ASSESSMENT

2.1 PHYSIOGRAPHY

An environmental assessment of an area is ultimately based on its physical characteristics, from which almost all other environmental properties are derived. First-order units include:

- Sedimentary substrates and soils upon which everything rests;
- Units that indicate the operation of natural processes in the basin;
- Biological features; and
- Man-made features.

Coastal areas such as the Inland Bays/Atlantic Ocean Basin are characterized by changes brought about by the operation of certain natural processes. The rate and direction of these changes may be affected by human activities. Thus, the environmental status of the Basin may be established by mapping first-order units, and periodic remapping can recognize changes. An understanding of these mapped units and the changes they are undergoing are essential to effective decision-making, planning, and management of all natural resources.

2.1.1 GENERAL SETTING

The Inland Bays/Atlantic Ocean Basin comprises approximately 313 square miles of eastern Sussex County, Delaware (*Figure 1.1-1 and Map 1.2-1*). Starting at Lewes and Cape Henlopen State Park at the southern edge of the entrance to Delaware Bay, the area extends southward approximately 24 miles along the Atlantic shoreline to the Maryland State Line. It includes the coastal towns of Rehoboth Beach, Dewey Beach, Bethany Beach, South Bethany Beach, and Fenwick Island. State Route 1 (SR 1) extends parallel to the shoreline and connects the towns.

At the Maryland State Line, the Basin boundary extends westward approximately 16 miles to the western edge of the Cypress Swamp and thence along an arcuate line extending northwestward about 19 miles to Georgetown, the county seat of Sussex County. Along this boundary, starting at the Maryland State Line and proceeding northward, the towns of Selbyville, Frankford, Dagsboro, Millsboro, and Georgetown are connected by U.S. 113.

The northern border of the Inland Bays/Atlantic Ocean Basin roughly parallels SR 9 and extends from Georgetown northeastward back to Lewes and Cape Henlopen State Park.

The dominant physiographic feature of the Basin is the three “inland bays” that are located just landward of the Atlantic Ocean shoreline. From north to south, these are Rehoboth Bay, Indian River Bay, and Little Assawoman Bay.

CONTENTS

PHYSIOGRAPHY

Other distinctive physiographic characteristics include the flat topography and man-made drainage ditches that are used to drain soils with perennially high water tables, which are mostly limited to the area south of Millsboro and Indian River Bay.

2.1.2 GEOLOGY AND GEOLOGIC HISTORY

The Inland Bays/Atlantic Ocean Basin lies entirely within the Atlantic Coastal Plain Physiographic Province. The Coastal Plain consists of a series of southeastward-thickening, unconsolidated sediments of Cretaceous through Holocene age deposited atop the Paleozoic and Precambrian crystalline "basement" rocks of the Appalachian Piedmont (*Table 2.1-1*).

Coastal Plain sediments thicken and dip toward the southeast at 10 – 30 feet per mile in the northern Delmarva Peninsula, and "plunge" up to 90 feet per mile (slightly less than one degree) in the Lewes area, with the older, deeper units dipping more steeply. These sedimentary deposits are as much as 8,000 feet thick beneath Fenwick Island in southeasternmost Delaware (Cushing et al., 1973). The configuration of the crystalline rock surface beneath these sedimentary deposits is poorly known due to their depth.

The sedimentary Coastal Plain deposits are an alternating sequence of sands, silts, and clays laid down in a variety of geological environments. The utility of the deeper aquifers in this sedimentary sequence is limited by increasing salinity and iron content with increasing depth. The shallower aquifers are vulnerable to contamination resulting from conflicting land uses, including shallow septic tanks, agricultural runoff, man-made alterations of natural drainage patterns, and commercial and residential land development. To date, there is little industrial development in the Inland Bays/Atlantic Ocean Basin.

To better understand and visualize the Basin's geology and hydrogeology, see the following maps:

- Map 2.1-1 *Surficial Geology* shows the locations of the most recent geologic formations, which are exposed at the ground surface.
- Map 2.1-2 *Subsurface Geology* shows the locations of the subcropping or underlying geologic formations. This map illustrates what the geology of the Basin would look like if the surficial sediments were removed.
- Map 2.1-3 *Columbia Aquifer & Manokin Formation Structure Contours* shows the thickness of the Columbia Aquifer, the Pocomoke Aquifer subcrop area, and the elevation of the base of the Manokin Formation.
- Map 2.1-4 *Ground-Water Recharge Potential* separates the Basin into areas of differing infiltration rates. Categorized from excellent to poor, these regions show the relative ease with which rainwater, or any surface discharge, can enter the subsurface and thus the ground-water system.

2.1.3 MODERN GEOLOGY

The land surface of the Basin rises from sea level in the east to an average elevation of 25 – 30 feet in the west. A barrier island separates the open ocean from the Inland Bays.

A typical barrier island has the following physiographic features, starting at the ocean and proceeding toward the back-barrier bay:

- Barrier beach;
- Dunes;
- Back-barrier flat; and
- Salt marsh and bay.

The barrier beach is the transition zone between land and sea and provides protection to the shore from damage by coastal storms and hurricanes.

The dunes are storage areas of sand that have been blown inland during dry periods. Unless disturbed by human activities, they are stabilized by vegetation that can withstand salt spray and even burial by sand. When they are stabilized by vegetation and are protected by a wide beach, dunes provide a very effective natural protection of the bays and inland areas against flooding during storms.

Back-barrier flats form from sand washed over the barrier during storms. When "washover" is infrequent, salt-tolerant grasses and other vegetation quickly colonize back-barrier flats.

Salt marshes occur landward of the back-barrier flats and are divided into low and high salt-marsh areas. The low marsh extends from mean sea level to the high neap-tide elevation, and the high marsh extends to the highest spring-tide elevation. The low salt marsh is biologically the most productive part of the marsh. Whenever washover occurs and sand is transported into the bay, it forms new low salt marshes that are intermittently flooded by tidal action.

The Inland Bays in Delaware are semi-enclosed and are protected by the barriers from direct action by the open ocean. The Inland Bays, which dominate the Inland Bays/Atlantic Ocean Basin, are shallow, with an average low-water depth of 3 to 8 feet and a tidal range of less than 3 feet. Rehoboth and Indian River bays are a maximum of 6.5 feet deep, and Little Assawoman Bay is a maximum of 20 feet deep (U.S. EPA, 1998). Fresh water enters these bays through ground-water discharges and surface runoff. Salt water from the Atlantic Ocean enters the bays through Indian River Inlet, Lewes-Rehoboth

Table 2.1-1

GEOLOGIC AND HYDROLOGIC UNITS OF THE DELAWARE COASTAL PLAIN

AGE	GEOLOGIC UNITS	HYDROLOGIC UNITS
HOLOCENE		
PLEISTOCENE	"Carolina Bay" deposits, upland bog deposits, bog deposits, Nanticoke deposits, Scotts Corners Formation, Lynch Heights Formation	Columbia/Unconfined/Pleistocene aquifer – poor to excellent yield, minor confining beds
	Omar Formation	Confining unit over Columbia aquifer only in southeasternmost Sussex County – minor poor aquifer
	Staytonville Unit, Columbia Formation	Columbia/Unconfined/Pleistocene aquifer – poor to excellent yield, minor confining beds
PLIOCENE	Beaverdam Formation	
MIOCENE	Bethany Formation	Interbedded confining units and Pocomoke aquifer – fair to excellent yield
	Manokin Formation	Manokin aquifer – fair to excellent yield and confining beds
	St. Mary's Formation	Confining beds – minor poor aquifer
	Choptank Formation	Interbedded unnamed aquifers; fair to good yields, and confining units Milford aquifer – fair to good yield
	Calvert Formation	Confining beds Frederica aquifer – fair to good yield Confining beds Federalsburg aquifer – fair to good yield Confining beds Cheswold aquifer – fair to excellent yield, confining beds
OLIGOCENE	Glauconitic Unit	
EOCENE	Glauconitic Unit	
	Piney Point Formation	Aquifer – poor to excellent yield, interbedded confining beds, confining beds
	Shark River Formation	Confining beds
	Manasquan Formation	Rancocas aquifer – fair to good yield, interbedded confining units
PALEOCENE	Vincentown Formation	
	Hornerstown Formation	Confining beds
CRETACEOUS	Navesink Formation	
	Mount Laurel Formation	Aquifer – poor to good yield
	Marshalltown Formation	Confining bed
	Englishtown Formation	Aquifer – fair to good yield
	Merchantville Formation	Confining bed
	Magothy Formation	Aquifer – fair to good yield
	Potomac Formation	Potomac aquifers and confining units – fair to excellent yields
"BASEMENT" OF PRE-CRETACEOUS ROCKS		

Source: Adapted from Delaware Geological Survey, 1999

Canal, and the Assawoman Canal, which connects Little Assawoman Bay to Indian River Bay. Natural channels connect Rehoboth and Indian River bays near Massey's Landing (*Map 1.2-1*).

Wave heights in the bays are low, except for periodic large storms. The bays are floored with fine sands and lesser amounts of organic-rich silts and clays. Because of washovers, the bay bottom sediments are most sandy along the landward side of the barrier islands that separate them from the Atlantic Ocean.

Delaware's Atlantic Ocean coastline consists of a wide sand barrier island. It is interrupted at Rehoboth Beach and Bethany Beach where Pleistocene headlands meet the coast and at Indian River Inlet about 4 miles north of Bethany Beach. Longshore currents are eroding almost the entire ocean coastline.

Cape Henlopen Spit Complex, at the south side of the entrance to Delaware Bay, is one of the few accreting beaches along Delaware's ocean coast. As sand is eroded from the Atlantic Ocean coastline, it is transported northward where it is deposited either at the tip of the spit or on tidal flats to the west. A field of sand dunes, which reach a maximum height of about 45 feet, covers the entire Cape Henlopen Spit Complex. The complex is moving northwestward approximately 100 feet per year (Kraft, 1988).

Indian River Inlet is the only tidal inlet along Delaware's Atlantic coastline. Geologic and historic evidence indicates that in the past, the inlet actively migrated north and south over a 3- to 4-mile stretch of coastline. The U.S. Army Corps of Engineers constructed two parallel jetties in 1939 to keep the present inlet open and stabilized in one location. The jetties are 1,566 feet long and are 500 feet apart (Kraft et al., 1976).

Although the jetties have stabilized Indian River Inlet, they interrupt the northward movement of eroded sand being transported in the surf zone. This has caused severe erosion on the north side of the inlet and necessitated a sand pumping operation to prevent the undermining of SR 1 (*Map 2.1-5 Indian River Inlet Shoreline Change*).

2.1.4 ACTIVE PROCESSES

Naturally occurring processes that are actively at work in the Inland Bays/Atlantic Ocean Basin include:

- Sea-level rise;
- Shoreline erosion;
- Coastal storms;
- Surface-water circulation; and
- Ground-water circulation and saltwater intrusion.

2.1.4.1 Sea-Level Rise

Before the last ice age, ocean waters covered most of what is now Delaware. As the polar icecaps grew and continental glaciers advanced southward, most of the water to form these massive bodies of ice came from the ocean. Sea level withdrew from the land and dropped to its lowest level to a position near the edge of the present continental shelf about 400 feet lower than present-day sea level (Kennett, 1982). Since then, the polar icecaps have decreased in size and the continental glaciers have retreated, causing a corresponding rise in sea level to where we see it today.

In addition, although Delaware is located south of the maximum extent of the last continental glacier, it is believed that the great weight of the massive continental glacier actually depressed the land it overrode. A corresponding marginal bulge formed in the area of present-day Delaware. As the glaciers retreated, the Earth's surface is rebounding upward in areas to the north and the marginal bulge previously formed in the area of Delaware is subsiding, causing a relative rise in sea level (Kraft et al., 1976).

Compaction of Coastal Plain sediments can also contribute to sea-level rise. As the Delaware, the Susquehanna and other rivers ran southeastward from the ancient Appalachian Mountains, they carried huge volumes of sediment, which were deposited on the edge of the Piedmont to form the present Coastal Plain and continental shelf. Over geologic time, these sediments began to compact, causing a drop in the elevation of the land surface. As the land sank, the ocean encroached onto the continental shelf causing it to flex downward and begin sinking. It is believed that the added weight of these sediments along with the weight of the ocean water has caused the Atlantic coast to subside about 9,800 feet over the last 150 million years (Thurman, 1981).

The current marine transgression began approximately 14,000 years ago when the polar ice caps began melting. The Delaware coastline at that time was approximately 80 – 100 miles east of its current location (Kraft et al., 1976). A rapid rise in sea level — about 3 inches per year — lasted until about 7,000 years ago, when sea level was about 33 feet below its present level. Since then, sea level has risen at a slower rate until about 3,000 years ago when it reached its present level (Kennett, 1982).

As the ocean advanced across the continental shelf, it flooded ancient river valleys and moved large masses of Pleistocene sediments in a landward direction, overtopping previous lagoons and marshes. Over time, Delaware's coastline, including both Delaware Bay and the Atlantic Ocean coastlines, began to evolve to its present-day configuration. The present coastline is moving landward and upward in response to longshore transport of sediments and storms. As sea level rises, waves attack the beach at higher elevations, which concentrates erosion on headland areas and works to straighten the coastline. At the same time, washover and blowing sand lead to formation of dunes and a landward movement of the shoreline.

The landward and upward movements of the beach and dunes cause the shoreline to roll over itself over time. Evidence of this can be seen on the beach following a coastal storm when peat deposits and remnants of ancient pine forests that were landward of the shoreline are exposed on the present beach face (refer to *Figure 2.1-1*). Radiocarbon dates taken from stumps and peat exposed in the surf zone of Dewey Beach have found that those stumps date to 320 – 420 years before the present. This indicates that the barrier island in this location has completely overtopped itself in only 400 years (Kraft et al., 1976).

Landward movement of the shoreline caused by sea-level rise does not proceed evenly. Rather, it is episodic, with periods of stability and accretion followed by periods of erosion and change. Sometimes this change can be rapid, such as at Fenwick Island where, between May 1977 and June 1979, the shoreline moved landward at an average rate of more than 30 feet per year. In general, Delaware's Atlantic coastline is moving landward at a rate of 1 to 3 feet per year. Even with our incomplete understanding, it is obvious that significant geologic changes can and do occur within a single human lifetime.

Figure 2.1-1

PEAT DEPOSITS AND REMNANTS OF ANCIENT PINE FORESTS UNCOVERED AFTER A COASTAL STORM

2.1.4.2 Shoreline Erosion

Littoral transport and coastal storms are both responsible for changes along Delaware's coastline. Littoral transport is the movement of beach sand parallel to the shore (longshore transport) and onshore and offshore (onshore-offshore transport) in response to waves and currents. Longshore transport occurs when waves breaking at an angle to the shoreline move sand-laden water in the direction of the longshore current. On Delaware's Atlantic coastline, the net longshore transport is from the South Bethany/Bethany Beach area northward to Cape Henlopen. There is a change — a nodal point — somewhere between Bethany Beach and Fenwick Island where the net longshore transport changes to southward.

Onshore-offshore transport occurs when sediment is moved perpendicular to the shore in response to wave action. During the summer months when waves are low, sand is deposited on the beach, forming a high and wide berm — the sloping area immediately landward of the crest of a barrier beach — and a smooth offshore profile. During the winter months and during storms when wave steepness increases, sand is moved offshore from the berm, creating one or more offshore sandbars. The berm is much narrower during this time, which can give the impression that the beach has disappeared. *Map 2.1-5 Indian River Inlet Shoreline Change, Map 2.1-6 Lewes/Cape Henlopen Shoreline Change, Map 2.1-7 Rehoboth Beach Shoreline Change, Map 2.1-8 Dewey Beach Shoreline Change, Map 2.1-9 Bethany Beach Shoreline Change, Map 2.1-10 South Bethany Shoreline Change,* and *Map 2.1-11 Fenwick Island Shoreline Change* show the shoreline changes from 1845 through 1993.

2.1.4.3 Coastal Storms

During storms when waves are higher and steeper and the tidal level increases, natural littoral transport processes are accelerated, which can cause extreme variations in the beach profile over a very short time, sometimes within hours. The beach elevation may be lowered considerably and the face of the dune may be eroded or completely flattened. As sand is removed from the dune, it is transported offshore causing the slope of the nearshore area to be reduced. This transport process extends shallow water depths seaward. This, in turn, causes waves to break farther offshore away from the barrier, dissipating the energy of the waves before they reach shore.

If a dune is not present, this natural process cannot occur and more erosion occurs. In some cases during major storms, sand is washed inland by storm waves in washovers deposited in the back-barrier marshes and bays. When normal wave action resumes, long, low waves move sand landward from the offshore bar. This sand moves up the beach until it restores the berm to its prestorm condition.

The March 1962 “Ash Wednesday Storm” was the most destructive storm known to ever hit Delaware’s coastline. It was a northeaster.

Northeasters form in low-pressure atmospheric systems and have winds that circulate counterclockwise. When such storms move northward along the Atlantic coastline, strong winds from the northeast result, hence the name. Maximum wind speeds are usually less than those associated with hurricanes, but because they are usually slow moving, northeasters are usually of longer duration, often lasting over several tidal cycles.

The “Ash Wednesday Storm” stalled offshore from Delaware’s coastline, where it slowly rotated over five complete tidal cycles. High-sustained winds (estimated at 60 miles per hour in Delaware), rain, and snow impacted an area from the Carolinas to New England. A storm surge of 8.1 feet was recorded at Lewes, and waves more than 40 feet high occurred at Rehoboth Beach. Dunes were flattened along the entire length of Delaware’s ocean coastline, boardwalks were completely destroyed at Rehoboth Beach and Bethany Beach, and large numbers of beach homes were destroyed. Waves up to 4 feet high rolled into Oak Orchard, a small community on the landward side of Indian River Bay, about 6.5 miles inland from the coastline. There were seven fatalities. It has been termed the worst disaster in the state’s history (Delaware Coastal Management Program, 1977; U.S. Army Corps of Engineers, 1996).

2.1.4.4 Surface-Water Circulation

Freshwater runoff from the land enters the three inland bays from watersheds and tributaries that drain a total of approximately 313 square miles (see Section 2.2 for details). The average daily freshwater flow into the bays is about 380 cubic feet per second.

Salt water enters the bays through Indian River Inlet, Lewes-Rehoboth Canal, Roosevelt Inlet, and Assawoman Canal. Tidal flushing rates vary in different parts of the three inland bays. For example, the eastern portion of Indian River Bay and the southern portion of Rehoboth Bay are well flushed by tidal action twice each day, while the remaining areas of the three bays are flushed at much slower rates.

This uneven flushing action creates a variety of highly productive biological environments. But the slow flushing action in many parts of the bays makes them highly vulnerable to contamination from a variety of sources (see Section 2.7).

2.1.4.5 Ground-Water Circulation and Saltwater Intrusion

As with surface water, ground water moves toward the Inland Bays from two directions:

- Fresh water from landward; and
- Saltwater intrusion from seaward.

The bottom of the Manokin Formation (*Map 2.1-3 Columbia Aquifer & Manokin Formation Structure Contours*) serves as the base of the freshwater aquifer system in the Inland Bays/Atlantic Ocean Basin. Deeper aquifers that may be present are too salty, too mineralized, or too deep to be commercially viable sources of fresh water. Water containing more than 250 milligrams per liter (about 250 parts per million) chloride is considered “salty.”

As long as the elevation of the shallow ground-water table is 5 feet or more, it exerts sufficient pressure, or “head,” to resist saltwater intrusion from seaward (Sundstrom et al., 1975).

Salty ocean water infiltrates aquifers that extend to the coastline and moves landward until it reaches a dynamic equilibrium with the “head” of freshwater moving seaward. This dynamic equilibrium can be shifted laterally rather quickly in response to natural causes such as a drought and man-made causes such as excessive pumping of the shallow freshwater aquifers. These changes decrease the “head” of freshwater and may result in fresh water being pushed out of areas near the coastline where it was formerly present. These same coastal areas are subject to development pressures and an accompanying increased demand for fresh water for use by a growing population.

One of the earliest documented cases of saltwater intrusion along the coast occurred in 1943 and 1944 when increased yield from Lewes and Rehoboth Beach well fields caused their unconfined wells to become contaminated with “salty” water. During this time, the Lewes well field was located very close to the then recently deepened Lewes-Rehoboth Canal, and the Rehoboth well field was located on the barrier island. Chloride levels as high as 1,420 milligrams per liter were recorded in the Lewes well field. Both towns abandoned these well fields and constructed new wells farther inland (Miller, 1971).

Another incident of saltwater intrusion occurred in the mid-1970s when unconfined domestic wells at the town of Fenwick Island began yielding salty water. In 1977, a chloride concentration of 9,500 milligrams per liter was recorded from a water sample taken near the base of the unconfined aquifer in this area. Due to these excessive chloride levels, residents in the area had new wells installed into the deeper, confined Pocomoke Aquifer. North of Fenwick Island, at South Bethany, home owners have had to install new wells 220 – 240 feet deep into the confined Pocomoke Aquifer because of saltwater intrusion into shallower aquifers (Phelan, 1987).

More recently, saltwater intrusion occurred in 1995 at Old Landing, on the north shore of Rehoboth Bay. Dewatering for construction of a county sewer line there captured saline bay waters and severely degraded the quality of the thin unconfined aquifer. The county abandoned the contaminated wells and replaced them with new Pocomoke Aquifer wells.

The Sussex County Coastal Monitoring Network was established with a two-year investigation beginning in 1985 under the joint sponsorship of the Department, the Delaware Geological Survey, and the U.S. Geological Survey to:

- Learn more about saltwater intrusion in eastern Sussex County;
- Assess the vulnerability of coastal aquifers to saltwater intrusion; and
- Identify areas where saltwater intrusion is occurring (Phelan, 1987).

The initial investigation showed that saltwater intrusion is not a widespread problem in coastal aquifers, but that intrusion has caused significant aquifer degradation in localized areas. It confirmed that coastal aquifers are vulnerable to saltwater intrusion when high-capacity wells are located near saline water bodies.

Soon after this initial two-year investigation, the Department and the Delaware Geological Survey established a coastal saltwater monitoring network. This network comprises 36 municipal public and observation wells, subdivision public wells, and monitoring and observation wells installed by the Delaware and U.S. geological surveys. Seven of the wells are screened in the unconfined aquifer, 15 are screened in the Pocomoke Aquifer, and 14 are screened in the Manokin Aquifer. Monthly water level readings are collected, and the water is analyzed for chloride content twice a year.

The following provides a summary of the major aquifers in the Inland Bays/Atlantic Ocean Basin (adapted from Talley and Bounds, 1999).

Columbia Aquifer

Chloride concentrations for wells not immediately along the coast or near a salt-water surface body range from 10 – 28 milligrams per liter. Saltwater intrusion has locally occurred at Fenwick Island, South Bethany, Rehoboth Beach, and along the Lewes-Rehoboth Canal.

Much of the Columbia Aquifer and hydraulically connected portions of the Pocomoke Aquifer beneath it are protected to some extent from saltwater intrusion by an adequate head of fresh water. This may not be the case in areas immediately adjacent to the Atlantic Ocean or the Inland Bays water bodies where excessive ground-water withdrawals or inundation during coastal storms result in infiltration of seawater into the unconfined aquifer. In order to prevent further saltwater intrusion, high-yield water-supply wells should be located where water table elevations are at least 10 feet or greater (Sundstrom and Pickett, 1969).

Pocomoke Aquifer

Chloride concentrations for wells not immediately along the coast or near a saltwater surface body range from 5 – 30 milligrams per liter. Chloride concentrations in water samples from wells at Delaware Seashore State Park, Quillans Point, the Narrows, and Fenwick Island State Park all exceed this range (the maximum concentration is 123 milligrams per liter). Any additional pumping from the Pocomoke in these areas could cause significant additional saltwater intrusion.

Manokin Aquifer

Chloride concentrations for wells producing from the Manokin Aquifer range from 450 milligrams per liter at Fenwick Island on the coast (Phelan, 1987) to less than 20 milligrams per liter farther inland. The drinking-water standard of 250 milligrams per liter is exceeded at Indian River Inlet, Bethany Beach, Sea Colony between Bethany Beach and South Bethany, and Fenwick Island.

2.1.5 SOILS

Soils begin at the land surface and extend downward to various depths, usually measured in inches or feet. Soils in the Inland Bays/Atlantic Ocean Basin may grade almost imperceptibly into the unconsolidated sedimentary geologic units below. “Soil” may be defined from a geologic, engineering, agricultural, or other point of view, depending on one’s purpose.

The soil survey of Sussex County shows six soil associations in the Inland Bays/Atlantic Ocean Basin (Ireland and Matthews, 1974). The most extensive soils are sandy loams that are well drained north of Indian River Bay and poorly drained to the south of the bay (*Map 2.1-12 Soil Types*).

Approximately 1,500 miles of drainage ditches drain the soils throughout the Basin. As residential development continues in the eastern portion of the Basin, the focus is shifting from soil drainage for agricultural purposes to storm-water management in residential areas.

Most soils in the Basin are generally not susceptible to erosion because of their low slopes and permeable nature (*Map 2.1-13 Soil Erodibility*). Erodible soils are concentrated along the coastline where wind erosion of sand dunes is the dominant process, commonly accelerated by construction activities.

The Inland Bays/Atlantic Ocean Basin is particularly favorable for agricultural production because the soils respond well to management, the temperate climate provides a fairly long growing season, and rainfall is well distributed. General soil management practices are applicable to all or nearly all of the soils used for crop production in the Basin. These practices include draining the soils that are too wet part of the year or most of the year, applying the proper soil amendments (manure, commercial fertilizer, lime), choosing suitable crop rotations, managing crop residue (cover crops), and irrigation.

2.1.5.1 Hydric Soils

Hydric soils are either:

- Saturated at or near the soil surface with water that lacks free oxygen for significant periods during the growing season; and
- Flooded frequently for long periods during the growing season.

The following soils have a potential to be considered hydric: Broadkill, Mullica/Berryland, Keyport, Fallsington, Hurlock, Matanuck, Mullica, Westbrook/Transquaking, Pawcatuck, and Manahawkin. Areas are considered to be wetlands when comprised of hydrophytic plants, hydric soils, and hydrology indicative of periods of continuous soil saturation during the growing season. Many of these soils are located within the headwater areas of the creeks and rivers. Headwater and flood plain areas comprise 48 percent of the Basin.

2.1.5.2 Excessively Well-Drained Soils

The Fort Mott, Runclint, and Evesboro are excessively well-drained soils that encompass broad areas of nearly level, moderately sloping, dune-like ridges, some depressions, and steeper slopes bordering Indian River and Rehoboth bays. They have rapidly permeable subsoil of sand to sandy loam. Most of the soil areas have been cleared for crop production and residential home sites, but small areas remain in forest in steeper slopes along drainages. In areas where high-value crops are grown, irrigation is commonly used. Most of the soils in this group are suitable for residential (high septic suitability) and non-farm uses, but there are limitations because of the loose sandy nature of the soils.

2.1.5.3 Well-Drained Soils

Well-drained soils occupy a large area that extends from Rehoboth Bay southward to Indian River. Small areas are scattered on upland landscape positions to the west. The soils in this group include Greenwich, Greenwich/Urban Complex, Henlopen, Fort Mott/Henlopen, Downer, Rosedale, Ingleside, Pits, and Psamments/Urban complex. The soils are nearly level to steep, deep, and well drained in upland areas. The Greenwich and Greenwich/Urban Complex soils have a silt loam surface layer and silty clay loam subsoil. The Henlopen, Fort Mott/Henlopen, Downer, and Ingleside soils have a sandy loam surface layer and a sandy loam and sandy clay loam subsoils.

Farming is the dominant land use on these soils and is both intensive and extensive. The potential for farming the soils in this well-drained grouping is better than any other part of the Basin. Except for slope and the hazard of erosion in some areas (silty Greenwich and Fort Mott/Henlopen soils), these soils have few limitations. In the eastern portion of the Basin, well-drained soils are dominantly used for residential development, which represents the greatest loss of farmland in the Basin.

2.1.5.4 Moderately Well-Drained Soils

These soils occupy nearly level rolling uplands and some local low spots separated by gently sloping ridges. These soils are scattered throughout the Basin, mostly in the northeastern portion. This group of soils consists mainly of Hammonton, Matawan, Pepperbox, Pepperbox/Rosedale, and Klej. The moderately well-drained soils in the Basin have a friable sandy loam to sandy clay loam subsoil and are associated with drainages and headwater areas. They are wet and slow to warm up in the spring, and in some places they are unsuitable for early crop planting. Ditches are needed in most nearly level areas for draining excess surface water at planting time and during the growing period. The soils have only a moderate suitability for residential septic systems because of a seasonal high water table during wet periods. As a result, pressure dosed septic systems are the dominant type used on these soils. Residential development continues in these areas, despite the fact that about 5 percent of all septic systems fail on these soils. Except for slope and susceptibility to erosion in small areas, most of these soils have moderate limitations for most land uses.

2.1.5.5 Poorly Drained Soils

These soils occupy 35 percent of the Basin — more than any other. They are mainly level or nearly level (2 percent slope), and occupy upland flats and local low areas. Parts of these soils have been cleared and are used for farming, but most of the areas remain as wet wood lots. Major soils in this group include Hurlock, Mullica, and Mullica/Berryland. Minor soils include Fallingston, Woozar, Broadkill, Manahawkin, Matanuck, Pawcatuck, and Westbrook/Transquaking. In Hurlock, Mullica, and Berryland soils, the surface layer is loam to sandy loam, and the subsoil is strongly mottled, friable to firm sandy clay loam that is underlain by sands. Broadkill, Woozar, Pawcatuck, Manahawkin, Matanuck, and Westbrook/ Transquaking soils have a mucky to silty surface layer and a subsoil of silty clay loam through which water moves very slowly. These soils are generally found in and around tidal marshes. For all uses, the chief limitation of these soils is the impeded or poor drainage caused by clay-rich subsoil. Intensive drainage practices are needed on all of the soils because of the nearly level terrain and the fact that ground water is often at the surface. Even if the soils are drained, the soils in this grouping generally have severe limitations that restrict their use for residential development and septic suitability.

2.1.6 DATA GAPS AND RECOMMENDATIONS

1. Prepare for climate change and sea-level rise by practicing retreat. Setback requirements should be increased along the shoreline. *Lead Agency: Sussex County*
2. Complete recharge-potential mapping for the rest of the state. This mapping shows areas where water and/or contaminants can rapidly enter the ground water.
3. Develop depth to ground-water maps for the entire state that highlight areas with an extremely shallow-water table.

2.1.7 REFERENCES

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