.7	1105.0
2.0	2.5	883.0	4.1	6.8	1.0	20.9	915.7	66.5	982.2
2.5	3.0	880.9	3.0	7.7	1.4	11.3	904.2	53.4	957.6
3.0	3.5	791.3	3.6	6.8	1.6	8.3	811.5	56.0	867.5
3.5	4.0	718.6	1.8	5.7	3.4	3.3	732.8	64.9	797.7
4.0	4.5	800.6	4.1	8.0	3.1	0.5	816.3	70.0	886.3
4.5	5.0	775.5	6.5	11.4	3.1	0.3	796.8	58.9	855.6
5.0	5.5	680.5	4.4	7.3	3.7	0.0	695.9	54.0	749.9
5.5	6.0	595.4	7.2	4.4	2.2	0.0	609.1	48.6	657.7

Ocean

Elevation above Spring High Water (m)		Area (hectares)							
Above	Below	Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
0.0	0.5	674	127	79	62	70	1012	791	1803
0.5	1.0	1800	244	77	48	76	2245	916	3161
1.0	1.5	2075	276	63	44	61	2519	829	3348
1.5	2.0	1304	225	67	35	26	1657	735	2392
2.0	2.5	972	203	60	25	13	1272	657	1929
2.5	3.0	1028	186	49	15	10	1288	525	1813
3.0	3.5	990	182	42	14	7	1234	474	1708
3.5	4.0	886	163	41	11	5	1106	429	1535
4.0	4.5	786	166	43	6	4	1004	404	1408
4.5	5.0	691	163	42	5	3	903	384	1287
5.0	5.5	645	158	61	4	4	872	374	1246
5.5	6.0	623	209	114	14	4	964	299	1263

Burlington (Coastal)

Elevation above Spring High Water (m)		Area (hectares)							
Above	Below	Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
0.0	0.5	25.7	44.0	25.2	56.9	0.0	151.7	712.6	864.3
0.5	1.0	25.9	44.0	24.7	55.5	0.0	150.2	700.9	851.1
1.0	1.5	25.6	44.1	22.0	54.6	0.0	146.3	688.2	834.5
1.5	2.0	25.6	44.0	22.6	53.8	0.0	146.0	684.0	830.0
2.0	2.5	27.3	56.1	19.5	152.5	0.0	255.4	425.4	680.8
2.5	3.0	27.7	57.9	18.1	180.7	0.0	284.3	393.8	678.1
3.0	3.5	27.7	57.9	18.1	180.6	0.0	284.2	393.8	678.0
3.5	4.0	27.7	57.9	18.1	180.6	0.0	284.2	393.8	678.0
4.0	4.5	27.7	57.9	18.1	180.6	0.0	284.2	393.8	678.0
4.5	5.0	27.7	57.9	18.1	180.6	0.0	284.2	393.8	678.0
5.0	5.5	8.6	22.3	15.7	237.0	0.0	283.6	362.2	645.8
5.5	6.0	2.3	10.6	15.2	275.9	0.0	303.9	356.3	660.2

Atlantic

Elevation above Spring High Water (m)		Area (hectares)							
Above	Below	Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
0.0	0.5	349	106	135	166	53	810	1426	2236
0.5	1.0	939	144	159	99	29	1370	908	2278
1.0	1.5	1040	142	150	62	29	1423	906	2329
1.5	2.0	739	125	143	52	33	1093	913	2006
2.0	2.5	454	172	204	73	31	934	870	1803
2.5	3.0	317	168	209	79	33	807	858	1665
3.0	3.5	298	169	211	75	31	784	852	1636
3.5	4.0	305	174	230	84	20	813	841	1654
4.0	4.5	285	167	228	85	13	778	833	1611
4.5	5.0	284	169	229	82	12	776	832	1608
5.0	5.5	334	237	321	76	14	982	829	1811
5.5	6.0	347	238	344	75	13	1018	850	1867

Cape May

Elevation above Spring High Water (m)		Area (hectares)							
Above	Below	Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
0.0	0.5	921	203	329	80	83	1617	2054	3670
0.5	1.0	1619	211	330	101	42	2302	1545	3847
1.0	1.5	1269	247	338	98	50	2002	1487	3489
1.5	2.0	861	234	385	104	48	1632	1371	3003
2.0	2.5	1003	465	609	193	30	2299	1006	3305
2.5	3.0	912	485	573	188	22	2180	982	3163
3.0	3.5	819	482	546	194	17	2057	949	3006
3.5	4.0	777	501	570	213	10	2070	718	2788
4.0	4.5	714	485	539	213	5	1956	696	2652
4.5	5.0	652	455	496	206	2	1811	663	2474
5.0	5.5	452	350	297	137	0	1236	417	1653
5.5	6.0	433	326	288	141	1	1189	409	1598

Cumberland

Elevation above Spring High Water (m)		Area (hectares)							
Above	Below	Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
0.0	0.5	229	267	482	200	6	1184	1808	2992
0.5	1.0	229	240	393	141	1	1004	1413	2417
1.0	1.5	229	240	393	141	1	1004	1413	2417
1.5	2.0	236	241	396	132	1	1005	1203	2209
2.0	2.5	284	260	433	136	0	1114	718	1831
2.5	3.0	284	260	433	136	0	1114	718	1831
3.0	3.5	264	245	418	136	0	1063	684	1747
3.5	4.0	238	219	394	141	0	992	627	1619
4.0	4.5	238	219	394	141	0	992	627	1619
4.5	5.0	234	205	377	140	0	957	613	1570
5.0	5.5	169	117	275	143	0	705	391	1096
5.5	6.0	169	117	275	144	0	705	392	1097

Salem

Elevation above Spring High Water (m)		Area (hectares)							
Above	Below	Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
0.0	0.5	776	154	588	457	27	2001	2184	4185
0.5	1.0	730	156	502	341	3	1733	848	2582
1.0	1.5	730	156	502	341	3	1733	848	2582
1.5	2.0	714	146	496	314	2	1672	751	2423
2.0	2.5	652	95	477	193	1	1419	309	1728
2.5	3.0	652	95	477	193	1	1419	309	1728
3.0	3.5	620	94	474	182	1	1370	304	1674
3.5	4.0	476	110	482	139	1	1207	266	1473
4.0	4.5	476	110	482	139	1	1207	266	1473
4.5	5.0	454	107	479	135	1	1176	271	1448
5.0	5.5	268	116	495	88	1	967	359	1326
5.5	6.0	268	116	495	88	1	967	359	1326

Gloucester

Elevation above Spring High Water (m)		Area (hectares)							
Above	Below	Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
0.0	0.5	381.7	231.2	62.9	0.0	1.3	677.1	649.6	1326.7
0.5	1.0	380.4	228.9	62.7	0.0	1.3	673.3	630.2	1303.5
1.0	1.5	380.4	228.9	62.7	0.0	1.3	673.3	630.2	1303.5
1.5	2.0	372.3	227.8	56.6	0.0	1.0	657.7	531.3	1188.9
2.0	2.5	331.0	230.8	35.6	0.0	0.0	597.5	134.8	732.2
2.5	3.0	331.0	231.4	35.9	0.0	0.0	598.4	134.3	732.7
3.0	3.5	331.0	231.4	35.9	0.0	0.0	598.4	134.3	732.7
3.5	4.0	331.0	231.2	35.9	0.0	0.0	598.1	134.3	732.4
4.0	4.5	331.0	231.2	35.9	0.0	0.0	598.1	134.4	732.4
4.5	5.0	324.6	221.8	34.0	0.0	0.0	580.4	128.0	708.5
5.0	5.5	278.1	152.0	19.9	0.0	0.1	450.0	75.3	525.2
5.5	6.0	278.7	153.3	20.3	0.0	0.1	452.3	74.6	527.0

Camden

Elevation above Spring High Water (m)		Area (hectares)							
Above	Below	Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
0.0	0.5	275.2	0.0	0.0	0.0	0.0	275.2	24.9	300.1
0.5	1.0	275.2	0.0	0.0	0.0	0.0	275.2	24.9	300.1
1.0	1.5	275.2	0.0	0.0	0.0	0.0	275.2	24.9	300.1
1.5	2.0	276.9	0.0	0.0	0.0	0.1	277.0	24.7	301.7
2.0	2.5	288.1	0.0	0.0	0.0	0.2	288.4	23.3	311.7
2.5	3.0	288.1	0.0	0.0	0.0	0.2	288.4	23.3	311.7
3.0	3.5	288.1	0.0	0.0	0.0	0.2	288.4	23.3	311.7
3.5	4.0	288.1	0.0	0.0	0.0	0.2	288.4	23.3	311.7
4.0	4.5	288.1	0.0	0.0	0.0	0.2	288.4	23.3	311.7
4.5	5.0	286.1	0.1	0.0	0.0	0.2	286.3	21.1	307.5
5.0	5.5	301.0	0.2	0.0	0.0	0.4	301.5	17.0	318.6
5.5	6.0	301.0	0.2	0.0	0.0	0.4	301.5	17.0	318.6

Burlington (Delaware River)

Elevation above Spring High Water (m)		Area (hectares)							
Above	Below	Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
0.0	0.5	281.8	24.7	6.4	0.0	0.4	313.3	44.6	357.9
0.5	1.0	281.8	24.7	6.4	0.0	0.4	313.3	44.6	357.9
1.0	1.5	281.8	24.7	6.4	0.0	0.4	313.3	44.6	357.9
1.5	2.0	276.5	24.7	6.4	0.0	0.4	308.0	42.4	350.4
2.0	2.5	275.1	24.7	6.4	0.0	0.4	306.6	41.8	348.4
2.5	3.0	275.1	24.7	6.4	0.0	0.4	306.6	41.8	348.4
3.0	3.5	275.1	24.7	6.4	0.0	0.4	306.6	41.8	348.4
3.5	4.0	275.1	24.7	6.4	0.0	0.4	306.6	41.8	348.4
4.0	4.5	275.0	26.9	7.5	0.0	0.4	309.9	43.0	352.8
4.5	5.0	318.8	87.4	40.4	0.0	0.1	446.7	63.1	509.7
5.0	5.5	332.0	88.0	40.3	0.0	0.0	460.3	59.4	519.7
5.5	6.0	332.0	88.0	40.3	0.0	0.0	460.3	59.4	519.7

Union

Elevation above Spring High Water (m)		Area (hectares)							
Above	Below	Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
0.0	0.5	503.0	0.0	0.0	0.0	3.1	506.0	11.8	517.9
0.5	1.0	503.0	0.0	0.0	0.0	3.1	506.0	11.8	517.9
1.0	1.5	503.0	0.0	0.0	0.0	3.1	506.0	11.8	517.9
1.5	2.0	420.7	0.0	0.0	0.0	2.0	422.7	9.2	431.9
2.0	2.5	290.6	0.0	0.0	0.0	0.4	291.0	4.9	295.8
2.5	3.0	290.6	0.0	0.0	0.0	0.4	291.0	4.9	295.8
3.0	3.5	290.6	0.0	0.0	0.0	0.4	291.0	4.9	295.8
3.5	4.0	290.6	0.0	0.0	0.0	0.4	291.0	4.9	295.8
4.0	4.5	290.6	0.0	0.0	0.0	0.4	291.0	4.9	295.8
4.5	5.0	277.2	0.0	0.0	0.0	0.3	277.5	4.4	281.9
5.0	5.5	242.0	0.0	0.0	0.0	0.2	242.2	3.0	245.1
5.5	6.0	242.0	0.0	0.0	0.0	0.2	242.2	3.0	245.1

Essex

Elevation above Spring High Water (m)		Area (hectares)							
Above	Below	Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
0.0	0.5	438.0	0.0	0.0	0.0	2.4	440.4	2.1	442.5
0.5	1.0	438.0	0.0	0.0	0.0	2.4	440.4	2.1	442.5
1.0	1.5	438.0	0.0	0.0	0.0	2.4	440.4	2.1	442.5
1.5	2.0	356.8	0.0	0.0	0.0	1.8	358.5	1.3	359.8
2.0	2.5	250.8	0.0	0.0	0.0	0.9	251.7	0.2	251.9
2.5	3.0	250.8	0.0	0.0	0.0	0.9	251.7	0.2	251.9
3.0	3.5	250.8	0.0	0.0	0.0	0.9	251.7	0.2	251.9
3.5	4.0	250.8	0.0	0.0	0.0	0.9	251.7	0.2	251.9
4.0	4.5	250.8	0.0	0.0	0.0	0.9	251.7	0.2	251.9
4.5	5.0	187.0	0.0	0.1	0.0	0.6	187.6	0.1	187.7
5.0	5.5	62.5	0.0	0.2	0.0	0.1	62.7	0.0	62.7
5.5	6.0	62.5	0.0	0.2	0.0	0.1	62.7	0.0	62.7

Hudson

Elevation above Spring High Water (m)		Area (hectares)							
Above	Below	Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
0.0	0.5	797.1	382.7	0.0	1.9	11.4	1193.2	11.1	1204.3
0.5	1.0	797.1	382.7	0.0	1.9	11.4	1193.2	11.1	1204.3
1.0	1.5	797.1	382.7	0.0	1.9	11.4	1193.2	11.1	1204.3
1.5	2.0	662.8	266.1	0.0	1.2	8.4	938.5	8.0	946.5
2.0	2.5	299.6	52.7	0.0	0.0	0.7	352.9	1.4	354.3
2.5	3.0	299.3	52.7	0.0	0.0	0.6	352.7	1.4	354.1
3.0	3.5	299.3	52.7	0.0	0.0	0.6	352.7	1.4	354.1
3.5	4.0	299.3	52.7	0.0	0.0	0.6	352.7	1.4	354.1
4.0	4.5	299.3	52.7	0.0	0.0	0.6	352.7	1.4	354.1
4.5	5.0	262.7	38.3	0.0	0.0	0.4	301.3	1.0	302.3
5.0	5.5	107.9	2.6	0.0	0.0	0.1	110.6	0.0	110.6
5.5	6.0	108.0	2.6	0.0	0.0	0.1	110.6	0.0	110.6

Bergen

Elevation above Spring High Water (m)		Area (hectares)							
Above	Below	Shore Protection Certain	Shore Protection Likely	Shore Protection Unlikely	No Shore Protection	Not Considered	Dry Land	Non Tidal Wetlands	All Land
0.0	0.5	726.8	384.2	0.0	18.4	13.3	1142.7	42.6	1185.3
0.5	1.0	726.8	384.2	0.0	18.4	13.3	1142.7	42.6	1185.3
1.0	1.5	726.8	384.2	0.0	18.4	13.3	1142.7	42.6	1185.3
1.5	2.0	511.2	214.5	0.0	15.9	10.2	751.8	23.6	775.4
2.0	2.5	196.4	18.0	0.0	1.6	1.3	217.3	1.1	218.4
2.5	3.0	193.8	18.0	0.0	1.5	1.2	214.4	1.0	215.4
3.0	3.5	193.8	18.0	0.0	1.5	1.2	214.4	1.0	215.4
3.5	4.0	193.8	18.0	0.0	1.5	1.2	214.4	1.0	215.4
4.0	4.5	193.8	18.0	0.0	1.5	1.2	214.4	1.0	215.4
4.5	5.0	193.4	12.6	0.0	5.6	0.7	212.4	4.8	217.1
5.0	5.5	205.2	3.1	0.0	29.2	0.1	237.6	35.2	272.7
5.5	6.0	205.0	3.1	0.0	29.5	0.1	237.6	35.3	273.0

Table B-2. Area of Land Vulnerable to a One Meter Rise in Sea Level (square kilometers)
By Watershed and County by Likelihood of Shore Protection

County	Likelihood of Shore Protection						Tidal Wetlands
	Certain	Likely	Unlikely	No Protection	Nontidal Wetlands	Total Nontidal Land[1]	
North Jersey							
Bergen	14.5	7.7	0.0	0.4	0.9	23.7	15.0
Essex	8.8	0.0	0.0	0.0	0.0	8.8	0.3
Hudson	15.9	7.7	0.0	0.0	0.2	24.1	12.0
Union	10.1	0.0	0.0	0.0	0.2	10.4	2.3
Middlesex	11.4	0.6	0.6	0.2	1.7	14.7	21.7
Monmouth[2]	7.1	0.2	0.1	0.0	0.5	8.3	7.7
Total	67.8	16.1	0.8	0.6	3.5	90.0	59.0
Atlantic Coast							
Monmouth[3]	6.8	0.0	0.1	0.1	1.2	8.5	4.4
Ocean	24.7	3.7	1.6	1.1	17.1	49.6	124.8
Burlington	0.5	0.9	0.5	1.1	14.1	17.2	37.3
Atlantic	12.9	2.5	2.9	2.7	23.3	45.1	204.0
Cape May[4]	23.1	3.0	2.5	0.5	4.9	35.0	153.2
Total	68.1	10.1	7.6	5.5	60.7	155.4	523.6
Delaware Estuary							
Cape May[5]	2.4	1.2	4.1	1.3	31.1	40.2	48.3
Cumberland	4.6	5.1	8.7	3.4	32.2	54.1	212.6
Salem	15.1	3.1	10.9	8.0	30.3	67.7	110.1
Gloucester	7.6	4.6	1.3	0.0	12.8	26.3	18.0
Camden	5.5	0.0	0.0	0.0	0.5	6.0	1.5
Burlington	5.6	0.5	0.1	0.0	0.9	7.2	5.4
Total	40.8	14.4	25.1	12.6	107.8	201.5	396.0
New Jersey	176.6	40.7	33.4	18.8	172.0	446.9	978.6

1. Total includes the five categories listed plus the "not considered" category.
2. Sandy Hook East, Sandy Hook West, and Keyport quadrangles.
3. Asbury Park, Farmingdale, Lakewood, Long Branch East, Long Branch West, and Point Pleasant quadrangles.
4. Atlantic City, Avalon, Marmora, Ocean City, Sea Isle City, Tuckahoe, and Wildwood quadrangles as well as portions of the Cape May, Rio Grande, Stone Harbor and Woodbine quadrangles east of US-9.
5. Heislerville and Port Elizabeth quadrangles as well as portions of the Cape May, Rio Grande, Stone Harbor, and Woodbine quadrangles west of US-9.

Table B-3. Area of Lands Close to Sea Level By County
Jurisdictions not included in study (hectares)

		Meters above Spring High Water									
County		**0.5**	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**	**4.5**	**5.0**
		----------Dry Land, by half meter elevation increment----------									
Mercer[1]		4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	3.5	0.3
Passaic		11.7	11.7	11.7	14.4	17.7	17.7	17.7	17.7	17.7	18.1
Somerset		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9
Wetlands	Tidal	---------Nontidal Wetlands, by half meter elevation increment---------									
Mercer[1]	178	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.0
Passaic	0	1.2	1.2	1.2	0.7	0.1	0.1	0.1	0.1	0.1	0.3
Somerset	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6

1. The “not considered” category includes Mercer County because we calculated these statistics before the Mercer County results had been incorporated into our data set.

Appendix C
ELEVATION UNCERTAINTY

Authors: James G. Titus, Russ Jones, and Richard Streeter

C-1. Low and High Estimates of the Area of Lands Close to Sea Level, by County: New Jersey (square kilometers)

		Meters above Spring High Water[1]																	
		low	high	Low	high	low	high	low	high	low	high	low	high	low	high	low	high	low	high
		0.5		**1.0**		**1.5**		**2.0**		**2.5**		**3.0**		**3.5**		**4.0**		**4.5**		**5.0**	
County		----------Cumulative (total) amount of dry land below a given elevation----------																	
Atlantic		4	13	14	29	29	42	41	54	50	63	57	71	65	79	73	88	81	96	88	106
Bergen		0.9	16	10	31	20	42	29	44	39	47	43	49	45	51	47	54	49	56*	51	58*
Burlington		0.1	6.3	1.7	12	5.1	18	9.3	25	13	33	18	40	24	47	29	55	35	63*	41	69*
Camden		<0.01	3.8	0.1	7.3	1.7	11	4.3	15	6.9	19	9.5	22	12	26	15	29	18	32*	20	35*
Cape May		8	25	26	50	48	69	65	93	80	117	99	139	120	161	141	182	161	199	180	212
Cumberland		3	16	12	29	21	41	30	53	39	65	50	77	61	88	71	98	81	107	91	114
Essex		0.4	6.1	3.9	12	7.6	17	11	20	15	23	18	25	20	28	23	31	25	32*	28	32*
Gloucester		0.2	9.2	6.1	18	12	27	18	33	23	40	30	47	36	53	42	60	48	65	54	69
Hudson		0.6	16	10	32	21	45	31	49	41	53	46	57	50	61	53	65	57	66*	60	67*
Mercer		0	0.1	0	0.1	0.03	0.19	0.1	0.2	0.1	0.3	0.2	0.4	0.2	0.4	0.2	0.4	0.3	0.4*	0.3	0.4*
Middlesex		0.4	8.8	4.3	17	9.2	25	15	31	20	37	25	44	30	50	36	55	41	59*	46	62*
Monmouth		4.1	10	11	20	21	30	31	39	40	47	49	57	58	65	66	73	74	80	82	87
Ocean		4.6	19	22	44	47	66	67	81	81	94	93	107	105	119	117	129	127	139	137	149
Passaic		0	0.2	0.1	0.3	0.2	0.5	0.3	0.7	0.4	0.9	0.6	1.1	0.7	1.3	0.9	1.5	1.1	1.7*	1.3	1.9*
Salem		5.9	27	21	49	38	70	54	84	69	99	84	114	98	127	111	139	123	151	135	160
Somerset		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0.1*	0	0.2*
Union		0.4	6.9	4.2	14	8.4	19	13	23	17	26	20	29	23	33	26	36	29	39*	32	41*
Statewide		**32**	**184**	**148**	**365**	**289**	**522**	**418**	**645**	**536**	**764**	**642**	**878**	**748**	**989**	**850**	**1096**	**949**	**1185***	**1046**	**1265***

*This value is probably too low because of a data limitation. See Annex 3 of this report

1. Low and high are an uncertainty range based on the contour interval and/or stated root mean square error (RMSE) of the input elevation data. Calculations assume that half of the RMSE is random error and half is systematic error. For a discussion of these calculations, see Annex 3 of this report.

		low	high	low	high	low	high	low	high	low	high	low	high	low	high	low	high	low	high
		0.5		**1.0**		**1.5**		**2.0**		**2.5**		**3.0**		**3.5**		**4.0**		**4.5**		**5.0**	
Wetlands	Tidal	---------Cumulative (total) amount of Nontidal Wetlands below a given elevation---------																			
Atlantic	204	4.8	18	15	29	23	41	32	50	40	59	48	68	57	77	65	86	74	94	82	103
Bergen	15	0.04	0.6	0.4	1.2	0.8	1.5	1.1	1.5	1.48	1.54	1.52	1.55	1.5	1.6	1.5	1.6	1.5	1.8*	1.6	2.1*
Burlington	43	0.2	10	6.2	20	13	30	19	35	26	40	32	45	36	50	40	54	45	59*	49	63*
Camden	2	<0.01	0.3	0.1	0.7	0.3	1	0.5	1.3	0.7	1.6	0.9	1.9	1.2	2.2	1.4	2.4	1.6	2.5*	1.8	2.7*
Cape May	201	7.2	27	22	45	37	63	50	73	63	84	74	94	83	102	92	109	99	115	106	119
Cumberland	213	4.7	24	18	42	31	58	44	65	55	73	63	81	71	87	77	94	84	99	90	103
Essex	0	<0.01	0.03	0.02	0.05	0.04	0.07	0.05	0.07	0.07	0.07	0.07	0.08	0.07	0.08	0.07	0.08	<0.08	0.08*	<0.08	0.08*
Gloucester	18	0.2	8.8	5.9	17	11	24	17	26	22	27	25	29	26	30	28	32	29	33	30	34
Hudson	12	0.01	0.2	0.1	0.3	0.19	0.42	0.3	0.4	0.38	0.45	0.4	0.5	0.4	0.5	0.4	0.5	0.46	0.49*	0.47	0.49*
Mercer	2	0	<0.01	0	0.01	<0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.03	0.01	0.03	0.02	0.03	0.02	0.03*	0.02	0.03*
Middlesex	22	0.1	1.2	0.7	2.3	1.4	3.3	2.1	3.9	2.9	4.6	3.5	5.3	4	5.9	4.6	6.5	5.1	7.2*	5.7	7.8*
Monmouth	12	0.6	1.3	1.4	2	2.1	2.6	2.7	3.3	3.4	3.9	4	4.5	4.5	5	5.1	5.7	5.8	6.3	6.4	6.9
Ocean	125	2.3	12	10	22	19	31	26	38	33	44	39	49	44	54	48	58	53	63	56	66
Passaic	0	<0.01	0.02	0.01	0.03	0.02	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05*	0.04	0.05*
Salem	110	9.6	25	22	36	30	46	38	49	45	52	49	55	52	58	55	61	58	64	60	68
Somerset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0.03*	0	0.04*
Union	2	0.01	0.2	0.1	0.3	0.2	0.4	0.3	0.5	0.4	0.6	0.4	0.6	0.5	0.7	0.5	0.7	0.6	0.8*	0.6	0.8*
Statewide	**980**	**30**	**128**	**102**	**219**	**169**	**301**	**233**	**348**	**293**	**393**	**341**	**436**	**381**	**474**	**420**	**513**	**455**	**546***	**491**	**576***
		Cumulative (total) amount of land below a given elevation																			
Dry Land		32	184	148	365	289	522	418	645	536	764	642	878	748	989	850	1096	949	1185*	1046	1265*
Nontidal Wetlands		30	128	102	219	169	301	233	348	293	393	341	436	381	474	420	513	455	546*	491	576*
All Land	980	1043	1292	1231	1564	1438	1803	1632	1974	1810	2137	1964	2294	2109	2443	2250	2589	2385	2712*	2517	2822*

*This value is probably too low because of a data limitation. See Annex 3 of this report

C-2. Likelihood of Shore Protection in New Jersey, High and Low Estimates of the Land within One Meter above Spring High Water[1]
(square kilometers)

County	Likelihood of Shore Protection								Nontidal Wetlands		Total[2]	
	Certain		Likely		Unlikely		No Protection					
	low	high	low	high	low	high	low	high	low	high	low	high
North Jersey	**30**	**92**	**7.3**	**22**	**0.4**	**1**	**0.3**	**0.8**	**1.7**	**4.7**	**41**	**122**
Bergen	6.5	20	3.5	10	0	0	0.2	0.5	0.4	1.2	11	32
Essex	3.9	12	0	0	0	0	0	0	0.02	0.05	3.9	12
Hudson	7	22	3.3	10	0	0	0.02	0.05	0.1	0.3	10	33
Union	4.1	14	0	0	0	0	0	0	0.1	0.3	4.2	14
Middlesex	3.6	15	0.3	0.8	0.3	0.9	0.1	0.3	0.7	2.3	5	20
Monmouth[3]	5.3	9.6	0.16	0.22	0.1	0.13	0	0	0.4	0.6	6.3	11
Atlantic Coast	**46**	**91**	**7**	**14**	**6.2**	**12**	**4.1**	**7.2**	**42**	**92**	**109**	**220**
Monmouth[4]	5.1	8.9	<0.02	0.02	0.07	0.09	0	0	1	1.4	6.5	11
Ocean	16	34	2.6	4.9	1.2	1.8	0.8	1.3	10	22	32	66
Burlington	0.2	0.7	0.4	1.2	0.2	0.7	0.5	1.5	6.2	19	7.5	23
Atlantic	8	18	1.5	3.3	1.7	3.8	2.1	3	15	29	29	58
Cape May[5]	17	30	2.5	4.6	2.9	5.1	0.7	1.3	10	20	34	62
Delaware Estuary	**16**	**53**	**6.7**	**19**	**13**	**31**	**7.1**	**16**	**59**	**122**	**101**	**241**
Cape May[6]	0.7	2.1	0.3	0.8	1.1	3.4	0.4	1.1	12	25	15	33
Cumberland	2.3	6.2	2.7	6.7	4.8	12	2.1	4.4	18	42	30	71
Salem	8.8	20	1.6	4.1	6	14	4.6	10	22	36	44	85
Gloucester	3.4	10	2.1	6.3	0.6	1.7	0	0	5.9	17	12	36
Camden	0.1	7.3	0	0	0	0	0	0	0.1	0.7	0.2	8
Burlington	0.4	7.5	0	0.7	0	0.2	0	0	0.03	1.2	0.4	9.5
New Jersey[7]	**92**	**236**	**21**	**54**	**19**	**44**	**11**	**24**	**102**	**219**	**250**	**583**

6. Low and high are an uncertainty range based on the contour interval and/or stated root mean square error (RMSE) of the input elevation data. Calculations assume that half of the RMSE is random error and half is systematic error. For a discussion of these calculations, see Annex 3 of this report.

7. Total includes the five categories listed as well as a small amount of low land that the authors did not analyze.

8. Sandy Hook East, Sandy Hook West, and Keyport quadrangles.

9. Asbury Park, Farmingdale, Lakewood, Long Branch East, Long Branch West, and Point Pleasant quadrangles.

10. Atlantic City, Avalon, Cape May, Marmora, Ocean City, Sea Isle City, Stone Harbor, Tuckahoe, and Wildwood quadrangles.

11. Heislerville, Port Elizabeth, Rio Grande, and Woodbine quadrangles.

12. Excludes Mercer and Passaic Counties.

C-3. Likelihood of Shore Protection in New Jersey, High and Low Estimates of the Land within Two Meters above Spring High Water[1]

(square kilometers)

County	Likelihood of Shore Protection								Nontidal Wetlands		Total[2]	
	Certain		Likely		Unlikely		No Protection					
	low	high	low	high	low	high	low	high	low	high	low	high
North Jersey	**90**	**150**	**21**	**31**	**1**	**1.4**	**0.8**	**1.3**	**4.6**	**7.4**	**119**	**193**
Bergen	19	29	10	14	0	0	0.5	0.7	1.1	1.5	31	46
Essex	11	20	0	0	0	0	0	0	0.1	0.1	11	20
Hudson	20	34	9.8	15	0	0	0.05	0.07	0.3	0.4	31	49
Union	13	23	0	0	0	0	0	0	0.3	0.5	13	23
Middlesex	13	27	0.8	1.9	0.8	1.3	0.3	0.5	2.1	3.9	17	35
Monmouth[3]	15	18	0.31	0.35	0.2	0.2	0	0	0.8	0.9	17	20
Atlantic Coast	**135**	**165**	**20**	**29**	**15**	**23**	**8.2**	**13**	**101**	**157**	**284**	**393**
Monmouth[4]	15	19	0.04	0.05	0.12	0.15	0.07	0.08	1.9	2.3	17	22
Ocean	53	63	7.8	9.7	2.5	3.3	1.7	2	26	38	93	119
Burlington	0.7	1.3	1.2	2.4	0.6	1.2	1.5	4	19	33	23	42
Atlantic	27	33	4.2	6.6	4.7	7.8	3.4	4.5	32	50	73	104
Cape May[5]	40	48	6.3	9.8	6.7	10	1.6	2.8	22	33	78	107
Delaware Estuary	**51**	**101**	**19**	**35**	**33**	**58**	**17**	**27**	**128**	**184**	**248**	**406**
Cape May[6]	2.3	5.6	1	2.9	3.9	8.5	1.4	2.8	28	40	37	60
Cumberland	6.5	12	7.1	13	12	21	4.8	7.4	44	65	74	119
Salem	23	35	4.6	7	15	25	11	16	38	49	92	133
Gloucester	10	19	6	12	1.6	2.8	0	0	17	26	34	59
Camden	4.3	15	0	0	0	0	0	0	0.5	1.3	4.8	16
Burlington	4.8	15	0.4	1.3	0.1	0.3	0	0	0.7	2.3	6.1	19
New Jersey[7]	**277**	**416**	**59**	**95**	**48**	**82**	**26**	**41**	**233**	**348**	**651**	**992**

1. Low and high are an uncertainty range based on the contour interval and/or stated root mean square error (RMSE) of the input elevation data.

Calculations assume that half of the RMSE is random error and half is systematic error. For a discussion of these calculations, see Annex 3 of this report.

2. Total includes the five categories listed as well as a small amount of low land that the authors did not analyze.

3. Sandy Hook East, Sandy Hook West, and Keyport quadrangles.

4. Asbury Park, Farmingdale, Lakewood, Long Branch East, Long Branch West, and Point Pleasant quadrangles.

5. Atlantic City, Avalon, Cape May, Marmora, Ocean City, Sea Isle City, Stone Harbor, Tuckahoe, and Wildwood quadrangles.

6. Heislerville, Port Elizabeth, Rio Grande, and Woodbine quadrangles.

7. Excludes Mercer and Passaic Counties.

C-4. Area of Land by Elevation by Shore Protection Likelihood, High and Low Estimates: New Jersey[1]

Elevation relative to Spring High Water (m)	Area (square kilometers)															
	Dry land: likelihood of shore protection															
	Shore Protection Certain		Shore Protection Likely		Shore Protection Unlikely		No Shore Protection		Not Considered[2]		Dry Land		Non Tidal Wetlands		All Land	
	low	high	low	high	low	high	low	high	low	high	low	high	low	high	low	high
0.5	18	114	3.8	28	5.2	24	3.8	14	1.6	4.3	32	184	30	128	62	311
1.0	92	236	21	54	19	44	11	24	4	6.9	148	365	102	219	250	584
1.5	189	340	41	77	34	62	19	33	6.3	9.1	289	522	169	301	458	823
2.0	277	417	59	95	48	82	26	41	8.1	10	418	645	233	348	652	993
2.5	352	488	78	112	63	102	32	50	9.7	12	536	764	293	393	829	1157
3.0	417	557	94	130	81	121	39	59	11	13	642	878	341	436	983	1314
3.5	479	621	110	147	99	139	47	67	12	14	747	988	381	474	1128	1462
4.0	540	683	126	164	116	159	55	75	13	14	850	1096	420	513	1270	1609
4.5	597	733*	142	179*	134	176*	63	83*	13	15*	949	1185*	455	546*	1405	1732*
5.0	652	775*	157	191*	152	193*	71	91*	14	15*	1046	1265*	491	576*	1536	1841*

*This value is probably too low because of a data limitation. See Annex 3 of this report

1. Low and high are an uncertainty range based on the contour interval and/or stated root mean square error (RMSE) of the input elevation data. Calculations assume that half of the RMSE is random error and half is systematic error. For a discussion of these calculations, see Annex 3 of this report.

2. The “not considered” category also includes Mercer County because we calculated these statistics before the Mercer County results had been incorporated into our data s

APPENDIX D: SUMMARY OF DATA SOURCES

This appendix describes data used to create the GIS-based maps accompanying this report. Data descriptions are organized by data source. Within each section we provide a brief summary of each layer obtained from that source. Summary information includes a description of how the data were developed, identifies the key elements of the data used in our analysis, and provides the date of publication.

NEW JERSEY OFFICE OF STATE PLANNING

1997 and 2002 State Plan

Data identify state planning areas, recreational parks, military lands, and The Meadowlands in New Jersey. State planning areas, drawn by the New Jersey State Planning Commission, are large parcels of land that share a common set of conditions, such as population density, infrastructure systems, level of development, or natural systems.

Key data elements: Polygons represent a state planning area, recreational park, or military land. Table D-1 provides a brief description of each planning area:

TABLE D-1. STATE PLANNING AREAS

Planning Area	Description
Planning area 1	Metropolitan areas
Planning area 2	Suburban areas
Planning area 3	Fringe areas
Planning area 4	Rural or environmentally sensitive areas
Planning area 5	Environmentally sensitive areas, including environmentally sensitive barrier islands

Source: http://www.nj.gov/dca/osg/plan/stateplan.shtml.

Scale: 1:24,000

Dates of publication: 1997 and 2002. The original planning study used the 1997 edition (NAD 83 at 1:24,000 in NJ State Plane feet).

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION (NJDEP)

State Open Spaces

Created under the Green Acres Program to assist open space planning, the data consist of state-owned and -protected open space and recreational areas in New Jersey. To create these data, NJDEP used an assortment of in-house and outside generated data sets. Coverage is acknowledged as currently incomplete.

Key data elements: Polygons depict open spaces and recreational areas. Attributes include the name, owner, and current use of the parcel.

Scale: 1:12,000

Date of publication: 1999

Federal Open Spaces

Data were created under the Green Acres Program to assist open space planning. Polygons identify open spaces and recreational parks held and protected by the federal government. To create these data, NJDEP used an assortment of in-house and outside generated data sets. Coverage is acknowledged as incomplete.

Key data elements: Polygons depict open spaces and recreational areas. Attributes include the name, owner, and current use of the parcel.

Scale: 1:24,000

Date of publication: 1999

Nonprofit Conservation Lands

Data consist of conservation easements and parcels owned by non-profit organizations such as The Nature Conservancy. A variety of in-house and outside generated data sets were used to create these data. Coverage is acknowledged as incomplete.

Key data elements: Polygons identify conservation lands owned by nonprofit organizations. Attributes include the name, owner, and current use of the parcel.

Scale: Unable to identify documentation. A visual inspection showed that the density of vertices are similar to a 1:100,000 (or better scale) data layer. However, no information was available to document whether the maps are accurate to such a scale under National Mapping Standards.

Date of publication: 1999

PINELANDS COMMISSION

Data identify New Jersey Pinelands Management Areas, as outlined in the New Jersey Pinelands Comprehensive Management Plan, which was created in accordance with the “Pinelands Protection Act.” Management areas are subject to different regulations with regard to development density and permitted uses.

Key data elements: Polygons delineate eight types of management areas within the National Pinelands Reserve. Table D-2 summarizes the characteristics of select management areas.

Scale: 1:24,000

Date of publication: 2003

TABLE D-2: PINELANDS MANAGEMENT AREAS

Management Area	Description
Preservation area district	Consists of largely undeveloped, ecologically important natural communities. Conventional residential, commercial, and industrial development largely prohibited. Only land uses compatible with the ecology of area are allowed (i.e., cultivation of berries and native plants).
Forest areas	Contains important natural resources. The same land uses that are permitted in preservation area districts are also permitted in the forest areas. A limited number of new uses are also permitted, such as commercial establishments.
Pinelands villages	44 small to medium rural settlements. Allows traditional development under certain rules.
Pinelands towns	Seven large rural settlements. Allows traditional development under certain rules.
Rural development areas	Transition zones where modest development is allowed to proceed. Designed to function as safety valves for development pressures that regional growth areas cannot handle.
Regional growth areas	Experiencing significant new development. Development allowed and encouraged.

1986 Land Use/Land Cover

Data consist of polygons identifying land use and land cover in New Jersey counties as of 1986. Land use/land cover polygons were created by combining two separate data sets, the land use/land cover layer from the county Integrated Terrain Unit (ITU) maps and the freshwater wetlands layer (made under the New Jersey Freshwater Wetlands Mapping Program). The NJDEP contracted to have aerial photographs interpreted and digital ITU maps prepared. These maps use a simple land use classification scheme. Areas of land with similar characteristics are mapped together as a single polygon. All of the land in the state is assigned to one class or another. Some of the data used here are dated; most of them were prepared from 1986 aerial photography.

Data are referenced to NAD83 and the coordinate system is N.J. State Plane Feet. Per the NJDEP's requirements the following statement is provided:

This report was developed using digital data developed under the auspices of the Department of Environmental Protection, Geographic Information System, but this secondary product has not been verified by NJDEP and is not state-authorized.

Key data elements: Each polygon is assigned a land use code according to the Anderson classification system. Table D-3 lists the land use codes used in this study and their descriptions.

TABLE D-3: LAND USE CODES AND DESCRIPTIONS

Land Use Code	Description
1000	Urban land
1100	Residential
1200	Commercial and services
1211	Military reservations
1300	Industrial
1400	Transportation/communication/ utilities
1500	Industrial and commercial complexes
1600	Mixed urban or built-up land
1700	Other urban or built-up land
1800	Recreational land
1804	Athletic fields (schools)

Scale: 1:40,000

Date of publication: 1986

1995/1997 Land Use/Land Cover

Data consist of polygons identifying land use and land cover in New Jersey as of 1995/1997. Land use/land cover polygons were created by comparing the 1986 land use/land cover layers to the 1995/1997 color infrared digital imagery, and delineating changes.

Key data elements: All polygons retain the original 1986 land use code, as well as being assigned a 1995/1997 land use code. Please see Table B-3 for a list of land use codes and their descriptions.

Scale: 1:40,000

Date of publication: 2000

STATE PLANNING CENTERS

These data are a statewide layer consisting of state planning centers, as delineated by the New Jersey State Development and Redevelopment Plan.

Key data elements: Data identify the type and common name of the state planning center. There are five types of state planning centers. Table D-4 provides a description of each center type.

TABLE D-4: TYPES OF STATE PLANNING CENTERS

Center Type	Description
Urban	Generally the largest centers. Distinguished by a diverse mix of industry, commerce, services, residences, and cultural facilities.
Regional	A compact mix of residential, commercial, and public uses that serves a large neighboring area. Public transportation feasible and available.
Town	Traditional areas of commerce or government with diverse residential neighborhoods served by a mixed-use core.
Village	Primarily residential areas with a small core.
Hamlet	Small-scale, compact residential settlements organized around a community focal point, such as a small park.

Source: http://www.nj.gov/dca/osg/plan/stateplan.shtml.

Scale: 1:24,000

Date of publication: 2001

CAFRA II

Data delineate the legislative boundaries of New Jersey's coastal area, as defined by the 1999 proposed revisions to the Coastal Areas Facilities Review Act (CAFRA). The data were created by combining CAFRA boundaries, the Pinelands Area boundaries, and line segments digitized from quarter quad aerial photography. These data have not been verified by NJDEP and are not state-authorized. As part of the procedure for revisions to the CAFRA rules, NJDEP prepared a CD-ROM version of the proposed rules, which also included ESRI GIS shape files of the affected portions of the state. The CD is titled:

Proposed Coastal Permit Program Rules and Rules on Coastal Zone Management (CAFRA), CD-ROM Version, updated: July 29, 1999

We used the "coastalctrs" and "cafraline" files from that CD to prepare this report. Per the NJDEP's requirements the following statement is provided:

This report was developed using digital data developed under the auspices of the Department of Environmental Protection, Geographic Information System, but this secondary product has not been verified by NJDEP and is not state-authorized.

Data is referenced to NAD83 and the coordinate system is N.J. State Plane Feet.

Key data elements: Polygons identify coastal centers and the coastal zone potentially under CAFRA regulation, as delineated by the 1999 proposal for revisions.

Scale: 1:12,000

Date of publication: 1999

Wetlands

Data consist of county by county layers identifying wetlands in New Jersey as of 1986. The layers were created by reselecting wetlands out of 1986 county land use/land cover.

Key data elements: Polygons encompass all wetlands and do not distinguish between tidal or nontidal and natural or disturbed.

Scale: 1:40,000

Date of publication: 1986

NEW JERSEY CONSERVATION FOUNDATION (NJCF)

Conservation Lands

Data delineate conservation easements and parcels owned by New Jersey land trusts as of 1999. Owners include New Jersey Conservation Foundation, New Jersey Audubon Society, Wildlife Preserves, D&R Greenway, the Natural Lands Trust of Media, Pennsylvania, and others. The layer was produced using NJCF digital data, but this end product has not been verified by NJCF.

Key data elements: Polygons outline conservation easements and parcels and identify their names and owners.

Scale: Unable to identify documentation. A visual inspection showed that the density of vertices is similar to a 1:100,000 (or better scale) data layer. However, no information was available to document whether the maps are accurate to such a scale under National Mapping Standards.

Date of publication: 1999

SALEM COUNTY

Salem County: Urban Areas

Data identify Smart Growth planning zones within Salem County, as of 2001.

Key data elements: Polygons represent Smart Growth zones, as delineated by the Salem County Planning Board. Zones were designated as agriculture, commercial, conservation, development, high density residential, historic, industry, low density residential, mid-density residential, mid-development, public, or rural residential.

Scale: 1:24,000

Date of publication: 2001

Salem County: Open Spaces

Data delineate state-owned and -protected open space and recreation lands, state-owned conservation easements, agricultural preservation areas, county-owned open space and recreation lands, federally-owned and -protected open space and recreation land, and natural heritage sites. The layer is a compilation of a variety of in-house and outside generated data sets.

Key data elements: Polygons depict protected areas. Attributes include the name, owner, and current use of the parcel.

Scale: 1:24,000

Date of publication: 2004

Salem County: State Plan

Data identify state planning areas, recreational parks, military lands, and The Meadowlands in New Jersey. State planning areas, drawn by the New Jersey State Planning Commission, are large parcels of land that share a common set of conditions, such as population density, infrastructure systems, level of development, or natural systems.

Key data elements: Polygons represent a state planning area, recreational park, or military land. Please see Table B-1 for more details.

Scale: 1:24,000

Date of publication: 2004

ESRI

ESRI Roads

Data identify major roads and their common names.

Key data elements: Polylines depict major roads such as interstates.

Scale: 1:50,000

Date of publication: 2002

APPENDIX E: STATE PLAN GOALS AND STRATEGIES

Goals and Strategies

The state plan was first formulated in 1992, based on principles identified in the New Jersey State Planning Act of 1986. The following goals and strategies are intended to preserve the state's resources and maintain a desirable quality of life:

Revitalize the state's cities and towns.

Conserve the state's natural resources and systems.

"Conserve the State's natural systems and resources as capital assets of the public by concentrating development and redevelopment in PA 1 and 2, and in Centers in PA 3, 4 and 5, and by restoring the integrity of natural systems in areas where they have been degraded or damaged. Plan, design, invest in and manage the use of land, water, soil, plant and animal resources to maintain biodiversity and the viability of ecological systems. Maximize the ability of natural systems to control runoff and flooding, and to improve air and water quality and supply."

Promote beneficial economic growth, development, and renewal for all residents of New Jersey.

Protect the environment, prevent and clean up pollution.

"Develop standards of performance and create incentives to reduce pollution and toxic emissions at the source and conserve energy. Actively pursue public/private partnerships, the latest technology and strict enforcement to prevent toxic emissions and clean up polluted air, land and water without shifting pollutants from one medium to another, from one generation to another or from one geographic location to another. Concentrate development and redevelopment in PA 1, PA 2 and Centers in PA 3, 4 and 5, to reduce automobile usage, land, water and energy consumption, and to minimize impacts on biological systems, water and air quality. Plant and maintain trees. Reduce waste and reuse and recycle materials."

Provide adequate public facilities and services at a reasonable cost.

Provide adequate housing at a reasonable cost.

Preserve and enhance areas with historic, cultural, scenic, open space and recreational value.

Ensure sound and integrated planning and implementation statewide.

Planning Areas

The state plan designates places into planning areas. Areas such as the "rural" or "environmentally sensitive" planning areas are supposed to be zoned to discourage development. Within the area covered by the plan, most of the land area is divided into one of five categories, some of which are further subdivided.

PA 1: metropolitan planning area—densities of greater than 1,000 people/square mile, existing infrastructure suitable for development/redevelopment.

PA 2: suburban planning area—suburbs, land adjacent to PA 1, land suitable for development, has infrastructure to accommodate future growth and new development.

PA 3: fringe planning area—adjacent to PA 1 or 2, development to be concentrated in existing places or in well designed new development.

PA 4A: rural planning area—rural areas used for agriculture or natural resource production and undeveloped land outside of centers, intent is to maintain rural characteristics.

PA 4B: rural/environmentally sensitive planning area—agricultural lands that contain valuable ecosystems or habitat.

PA 5: environmentally sensitive planning area—land outside of centers that contains valuable ecosystems, geologic features, or wildlife habitat, includes coastal wetlands and barrier spits/islands. PA 5B includes coastal barriers, PA 5A is other sensitive lands.

In addition, park lands and secured installations are divided into their own planning areas. The Pine Barrens and Meadowlands have their own plans.

Within planning areas 1–5 are locations termed "centers." These areas are also intended for development. Another concept, environs, refers to areas outside the boundaries of centers in planning areas 3, 4, and 5. State policy in planning areas 3, 4, and 5 calls for protection of the environs through concentration of development in centers.

The planning area designations are to be implemented through a process termed "cross-acceptance." Cross-acceptance is an interactive process in which the state and county and local representatives reach agreement on policy aims. Following that consensus, local government officials should rezone their communities to accommodate those objectives.

CREDITS AND ACKNOWLEDGMENTS

Michael Craghan devised the general approach of supplementing local government consultation with the use of planning data, during the pilot phase of this study. With modifications, that approach was applied for most of the other states in this nationwide study. He also met with New Jersey state officials at the beginning of this project, and consulted with the planning departments of the six counties with substantial coastal development along the Atlantic Ocean and Delaware Bay, both before and after creating the sea level rise planning maps using their input. He also wrote the first draft of this report and conducted follow-up meetings with the six planners to review the initial results.

Jennifer Kassakian visited the planning departments of the three primary counties along the Delaware River, prepared the corresponding discussion notes and response summaries, and contacted most of the counties for the stakeholder review.

Daniel Hudgens devised a data-based approach to distinguish those areas certain to be protected from those that will probably be protected, and undertook other GIS work to create the revised maps that were shown to the counties during second visits. James G. Titus visited all or part of the shorelines of all counties analyzed in this report, conducting a “reality check” on the draft maps where the data used by the report contradicted what the eye can see. He also reviewed each site-specific departure suggested by the various county reviews, primarily to ensure that county suggestions were implemented correctly. He wrote the summary, the methods sections, the text box on tides and reference elevations, and the “baseline plan for sea level rise” subsections for each of the counties. He also met with the planning directors of Cumberland and Salem counties and made final contacts with Ocean and Cape May counties.

The diagram on tides, wetlands, and reference elevations was produced by collaboration between EPA and NOAA. Titus prepared the rough sketch and dimensions of the diagram by adapting a graphic originally prepared in 1988 for EPA by Tim Kana of Coastal Science and Engineering. Deb Misch of STG, Inc. did the artwork, under contract to NOAA's National Climatic Data Center.

Ken Smith assisted with the stakeholder review for Ocean County. Dan Hudgens made editorial suggestions and managed the contracts and subcontracts. Craghan, Hudgens, and Titus revised the report to take account of the peer review comments.

We are also indebted to Mark Mauriello of NJDEP for providing substantive comments several times throughout the evolution of this study.

Most important, staff from 14 local governments (see Table 3-4) reviewed the report and maps—in many cases more than once. The intent of this project is to characterize the current baseline plan for sea level rise of land use authorities—without their participation, that would have been impossible. Karen Scott of EPA directed the peer review. Finally, David Aubrey (Woods Hole Group) and Ruth Ehinger (NJDEP) provided very helpful comments during the peer review of this report.