Water Resources Inventory and Assessment

Cape May National Wildlife Refuge

Cape May Courthouse, New Jersey

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1. EXECUTIVE SUMMARY

Water Resources Inventory and Assessments (WRIA) are being developed by a national team of hydrologists within the U.S. Fish and Wildlife Service (Service). The purpose of these assessments is to provide reconnaissance level information on water resources at National Wildlife Refuges and National Fish Hatcheries. The goal of every WRIA is to provide a basic understanding of the water resources that are important to the facility and assess the potential threats to those resources. Data collected in the WRIAs is being incorporated into a national database so water resources can be evaluated nationally and between regions. Information collected for the WRIAs can be used to support CCPs, Hydro-Geomorphic Assessments, and other habitat management plans.

1.1 FINDINGS

1. Average total precipitation for the year in the vicinity of Cape May NWR is about 40 inches. Precipitation is distributed evenly throughout the year, averaging 3.3 inches/month

2. Approximately 70% of the land in the Cape May acquisition boundary is considered wetland habitat using the National Wetland Inventory classification system. About 73% of the wetland habitat is considered freshwater wetlands (Palustrine) while the remaining 27% is estuarine or marine.

3. Vernal pools are found on the Cape May refuge. A New Jersey Department of Environmental Protection database suggests as many as 150 vernal pools are on, or within, 0.1 mile of the refuge acquisition boundary.

4. Groundwater supplies more than 90% of the water used for municipal, industrial, and agricultural purposes in Cape May County. Groundwater pumping has caused water levels in underground aquifers to decline and has exacerbated saltwater intrusion into those aquifers.

5. Up to 80% of the non-tidal freshwater flow in Cape May peninsula streams is derived from shallow groundwater aquifers.

6. A 2009 USGS report suggests groundwater pumping locally lowers the water table in the shallow groundwater aquifers of the Cape May peninsula and may contribute to more rapid drying of some vernal pools.

7. There are 22 water quantity and 43 water quality monitoring sites near Cape May NWR. Water monitoring near the refuge is focused on water levels and water quality in the peninsula's groundwater aquifers.

8. Long-term climate records indicate minimum air temperatures near Cape May NWR have risen approximately 3.4 degrees Fahrenheit (°F) since 1925.

9. Long term tide gage data at the Cape May NJ indicate the sea level is rising approximately 4.06 mm/year. About double the global average of 1.8 mm/yr

1.2 RECOMMENDATIONS / FURTHER ACTIONS

Because of its proximity to the Delaware Bay and Atlantic Ocean, sea level rise is the most obvious long-term threat to wetland habitat at Cape May NWR. However, 73% of the refuge's wetlands are considered freshwater and are located in the headwaters of tidal creeks or in the Great Cedar Swamp Division and are not immediately threatened by sea level rise. A more immediate threat to freshwater wetland systems is groundwater development in the shallow aquifers of the Cape May peninsula. Recommendations for addressing this threat are below:

1. Pierre Lacombe's 2009 study of groundwater pumping scenarios on the Cape May Peninsula indicated that wetland habitat, like vernal pools, may be affected by groundwater pumping for municipal purposes. For the 2009 report, Lacombe established several vernal pool water level monitoring sites on the refuge. Recommend re-activating water level monitoring at Lacombe's vernal pool monitoring sites. This will help build a data record that helps confirm if the pools near pumping centers are drying earlier than pools far from areas of groundwater development.

2. Data reviewed for this report indicate that the shallow groundwater aquifer in the Cape May peninsula is an important source of water for Cape May streams and supports unique wetland communities on the peninsula. Recommend consulting with Regional Hydrologist to develop an approach for identifying and inventorying groundwater discharge areas on refuge property. These sites may harbor unique flora and fauna and will be particularly sensitive to future groundwater development plans and groundwater contamination.

2. INTRODUCTION

This Water Resource Inventory and Assessment (WRIA) Summary Report for Cape May National Wildlife Refuge (NWR) describes current hydrologic information, provides an assessment of water resource issues of concerns, identifies water resource needs, and makes recommendations regarding refuge water resources. The information contained within this report and supporting documents will be entered into the national WRIA database.

Together, the national WRIA database and summary reports are designed to provide a reconnaissance level inventory and assessment of water resources on National Wildlife Refuges and National Fish Hatcheries. A national team of U.S. Fish and Wildlife Service (Service) Water Resource staff, Environmental Contaminants Biologists, and other Service employees developed the standardized content of the national WRIA database and summary reports.

The long term goal of the National Wildlife Refuge System (NWRS) WRIA effort is to provide up-to-date data on a facility's water quantity and quality in order to protect adequate supplies of clean and fresh water. An accurate water resources inventory is essential to prioritize issues and tasks, and to take prescriptive actions that are consistent with the established purposes of the refuge. Reconnaissance-level water resource assessments evaluate water rights, water quantity, known water quality issues, water management, potential water acquisitions, threats to water supplies, and other water resource issues for each field station.

WRIAs are recognized as an important part of the NWRS Inventory and Monitoring (I&M) Program and are outlined in the I&M Draft Operational Blueprint as Task 2a. Hydrologic and water resource information compiled during the WRIA process will help facilitate the development of other key documents for each refuge including Hydrogeomorphic Analyses (HGM) and Comprehensive Conservation Plans (CCP).

Cape May National Wildlife Refuge WRIA

This WRIA Summary Report for Cape May NWR incorporates hydrologic information compiled between August 2010 and November 2010. The report is intended to be a reference for ongoing water resource management and strategy development. However, the document is not meant to be exhaustive or a historical summary of activities at Cape May NWR.

3. FACILITY INFORMATION

Cape May National Wildlife Refuge

Cape May National Wildlife Refuge was established in 1989 for the purpose of protecting migratory bird habitat in coastal New Jersey. Authority for managing and

acquiring the land for the National Wildlife Refuge System falls under the Migratory Bird Conservation Act, Fish and Wildlife Act of 1956, and the Emergency Wetlands Resources Act of 1986. The refuge protects approximately 11,025 acres in Cape May County New Jersey. The refuge is grouped into three units: The Delaware Bay Division, the Great Cedar Swamp Division, and the Two Mile Beach Unit (Figure 1).

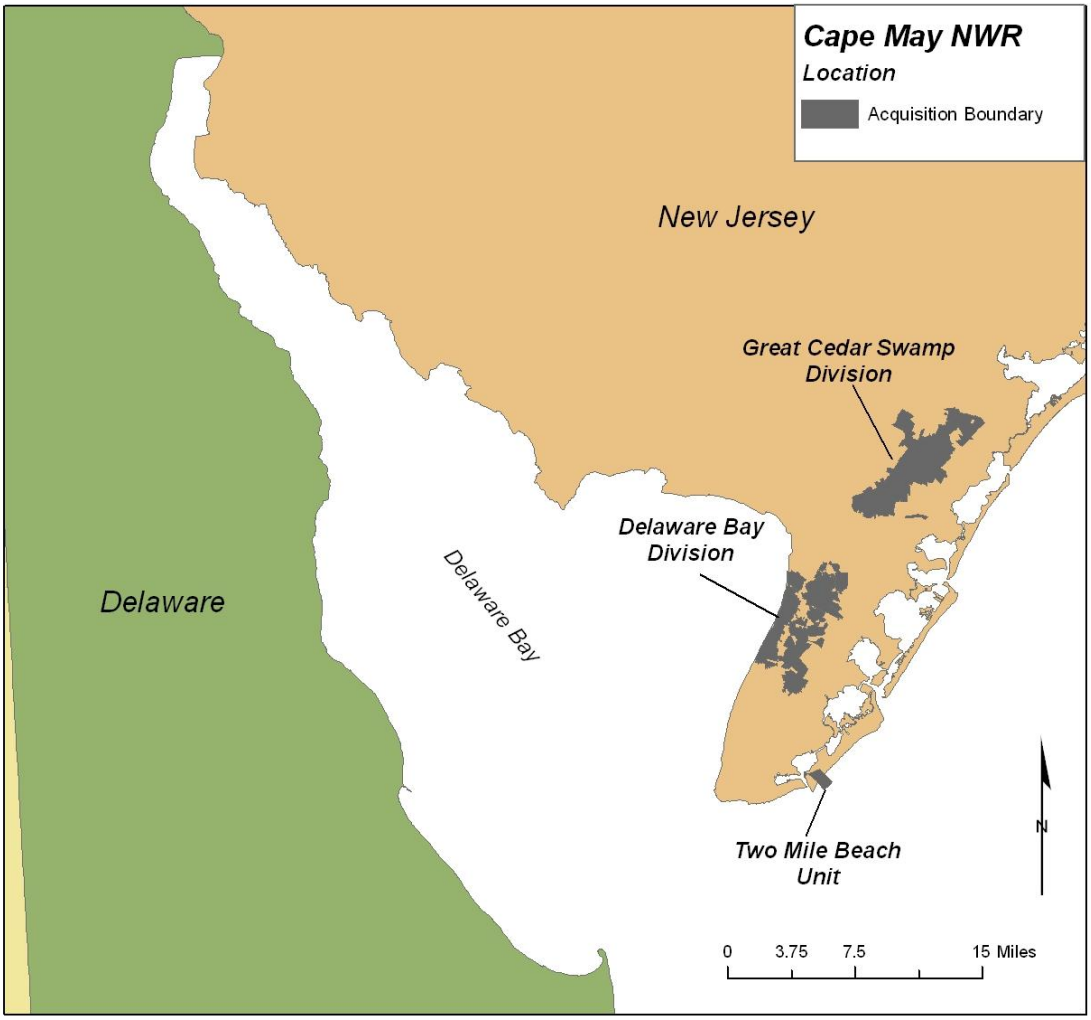

Figure 1: Location of Cape May National Wildlife Refuge, Cape May Courthouse, NJ.

4. WATER RESOURCES

4.1. *Rivers / Streams / Creeks*

The WRIA relies on U.S. Geological Survey 1:24,000 scale National Hydrography Dataset (NHD) to inventory streams at Cape May NWR (Table 1, Figure 2). The focus of the preliminary analysis is on named NHD features because they tend to be the largest and, theoretically, of most interest to Service facilities.

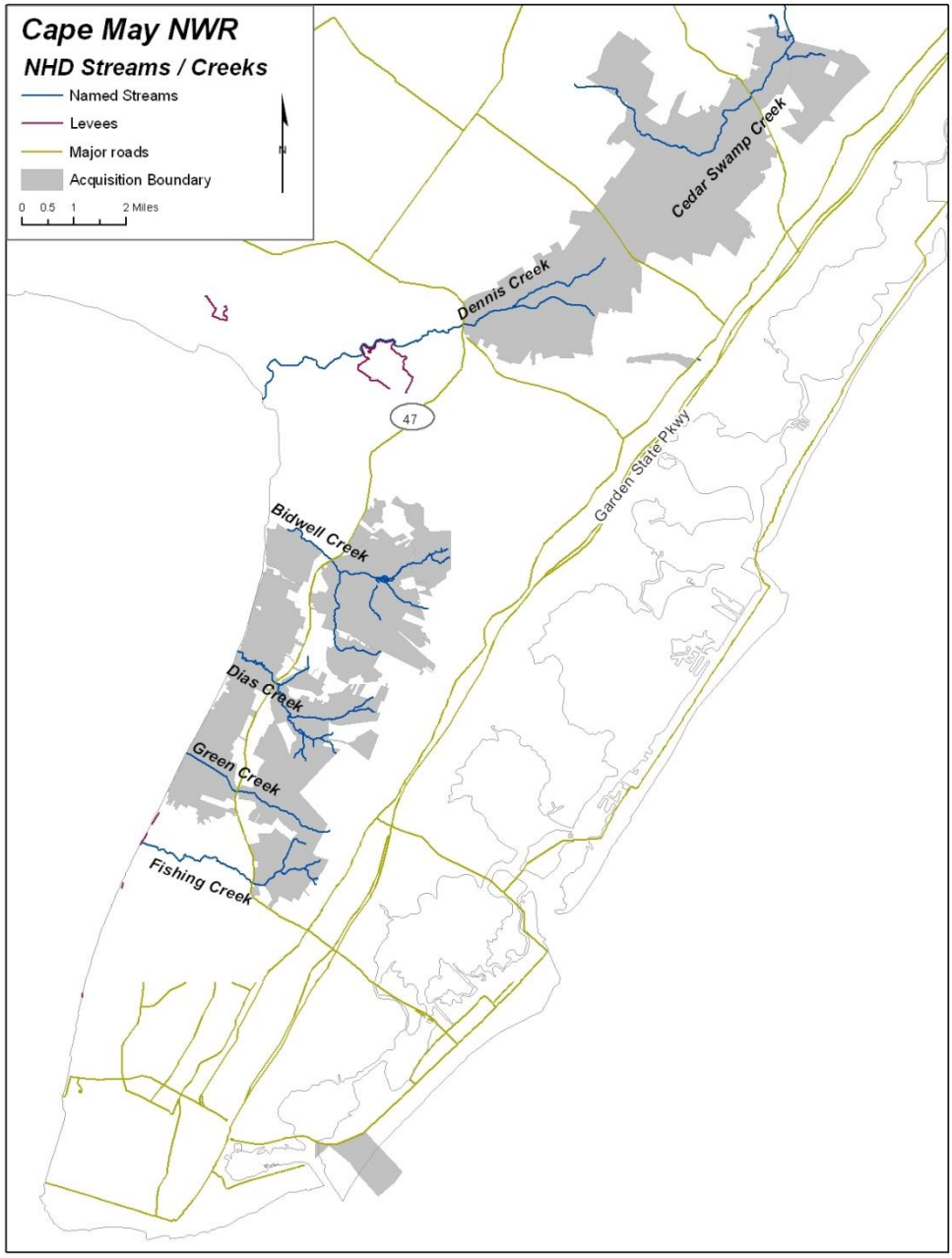

Figure 2: Named creeks or streams from the USGS National Hydrography Dataset on and within 0.1 mile of the Cape May National Wildlife Refuge approved boundary, Cape May County, NJ.

Table 1: Named creeks and streams from the USGS 1:24,000 National Hydrography Dataset. Includes features on or within 0.1 miles of Cape May's approved boundary. Miles above the estuary are calculated by measuring the stream length above the NWI estuarine wetland classification.

Stream Name	Miles in Acquisition Boundary	Miles Upstream of Estuary	% of Miles Upstream of Estuary
Bidwell Creek	11.0	2.5	23
Dias Creek	8.6	4.4	51
Cedar Swamp Creek	7.3	2.9	40
Dennis Creek	5.1	3.7	73
Green Creek	3.3	1.9	57
Fishing Creek	3.1	3.1	100
Total	***38.4***	***18.5***	***48***

For much of their length, Cape May County streams are considered estuaries with daily tidal fluctuations and brackish water. On many streams, tide gates, levees, low-head dams, and roads control how far brackish water extends upstream. The headwaters of streams on the Cape May peninsula are typically low-gradient seeps with poorly defined channels. The streams flow primarily towards Delaware Bay, with the exception of Great Cedar Swamp Creek which flows northeast into Great Egg Harbor Bay on the Atlantic Ocean.

Cape May County streams have a strong seasonal flow pattern (Figure 3). Flow peaks in March and April then gradually declines during the summer months. In many creeks flow may cease between July and October in particularly dry years.

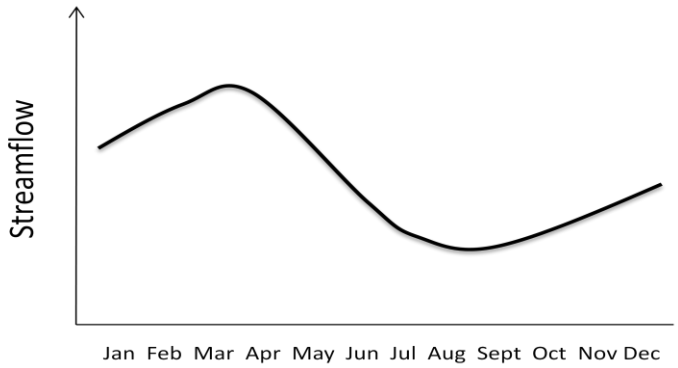

Figure 3: Conceptual hydrograph of a typical Cape May county stream. From Lacombe et al. 2009.

4.2 Lakes, Ponds, and Impoundments

Most open-water features at Cape May are man-made waterbodies. Many are sand and gravel pits that have filled with water, small drainages that have been dammed, or ponds that formed when roads blocked surface water runoff. For this preliminary analysis the WRIA focuses on named ponds and lakes in the NHD dataset (Table 2 and Figure 4).

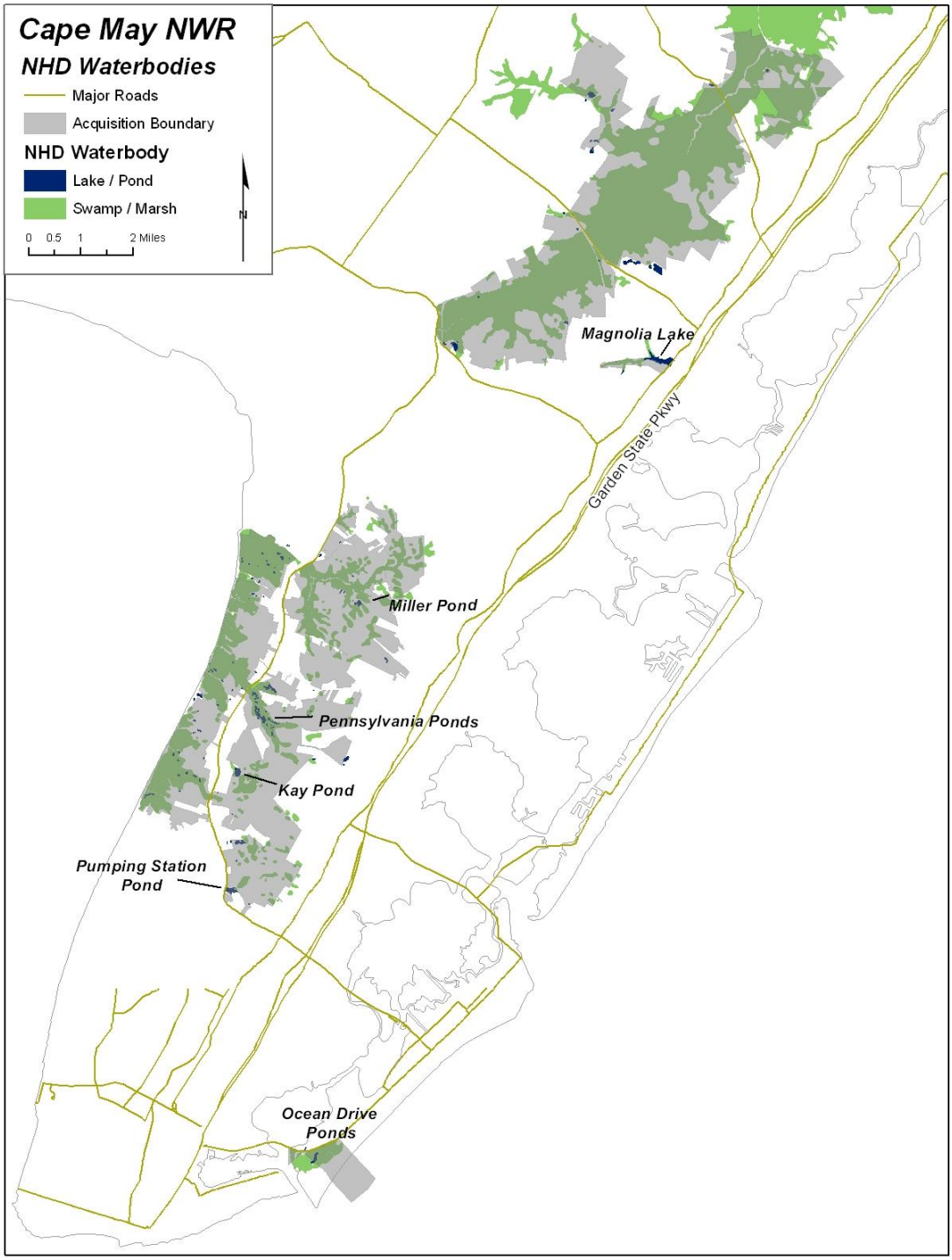

Figure 4: Lakes, ponds, impoundments, and swamp/marsh habitat identified in the 1:24,000 National Hydrography Dataset (NHD) on or within 0.1 miles of Cape May National Wildlife Refuge acquisition boundary, Cape May County, NJ.

Total acreage of the named ponds and lakes is 54 acres. The NHD dataset identifies an additional 131 ponds inside the acquisition boundary that have no name. These are mostly small features with an average size of 0.74 acres. Total acreage of named and unnamed ponds is approximately 174 acres, or 1.5% of the refuge's current land holdings (11,025 acres) and 0.8% of the land in the acquisition boundary (21,200 acres).

Table 2: Acreage of named ponds and swamp/marsh habitat identified in the USGS National Hydrograph Dataset. Includes features on or within 0.1 miles of Cape May NWR acquisition boundary.

Pond Name	Acres
Pumping Station Pond	8.6
Pennsylvania Ponds	6.9
Miller Pond	3.2
Magnolia Lake	27.7
Kay Pond	7.9
Unnamed Ponds	119
Total	***174***

4.3 National Wetland Inventory Wetlands

The National Wetland Inventory (NWI) is a branch of the U.S. Fish and Wildlife Service established in 1974 to provide information on the extent of the nation's wetlands (Tiner 1984). NWI produces maps of wetland habitat as well as reports on the status and trends of the nation's wetlands. Using the *Classification of Wetlands and Deepwater Habitats of the United States* (Cowardin et al. 1979) wetlands have been inventoried and classified for approximately 90% of the conterminous United States and approximately 34% of Alaska. Cowardin's classification places all wetlands and deepwater habitats into 5 "systems": marine, estuarine, riverine, lacustrine, and palustrine. Most of the wetlands in the United States are either estuarine or palustrine (Tiner 1984). The two predominant wetland classes at Cape May NWR are defined in Cowardin et al. (1979) as:

> **Estuarine:** the Estuarine System consists of deepwater tidal habitats and adjacent tidal wetlands that are usually semi-enclosed by land but have open, partly obstructed, or sporadic access to the open ocean . . . The Estuarine System extends (1) upstream and landward to where ocean-derived salts measure less than $0.5^{o}/_{oo}$ during the period of average annual flow; (2) to an imaginary line closing the mouth of a river, bay, or sound; and (3) to the seaward limit of wetland emergents, shrubs, or trees where they are not included in (2).
>
> **Palustrine**: the Palustrine System includes all non-tidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean derived salts is below $0.5^{o}/_{oo}$ (e.g., inland marshes, bogs, fens, and swamps)

The different systems can be broken down into subsystems, classes and hydrologic regimes based on the wetland's position in the landscape, dominant vegetation type, and hydrology.

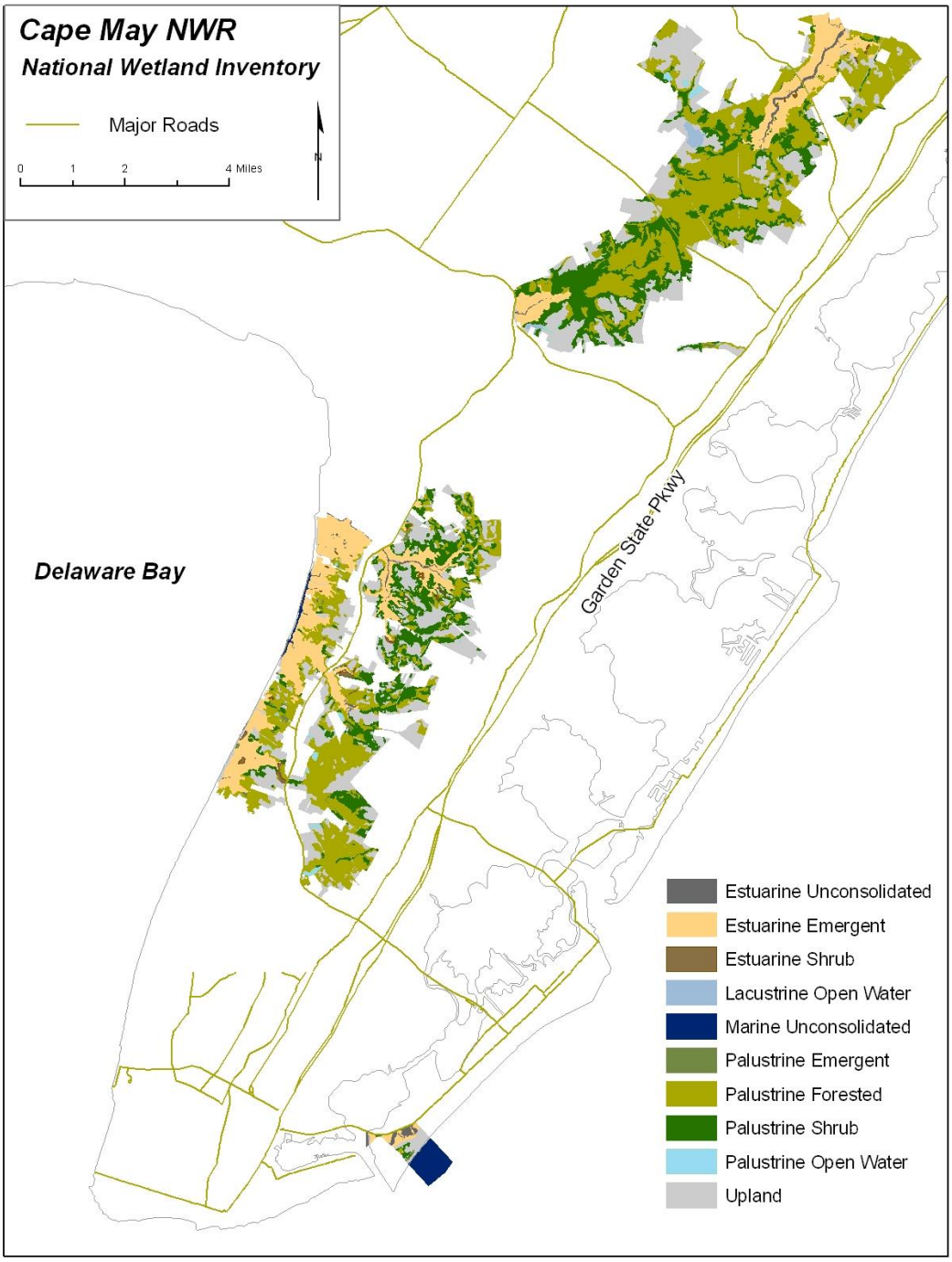

Figure 5: National Wetland Inventory wetlands in the Cape May NWR acquisition boundary, Cape May County, NJ.

Approximately 70% (15,275 acres) of the land in the acquisition boundary is considered wetland using NWI's classification. 73% (11,105acres) of the refuge's wetlands are considered freshwater wetlands (Palustrine). Forested and shrub-dominated freshwater wetlands are the largest wetland type in the acquisition boundary. Most of these are found in the Great Cedar Swamp Division and the headwaters of small streams flowing to Delaware Bay. Emergent salt marsh is the third most extensive wetland type and typical of the land in the Delaware Bay Division (Figure 5, Table 3).

Table 3: Wetland habitat delineated by the National Wetland Inventory inside the Cape May NWR acquisition boundary.

NWI	Alias	Acres	Percent of Total
Estuarine Unconsolidated	Mudflat	246	1.2
Estuarine Emergent	Emergent salt marsh	3,544	16
Estuarine Shrub	Shrub dominated salt marsh	95	0.4
Lacustrine	Lake, permanently flooded	83	0.4
Marine Unconsolidated	Beach / Sandbars	284	1.3
Palustrine Emergent	Freshwater emergent marsh	71	0.3
Palustrine Forested	Forested Wetland	7,114	33
Palustrine Shrub	Shrub-dominated wetland	3,732	17
Palustrine Unconsolidated	Ponds	105	0.5
Upland		6,138	29
Total Wetland Acres		***21,413***	***100***

4.4 Vernal Pools

The New Jersey Department of Fish and Wildife, Endangered and Nongame Species Program (ENSP) considers vernal pools important wetland habitat in New Jersey. ENSP defines them as:

- A confined basin/depression lacking a permanent outlet
- Harbor documented obligate or facultative vernal habitat species (as identified in N.J.A.C. 7:7A, Appendix 1)
- Maintains water for at least two continuous months between March and September of a normal rainfall year
- The area is free of fish populations, or dries up at some time during a normal rainfall year.

The absence of fish reduces predation which makes vernal pools ideal habitat for amphibians, some of which are endemic to New Jersey pools. ENSP estimates there are 3,000 – 5,000 vernal pools in New Jersey and began to inventory them in 2002. The inventory effort relied on remote sensing techniques to identify possible vernal pool locations coupled with field visits to verify the presence or absence of pools. ENSP data

indicates there are 150 potential vernal pool sites located within 0.1 mile of the refuge's acquisition boundary (Figure 6).

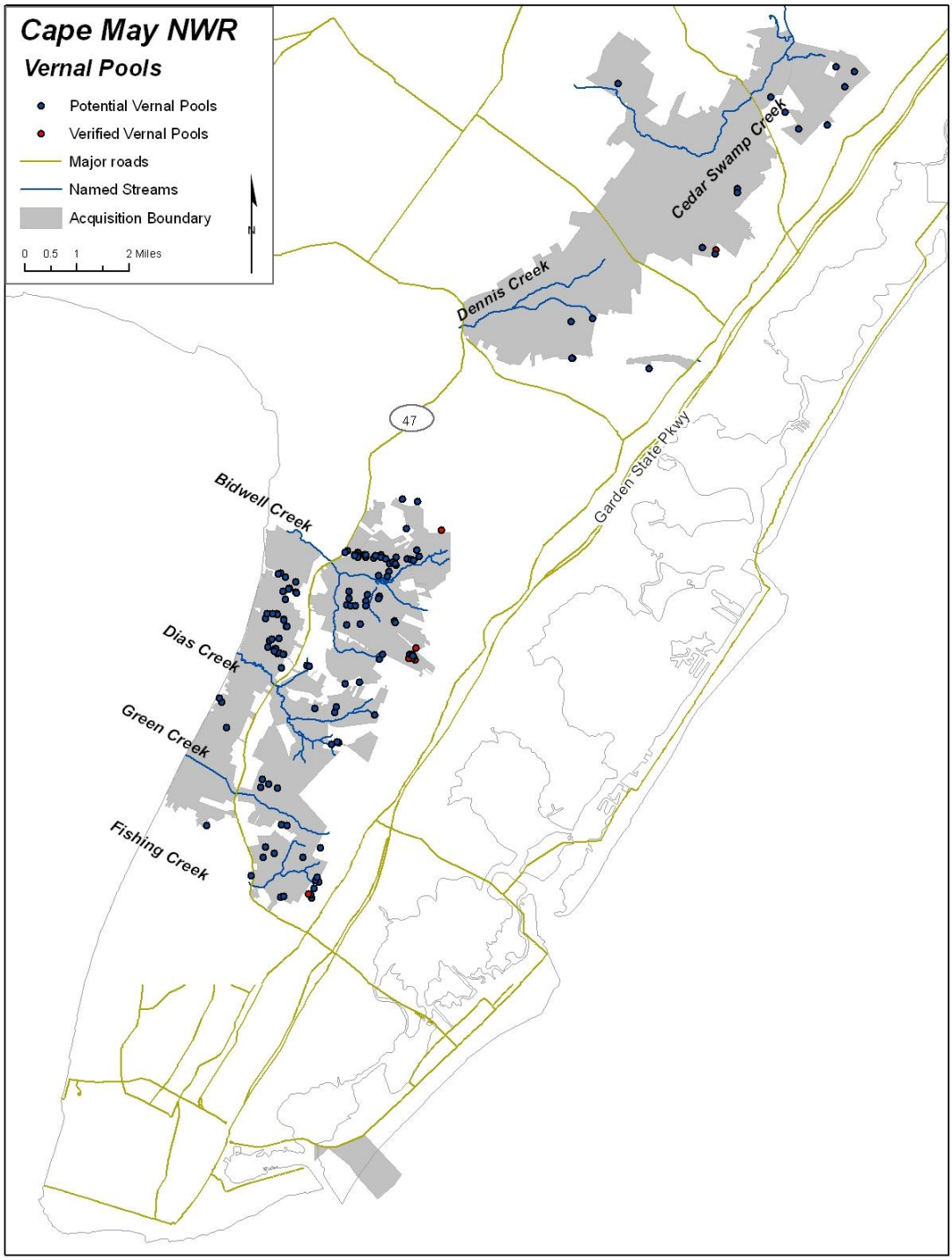

Figure 6: Location of potential and confirmed vernal pools in the NJDEP Endangered and Nongame Species Program database within 0.1 miles of the Cape May NWR acquisition boundary.

Twelve (8%) of the 150 possible sites are confirmed vernal pools. The remainder were identified using remote sensing techniques and need site visits to verify whether or not they are pools.

5. GROUNDWATER RESOURCES

Cape May overlies the Northern Atlantic Coastal Plain Aquifer System. The aquifer is described generally in the USGS ground water atlas of the United States (Trapp and Horn 1997). More detailed analysis of the peninsula's groundwater aquifers is discussed in USGS Water Resources Investigation Report 01-4246 (Lacombe and Carleton 2002) and USGS Scientific Investigations Report 2009-5187 (Lacombe et al. 2009).

In general the aquifer system under the Cape May Peninsula is comprised of unconsolidated gravel, sand, and silt separated by layers of less permeable silts and clays. Groundwater aquifers used for public water supply are found in the sand and gravel deposits between the silts and clays. The aquifer names, from shallowest to deepest are: Holly Beach water-bearing zone, Estuarine sand aquifer, Cohansey aquifer, Rio Grande water-bearing zone, and Atlantic City 800 foot sand (Figure 7).

Groundwater supplies more than 90% of the water used for municipal, agricultural, and industrial uses in Cape May County (Domber et al. 2006). The widespread use of groundwater has led to water level declines and saltwater intrusion in the county's aquifers. As a result, Cape May County has the distinction of being the first location in the nation to desalinate seawater for public water supply and implement aquifer storage and recovery techniques in water supply well fields (Lacombe and Carleton 2002). Cape May NWR does not rely on groundwater to maintain refuge habitat, however there is concern that groundwater pumping could detrimentally affect refuge wetlands.

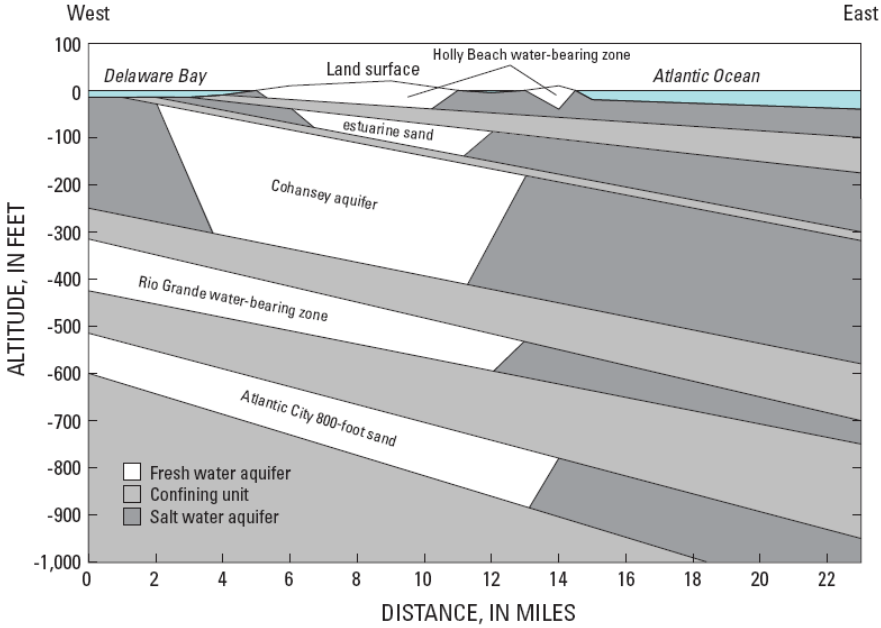

Figure 7: Conceptual model of aquifers under the Cape May Peninsula, New Jersey. From Lacombe et al. (2009, p.10).

In order for groundwater development to affect wetlands there must be; 1) a physical connection between the aquifers in Figure 7 and refuge wetlands and, 2) groundwater pumping must be lowering the water level in the aquifer connected to the wetlands. On the Cape May Peninsula refuge wetlands are in direct connection with the Holly Beach water bearing zone (Figure 7). Therefore activities that lower the water table in the Holly Beach water bearing zone are more likely to affect refuge wetlands and streams than activities in deeper aquifers like the Atlantic City 800-foot sand.

Water in the Holly Beach moves laterally from the center of the peninsula to Delaware Bay and the Atlantic Ocean (Lacombe and Carleton 2002). In places where this lateral groundwater movement intersects the ground surface, groundwater exits the aquifer and enters local streams and wetlands. These places are known as zones of groundwater discharge and are often found at the headwaters of streams or in wetlands at the toe of small scarps (Winter 1998). Evidence of groundwater discharge includes seeps, springs, and year-round saturated soil conditions (Mitsch and Gosselink 2000). Groundwater discharge zones can be important because they often harbor unique plants and animal species. Although a complete review of groundwater discharge areas at Cape May NWR is beyond the scope of this report, Lacombe and Carleton (2002) suggest groundwater discharge is an important component of freshwater inputs to the peninsula's streams and wetlands. For example, in the Tuckahoe River nearly 80% of the river's annual flow is contributed by groundwater discharge.

Lacombe and others (2009) evaluated the impact of existing groundwater development and future groundwater development plans on Cape May County aquifers. In the report, there is evidence suggesting high volume groundwater pumping in deep aquifers like the Cohansy, may locally affect streams and freshwater wetlands on the Cape May peninsula. For instance, the authors noted that vernal pools near municipal well fields tend to dry earlier than vernal pools far from well fields. Additionally, models of future groundwater use scenarios show non-tidal freshwater streamflow decreases as groundwater pumping increases. However, the report's author suggests more monitoring should be done before drawing definitive conclusions about the effects of pumping on refuge wetlands (Lacombe personal communication). If groundwater pumping is having an impact on refuge wetlands it will most likely be in portions of the Delaware Bay Division near the Wildwood Water Utility well field.

6. WATER RELATED INFRASTRUCTURE

Water related infrastructure refers to the assets at a refuge that create or support refuge water resources and objectives. Examples include impoundments for waterfowl habitat, water control structures and water supply wells used to maintain wetland habitat. Many of these types of features are accounted for in the National Wildlife Refuge System's SAMMS database. The aim of the WRIA is to summarize information and provide additional context on a refuge's water resource infrastructure.

Cape May NWR does not have any water-resource related infrastructure, primarily because the refuge does not manage waterfowl impoundments. Refuge wetlands are tidally influenced or have a natural hydrologic regime that is not being manipulated by refuge staff using infrastructure such as dikes, water control structures, or water supply wells. Other infrastructure that affects water resources in the vicinity of the Cape May NWR is discussed below.

6.1 Southern New Jersey Levee Inventory

Levees were constructed in Cape May County as much as 200 years ago to facilitate grazing and salt hay harvesting in low lying areas. A recent inventory of levees in southern New Jersey did not identify any levees on refuge property (NRCS 2010). Levees did exist on Green Creek, however it was breached in the mid-1990s to re-establish tidal inundation. The closest off-refuge levees are found on Fishing Creek and Dennis Creek (see Figure 2).

6.2 Mosquito Control Ditches

Grid ditching salt marshes was a common practice for limiting mosquito populations on the U.S. East Coast in the 1920s and 30s. Although the practice is no longer an accepted tool for mosquito control, grid ditches continue to affect water levels and the biotic community in estuarine wetlands (James-Pirri et al. 2008). Data in the USGS 1:24,000 NHD dataset illustrate the extent of grid ditching in the Delaware Bay Division of Cape May NWR (Figure 8).

The Cape May County Department of Mosquito Control uses a variety of techniques to control mosquito populations in the county. These methods include use of insecticides, introduction of mosquito eating fish, and water management strategies known as open marsh water management (OMWM). OMWM practices are designed to physically alter grid-ditched marshes so there is less habitat for mosquito larvae and egg deposition. In the mid-90s the Cape May Mosquito Control implemented OMWM strategies on salt marshes on Green Creek, Dias Creek and Bidwell Creek (Sokorai personal communication)

6.3 Wildwood Water Utility Well Field

The Service recently acquired land near Pumping Station Pond where the Wildwood Water Utility (WWU) operates a network of 9 production wells. The wells in the well field remove approximately 1,300 million gallons per year from the Cohansy, estuarine sand, and Rio Grande aquifers. Water from the well field supplies drinking water to 4 communities in Cape May County and water demand typically peaks during the summer months (Domber et al. 2006). The impact of pumping on the refuge's wetlands is not well quantified. However, this well field is one of the largest pumping centers in the county and the 2009 USGS report suggests water levels in vernal pools near the WWU might be influenced by groundwater pumping in the summer months.

6.4 Culverts, Tide Gates, Dams

Review of existing literature suggests there are numerous structures like old levees, tide gates, culverts, and small dams restricting flow on both tidal and non-tidal sections of Cape May County streams. In some cases this infrastructure controls the upstream extent of saline water in stream channels. Alternatively it may cause flooding by restricting the downstream movement of runoff. Although it was beyond the scope of the WRIA to inventory these sites, it would be beneficial for the Service to inventory infrastructure like this that influences refuge water resources. Modifications and upgrades to some of these sites may help restore the natural hydrologic regime of refuge water resources. Additionally, this infrastructure may be important for mitigating the impacts of saltwater intrusion on freshwater wetlands.

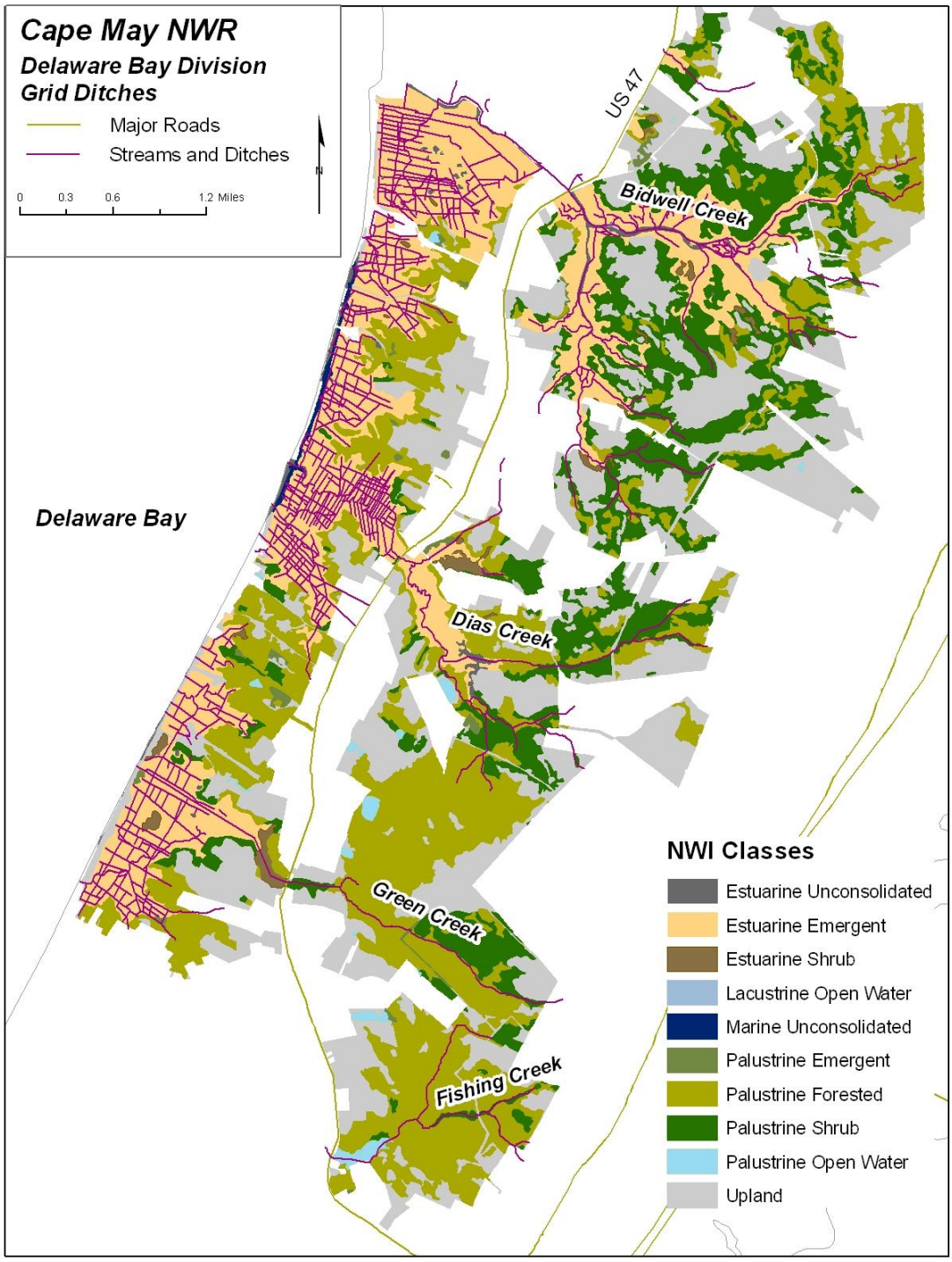

Figure 8: Extent of grid ditches in estuarine wetlands of the Delaware Bay Division of Cape May NWR. Ditch network is from the USGS 1:24000 National Hydrographic Dataset.

7. WATER QUALITY

Water quality information included in the WRIA is derived from the Reach Access Database (RAD) maintained by the U.S. Environmental Protection Agency (EPA). Additional data is publically available at the EPA's "Envirofacts" website. These databases were used to collect information on listed waters and National Pollutant Discharge Elimination System (NPDES) permits in and around Cape May National Wildlife Refuge (Figure 9, Tables 4 and 5).

Section 303(d) of the Clean Water Act requires that each state identify water bodies where water quality standards are not met. New Jersey Department of Environmental Protection (NJDEP) develops lists of known water quality limited rivers and lakes. Three streams at Cape May NWR are identified as impaired waterbodies in New Jersey's 303(d) list (Table 4). Although the entire length of listed streams are mapped, most of the water quality sampling on these creeks takes place in the tidal estuaries. Therefore water quality impairment may be more acute in the off-refuge, estuarine reaches than the on-refuge headwaters.

Table 4: Listed waterbodies at the Cape May National Wildlife Refuge. From EPA RAD database.

List ID	Waterbody Name	Latest Listing	Impairment
NJ-15-0014_Tuckahoe_River_Estuary	Cedar Swamp Creek	2004	Total Coliform
NJ-16-0019-Dennis_Creek_Estuary	Dennis Creek	2004	Total Coliform
NJ-02040206230040-AN0770	Green Creek	2004	Impaired Biota

Total Coliform is a measure of pathogens that can be harmful to human health. Elevated levels of pathogens are associated with concentrated stormwater runoff, septic system outfall, and marina discharges. The reason Green Creek has impaired biota is unknown. The listing may be based on an aquatic organism survey that showed low species diversity or high numbers of organisms able to tolerate polluted waters.

NPDES permits are issued to businesses by NJDEP to regulate the quality and quantity of pollutants discharged into waters of the United States. Stormwater and treated wastewater are two examples of discharges regulated under the NPDES program. NPDES permits the EPA's RAD database within 0.5 miles of Cape May's acquisition boundary are illustrated in Figure 9 and Table 5. It is expected that wastewater discharged under these permits finds its way into rivers and groundwater that are inside the boundary of Cape May NWR. The complete list of NPDES permits is available through the EPA's Permit Compliance System database, more detailed review of all the permits in the vicinity of the refuge is beyond the scope of this document.

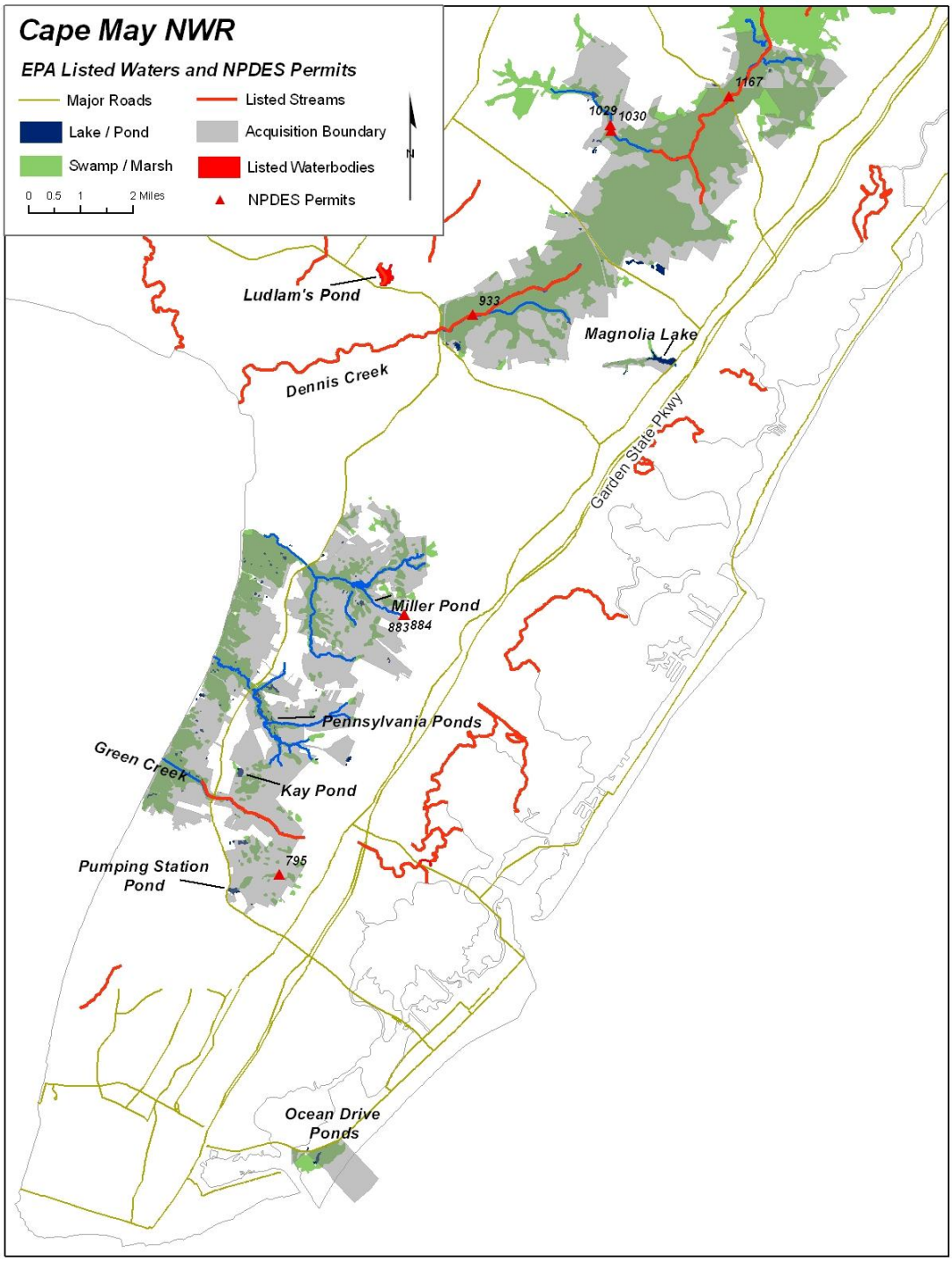

Figure 9: EPA listed waters and NPDES permits from EPA's RAD database in and around the Cape May National Wildlife Refuge.

Table 5: NPDES permits listed in the EPA's Reach Address Database (RAD) within 0.5 miles of Cape May National Wildlife Refuge acquisition boundary.

NPDES-ID	Figure 5 ID	NAME	Receiving Water
NJ0156175	1167	Seashore Asphalt Corp	Cedar Swamp Creek
NJ012954	1030	Upper Township Sand & Gravel	Cedar Swamp Creek
NJ0137278	1029	Penn Jersey Building Materials	Cedar Swamp Creek
NJ0150291	933	Dennis Township	Dennis Creek
NJ0137626	882	Raff Recycling International	Not clear from online info
NJ0163350	883	Albrecht & Huen Inc.	Not clear from online info
NJ0146838	795	Clarks Moving & Storage	Not clear from online info

Water quality concerns at Cape May NWR were summarized in the 2005 Contaminants Assessment Report prepared by the New Jersey Ecological Services Field Office. The report concludes that non-point source discharges like stormwater runoff and septic system outfalls are the greatest water quality concerns at Cape May NWR (USFWS 2005). Review of the available information in the WRIA report supports this conclusion. Although development in Cape May County is not as dense as other portions of the state, the numerous roads and suburban development help transmit pollutants and serve to fragment the wetland habitat on the refuge.

8. WATER RESOURCES MONITORING

WRIAs identify water-related monitoring that is taking place on, or near, wildlife refuges and fish hatcheries. For this preliminary review, the WRIA collects information stored in the USGS National Water Information System (NWIS) database. Water monitoring can be broadly categorized as either water quality or water quantity focused. Water quality monitoring typically consists of collecting surface water or groundwater samples for chemical analyses in a laboratory or with sensors deployed in the field. Alternative protocols may use techniques such as aquatic invertebrate sampling as a proxy for water quality. Water quantity monitoring typically includes the flow rate in a stream or the water level in a groundwater aquifer. WRIAs also consider weather stations and tide gages as other types of water-related monitoring.

8.1 Water Quantity Monitoring

A variety of federal, state, and local agencies conduct water monitoring near Cape May refuge (Table 6 and Figure 10). There are at least 23 water quantity monitoring sites near the refuge in Cape May County. Fifteen of these sites track water levels in aquifers beneath the peninsula. Although, the list below is the best collection of known monitoring near Cape May NWR it should not be considered complete.

In addition to the list in Table 6, the USGS maintained several temporary stream gages and vernal pool water monitoring wells to support the 2009 investigation of groundwater

conditions in Cape May County. The closest temporary stream gages to the refuge were on Dennis Creek, Bidwell Creek, Dias Creek, and Fishing Creek (Lacombe et al. 2009 p. 50).

Table 6: Water quantity monitoring sites in Figure 10. USGS = U.S. Geological Survey, NOAA = National Oceanic and Atmospheric Administration, NIFC = National Interagency Fire Center. See Figure 7 for aquifer location information. Hyperlinks were last accessed on 1/3/2011.

ID in Figure 10	Site ID	Type	Agency	Aquifer
0	USGS - 01411300 Tuckahoe River	streamflow	USGS	n/a
1	385616074580001 - 090020-- Traffic Circle Obs	groundwater	USGS	Holly Beach
2	385607074555201 - 090150-- West Cape May 1 Obs	groundwater	USGS	Cohansy
3	385804074574201 - 090049-- Higbee Beach 3 Obs	groundwater	USGS	Cohansy
4	385748074553301 - 090048-- Canal 5 Obs	groundwater	USGS	Cohansy
5	385709074512801 - 090302-- Coast Guard 800 Obs	groundwater	USGS	Kirkwood
6	390002074541002 - 090304-- Airport Rio Grande Obs	groundwater	USGS	Kirkwood
7	390058074542701 - 090060-- Airport 7 Obs	groundwater	USGS	Cohansy
8	390156074533401 - 090333-- Pump Pond N Obs	groundwater	USGS	Holly Beach
9	390211074505501 - 090080-- Cape May 42 Obs	groundwater	USGS	Cohansy
9*	390211074505502 - 090081 -- Cape May 23 Obs	groundwater	USGS	Holly Beach
10	390012074472001 - 090337-- N Wildwood 800 Obs	groundwater	USGS	Kirkwood
11	390422074544701 - 090306-- Oyster 800 Obs	groundwater	USGS	Kirkwood
12	390608074483801 - 090099-- Cape May Co Pk 8 Obs	groundwater	USGS	Cohansy
13	391145074520401 - 090510-- Belleplain MW44	groundwater	USGS	Cohansy
14	391621074435401 - 090186-- Ac 14 Obs	groundwater	USGS	Cohansy
15	USGS 01411390	tidal	USGS	n/a
16	USGS 01411360	tidal	USGS	n/a
17	USGS 01411350	tidal	USGS	n/a
18	USGS 01411355	tidal	USGS	n/a
19	USGS 01411435	tidal	USGS	n/a
20	NOAA 8536110 - Cape May, NJ	tidal	NOAA	n/a
21	USGS 385655074532601	weather	USGS	n/a
22	RAWS - Woodbine, NJ	weather	NIFC	n/a

NOTE: Kirkwood refers to the geologic formation below the Cohansy aquifer. Aquifers in this location include the Rio Grande water bearing zone and the Atlantic City 800 foot sand.

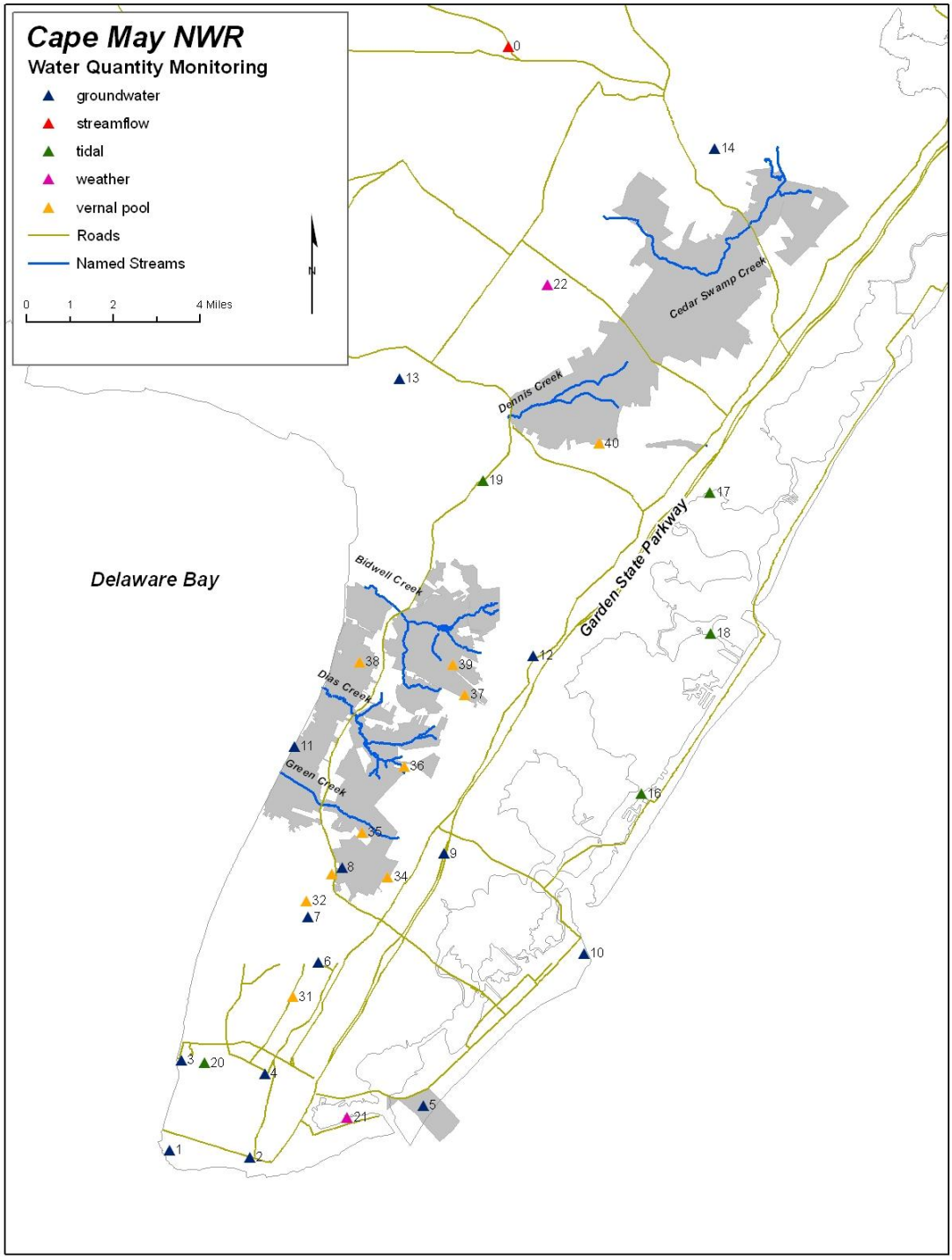

Figure 10: Location of water quantity monitoring sites near Cape May NWR, NJ. Additional information on these sites is listed in Table 6.

8.2 Vernal Pool Water Level Monitoring

Vernal pool monitoring sites identified in Figure 10 were established by Pierre Lacombe at the USGS New Jersey Water Science Center. Monitoring sites consist of a ¾" diameter well installed near the deepest section of the vernal pools. Data from these sites was used to compare the duration that pools were flooded (Lacombe et al. 2009). These sites are not actively monitored but could be incorporated into future abiotic monitoring efforts at the refuge.

Table 7: List of vernal pool monitoring sites established by Pierre Lacombe for 2009 report on Cape May county water supplies.

ID in Figure 10	Name	On refuge property?
31	Bennet's Bog	no
32	Lower Township Landfill	no
33	Wildwood Well field	no
34	Atlantic Electric	no
35	ZigZag Road	no
36	Mid Township Landfill	no
37	W. of Mid Twp Maintenance	yes
38	Kimbel Road	yes
39	Tick Neck Rd.	yes
40	S. Dennis Oceanview Rd.	yes

8.3 Water Quality Monitoring

NWIS contains 43 water quality monitoring records within 0.5 miles of the Cape May NWR acquisition boundary (Figure 11). Of the 43 sampling sites, 38 (88%) were collected from groundwater wells.

The NWIS database includes sites where samples are collected regularly and sites that may have been sampled once. Of the 43 samples in Figure 11, 32 (74%) were sampled less than 10 times. Only USGS site 01411400 on Fishing Creek at Rio Grande might be considered a long-term record with 82 samples collected since 1997.

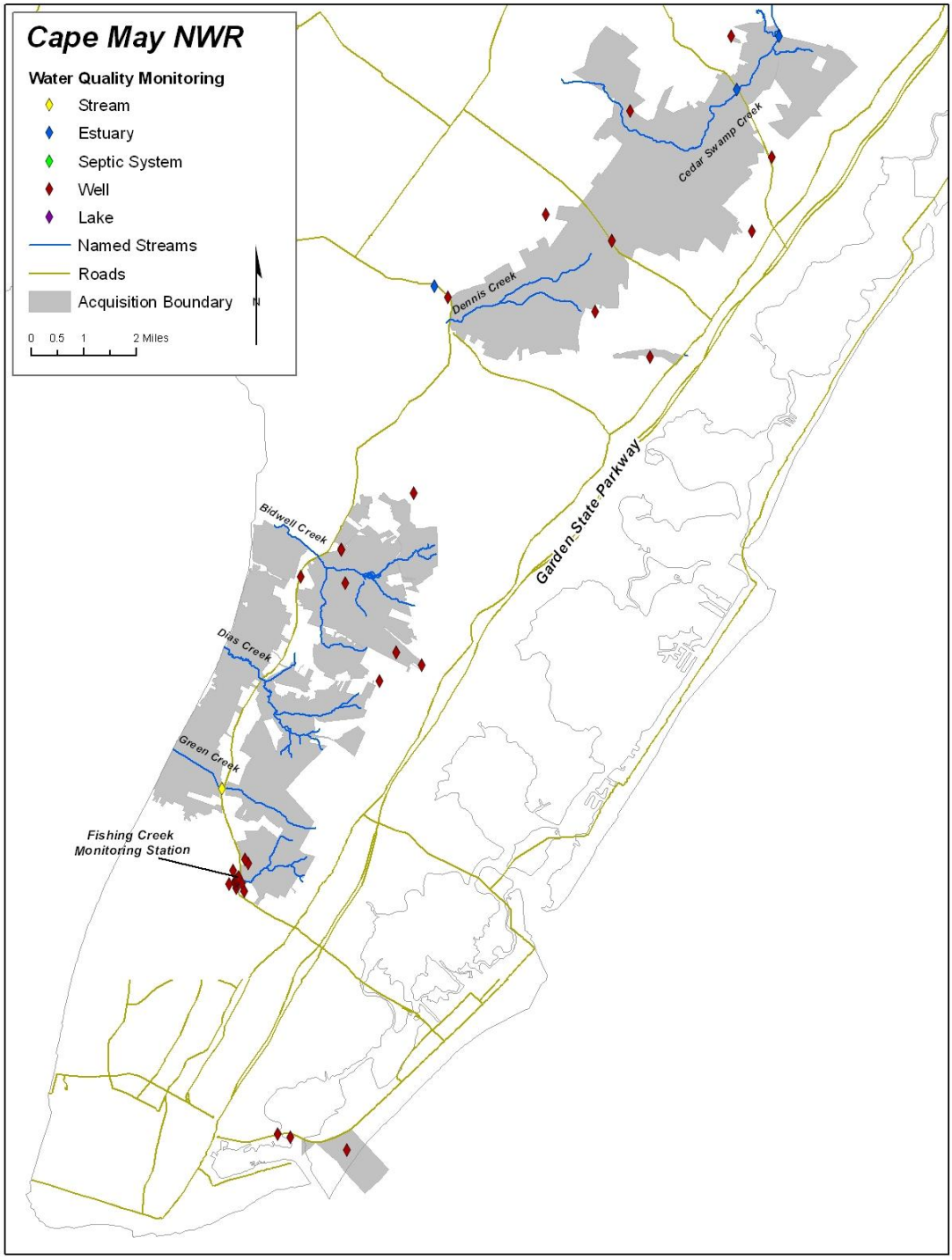

Figure 11. Location of water quality monitoring sites within 0.5 miles of Cape May NWR.

Given the importance of groundwater resources for Cape May municipalities, it is not surprising there are numerous active groundwater monitoring sites near the refuge. However, the current suite of monitoring sites does not appear to focus on wetland or headwater stream habitat that is dependent on groundwater discharge from the Holly

Beach water bearing zone. Initiating water monitoring in streams or wetlands dependent on groundwater discharge could help determine how sensitive these habitat are to existing and proposed groundwater development.

9. LONG-TERM CLIMATE PATTERNS

A variety of datasets exist that can be used to evaluate long-term climate trends at refuges in Region 5. Some of these data are included in the WRIA to provide a preliminary analysis of trends in precipitation, temperature, and stream runoff. Data were analyzed for trends using the nonparametric Mann-Kendall statistical test. This test can be used to determine if there is a linear trend in a dataset and whether or not that trend is statistically significant ($P < 0.05$) (Helsel and Hirsch 2002).

9.1 U.S. Historical Climatology Network (USHCN)

The USHCN is a network of climate monitoring sites maintained by the National Weather Service. Sites in the network are selected because their location and data quality make them well suited for evaluating long-term trends in regional climate. The closest site to Cape May National Wildlife Refuge is located in Atlantic City, NJ. Data from the site illustrates trends in precipitation and air temperature in coastal New Jersey from 1925 to the present (Figures 12-14).

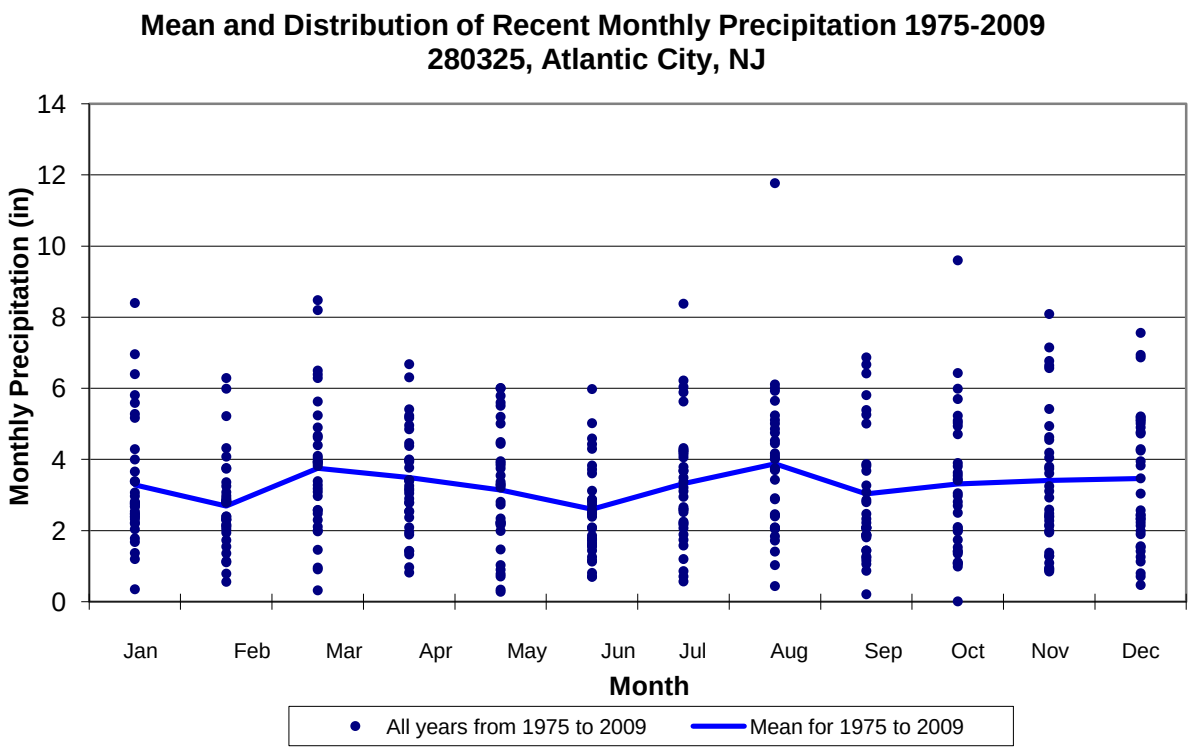

Figure 12: Distribution of total monthly precipitation at USHCN site 280325 in Atlantic City, NJ: 1975-2009.

Trends presented in Figure 12:

- Relatively uniform precipitation distribution across the year. No obvious trend in seasonal precipitation patterns.
- Average monthly precipitation in Atlantic City is 3.3 inches
- Average annual precipitation total for the year is 38.9 inches

Precipitation patterns were evaluated by calculating the difference between each year's average precipitation and the average for all years. Presented as a percent, this approach can be used to identify years of above average, or below average, precipitation (Figure 13).

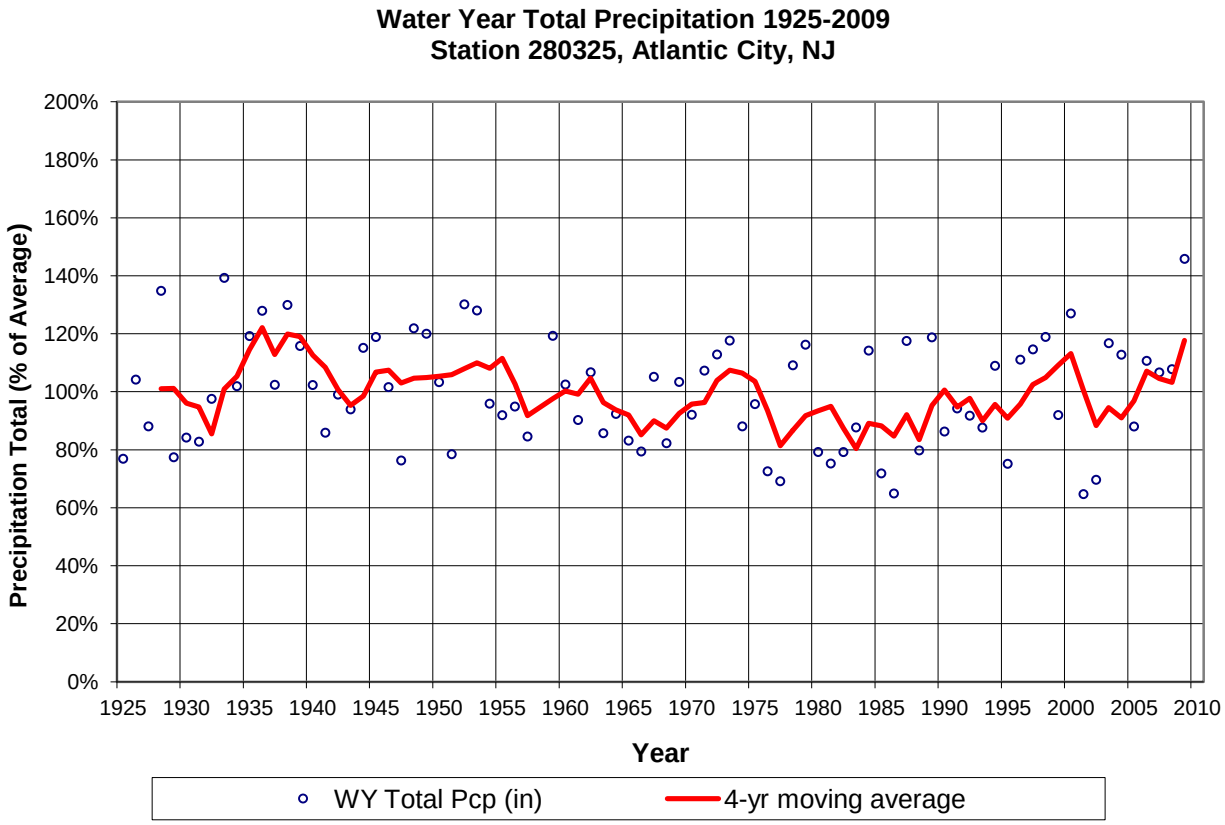

Figure 13: Percent of total Water Year precipitation at the Atlantic City, NJ USHCN site between 1925 and 2009. The Water Year is from 10/1 – 9/30 of each year.

Trends presented in Figure 13:

- The period between 1975 and 1995 was an extended period of below average precipitation.
- Between 1935 and 1955 is an extended period of above average precipitation.
- Data in Figure 13 suggest a slight decreasing trend in precipitation totals over the period of record.

Monthly temperatures at the Atlantic City, NJ USHCN site were also reviewed to identify any patterns in air temperature since 1925 (Figure 14).

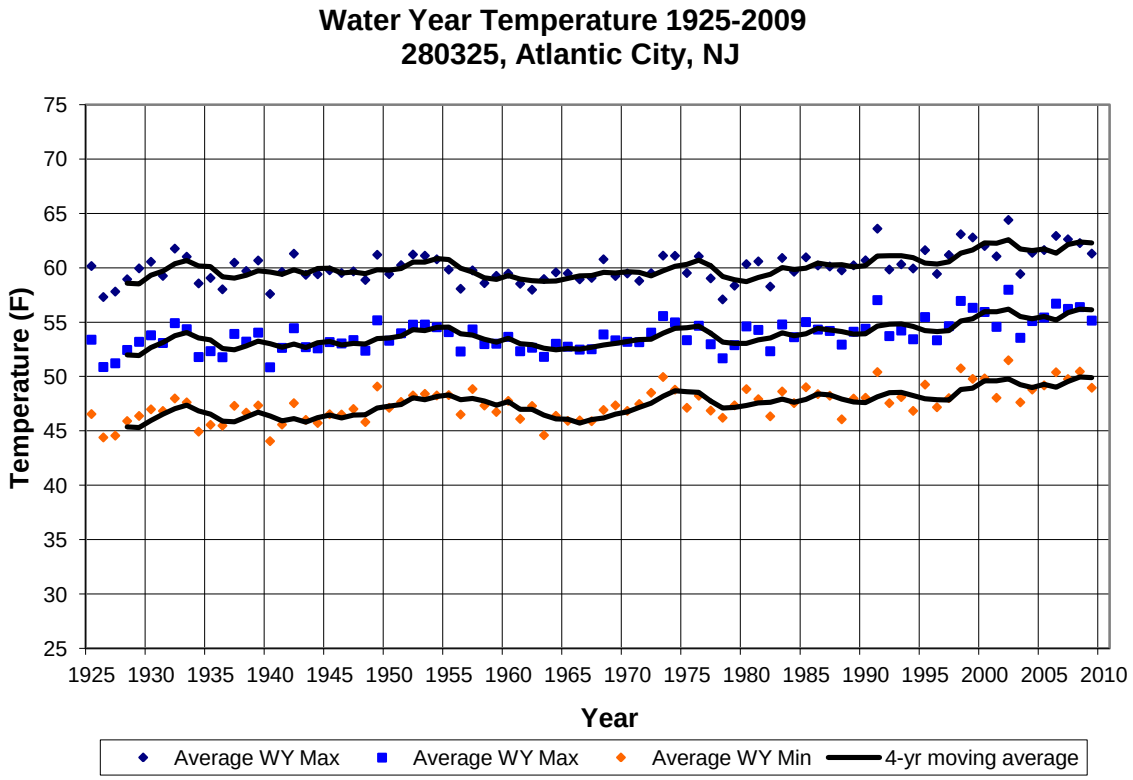

Figure 14: Average temperatures for the Water Year: 1925 – 2009 at the USHCN station in Atlantic City, NJ. The Water Year extends from 10/1 – 9/30 of a year.

Trends presented in Figure 14:

- Average water year maximum temperatures have increased approximately 0.03 °F / year during the period of record (statistically significant trend).
- Average water year mean temperatures have increased approximately 0.03 °F / year during the period of record (statistically significant trend).
- Average water year minimum temperatures have increased approximately 0.04 °F / year during the period of record (statistically significant trend).

Maximum, mean, and minimum water year temperatures measured at the Atlantic City, NJ USHCN station have a statistically significant increase since 1925. These increases agree with studies showing global temperatures are rising (Bates et al. 2008) and regional studies showing increasing air temperatures in the mid-Atlantic region of the United States (Polsky et al. 2000).

9.2 USGS Hydro-Climatic Data Network (HCDN)

The HCDN is a network of USGS stream gaging stations that are considered well suited for evaluating trends in stream flow conditions. Sites in the network have periods of record that exceed 20 years and are located in watersheds that are relatively undisturbed by surface water diversions, urban development, or dams.

The closest HCDN stream flow gage near Cape May National Wildlife Refuge is located on the Great Egg Harbor River near Folsom, NJ. Although the station has a record that begins in 1925 it is sufficiently far enough away from the refuge that it is more appropriate to review the record from Tuckahoe River stream gage near the refuge's Great Cedar Swamp division (see Figure 7). Lacombe et al. (2009) use this gage as a reference to evaluate flow conditions in the other rivers on the Cape May peninsula (Figure 15). The runoff patterns at the stream gage on the Tuckahoe are thought to reflect typical runoff patterns in creeks near the refuge, like Bidwell Creek, Dias Creek and Dennis Creek.

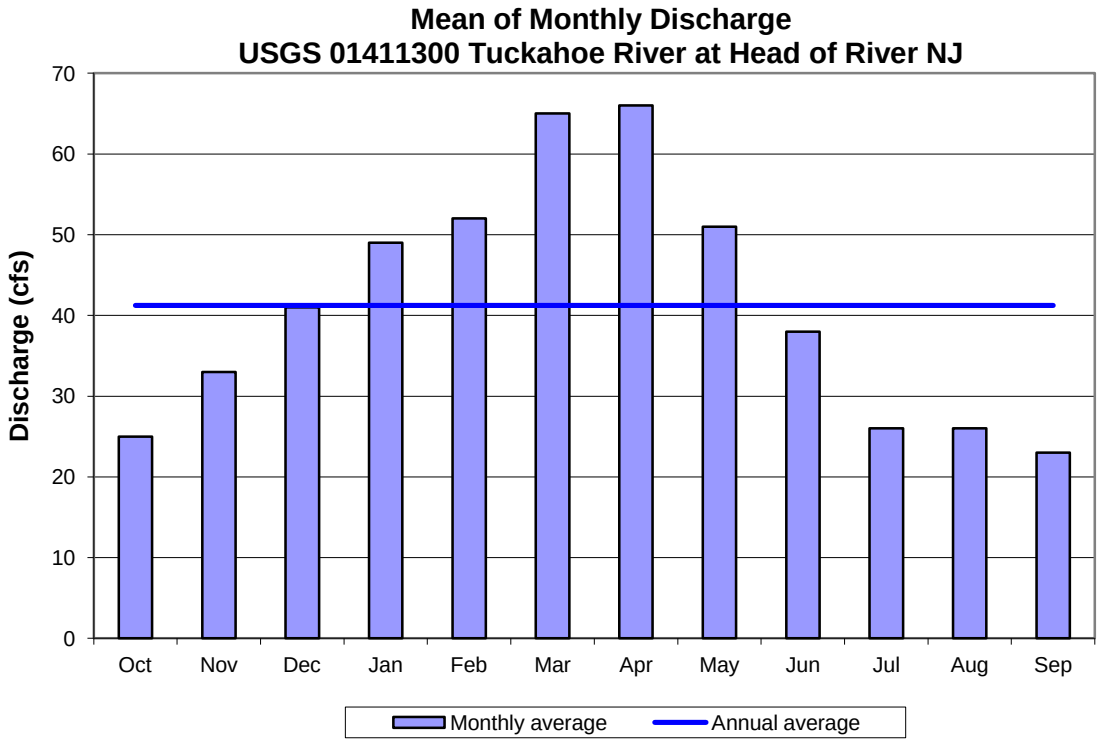

Figure 15: Average monthly discharge on the Tuckahoe River near Head of the River, NJ 1970-2009

Trends presented in Figure 15:

- Highest flows occur during the late winter and early spring. Typically peaking in March or April of each year.
- Lowest flow conditions of the year occur in the summer months.
- Average mean monthly discharge for the year is approximately 42 cfs.

Flow patterns were evaluated by calculating the difference between each year's average discharge and the average for all years. Presented as a percent, this approach can be used to identify years of above average, or below average, runoff (Figure 16).

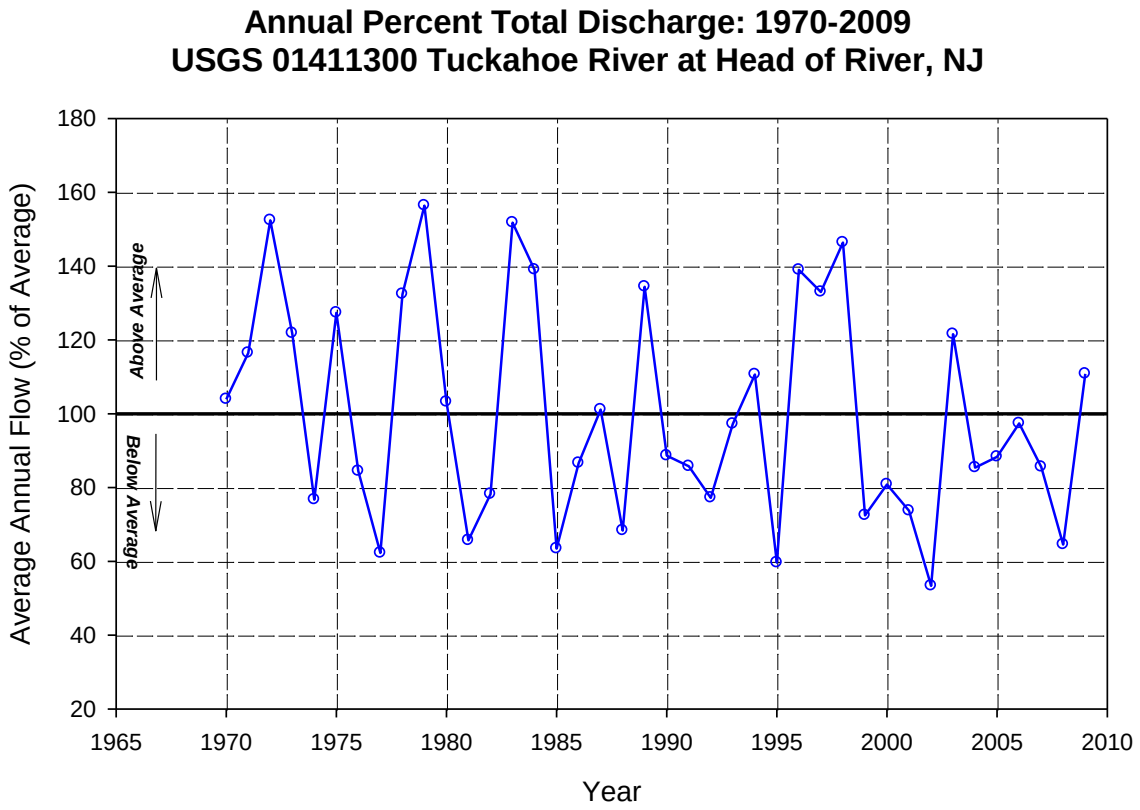

Figure 16: Percent of average annual flow on the Tuckahoe River at Head of River, NJ: 1970 – 2009. Average annual flow from the period of record is 42 cubic feet per second (cfs).

Trends presented in Figure 16:

- 1985-1995 and 1999-2008 are periods of consistent below average streamflow at this site.
- The highest average annual flow was 65 cfs in 1979
- The lowest average annual flow was 22 cfs in 2002

9.3 NOAA Tide Gages

The nearest NOAA tide gage to Cape May NWR is located near the Cape May, NJ – Lewes, DE ferry terminal (data link). NOAA reviews information from each gage to evaluate trends in sea level recorded at the gage (Figures 17 and 18). Sea level trends for this site are most representative of conditions in the Delaware Bay Division of the refuge.

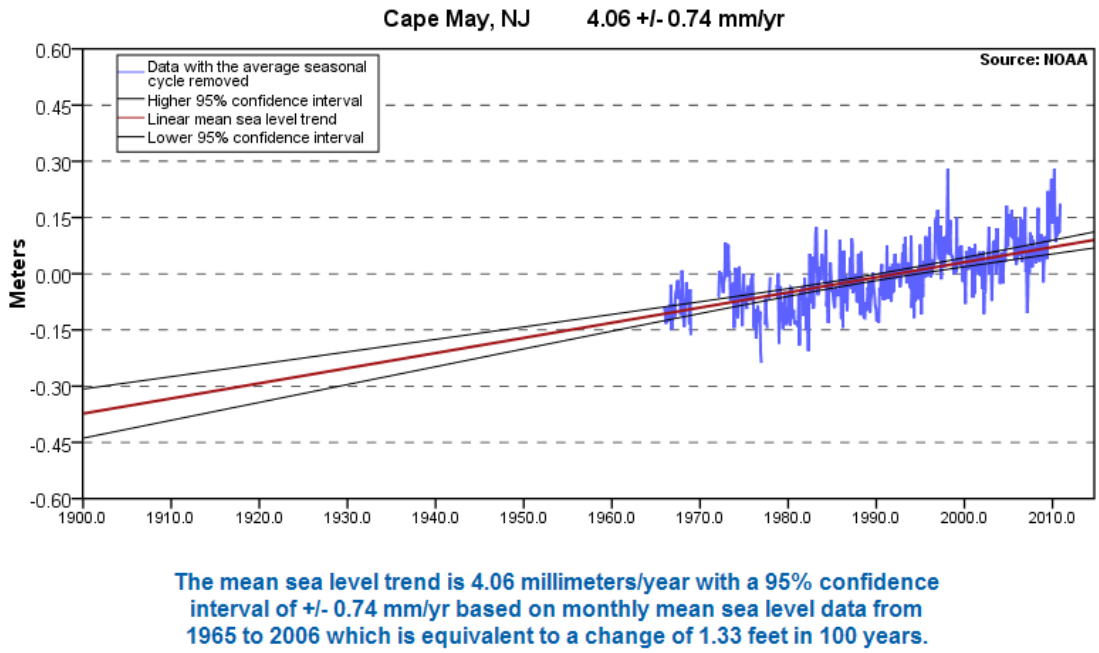

Figure 17: Monthly mean sea level and long-term linear trend at the Cape May, NJ tide gage (Site No. 8536110). Graph is from the station's website (link).

Data from the Cape May tide gage indicate the local sea level is rising about 4 millimeters per year, or 6.6 inches since 1970. This rate is about double the global rate of 1.8 mm/yr (Horton and Miller 2010). Tide gages record a local measurement of sea level relative to a fixed point on land near the gage site. Sea level in New Jersey is rising faster than the global average because the land surface is subsiding, or sinking. Subsidence of the land surface in the mid-Atlantic is largely a response of the earth's crust to the melting of the Laurentide ice sheet over 10,000 years ago. The weight of the ice sheet caused the land surface in the mid-Atlantic to bulge upward. Once the ice sheet melted and its massive weight was removed from the earth's crust, land in the mid-Atlantic began to subside (Horton and Miller 2010).

Seasonal changes in local sea level measured at the Cape May, NJ tide gage indicate ocean levels are at their highest between August and October and lowest between December and February (Figure 18). The difference between the mean monthly maximum and minimum sea level in Figure 18 is approximately .16 m, or 6.2 inches. Seasonal changes are a function of dominant weather patterns that drive water into or out of Delaware Bay including; seasonal weather patterns, changing ocean currents, increase runoff, and thermal expansion of water.

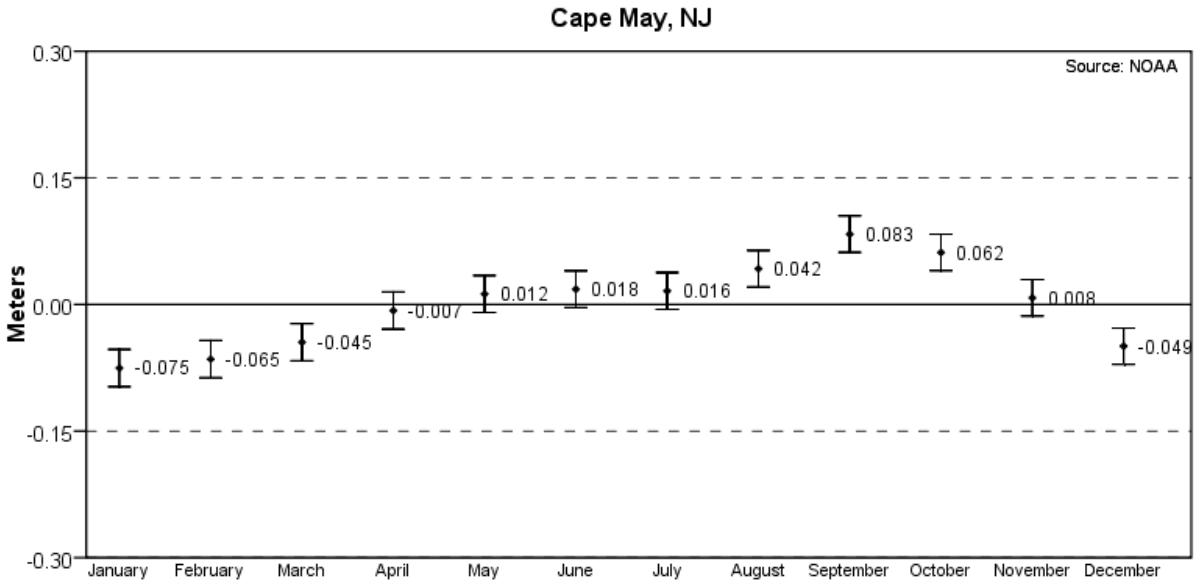

Figure 18: Average monthly variation in mean sea level due to temperature, ocean currents, and weather patterns. Graph is from the station's website (link).

10. FUTURE CLIMATE PREDICTIONS

The Intergovernmental Panel on Climate Change (IPCC) predicts the U.S. Northeast will experience earlier spring snowmelt and reduced summer runoff as the global climate warms in response to human emissions of greenhouse gasses (Bates et al. 2008, Mack 2008). Hayhoe et al (2007) review historic climate data and climate change models to evaluate the Northeast's response to global climate change. Results of their analyses are summarized below:

1. Air temperature records in the US Northeast show consistent signs of warming since the 1970s.

2. In the last 40 years winter snowpack has been decreasing, the onset of peak streamflow has occurred earlier in the year, the duration of ice cover on lakes has decreased, and the length of the growing season has increased.

3. Under current greenhouse gas emission scenarios winter precipitation is predicted to increase 10-15% and summer precipitation is predicted to not change or decrease.

4. All model scenarios show increases in air temperature and continuation of the trends observed since the 1970s.

At Cape May NWR, changes in winter snowpack are not expected to affect the refuge water resources significantly. However, warmer summer temperatures and longer growing seasons will increase the water demand plants place on the shallow groundwater aquifer during the growing season.

10.1 Sea Level Rise

The amount of local sea level rise and the impacts on estuaries at Cape May NWR will depend on many factors including the morphology of the coast line and human modifications to the coast like tide gates and levees (Horton and Miller 2010). Predictions included in the Intergovernmental Panel on Climate Change (IPCC) report put the range of global sea level rise between .75 and 1.90 m by 2100. Additionally, the land surface in the mid-Atlantic is expected to subside .1 and .2 m by 2100 which will enhance these global sea level trends. The Sea Level Affecting Marshes Model (SLAMM) attempts to quantify these changes to coastal wetland habitat using data from NOAA tide gages, USFWS National Wetland Inventory maps, and USGS digital elevation models. For Cape May NWR, SLAMM was used to predict wetland community changes by 2100 to five sea level rise scenarios: 0.39m, .69m, 1.0m, 1.5m, and 2.0m (Clough and Larsen 2009).

In all model scenarios there is a loss of wetland habitat at Cape May NWR. The loss is greatest under the scenario that predicts a 2.0 m rise in sea level by 2100 (Table 8). The model results show that as sea level rises the existing wetland communities will migrate landward. The Delaware Bay Division wetlands, west of US Highway 47 will probably shift the most, from what is considered tidal swamp now, to open-water estuaries.

Table 8: Predicted loss from existing acreages rates for wetland habitat under different sea level rise scenarios. From the Cape May NWR SLAMM report (Clough and Larsent 2009 p. 11)

	Sea Level Rise Scenarios (meters)				
SLAMM Habitat Type	**0.39**	**0.69**	**1**	**1.5**	**2**
Swamp	1%	5%	11%	38%	59%
Dry Land	8%	10%	12%	29%	42%
Brackish Marsh	42%	78%	88%	59%	66%
Tidal Swamp	10%	16%	27%	83%	99%

For the changes presented in Table 8 to occur, the current rate of sea level rise will need to increase considerably. At the current rate of 4.06 mm/yr, Cape May NWR will experience sea levels equivalent to Scenario 1 (0.39 m) around the year 2100. At current rates, a sea level increase equivalent to Scenario 2 (0.69 m) would be reached in the year 2181 and Scenario 5 (2 m) would be reached in the year 2504.

11. WATER RIGHTS

The laws governing water use in New Jersey are outlined in the Water Supply Management Act of New Jersey which was prepared in 1981 and amended in 2008. The state considers surface water and groundwater public assets "held in trust by the state for the "health, safety, economic welfare, recreational, and aesthetic enjoyment, and general welfare of the people of New Jersey". Individuals, corporations, municipalities, and federal agencies are considered "persons" that can apply to use waters of the state. The New Jersey Department of Environmental Protection (NJDEP) manages and administers water use in the state through a permitting, monitoring, and inspection program.

NJDEP is primarily concerned with fresh water diversions from surface water features and groundwater aquifers. Surface water diversions cannot take place unless the applicant owns land adjacent to the surface water body, or has made legal arrangements with the landowner to access the property and divert water.

New water uses cannot have an "adverse" impact on other water users. NJDEP determines whether or not a new use is "adverse" on a case by case basis. In addition to other water users, NJDEP considers the impacts of a diversion on natural habitat such as minimum streamflows in rivers or water levels in wetlands. However, there are no explicit protections afforded aquatic habitat in New Jersey water law. Instead, the regulating agency tries to consider these effects in its decision making process.

Water use allocations are either "registered" or "permitted" under New Jersey water law. A user needs to "register" their use if it is less than 100,000 gallons/day. The requirements for registering a water use are less rigorous than uses that require a Water Allocation Permit. Permitted uses are greater than 100,000 gallons per day and require a more comprehensive suite of additional information for approval.

Additional details of New Jersey's water use regulations are outlined below:

1. Water diversions in excess of 100,000 gallons/day from surface water or groundwater sources requires a permit from NJDEP.

2. Permits are obtained from New Jersey Department of Environmental Protection: Division of Water Supply

3. New permit applications are posted in the public notices section of local newspapers. Additionally, public water systems within 5 miles of a new water use will be notified of the permit application.

4. If there is concern surrounding a new water use application the concerned group must submit a letter to NJDEP stating those concerns or request a public hearing to address the concerns.

5. The permit process takes approximately 400 days from start to finish if the applicant has submitted all the appropriate paperwork and there are no controversies associated with the application.

6. Permitted uses are required to report water use to the state every quarter unless the use is agricultural, which reports water use annually.

7. Registered water uses are required to report water use annually.

8. NJDEP considers impacts of water allocation permits on river flows. However, NJDEP has been directed by court order to no consider the potential effects of a new diversion on freshwater wetlands.

9. NJDEP is primarily concerned with "consumptive" uses. A use is consumptive when the water is removed from a source and not returned to it.

10. Typical USFWS water use like flooding impoundments would need a permit if water for the impoundment was diverted from a surface water body or a groundwater aquifer.

Item No. 8 has particular relevance to Service owned properties and trust species. When reviewing new applications NJDEP will consider the impacts of a new water allocation on streamflow. However, the agency will not review the impacts of a new diversion on freshwater wetlands unless outside entities request it. An interested party would need to submit a letter of interest during the 30 day public review period for new water allocation permits. For example, if the Service is aware of a new water use application near Cape May NWR vernal pools or other wetlands, the agency could submit a letter stating its concerns to NJDEP. In the letter, the Service could request NJDEP evaluate the potential impacts of the new allocation on water levels in the wetland system of concern. With such a letter, NJDEP would be compelled to review the Service's concerns. However, if the letter is never submitted, NJDEP is limited on how much it can evaluate impacts to wetlands when issuing permits.

12. PERCEIVED THREATS

This section discusses some of the challenges the refuge's water resources face. For the purposes of this initial review the primary water resources of interest are the freshwater wetland habitat that occupies about 50% of the land in the acquisition boundary.

12.1 Groundwater Development

Data presented in Lacombe et al. (2009) suggest wetlands and shallow groundwater may be locally affected by groundwater pumping in Cape May County. Groundwater modeling predictions of future pumping scenarios suggest streamflow on the peninsula could decline as much as 26% or water levels in the Holly Beach aquifer could drop as

much as 0.5 ft by 2050 if water use increases to the full allocation of 11,730 million gallons/yr (Lacombe et al. 2009). Although this is an extreme scenario, Lacombe's modeling and monitoring indicate groundwater development on the peninsula could be a potential threat to refuge wetlands. This is particularly true at wetlands close to groundwater pumping centers. When the Service has the opportunity to review future groundwater development plans it should consider the potential impacts of that development on refuge water resources. Additionally, the Service should consider establishing long-term water level monitoring at selected high-priority freshwater wetlands on the refuge. Areas that may be particularly sensitive to groundwater development are the headwaters of the creeks in the Delaware Bay Division.

12.2 Sea Level Rise / Saltwater Intrusion

The SLAMM report for Cape May NWR predicts how refuge wetlands will change in response to sea level rise. The refuge can expect a shift in wetland habitat landward and will need to use that knowledge to prioritize future land acquisitions or management activities. The tidal creeks entering Delaware Bay are the pathways for saltwater to reach the interior of the peninsula. As sea level continues to rise, the transition from freshwater to saltwater wetland will be most rapid along these channels. In places, infrastructure like old levees, culverts, and tide gates will restrict saltwater movement inland. Upgrades or modifications to some of this infrastructure might provide a way to mitigate or limit the extent of saltwater intrusion. Recommend, the Service inventory infrastructure on, and off, refuge property that influences saltwater movement.

12.3 Groundwater Quality

Contaminants in surface water easily infiltrate through the Cape May peninsula's sandy sediment into the shallow groundwater of the Holly Beach water bearing zone. Septic tank outfalls and leachate from local landfills find their way into Holly Beach water bearing zone (USFWS 2005). Once in the groundwater, these contaminants have the potential to migrate into streams and wetlands via groundwater discharge. Impacts will likely be concentrated in the headwaters of Cape May peninsula streams, where groundwater discharge is an important water source for freshwater wetlands.

13. RECOMMENDATIONS / FURTHER ACTIONS

Because of its proximity to the Delaware Bay and Atlantic Ocean, sea level rise is the most obvious long-term threat to wetland habitat at Cape May NWR. However, 73% of the refuge's wetlands are considered freshwater and are located in the headwaters of tidal creeks or in the Great Cedar Swamp Division and are not immediately threatened by sea level rise. A more immediate threat to freshwater wetland systems is groundwater development in the shallow aquifers of the Cape May peninsula. Recommendations for addressing this threat are listed below.

1. Pierre Lacombe's 2009 study of groundwater pumping scenarios on the Cape May Peninsula indicated that wetland habitat, like vernal pools, may be affected by groundwater pumping for municipal purposes. For the 2009 report, Lacombe established several vernal pool water level monitoring sites on the refuge. Recommend re-activating water level monitoring at Lacombe's vernal pool monitoring sites. This will help build a data record that helps confirm if the pools near pumping centers are drying earlier than pools far from areas of groundwater development.

2. Data reviewed for this report indicate that the shallow groundwater aquifer in the Cape May peninsula is an important source of water for Cape May streams and supports unique wetland communities on the peninsula. Recommend consulting with Regional Hydrologist to develop an approach for identifying and inventorying groundwater discharge areas on refuge property. These sites may harbor unique flora and fauna and will be particularly sensitive to future groundwater development plans and groundwater contamination.

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