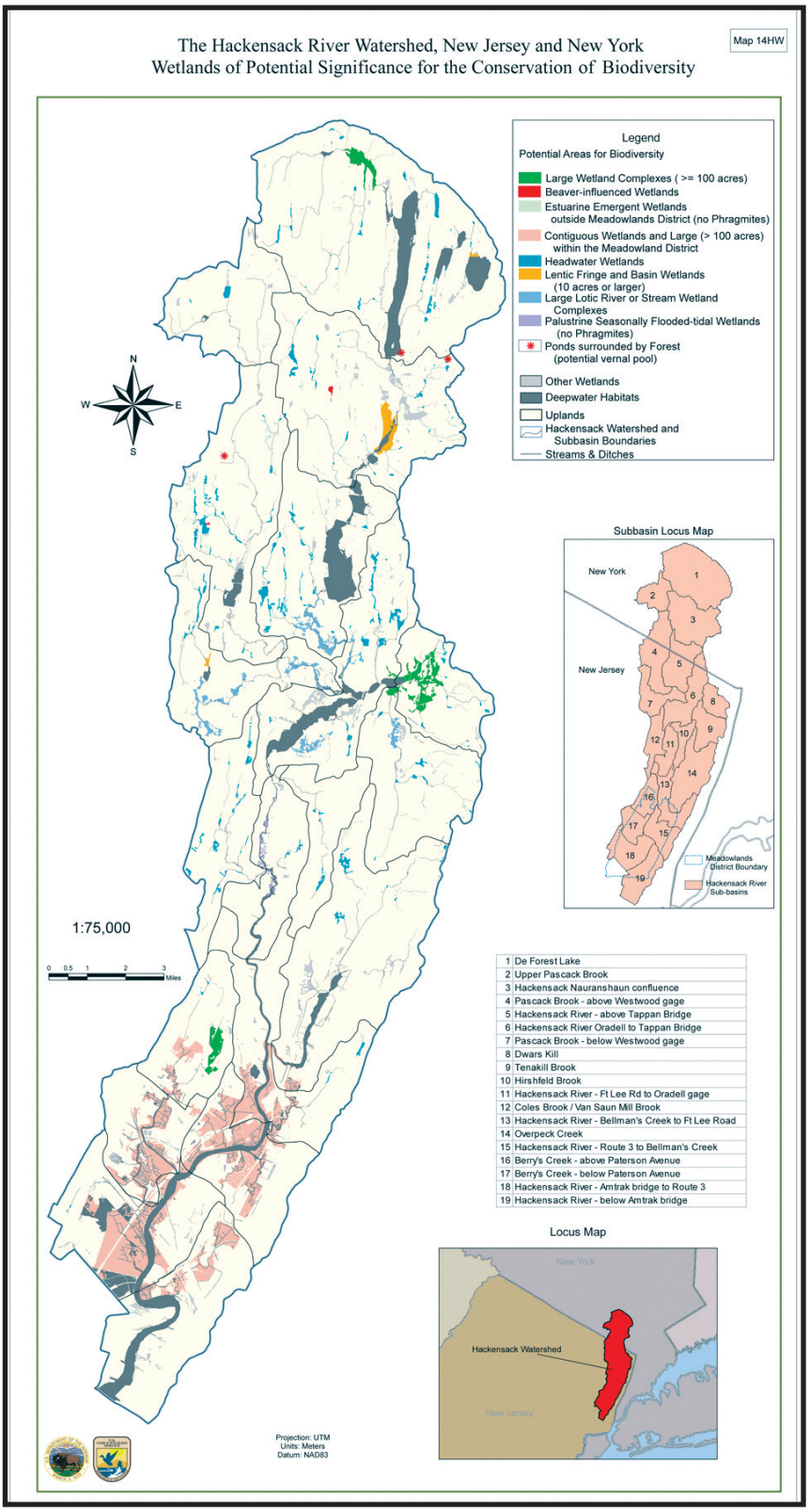
V. Wetland and Upland Land Use



Map from Tiner and Bergquist (2005).

A contaminated site along the Hackensack River.

An abandoned industrial site on the Hackensack River.

An abandoned tide-gate on Mill Creek.

A river view of Snake Hill and the Pulaski Skyway.

Marshes along the Berry's Creek Canal.

V. Wetland and Upland Land Use

Wetlands and uplands along Mill Creek.

Along Overpeck Creek, garbage bags and other debris from a covered landfill slowly erode into the Hackensack River. At another site, a foul-smelling, yellowed stratum of chromium stretches along the shoreline, lying under the shell of the factory that once refined the metal. Powerlines, roads, railroads, and highways crisscross the Meadowlands. A dam blocks flows on Overpeck Creek; the much larger Oradell Dam drastically increases the extent of tidal inundation, sharply differentiating the nature of wetlands on the upper and lower Hackensack. Docks jut into waters, and bulkheads turn shorelines into rigid, artificial barriers. Diking and dredging scar the landscape. All of these features bear witness to past land-use decisions, many of which filled wetlands and fragmented and degraded fish and wildlife habitat. In the process, more than 70 percent of the wetlands that comprised the Hackensack Meadowlands before European colonization have been destroyed.

Thoughtful land use and management are crucial to reversing this destructive trend and restoring wildlife habitat functions in the Meadowlands. Even now, palustrine wetlands and their adjoining uplands along the Upper Hackensack improve water quality and help sustain biodiversity. In fact, even in the degraded Meadowlands, uplands provide important habitat for fish and wildlife. Fishes and invertebrates use overhanging banks as cover; birds and mammals feed, nest in, and migrate along riparian habitats by the water's edge. Uplands also "buffer" wetlands by moderating stormwater flows, retaining stormwater run-off, and trapping sediments laden with contaminants and nutrients. Thus, future land-use planning in the Meadowlands must address the use of remaining open space—both uplands and wetlands.

V. WETLAND AND UPLAND LAND USE

A. INTRODUCTION

B. HISTORICAL WETLAND CHANGES

1. Historical Wetland Losses
2. Historical Wetland Alterations

C. CURRENT WETLAND STATUS

1. Wetland Types, Landscape Positions, and Landforms in the HMD
2. Wetland Types, Landscape Positions, and Landforms Outside the HMD in the Hackensack River Watershed
3. Fragmentation
4. Other Wetland Disturbances
5. Wetlands Functioning in the HMD and the Hackensack River Watershed

D. UPLAND LANDSCAPE COVER, LAND USE, BUFFERS, AND CORRIDORS

1. Upland Landscape Cover and Land Use
2. Upland and Riparian Buffers
3. Upland Corridors

E. SUMMARY

Forests once covered extensive areas of the Hackensack Meadowlands and the watershed. Only a few hundred acres remain.

V. WETLAND AND UPLAND LAND USE

A. INTRODUCTION

Throughout the history of the United States, coastal areas have been home to more than half of the country's population (Beach, 2002). Historic use of the Meadowlands and adjoining uplands in this densely populated area has resulted in substantial losses of wetlands and uplands, altered and fragmented remaining natural habitats, and disrupted the Meadowlands ecosystem and diminished its capacity to sustain fish and wildlife populations. Presently, nearly all uplands within the HMD and most uplands within the HRW are developed (Balzano *et al.*, 2002; New Jersey Meadowlands Commission, 2004d). The population of coastal areas will continue to grow in New Jersey and throughout the world (U.S. Census Bureau, 2005a; United Nations, 2005). Remaining natural habitats within coastal urban areas are of increasing importance to preserving biodiversity as well as the quality of human life (Crooks and Turner, 1999; Crane and Kinzig, 2005). A comprehensive assessment of urban land-use effects and integration of urban land-use into protection, restoration, and management of natural resources are widely lacking in coastal areas (Beach, 2002; Crane and Kinzig, 2005). Moreover, addressing these informational and management needs is vital to protecting, conserving, and enhancing fish and wildlife habitats in the Meadowlands.

The Service's National Wetlands Inventory (NWI) has recently documented the status and trends of wetlands in the Meadowlands from the 1890s to the mid-1990s (Tiner *et al.*, 2002); some of that information is summarized below (Section B). Using imagery provided by the NJMC and the State of New Jersey, the NWI has updated and improved an earlier status and trends effort by: (1) providing a more detailed (by USGS subbasin) analysis of wetlands within the HMD (Tiner *et al.*, 2005); (2) expanding wetlands interpretation and analyses to the entire HRW (Tiner and Bergquist, 2005); and (3) assessing remotely-sensed vegetative-cover and disturbance indicators (*e.g.*, roadway extent within hydrologic subbasins; Tiner, 2004) to evaluate wetlands more thoroughly within the HMD and the watershed (Tiner and Bergquist, 2005). Those findings (Tiner and Bergquist, 2005; Tiner *et al.*, 2005) are summarized below to provide an overview of: (1) historic wetland losses and alterations throughout the watershed; (2) the current status of remaining wetlands, including their types, fragmentation, disturbance, and functioning; and (3) adjoining upland land use, including vegetative buffers and corridors. The NWI reports clearly document the extensive losses of wetlands that have occurred throughout the HRW; moreover, the substantial losses of wetlands and alterations to the landscape establish the need for a comprehensive assessment of the cumulative adverse impacts to the watershed and especially to the Meadowlands. The full text and figures of those reports (Tiner and Bergquist, 2005; Tiner *et al.*, 2005) will be available on the Service's website at www.fws.gov.

The human population in New Jersey and in the HRW is expected to grow substantially in the next 25 years (U.S. Census Bureau, 2005a; 2005b). Therefore, remaining natural areas within the watershed, and especially its wetlands, remain at risk to direct impacts from development and to indirect and cumulative adverse impacts from surrounding land-use activities. For these reasons, stakeholders and decision-makers must better understand the Meadowlands ecosystem, its values to society and the natural world, and the interactions among its waterbodies, wetlands, and uplands (including developed areas). Using such landscape information, stakeholders can

effectively address and mitigate the adverse impacts of land-use activities through restoration and other land-use planning. For example, the NJDEP's Landscape project (Niles *et al.*, 2004) is using landscape information to identify and manage natural areas to protect the State's biodiversity. Elsewhere in the Northeast, the USGS and the Service (2005) are using landscape information to assess responses of the marsh surface to different vegetative cover types to address potential impacts of SLR on the Blackwater NWR in Maryland. Landscape-scale planning is considered by many conservation biologists as among the most effective mechanisms to protect biodiversity and ecosystems vulnerable to human threats (*e.g.*, Dramstad *et al.*, 1996; Noss *et al.*, 1997; Peck, 1998) and is increasingly used by the Service to protect habitat for fish and wildlife (*e.g.*, the North American Waterfowl Management Plan). Thus, developing a comprehensive understanding of the Meadowlands landscape and land use is critical to (1) formulating effective plans to improve water quality and sustain biodiversity, (2) promoting a more positive image of this long-neglected urban area, and (3) educating the public on the value of its fish and wildlife resources.

B. HISTORICAL WETLAND CHANGES

1. Historical Wetland Losses

Just 150 years ago, the Hackensack Meadowlands was comprised of more than 21,000 acres of waterways and wetlands. Since that time, wetland losses from the Meadowlands have shrunk and fragmented its once vast open spaces into a checkerboard of industrialized and commercial sites, transportation corridors, and small oases of degraded, semi-natural wetlands. From 1889 to 1995, more than 70 percent of the total wetlands in the HMD (20,045 acres, which included most but not all wetlands in the Hackensack Meadowlands) were destroyed by human activities (Figure 42; Tiner *et al.*, 2002). Details regarding the exact location, timing, and acreage of wetland losses from the 1890s to the 1950s are poorly known; however, the overall rate of wetlands loss during that time was approximately 102 acres per year (Table 22; Tiner *et al.*, 2002). Most of the losses during that 60-year period were due to filling activities; however, nearly 1,400 acres of wetlands were converted to open water habitats when historic marsh dikes near Sawmill Creek were breached by a storm in 1950 (Figure 42). Sea level rise has been implicated as a contributing factor in the conversion of other Mid-Atlantic wetlands, including those in NWRs, to deepwater habitats (Tiner, 2005) and may be a factor in the Meadowlands as well. In addition, land-use activities and landscape alterations (*e.g.*, dam construction, dredging) may disrupt sediment transport to estuaries, decrease vertical accretion of marshes, and result in conversion of wetlands to deepwater habitats (*e.g.*, French and Burningham, 2003). The interaction of local land uses and SLR has the potential to compromise restoration efforts and illustrates the importance of the Service's recommendations throughout this document to better understand the effects of human activities on many natural processes (*e.g.*, sediment transport, marsh accretion rates) throughout the Meadowlands. Additional information about SLR is provided in Section IV.B.

The temporal pattern of wetland losses in the HMD (Table 22; Tiner *et al.*, 2002) paralleled national trends during the past century (Dahl, 1990; Dahl and Johnson, 1991; Dahl, 2000). The rate of wetland losses in the Meadowlands more than doubled from the mid-1950s to the mid-

1960s (231 acres per year), and increased further from the mid-1960s through the mid-1970s (304 acres per year). Fortunately, wetland loss rates in the following 10 years decreased due to implementation of the Clean Water Act, which provides regulation of water development projects and specifically seeks to protect wetlands; nonetheless, rates of marsh loss remained fairly high (208 acres per year). From the mid-1980s through the mid-1990s, the rate of wetland losses declined substantially (20 acres per year). Wetland losses in the Meadowlands since the mid-1990s have been comprised mostly of small parcels (*i.e.*, less than 2 acres), although there have been a few notable exceptions of large, publicly and privately owned wetlands that were filled (*e.g.*, a 24.3-acre wetland adjacent to the Teterboro Airport, a 53.5-acre wetland along Penhorn Creek). Although the rate of wetlands loss has decreased dramatically in the past twenty years, the Service nonetheless remains concerned about the contribution to cumulative adverse impacts from wetlands losses that have occurred since implementation of the CWA.

Table 22. Annual wetland loss rates from 1889 to 1995 for the Meadowlands ecosystem (Tiner *et al.*, 2002). The average annual rate of wetland loss has decreased since the early 1990s.

Time Period	Total Wetland Losses (acres)	Annual Wetland Loss Rate (acres per year)
1889-1953/54	6,626	102
1953/54-1966	2,769	231
1966-1976	3,043	304
1976-1984/85	1,868	208
1984/85-1995	198	20

The chronology of wetland losses within present-day individual subbasins of the HRW is not well known. These subbasins are portions of the larger watershed units that reflect fragmentation and isolation by roads and railroad beds in the HMD and by dams elsewhere in the watershed (Figure 43; Tiner and Bergquist, 2005; Tiner *et al.*, 2005). In other words, they are basins within basins and were artificially created through development practices. Nearly all subbasins in the HMD have lost most of their wetland acreage (Table 23; Figure 43). More than 1,000 acres in each of the HMD subbasins were filled (Table 23) once primarily for agriculture, and are now used for transportation, industrial, commercial, residential, and other purposes. The Hackensack River subbasin between the Amtrak Bridge and Rt. 3 has lost roughly 7,765 acres. Moreover, nearly 40 percent of wetlands (approximately 2,400 acres) have been lost from Hackensack River subbasins outside of the HMD (Table 23). Most wetland losses in the upper watershed have occurred in subbasins: (1) along the main stem of the Hackensack River (*e.g.*, Hackensack-Nauranshaun Confluence), (2) along Pascack Brook (*e.g.*, Upper Pascack Brook), and (3) where dams were constructed to create water storage reservoirs (*e.g.*, De Forest Lake).

Figure 42. Changes in the landscape: a time sequence of wetlands losses for the Hackensack Meadowlands (from Tiner *et al.*, 2002). Note the extensive filling of wetlands (light green) to create uplands (off-white). A major storm breached a man-made dike in 1950; as a result, an extensive area of marshes along Sawmill Creek in the lower western portion of the Meadowlands were converted into open water (shown in blue) from the mid-1950s through the early 1960s.

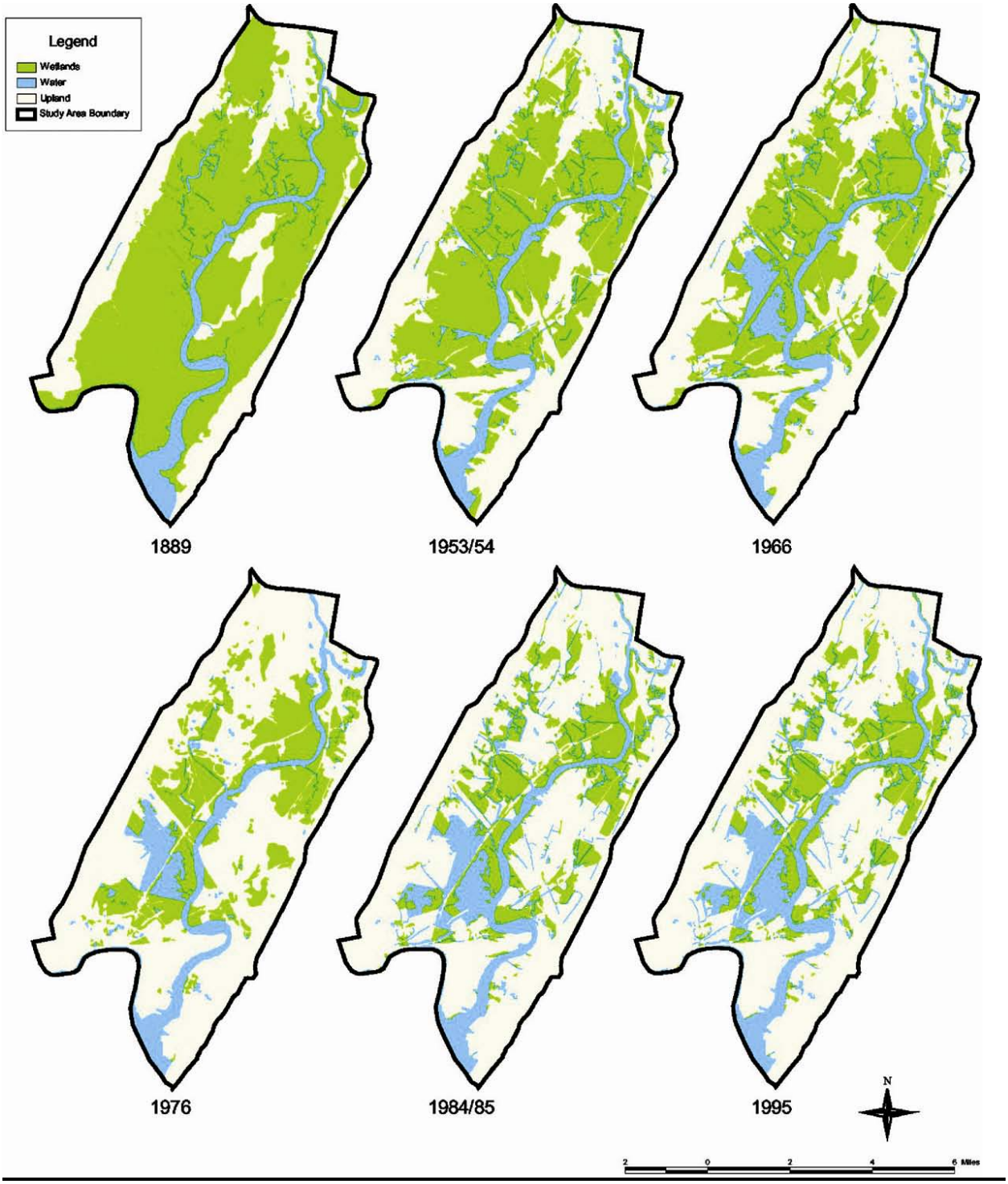
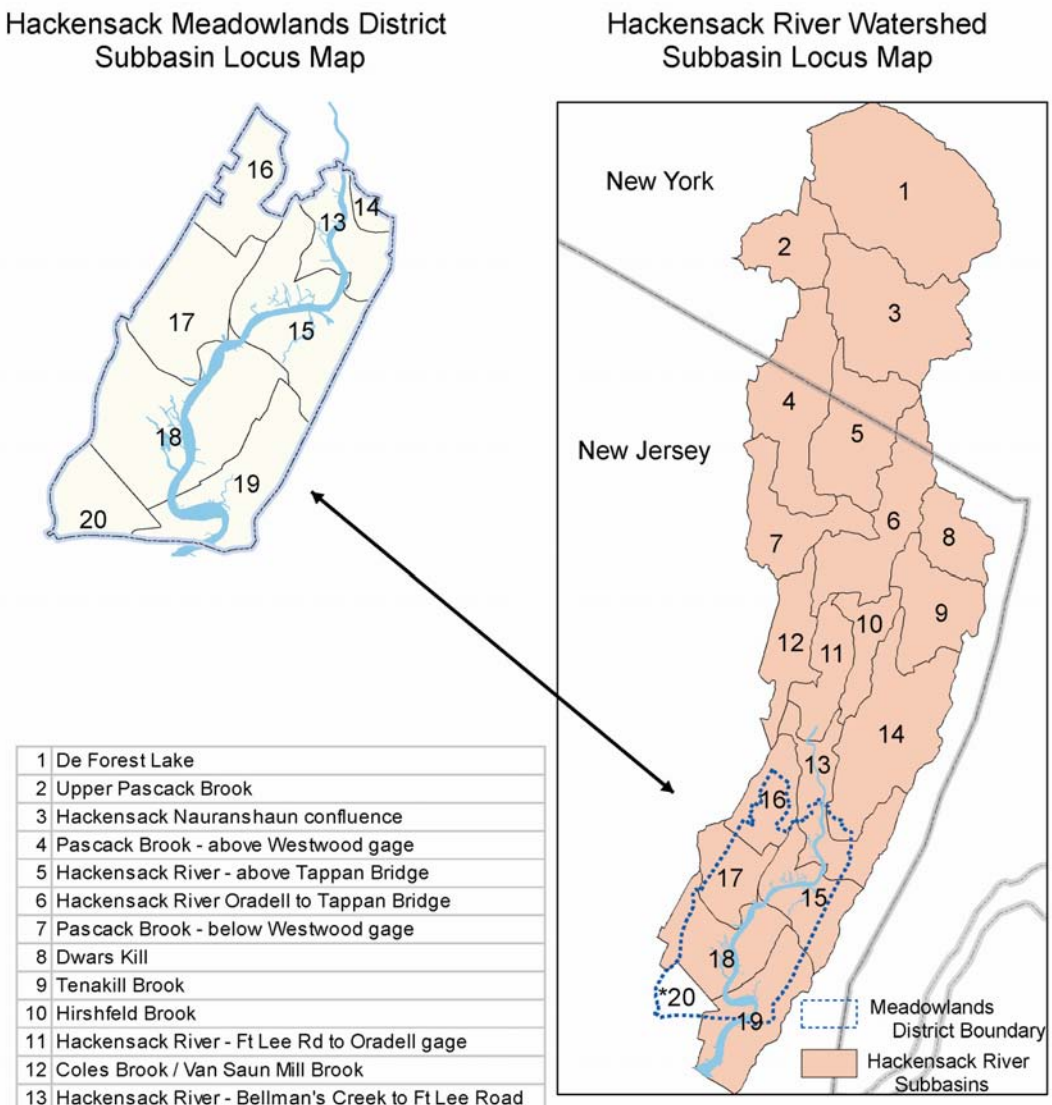


Figure 43. Hydrologic subbasins within the Hackensack Meadowlands District (HMD) and the HRW (from Tiner and Bergquist, 2005). These subbasins are subdivisions of watersheds in the USGS hierarchy of hydrologic units. Subbasins are geographic areas representing part or all of a surface drainage area, a combination of drainage areas, or a distinct hydrologic feature (Seaber *et al.*, 1987). Portions of several subbasins in the HMD extend beyond the HMD's boundaries. Subbasin #20 (Passaic River Lower) is part of the Passaic River watershed.



1	De Forest Lake
2	Upper Pascack Brook
3	Hackensack Nauranshaun confluence
4	Pascack Brook - above Westwood gage
5	Hackensack River - above Tappan Bridge
6	Hackensack River Oradell to Tappan Bridge
7	Pascack Brook - below Westwood gage
8	Dwars Kill
9	Tenakill Brook
10	Hirshfeld Brook
11	Hackensack River - Ft Lee Rd to Oradell gage
12	Coles Brook / Van Saun Mill Brook
13	Hackensack River - Bellman's Creek to Ft Lee Road
14	Overpeck Creek
15	Hackensack River - Route 3 to Bellman's Creek
16	Berry's Creek - above Paterson Avenue
17	Berry's Creek - below Paterson Avenue
18	Hackensack River - Amtrak bridge to Route 3
19	Hackensack River - below Amtrak bridge
20	Passaic River Lower - Newark Bay to 4th St Bridge

2. Historical Wetland Alterations

In addition to the cumulative wetland losses discussed above, wetland alterations have occurred throughout the HRW. Beginning in the 1800s, wetlands were extensively diked and ditched, primarily for farming and mosquito control (Section II.C). During that time, the Hackensack River initially comprised a tidal freshwater ecosystem with extensive palustrine (swamp) wetlands (approximately 6,000 to 10,000 acres) forested by Atlantic white-cedar (Figure 44). Beginning in the 1900s, wetlands throughout the watershed began to experience changes and losses with the construction of dams along the Hackensack River (Section IV.B.). With freshwater flows in the Hackensack River decreased by dams, especially at Oradell, tidal currents upstream in the HRW subsequently increased the salinity of these once fresh- or low-salinity waters and contributed to the extensive development of latter-day estuarine wetlands in the subbasins that now comprise the HMD (Table 23).

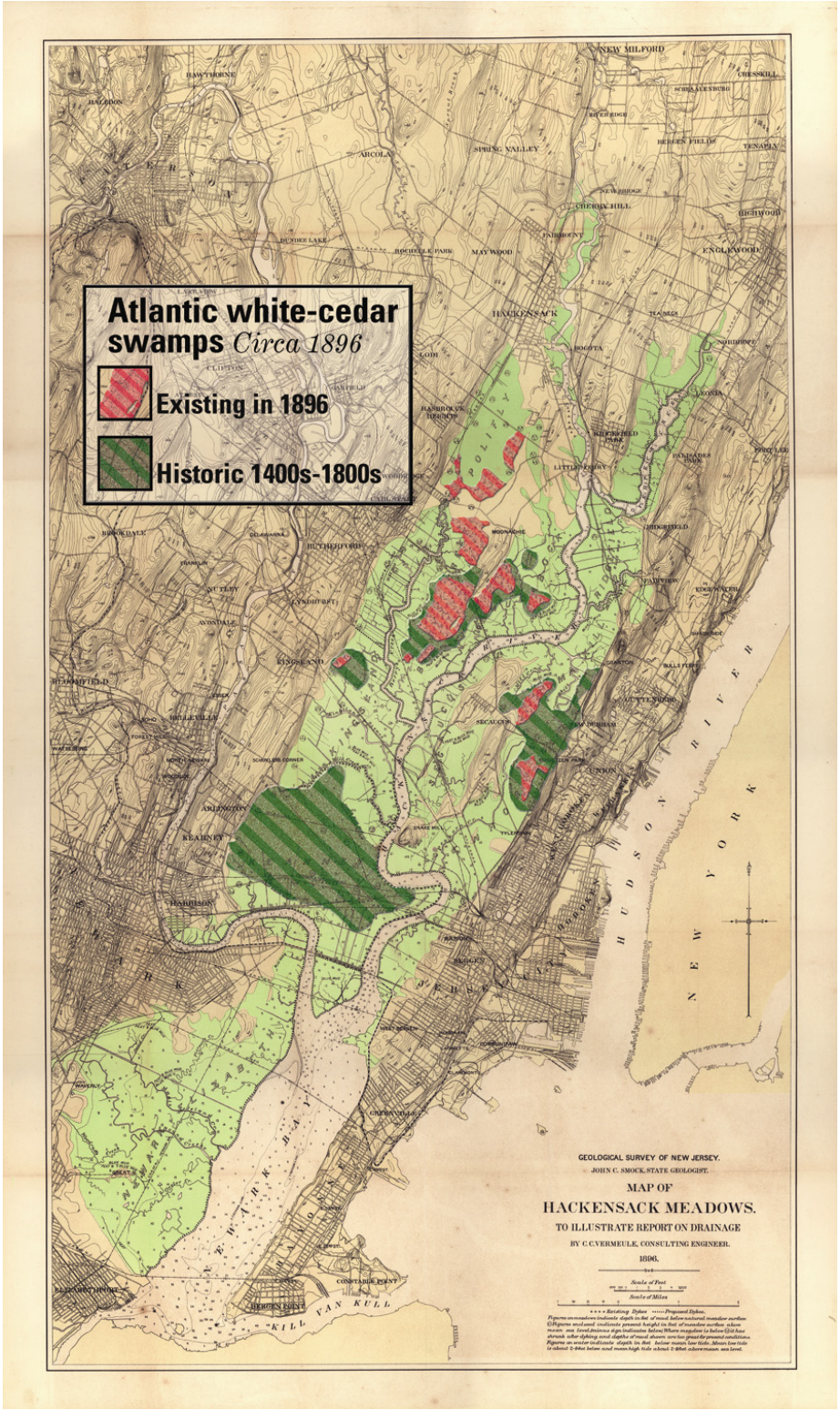
Although the rate of wetland losses in the Meadowlands has decreased substantially since 1985, owing to regulatory overview and protection, changes in remaining wetlands appear to be increasing as a result of several factors, some of which are unknown. Estuarine wetlands with unconsolidated shores (an NWI wetland type represented primarily by mudflats in the HMD; Tiner *et al.*, 2005) totaled approximately 400 acres in 1995 but increased to more than 1,187 acres in 2002. Some increase of unconsolidated shore acreage undoubtedly has resulted from: (1) restoration activities (*i.e.*, excavation and regrading of the marsh surface to eradicate common reed and create mudflats as habitat; *e.g.*, Skeetkill and Mill Creek marshes; U.S. Army Corps of Engineers, 2004a); and (2) dredging. In addition, an increase in acreage may also be the result of a methodological artifact in which the use of boundaries for the wetland areas in current analyses were different from those used in analyses in 1995 (Tiner *et al.*, 2002) and 2002 (Tiner and Bergquist, 2005; Tiner *et al.*, 2005). However, these explanations appear inadequate to account for the majority of increases in the extent of unconsolidated shores. Increases in the extent of unconsolidated shores and wetlands in other Mid-Atlantic coastal estuaries (*e.g.*, Delaware's Nanticoke River estuary; Tiner, 2005; Blackwater NWR, U.S. Geological Survey and U.S. Fish and Wildlife Service, 2005) have been attributed to SLR, which may be a factor in the HMD. (See Sections B [above] and IV.B for additional concerns and information about SLR.) To understand these wetland changes, wetland elevation in the Meadowlands should be closely monitored with the use of surface elevation tables (*e.g.*, Cahoon and Lynch, 2005) and investigated regarding their causes (*e.g.*, dredging, controlled river flows, and other processes affecting sediment transport in the estuary). Significant wetland changes ongoing in the Meadowlands necessitate comprehensive assessments of their cumulative adverse impacts and their interaction with other factors (*e.g.*, SLR). Such assessments are critical to guide long-term land-use decisions, especially those regarding remediation and restoration.

Wetland alterations in subbasins in upper portions of the HRW are not as extensive as in lower subbasins; however, construction of the Oradell and other dams to create water storage reservoirs clearly resulted in alterations to lotic (flowing water) wetlands above the dams. Extensive stretches of riverine wetlands were converted to open water, and remaining lotic sites (*i.e.*, streams, adjoining wetlands, riparian areas) were fragmented by dams, water storage reservoirs,

Table 23. Historic wetland losses of subbasins of the Hackensack Meadowlands District and in the Hackensack River watershed (from Tiner and Bergquist, 2005 and Tiner *et al.*, 2005). The location of subbasins and the ID number are shown in Figure 43. Note that wetlands losses are extensive throughout all subbasins. Subbasin 20 in the HMD is part of the Passaic River watershed.

Hackensack River Watershed Subbasin (Subbasin ID)	Historic Wetland Acreage	Estuarine/ Palustrine Acreage	Current Wetland Acreage	Lost Wetland Acreage	Current Percent of Watershed
Hackensack Meadowlands District					
Berry's Creek above Paterson Ave. (16)	1,495	83.8 / 379.5	463.3	1,032	4.8
Berry's Creek below Paterson Ave. (17)	2,717	909.3 / 42.1	951.4	1,766	9.9
Hackensack River, Amtrak Bridge to Rt. 3 (18)	9,244	1,431 / 47.9	1,479.2	7,765	15.3
Overpeck Creek (14)	867	162.6 / 149.5	312.1	555	3.2
Hackensack River, Bellman's Creek to Ft. Lee Rd. (13)	904	651.7 / 55.6	707.3	197	7.3
Hackensack River, Rt. 3 to Bellman's Creek (15)	3,637	1,445 / 9.6	1,455.2	2,182	15.1
Hackensack River below Amtrak Bridge (19)	2,419	563.1 / 89.9	653.0	1,766	6.8
Lower Passaic River (20)	1,912	216.4 / 51.4	267.8	1,645	0.0
Elsewhere in the HRW					
Coles Brook/Van Saun Mill Brook (12)	149	-- / 123.7	123.7	25	1.3
De Forest Lake (1)	1,297	-- / 506.0	506.0	791	5.2
Dwars Kill (8)	583	-- / 408.0	408.0	175	4.2
Hackensack-Nauranshaun Confluence (3)	1,104	-- / 596.4	596.4	508	6.2
Hackensack River, Ft. Lee to Oradell Gage (11)	118	-- / 118.0	118.0	0	1.2
Hackensack River, above Tappan Zee Bridge (5)	536	-- / 397.4	397.4	139	4.1
Hackensack River, Oradell to Tappan Zee Bridge (6)	699	-- / 510.6	510.6	188	5.3
Hirshfeld Brook (10)	41	-- / 30.0	30.0	11	0.3
Pascack Brook above Westwood Gage (4)	511	-- / 301.7	301.7	209	3.1
Pascack Brook below Westwood Gage (7)	402	-- / 337.6	337.6	64	3.5
Tenakill Brook (9)	204	-- / 202.3	202.3	2	2.1
Upper Pascack Brook (2)	402	-- / 96.4	96.4	306	1.0

Figure 44. Geological Survey of New Jersey's 1896 Map of the Hackensack Meadows, colored to show change in distribution of Atlantic white-cedar from the 1400s (striped green) to 1896 (striped red). Other vegetation, mostly grasses, is shown in light green.



and other land-use changes. Small lotic areas are vulnerable to hydrologic changes (*e.g.*, water temperature, sedimentation) and degradation in water quality due to other land-use changes, especially changes that create impervious surfaces (*e.g.*, Limberg and Schmidt, 1990; McMahon and Cuffney, 2000; Paul and Meyer, 2001). Wetlands may become degraded by poor water quality when impervious cover in the watershed exceeds 10 percent or more (*e.g.*, Garie and McIntosh, 1986; Limberg and Schmidt, 1990); however, urban land-use and runoff / impervious cover effects are variable and site-specific (Pitt, 2003). Headwater and other low-order streams are often critical to ecosystem functioning and water quality downstream (*e.g.*, McMahon and Cuffney, 2000; Paul and Meyer, 2001). Thus, the Service recommends that stakeholders with applicable authorities: (1) acquire and protect remaining lotic wetlands throughout the Hackensack watershed, including those in New York; (2) restore lotic wetlands, especially where contaminated or where restored wetlands will re-connect fragmented lotic wetlands; and (3) protect, restore, and create vegetated riparian areas adjoining lotic wetlands. The Service's recommendation expands upon a recommendation in a previous DOI (1994) report to Congress on the impact of federal programs on wetlands. In the report, the DOI cited the economic value of wetlands and recommended acquisition of "critically important and vulnerable wetland complexes" in northeastern New Jersey, which include those in the HRW, largely for the purpose of flood control. The DOI (1994) recommended direct purchase or cost sharing with the State or local municipalities.

C. CURRENT WETLAND STATUS

Despite extensive historical losses, substantial wetland acreage remains throughout the HRW, especially within the HMD. Approximately 9,650 acres of wetlands occur in the HRW (Figure 45; Tiner and Bergquist, 2005), of which approximately 60 percent (5,844 acres) occur in the HMD (Tiner *et al.*, 2005). However, wetland types present today within the HMD reflect the increasing influence of salt water in the watershed below the Oradell Dam since it was built in 1922. Wetlands in the HMD are predominantly estuarine, whereas wetlands in other portions of the HRW upstream are predominantly palustrine (Table 23; Tiner and Bergquist, 2005; Tiner *et al.*, 2005). This distribution of wetland types underscores the anthropogenic changes to the Meadowlands ecosystem and the importance of carefully considering the goals and objectives of any efforts to enhance and restore wetlands in different subbasins. The value of ecosystem functions provided by all wetlands throughout the HRW also emphasizes the importance of acquiring and protecting these remaining wetlands. The DOI (1994) recommended purchasing wetlands throughout northern New Jersey for flood control, and emphasized the value of wetlands as a non-structural means of flood control.

1. Wetland Types, Landscape Positions, and Landforms in the HMD

Wetland types now present in the HMD, in comparison with conditions throughout most of the 1900s, reflect the increased presence of saltwater within the Hackensack River due to both decreased upstream flow as a result of dams, increased water usage, and possibly SLR. The HMD now contains approximately 5,300 acres of estuarine wetlands (Figure 46). Estuarine wetlands with emergent vegetation (4,100 acres; approximately 70 percent) and

Figure 45. Wetlands (9,650 acres) and deepwater habitats classified by National Wetlands Inventory types in the Hackensack River watershed (from Tiner and Bergquist, 2005).

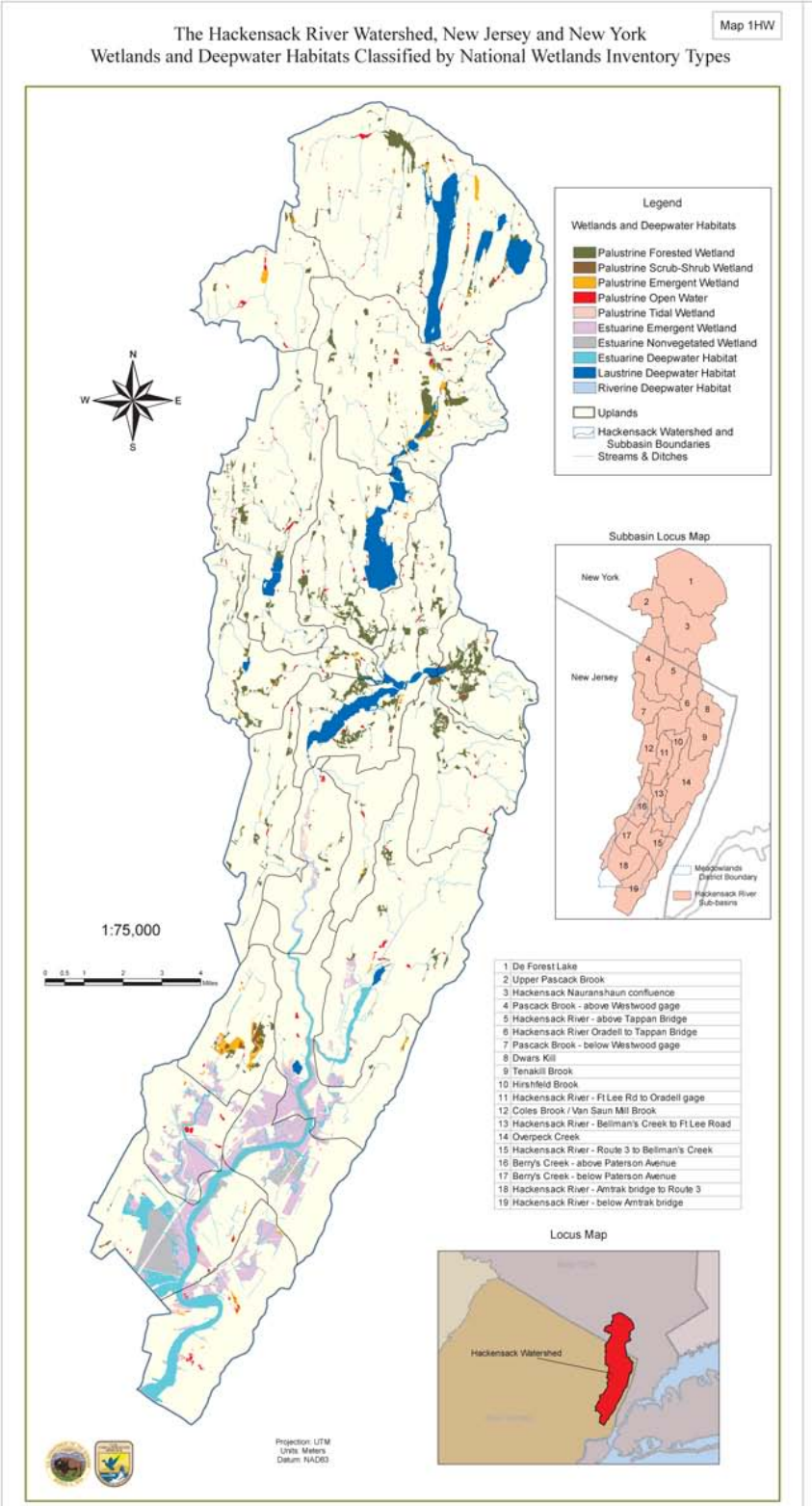


Figure 46. Wetlands (5,844 acres) and deepwater habitats classified by National Wetlands Inventory types in the Hackensack Meadowlands District (HMD; from Tiner *et al.*, 2005). Vegetated (4,100 acres) and non-vegetated (1,200 acres) estuarine wetlands are the most common types in the HMD.

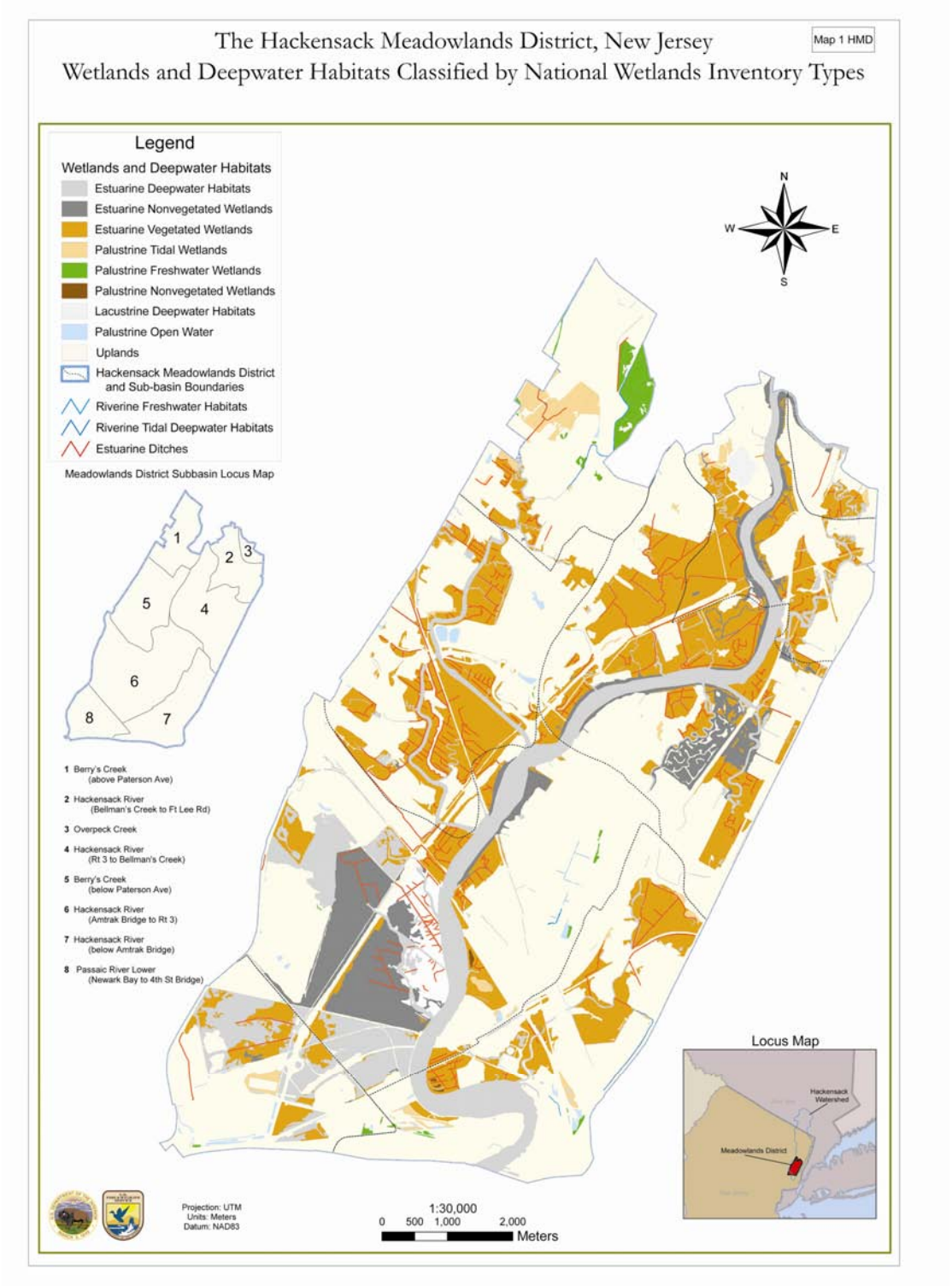


Table 24. Acreage of wetlands by National Wetland Inventory types in subbasins (ID numbers as in Figure 43) of the Hackensack Meadowlands District (from Tiner and Bergquist, 2005 and Tiner *et al.*, 2005). Note that estuarine wetlands with emergent vegetation are the most common wetland type; estuarine wetlands with unconsolidated shores are increasing.

Hackensack Meadowlands District Subbasin (ID number)	Estuarine Wetland Acreage		Palustrine Wetland Acreage			Total Wetland Acreage
	Emergent vegetated	Other vegetated/ unconsolidated	Emergent vegetated	Forest/ scrub	Uncon-solidated	
Berry's Creek above Paterson Ave. (16)	81.2	2.5	160.4	144.9	3.4	392.4
Berry's Creek below Paterson Ave. (17)	908.5	1.1	7.1	4.9	26.3	947.9
Hackensack River Amtrak Bridge to Rt. 3 (18)	655.9	776.1	20.3	0.4	16.3	1,469.0
Overpeck Creek (14)	51.3	8.3	0.4	4.5	0.2	64.7
Hackensack River, Bellman's Creek to Ft. Lee Rd. (13)	522.7	103.7	5.7	18.6	0.7	651.4
Hackensack River Rt. 3 to Bellman's Creek (15)	1,155.3	291.0	4.2	3.9	1.5	1,455.9
Hackensack River below Amtrak Bridge (19)	529.9	0.4	47.5	---	18.2	596.0
Lower Passaic River (20)	210.9	5.5	29.3	---	22.1	267.8
Total acreage	4,115.7	1,188.6	274.9	177.2	88.7	5,845.1

unconsolidated substrates (*e.g.*, tidal mudflats; 1,200 acres; approximately 20 percent) are now the predominant wetland types in the HMD (Figure 46, Table 24). Palustrine (tidal and non-tidal freshwater) wetlands are now restricted almost entirely to the upper Berry's Creek subbasin. Palustrine wetlands now comprise only 9 percent (approximately 540 acres) of wetlands in the HMD.

Wetland landscape positions (relationship to the adjoining waterbody [*e.g.*, lotic, lentic]) and landforms (*i.e.*, wetland form or shape [*e.g.*, flat, slope]) present in the HMD (Tiner, 2003) reflect extensive landscape and hydrologic alterations. Because of alterations in the flow of the Hackensack River and subsequent ecosystem changes, nearly all HMD wetlands are classified as estuarine (5,445 acres; Figure 47). Within the HMD, lotic (156 acres), lentic (89 acres), and terrene (154 acres) wetlands remain primarily in upper subbasins (*e.g.*, upper Berry's Creek; Figure 47; Tiner *et al.*, 2005). Filling and other activities have altered the present-day landforms of the HMD's wetlands (Tiner *et al.*, 2005). Presently, the HMD's wetlands are comprised almost entirely of: (1) fringe wetlands (*i.e.*, estuarine landforms with unrestricted flows) along the main stem of the Hackensack River (57 percent), and (2) basin wetlands (*i.e.*, estuarine landforms with restricted tidal flows) isolated by the New Jersey Turnpike and other major roadways (43 percent; Figure 48; Tiner and Bergquist, 2005).

The current distribution of wetland types and their vegetation within different subbasins have four important implications for remediating and restoring the Meadowlands. First, the two subbasins that straddle the Hackensack River (Rt. 3 to Bellman's Creek, and the Amtrak Bridge to Rt. 3; Figure 43) collectively comprise slightly more than half (54 percent) of the HMD's estuarine wetlands. Wetlands within those subbasins are relatively large in comparison to wetlands in other subbasins in the HMD (*e.g.*, the Hackensack River subbasin below the Amtrak Bridge, which includes several isolated wetlands along Penhorn Creek; Figure 43). Second, reestablishing large contiguous wetlands is an important goal for sustaining and managing fish and wildlife resources in the Meadowlands (U.S. Fish and Wildlife Service *et al.*, 2000). A large contiguous natural landscape of high quality habitats for fish and wildlife could be created by remediating and restoring the Lower Berry's Creek subbasin (Figure 43), which includes 909 acres of wetlands (17 percent of HMD wetlands) that currently separate the two large subbasins described above. Third, the upper subbasins of the HMD (*e.g.*, Berry's Creek above Paterson Avenue, Hackensack River-Bellman's Creek to Ft. Lee Rd.; Figure 43) are comprised of more diverse wetland types than lower subbasins (Figure 47; Table 24); preserving the existing native biodiversity is one of the restoration principles for the Meadowlands (See Section I.B.). Finally, the Service has fewer concerns about the potential adverse impacts of environmental contaminants in upriver portions of the HMD (Section III.C.3).

2. Wetland Types, Landscape Positions, and Landforms Outside the HMD in the Hackensack River Watershed

Although reduced from historical times, several thousand acres of wetlands (Table 25; Figure 48) remain upriver of the HMD in upper portions of the HRW. Except for approximately 100 acres of estuarine wetlands located north of the HMD along Overpeck Creek, all other wetlands

Figure 47. Wetlands and deepwater habitats in the Hackensack Meadowlands District (HMD) classified by landscape position (from Tiner *et al.*, 2005). Freshwater habitats and lotic and terrene wetlands occur mostly in upper portions of the HMD.

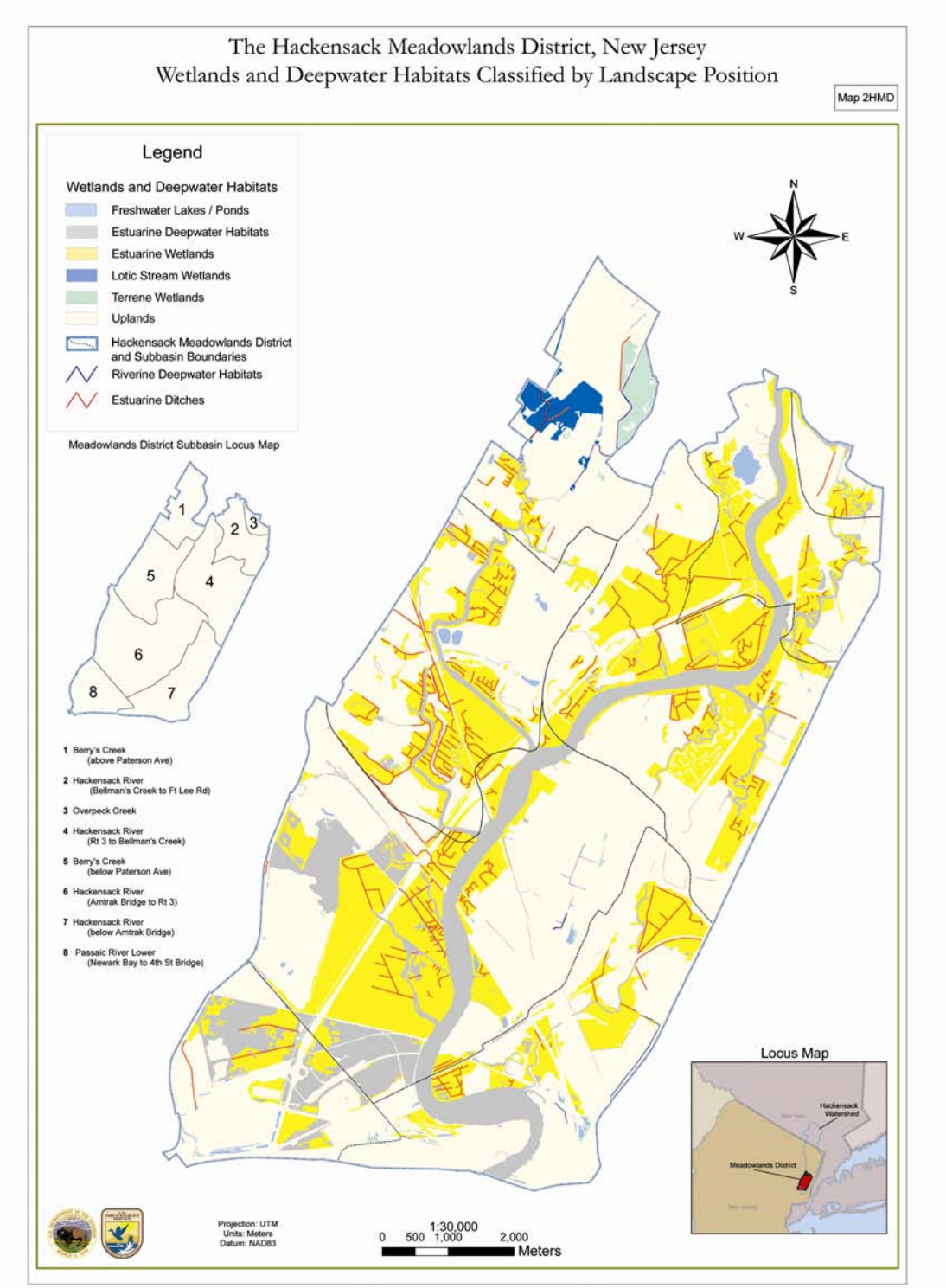
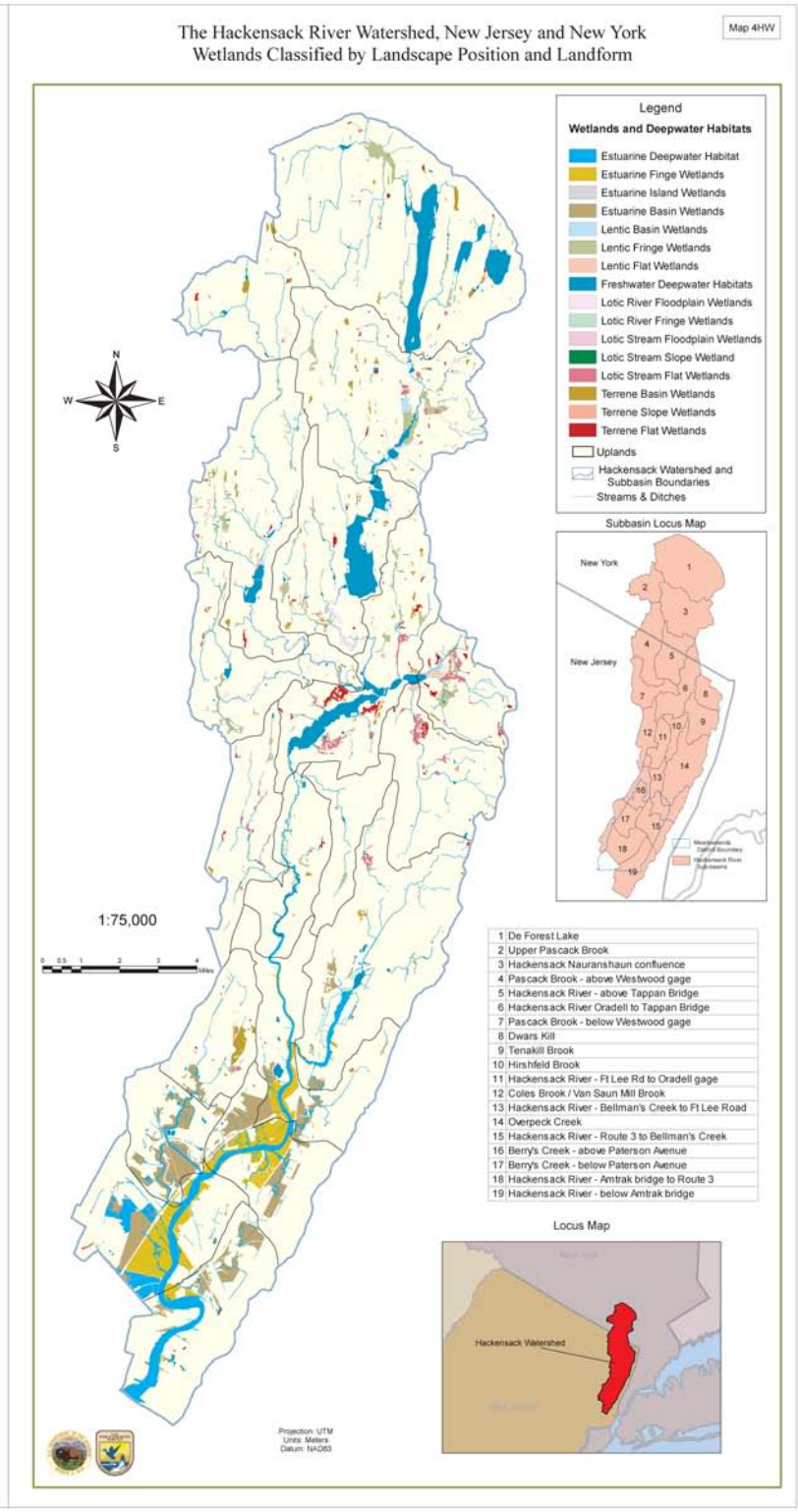


Figure 48. Hackensack River watershed wetlands classified by landscape position and landform (from Tiner and Bergquist, 2005). Note the thin upland roadbed that separates fringe and basin wetlands in the HMD.



upriver of the HMD in the HRW are palustrine (Table 25). Overall, palustrine wetlands are numerous and widely distributed throughout the upper HRW; however, in comparison to wetlands in the HMD, wetlands are smaller and less contiguous with one another in the upper watershed. Extensive palustrine wetlands are located only in certain subbasins along the upper Hackensack River (from Oradell Dam to Tappan Zee Bridge [488 acres], above the Tappan Zee Bridge [370 acres]) and along Pascack Brook (above [277 acres] and below [321 acres] Westwood Gage). Increasing the connectivity among the many small wetland areas in the upper HRW (many of which were connected previously) potentially improves: (1) water quality downstream in lower, estuarine portions of the watershed (*e.g.*, Lin and Kuo, 2003), and (2) certain ecosystem functions, such as the suitability of the wetlands to provide habitats for fish and wildlife species (*e.g.*, U.S. Fish and Wildlife Service, 1980; 1981; Brinson, 1993). Therefore, the Service recommends that, before such areas are acquired or considered for restoration, these small wetlands be assessed for fish and wildlife resources, historical connectivity, contaminants, and overall condition, potential for restoration, and water quality. An assessment will provide an essential planning step by regional and local stakeholders and decision-makers prior to acquiring and protecting these wetlands and adjoining upland sites in the upper HRW. Efforts to identify which sites to acquire, protect, and restore can be as important as efforts to identify how much area to protect (Huxel and Hastings, 1999), especially when fish and wildlife populations are supported by minimal and fragmented areas (Fahrig, 1997). Land-use activities that affect run-off and input of certain materials (*e.g.*, nutrients, contaminants) in upper portions of watersheds may significantly affect water quality of (*e.g.*, Jordan *et al.*, 1991, Mallin *et al.*, 1999), and aquatic communities in (*e.g.*, Fry, 1999), lower portions of watersheds including estuaries.

Two subbasins comprising nearly 1,000 acres of palustrine wetlands, the De Forest Lake and Hackensack-Nauranshaun confluence subbasins (Subbasins 1 and 3, respectively, in Figure 43), are located entirely in New York. Substantial palustrine wetland acreage in these subbasins is contiguous, and potentially provides habitats for species that require extensive area or are sensitive to disturbance (*e.g.*, forest-interior nesting bird species). Thus, the Service considers the acquisition and protection of these wetlands a high priority. Because upper portions of the HRW lie outside of New Jersey and the operating authorities of some stakeholders, the Service recommends that Meadowlands stakeholders include government agencies (*e.g.*, New York Department of Environmental Conservation) and NGOs (*e.g.*, the Sierra Club's Eastern New York Chapter) operating in New York to evaluate the necessity and feasibility of habitat restoration, acquisition, and protection of these wetlands. Land acquisition priorities should be based on such assessments throughout the watershed.

The greater variety of wetland landscape positions and landforms in upper portions of the Hackensack River (Figure 48; Tiner and Bergquist, 2005) generally reflects less extensive landscape alteration and land-use of the upper watershed (Section V.D below). Substantial acreage of lentic (449 acres), lotic (riverine, 466 acres; stream, 1,611 acres), and terrene (843 acres) wetlands is present throughout the upper watershed (Table 25; Figure 48; Tiner and Bergquist, 2005). Most lentic wetlands occur in subbasins located: (1) in the most northern portion the watershed, (2) along Pascack Brook, and (3) east of the Oradell Reservoir. As

Table 25. Acreage of wetlands by National Wetland Inventory type and landscape position in subbasins (ID number as in Figure 43) in the Hackensack River watershed that are located outside of the Hackensack Meadowlands District (from Tiner and Bergquist, 2005 and Tiner *et al.*, 2005).

Hackensack River Watershed Subbasin (ID number)	Estuarine Acreage	Lentic Acreage	Lotic River Acreage	Lotic Stream Acreage	Terrene Acreage	Total Wetland Acreage
Coles Brook/Van Saun Mill Brook (12)	--	--	3.9	92.6	19.8	116.3
De Forest Lake (1)	--	45.1	--	280.0	114.0	439.1
Dwars Kill (8)	--	84.8	--	240.8	77.3	402.9
Hackensack-Nauranshaun Confluence (3)	--	211.5	23.9	204.2	120.2	559.8
Hackensack River;						
Ft. Lee to Oradell Gage (11)	1.0	--	79.8	13.5	15.4	109.7
above Tappan Zee Bridge (5)	--	5.8	148.2	145.2	71.0	370.2
Oradell to Tappan Zee Bridge (6)	--	3.3	31.4	248.3	205.8	488.8
Hirshfeld Brook (10)	--	--	--	26.3	--	26.3
Pascack Brook above Westwood Gage (4)	--	27.6	36.7	132.7	80.4	277.4
Pascack Brook below Westwood Gage (7)	--	41.8	129.6	123.4	26.2	321.0
Tenakill Brook (9)	--	28.6	11.6	102.7	43.9	186.8
Upper Pascack Brook (2)	--	--	0.6	1.3	68.9	70.8
Total acreage	1.0	448.5	465.7	1,611	842.9	3,369

expected, lotic riverine wetlands occur in subbasins located along the Hackensack River (Ft. Lee to Oradell, Oradell to Tappan Zee Bridge, and above Tappan Zee Bridge) and the Pascack Brook (above and below Westwood Gage), whereas lotic stream wetlands occur within most subbasins in the upper watershed. For most wetland types in the upper watershed, basin (located in a distinct depression) and flat (located in a relatively level landscape) wetlands are the most common wetland landforms in the upper HRW (Tiner and Bergquist, 2005). These wetlands, like others in northeastern New Jersey, likely remain under considerable threat from development (U.S. Department of the Interior, 1994; New Jersey Meadowlands Commission, 2004d); thus, the Service reiterates the recommendation to acquire and protect remaining wetlands in accordance with a prioritized acquisition/restoration plan for the watershed developed by the principals' group.

3. Fragmentation

Fragmentation, any disruption in the continuity within an ecosystem, is recognized as a primary concern in conservation biology (Lord and Norton, 1990; Meffe and Carroll, 1997). An example is the breaking up of a large intact area, such as a forest or wetland, into smaller areas, which fragments habitats for individual species. Such habitat fragmentation is widely recognized as a threat to biodiversity (Wilcox and Murphy 1985; Lord and Norton, 1990). Fragmentation may exacerbate the problem of habitat loss: as large continuous parcels are disrupted by roads, power lines, culverts, or stands of non-native vegetation, remaining areas become too small (area or scale effect), too distant (isolation effect), and too influenced by habitat discontinuities (edge effect) to support viable populations or even individuals of some species (Fagan *et al.*, 1999; Franklin *et al.*, 2002). Basically, habitat suitability for some species is decreased by fragmentation even without any other changes. For example, predatory animals requiring large areas of contiguous habitat may be sensitive to discontinuities in or the arrangement or shape of a habitat (Fahrig, 2003). Movements among isolated habitat islands may be greatly reduced (*e.g.*, amphibians, Lehtinen *et al.*, 1999), even for species able to traverse considerable distances (*e.g.*, certain migratory bird species; Belisle and St. Clair, 2001). Dispersal of propagules (*e.g.*, plant seeds; Soons *et al.*, 2004) and colonization of isolated habitat "islands" (including restored sites; *e.g.*, Huxel and Hastings, 1999) may also be affected. Interactions of species with predators, competitors, and parasites also may change along the edges of different habitats (*e.g.*, Bolen and Robinson, 2003; Patten and Bolger, 2003). The conservation community has been as concerned for the potential adverse effects of fragmentation in the Meadowlands as for the actual loss and deterioration of quality of habitats, and has emphasized the importance of protecting, restoring, and maintaining large blocks of wetlands and other open space to provide habitats for fish and wildlife (U.S. Fish and Wildlife Service *et al.*, 2000).

Certain effects of fragmentation can be especially pronounced in suburban and urban areas (Fahrig, 2003). First, fragmentation in developed landscapes changes physical features of remaining habitats. For example, fragmentation increases solar radiation reaching the ground, which contributes to lower soil moisture and other conditions (*e.g.*, low soil fertility, increased soil erosion) that increase tree death in urban areas (Soulé, 1991). Second, invasive species are more likely to invade and adversely affect fragmented and other disturbed systems (Marvier *et al.*, 2004; With, 2004). Third, though not generally considered invasive species, domestic dogs (*Canis familiaris*) and cats (*Felis silvestris*) that roam free in urban areas also have adverse

impacts on wildlife (Crooks and Soulé, 1999). Domestic cats especially kill considerable numbers of birds and other wildlife (*e.g.*, Coleman and Temple, 1996; Lepczyk *et al.*, 2003). Finally, fragmentation exacerbates certain human disturbance problems, such as unauthorized use of off-trail areas and accidental fires, which may further degrade wildlife habitats (*e.g.*, Watts, 2000).

The Tiner and Bergquist (2005) preliminary assessments indicate that fragmentation due to roadways is a greater problem in the HMD than elsewhere in the HRW. Numerous roadways and railways cross the Meadowlands; some roadways and railways are elevated along much of their length, whereas others have been built atop causeways that completely sever surface water flows. Indices of habitat fragmentation due to roadways (Table 26) indicate that, on average, nearly twice as much area is occupied by roadways in each subbasin of the HMD (Index average = 0.76) compared to other subbasins in the HRW (Index average = 0.41; Table 26).

Certain wildlife species recognized as most susceptible to fragmentation are disappearing from the HMD. For example, northern harrier, a State-listed species that has large territorial requirements (MacWhirter and Bildstein, 1996; Temeles, 1989), has disappeared along Penhorn Creek, where filling has reduced and fragmented remaining wetlands. Two other State-listed species occurring in the Meadowlands (savannah sparrow and bobolink) are sensitive to fragmentation (Swanson, 1996). For example, bobolink breed in grasslands as small as 5 to 10 acres but have higher nest densities and reproductive success in larger fields (Jones and Vickery, 1997). The NJDEP, NJMC, and other stakeholders should consider potential fragmentation effects in developing a wildlife management plan for the HMD (Section X.E). Government agencies (during regulatory and zoning [permit] processes) and other stakeholders should also consider the need for, and alternatives to, any proposed projects that would further fragment remaining wetlands in the Meadowlands. In addition, stakeholders should seek diverse and innovative means of addressing the historic fragmentation of the Meadowlands and its impacts to fish and wildlife resources. For example, long-range planning for future transportation (and other public) projects should consider ways to reverse and rectify the impacts of previous public projects that initially fragmented and altered the hydrology of wetlands. One stated intent of Executive Order 13274 ("Environmental Stewardship and Transportation Infrastructure Project Reviews") is for federal agencies to promote environmental stewardship in the Nation's transportation system and to "advance environmental stewardship through cooperative actions with project sponsors to promote protection and enhancement of the natural and human environment in the planning, development, operation, and maintenance of transportation facilities and services." Without addressing and rectifying the historical fragmentation impacts on the Meadowlands, functional restoration will be difficult if not impossible to achieve.

4. Other Wetland Disturbances

Many types of human disturbance to wetlands in the HMD are commonly recognized; however, relatively few efforts have been made to assess certain other types of disturbance and their adverse effects on different wetlands within the Meadowlands. For example, most small

Table 26. Three different measures of habitat disturbance for subbasins in the Hackensack Meadowlands District (HMD) and elsewhere in the Hackensack River watershed (HRW; from Tiner and Bergquist, 2005 and Tiner *et al.*, 2005). The Habitat-Fragmentation by Roadway Index (I_{HFR}) indicates the area in a subbasin relative to Secaucus, New Jersey, a "built-out" urban city in which 6 percent of the land area is occupied by roadways. The Channelized-Stream Length Index (I_{CSL} = sum of channelized stream lengths / sum of total stream lengths) is a measure of stream alteration, whereas the Index of Wetlands Disturbance (I_{WD} = is the area of disturbed [*e.g.*, diked, ditched] wetlands / total area of wetlands) indicates the percentage of the wetland area in which the land is disturbed or the local hydrology has been altered. High indices reflect greater alteration of wetlands; note that nearly all indices indicate greater alteration of wetlands in the HMD in comparison to the HRW.

HMD Subbasin (ID number)	Wetland Acreage	I_{HFR}	I_{CSL}	I_{WD}
Berry's Creek above Paterson Ave. (16)	392	0.61	1.00	0.61
Berry's Creek below Paterson Ave. (17)	948	0.72	--	0.87
Hackensack River, Amtrak Bridge to Rt. 3 (18)	1,469	0.56	1.00	0.55
Overpeck Creek (14)	65	0.69	0.56	0.36
Hackensack River, Bellman's Creek to Ft. Lee Rd. (13)	651	0.77	0.88	0.72
Hackensack River, Rt. 3 to Bellman's Creek (15)	1,456	0.91	--	0.69
Hackensack River, below Amtrak Bridge (19)	596	0.82	1.00	0.77
Lower Passaic River (20)	268	1.00	--	0.99
	HMD averages	0.76	0.89	0.70
HRW Subbasin (ID number)				
Coles Brook/Van Saun Mill Brook (12)	149	0.58	0.13	0.10
De Forest Lake (1)	1,297	0.34	0.29	0.66
Dwars Kill (8)	583	0.26	0.09	0.07
Hackensack-Nauranshaun Confluence (3)	1,104	0.58	0.29	0.41
Hackensack River, Ft. Lee to Oradell Gage (11)	118	0.54	0.03	0.10
Hackensack River, above Tappan Zee Bridge (5)	536	0.26	0.19	0.72
Hackensack River, Oradell to Tappan Zee Bridge (6)	699	0.31	0.24	0.63
Hirshfeld Brook (10)	41	0.54	0.36	0.12
Pascack Brook above Westwood Gage (4)	511	0.41	0.09	0.41
Pascack Brook below Westwood Gage (7)	402	0.36	0.45	0.18
Tenakill Brook (9)	204	0.38	0.43	0.45
Upper Pascack Brook (2)	402	0.40	0.67	0.34
	HRW averages	0.41	0.27	0.35

waterways (*e.g.*, 63 percent of the total length of streams) in the HMD have been altered by channelization and dredging; however, stream channelization is more extensive in some subbasins (*e.g.*, lower Berry's Creek) than in others (*e.g.*, Overpeck Creek; Table 26; Tiner and Bergquist, 2005). Also, water flow on more than 60 percent of the wetland area within the HMD has been disrupted as a result of diking, ditching, and filling (Table 26; Tiner and Bergquist, 2005). Assessments of disturbance across the landscape must be expanded to include factors such as the extent of impervious cover, and roadway and traffic effects (Spellerberg, 2002) when planning any remediation and restoration activities in the Meadowlands (Louis Berger Group Inc., 2004a; Tiner and Bergquist, 2005).

Some disturbances to wetlands in the Meadowlands are widespread but have never been carefully evaluated for their actual or potential effects, especially cumulative adverse impacts, on fish and wildlife resources. For example, a number of communication towers and power lines have been located in wetlands in the Meadowlands. Some of these structures have the potential to cause substantial mortality of migratory birds through electrocution and collision with guywires and the towers themselves, especially during the periods of peak migration (Shire *et al.*, 2000; Edison Electric Institute and U.S. Fish and Wildlife Service, 2005). However, neither individual nor cumulative impacts of these structures in the HMD have been adequately assessed. Tidegates, bulkheads, and other flood control structures have been placed in many creeks within the HMD to prevent flooding (Section IV.B). Such structures have adverse impacts on fish and wildlife resources, such as facilitating spread of invasive species (Roman *et al.*, 1984) or reducing occurrence of rare species (Chapman, 2003; Giannico and Souder, 2004); however, cumulative effects of flood control structures have not been assessed in the HMD. The Service is committed to improving assessment, and reducing adverse impacts of, communication towers, wind turbines, and certain other features of the built environment (*e.g.*, roads) on fish and wildlife populations (*e.g.*, Interim Guidance on Avoiding and Minimizing Wildlife Impacts from Wind Turbines, *Federal Register*, July 10, 2003, Volume 68, Number 132). Regional stakeholders and decision-makers should pursue assessment of cumulative impacts of the above-mentioned structures on fish and wildlife resources in the Meadowlands and seek to identify creative and feasible means to mitigate any current and future impacts.

5. Wetlands Functioning in the HMD and the Hackensack River Watershed

Preliminary assessments indicate that wetlands remaining in the HMD provide many commonly recognized wetland functions (Tiner and Bergquist, 2005). For example, the estuarine wetlands that occur throughout the HMD have considerable potential to provide coastal storm surge detention (Figure 49) and nutrient transformation (Figure 50). In addition, different habitats within those estuarine wetlands are also critical for sustaining the Meadowlands biodiversity, such as waterfowl and waterbirds (Figure 51), though these habitats will require further assessment and consideration of contaminant loads. Tiner and Bergquist's (2005) preliminary assessments are based on studies from other ecosystems and do not incorporate the potential adverse effects of environmental contaminants. Thus, in some ways, these assessments represent the potential for the Meadowlands to sustain fish and wildlife subsequent to determining whether appropriate remediation and restoration are feasible. In any case, additional study is clearly needed to assess cumulative adverse impacts resulting from land use and other human activities throughout the HRW in addition to contaminant and hydrological obstacles.

Figure 49. Wetlands of potential significance for coastal storm surge detention in the Hackensack River watershed (from Tiner and Bergquist, 2005). Note that wetlands with high potential are located almost entirely in the Hackensack Meadowlands District.

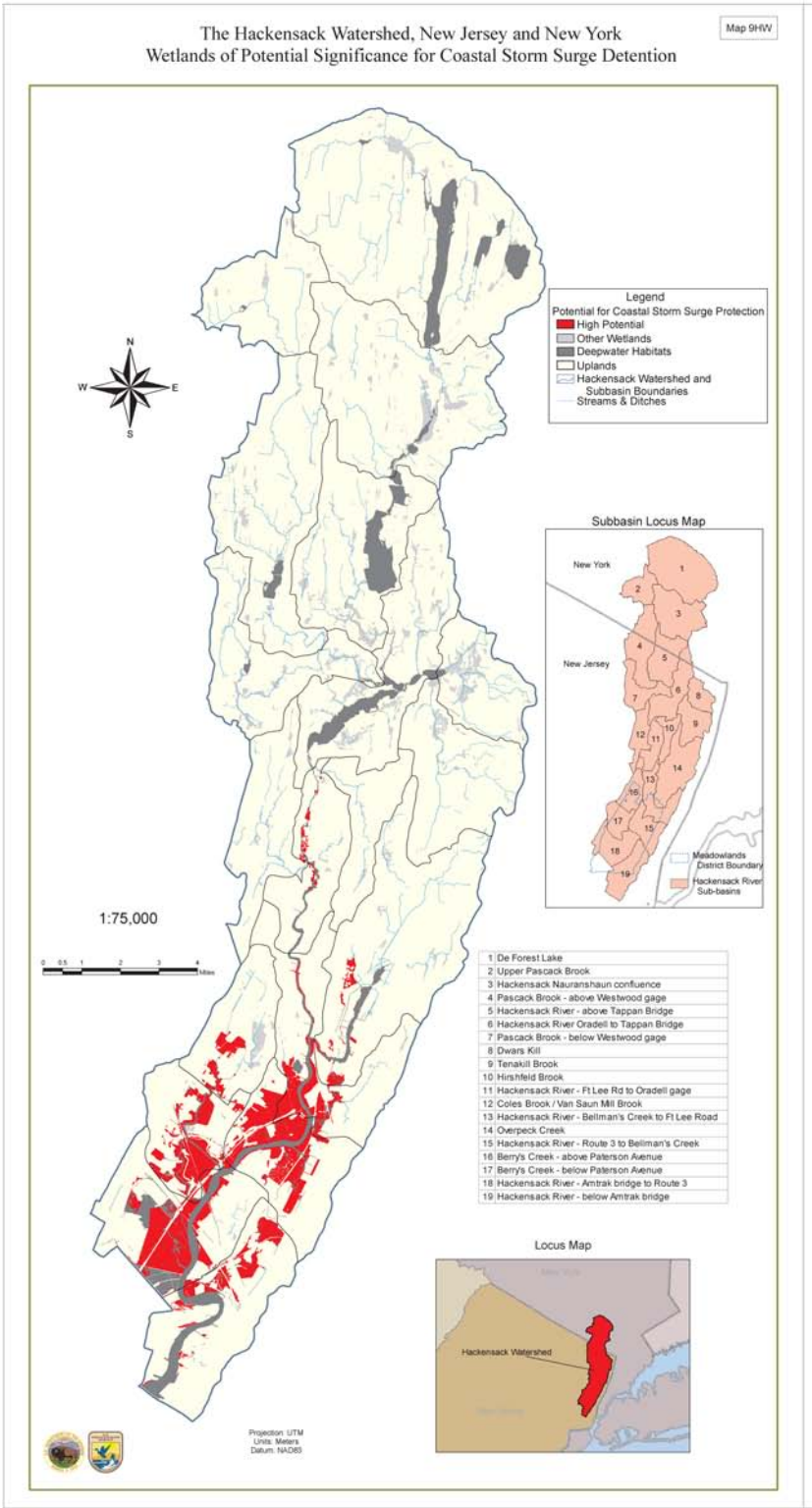


Figure 50. Wetlands of potential significance for nutrient transformation in the Hackensack River watershed (from Tiner and Bergquist, 2005). Estuarine and palustrine wetlands throughout the watershed have the potential to transform nutrients and improve water quality.

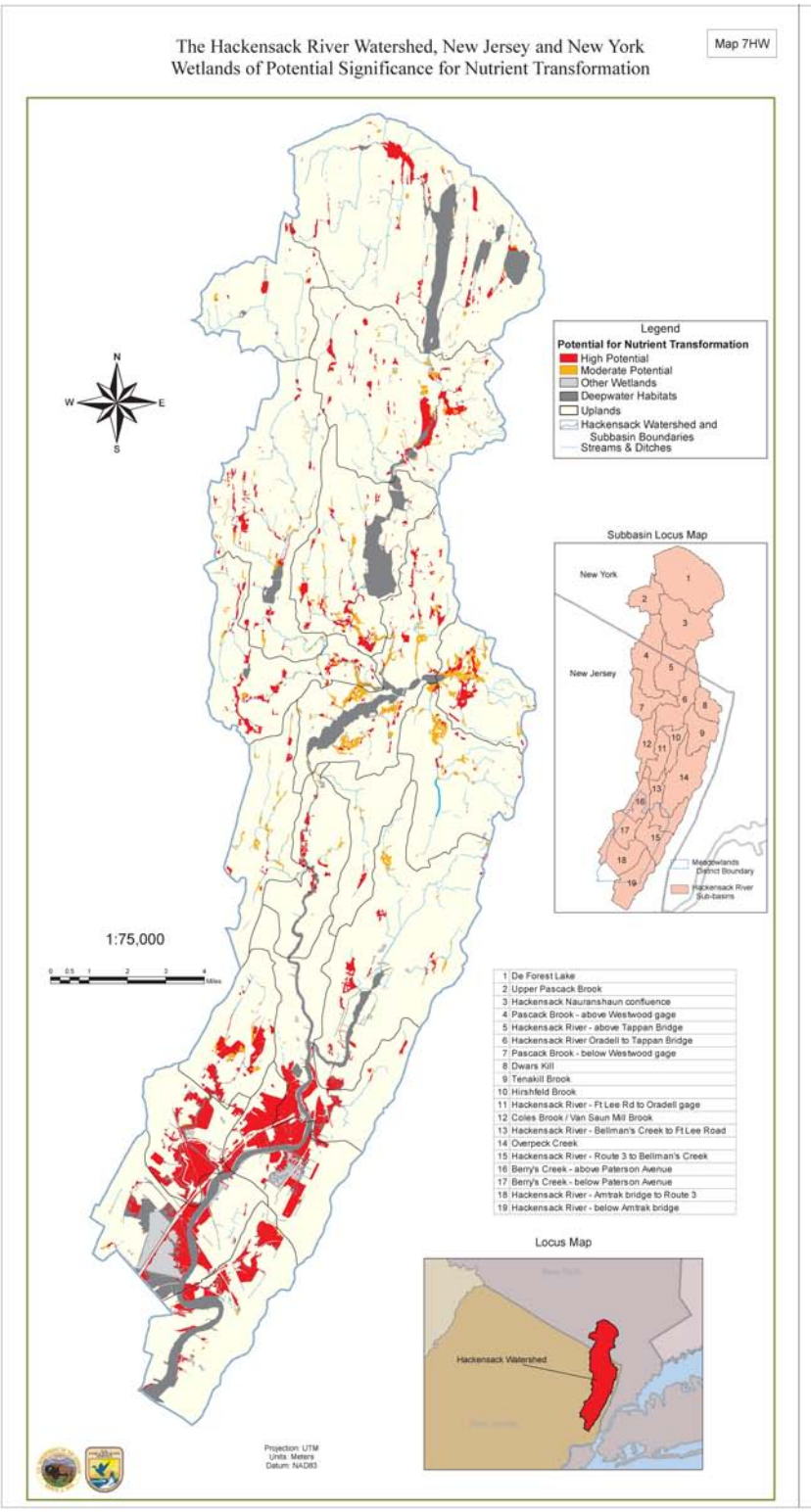
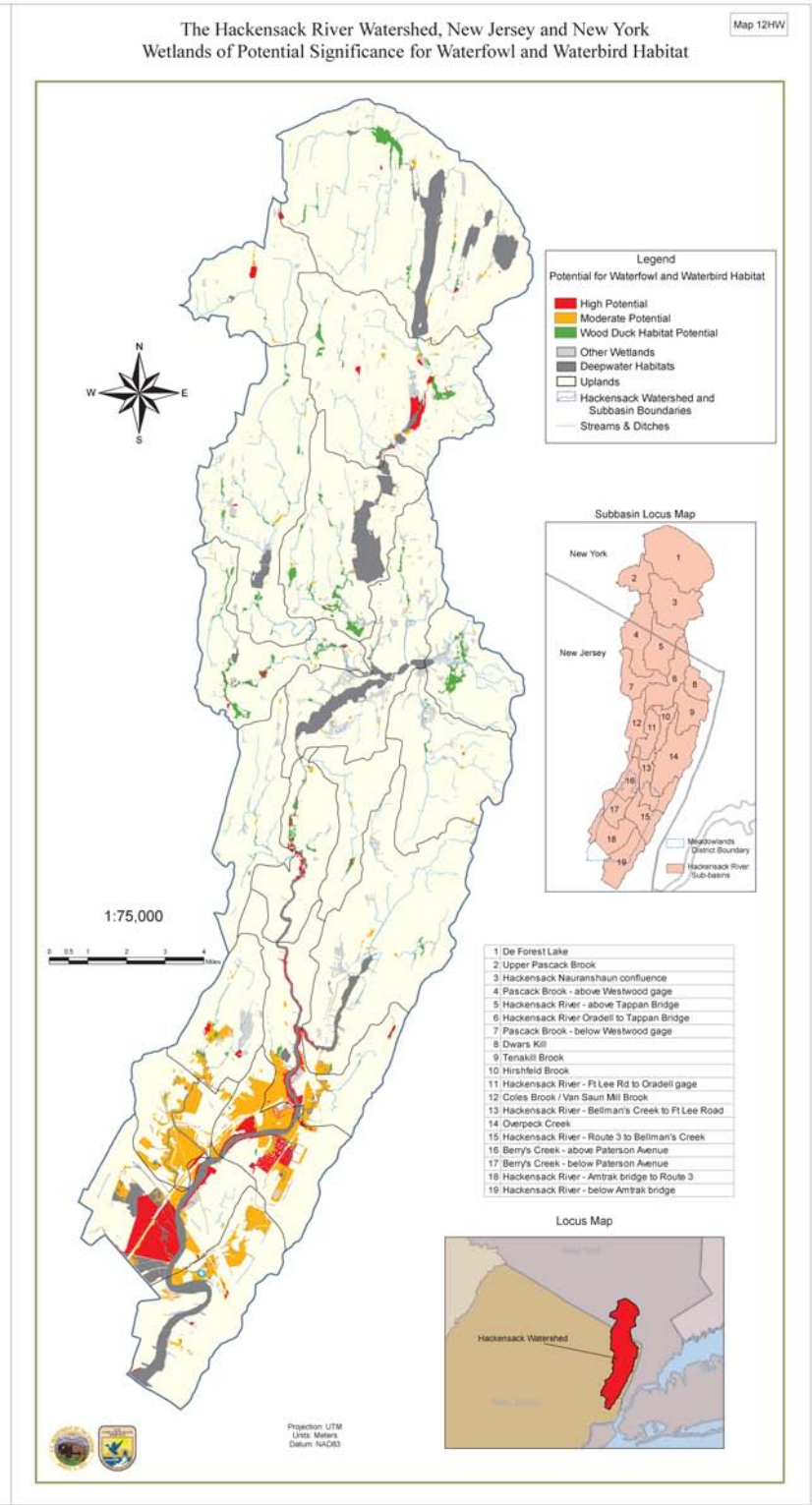


Figure 51. Wetlands of potential significance for waterfowl and waterbirds in the Hackensack River watershed (from Tiner and Bergquist, 2005). Certain estuarine, lotic riverine, and lotic stream habitats have high or moderate potential to support waterfowl and waterbirds.



In summary, preliminary assessments indicate that the extensive palustrine wetlands that occur throughout the HRW are important to restoring the Meadowlands and to sustaining its fish and wildlife resources. For example, palustrine wetlands throughout the HRW appear to be important sites for nutrient transformation (Figure 50; Tiner and Bergquist, 2005) and thus improve water quality in lower portions of the watershed. Palustrine wetlands also maintain stream flows in upper portions of the watershed (Figure 52); maintenance of stream flows is important for water quality and sustaining the biodiversity in the upper portions of the watershed (Figure 53). Preliminary assessments indicate that wetlands in upper portions of the watershed are less disturbed than those in the Meadowlands and are located within a less-developed upland landscape (Tiner and Bergquist, 2005). The quality of wetlands in the upper watershed must be protected because water quality and biodiversity in the entire watershed depend, in part, on them. Stakeholders need to expand their efforts to evaluate and protect land and water use in the upper HRW as part of any overall strategic restoration effort for the Meadowlands.

D. UPLAND LANDSCAPE COVER, LAND USE, BUFFERS, AND CORRIDORS

1. Upland Landscape Cover and Land Use

Landscape cover throughout the HRW and the HMD has been altered extensively to accommodate human activities and land uses that are typical of the heavily populated northeastern United States. Approximately 70 percent of the Hackensack-Pascack watershed (Figure 54) that lies within the State of New Jersey has been developed for human use and is defined as "urban" (New Jersey Department of Environmental Protection, 2004b; Tiner and Bergquist, 2005). As defined by NJDEP (2004c), the urban land-use classification includes land primarily developed for industrial, commercial, residential, utility, and transportation uses. Agricultural and certain barren lands (*e.g.*, landfills, recently cleared areas) occupy less than 1 percent of the HRW within the State of New Jersey. Natural landscape types remaining within the entire watershed include forests (13.6 percent), open water (2.6 percent), and wetlands (4.7 percent; Table 27; New Jersey Department of Environmental Protection, 2004c). Extensive alteration of the landscape emphasizes the importance of comprehensive efforts to preserve open space remaining throughout the watershed for fish and wildlife and other functions.

The natural vegetative cover on nearly all uplands in the HMD has been altered to accommodate past and present human land uses (Figure 55). Except for landfills, recreation areas, some vacant and transitional lands, and a few other areas (*e.g.*, open area around Teterboro airport runways), most upland areas within the HMD are developed for transportation, industrial, utilities, government, commercial, residential, communication, or other purposes (Table 27; New Jersey Meadowlands Commission, 2004d). Until recently, common reed, other grasses, and scrub-shrub vegetation covered more than 1,400 acres of closed landfills; however, approximately 45 percent of that land cover has been cleared to accommodate landfill remediation and closure, and subsequent redevelopment (*i.e.*, EnCap's Meadowlands Golf Project). Fewer than 100 acres of forested uplands occur throughout the HMD. Despite the extensive alteration of natural landscape cover within the HMD, urban and other human land-uses within the HMD occupy a less extensive area percentage-wise in the HMD (59 percent; 11,457 acres) than in the entire HRW and in many other coastal watersheds (Pew Oceans Commission, 2004). Again, although

greatly reduced from its historical dimensions, the extensive acreage of remaining wetlands and waterways within the HMD as compared to the remainder of the watershed underscores the importance of restoring and protecting its aquatic and adjoining terrestrial habitats.

Table 27. Acreage and percent of upland landscape cover and land use in the Hackensack Meadowlands District (HMD) and that portion of the Hackensack River watershed (HRW) in New Jersey. Because information sources include the NJMC, NJDEP, and the Service (*i.e.*, Tiner and Bergquist, 2005 and Tiner *et al.*, 2005), acreage totals may vary slightly from other estimates for the HMD. Percentages pertain to the respective area (HMD or HRW). Dashes (--) indicate the cover type was not reported.

	HMD		HRW	
Landscape Cover or Land Use	Acres	Percent	Acres	Percent
Open water	1,870	9.6	2,397	2.6
NWI wetlands	5,784	29.7	4,402	4.7
Forested uplands	92	0.5	12,778	13.6
Herbaceous/shrub	282	1.4	--	--
Agricultural	0	0.0	230	0.2
Altered and vacant lands	1,800	9.2	1,200	1.3
Recreational lands	757	3.9	--	--
Urban	8,900	45.7	72,935	77.6
Total	19,485		93,942	

Figure 52. Wetlands of potential significance for streamflow maintenance in the Hackensack River watershed (from Tiner and Bergquist, 2005). These headwater areas contribute to improved water quality in lower portions of the watershed.

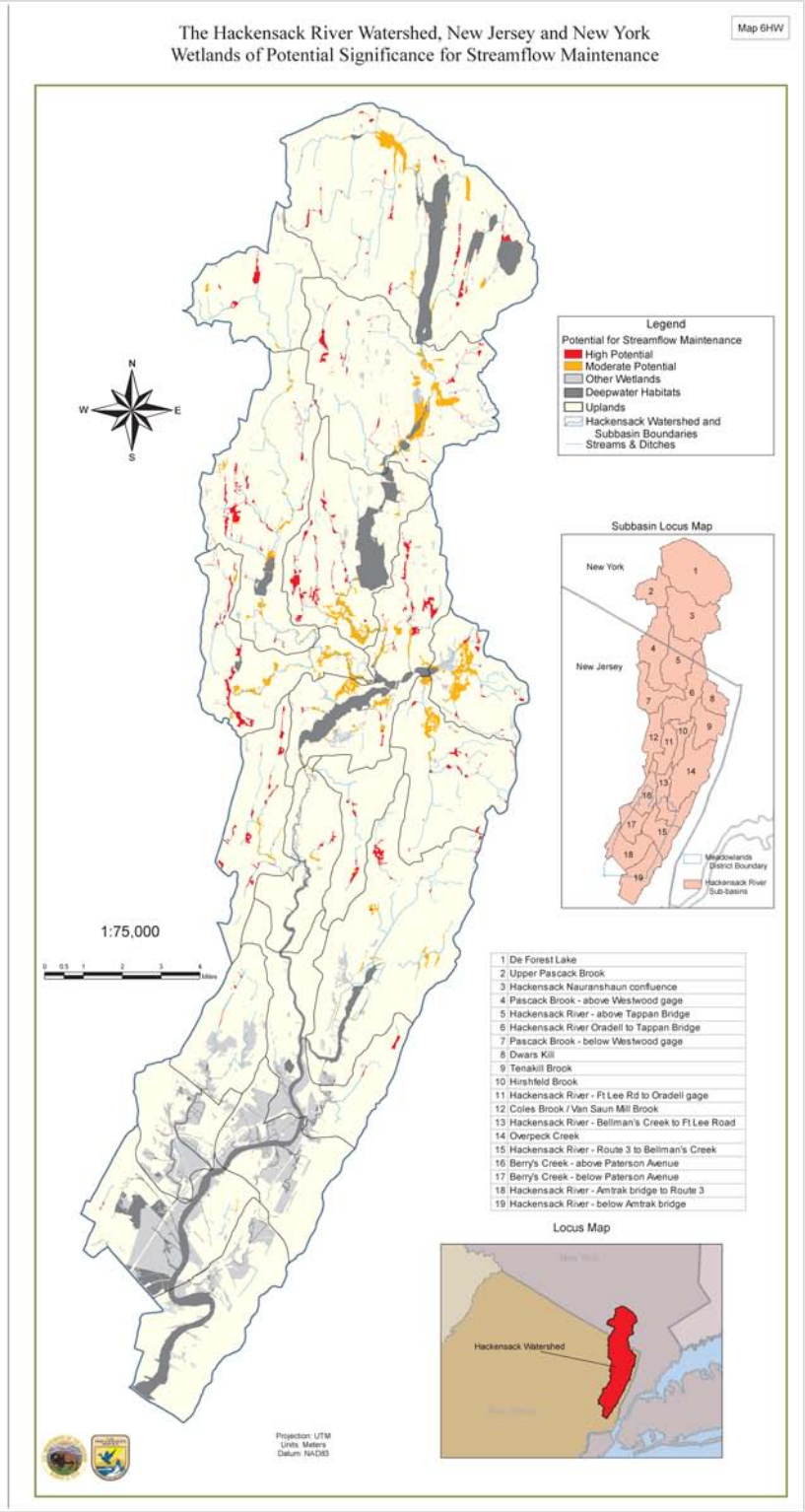


Figure 53. Wetlands of potential significance for sustaining biodiversity in the Hackensack River watershed (from Tiner and Bergquist, 2005). Estuarine and palustrine wetlands throughout the watershed help sustain the biodiversity of the Meadowlands and the region.

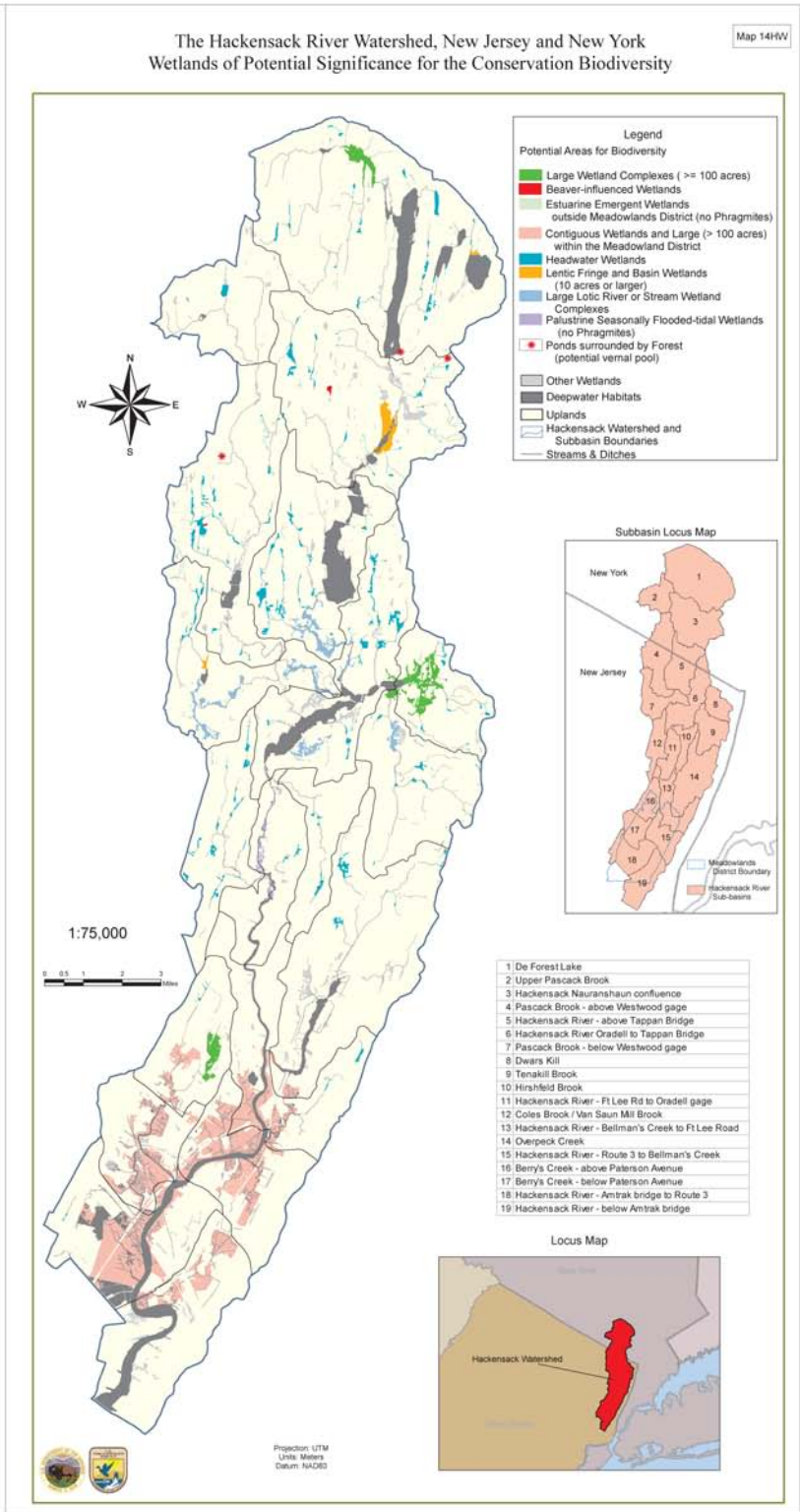


Figure 54. The extent of natural (upland and wetland) habitat in the Hackensack River watershed (from Tiner and Bergquist, 2005). The Hackensack Meadowlands District includes the most extensive area of natural habitat remaining in the entire watershed.

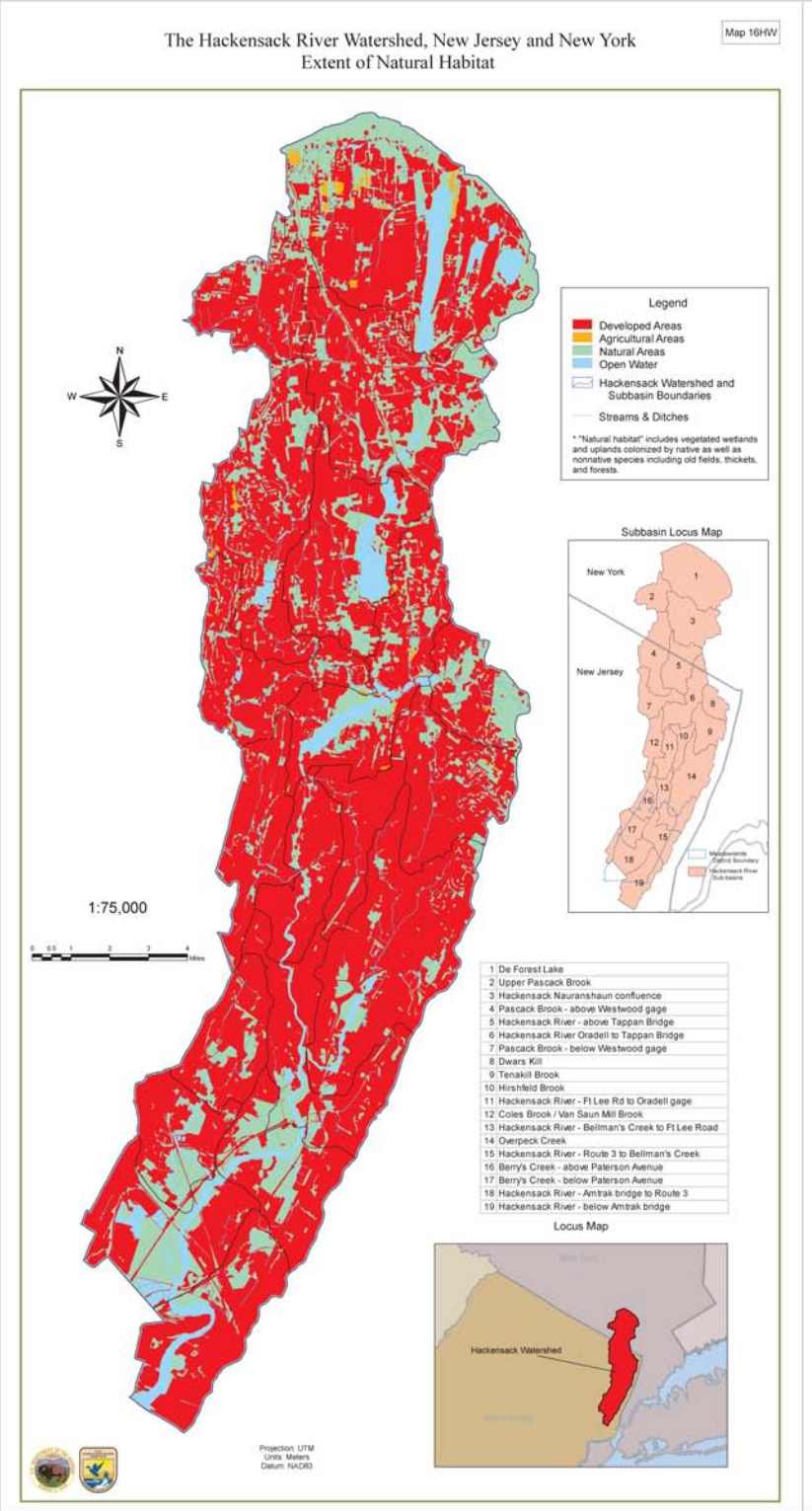
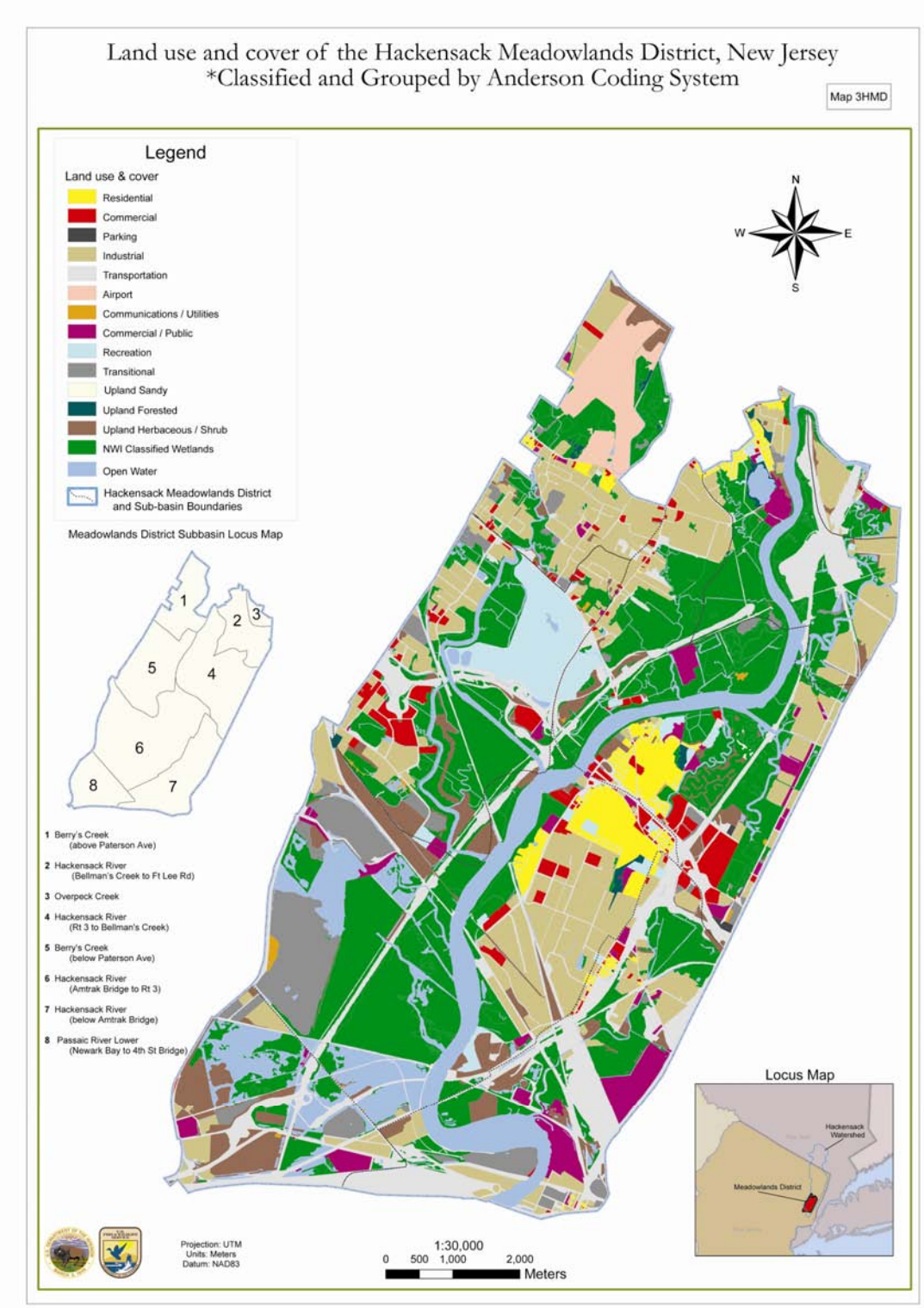


Figure 55. Land use and landscape cover in the Hackensack Meadowlands District (HMD; from Tiner *et al.*, 2005). Uplands in the HMD are extensively developed; however, its remaining wetlands and waterways are among the largest open areas in the northeastern United States.



2. Upland and Riparian Buffers

The term *buffer* is most often applied to areas that separate natural lands from lands modified for human activities, such as agriculture; however, *buffer* is used in this document to describe all lands that adjoin wetlands or waterways. Buffers include vegetated upland and transitional riparian areas (see below) that protect wetlands from disturbances and adjacent land uses and support ecosystem functions of wetlands (*e.g.*, Bren, 1993; Castelle *et al.*, 1994; Leavitt, 1998; Wenger, 1999; Fischer and Fischenich, 2000). Buffers provide or support many ecosystem functions by: (1) trapping sediment and controlling erosion, (2) storing and moderating the flow of storm and flood waters, (3) processing certain nutrients (*e.g.*, nitrates) and contaminants (*e.g.*, heavy metals), and (4) providing habitats for aquatic and terrestrial organisms (*e.g.*, Naiman *et al.*, 1993; Schueler, 1994; Weller *et al.*, 1998). In addition, buffers offer recreational and educational opportunities and improve aesthetics, and may increase property values (Wenger, 1999). Riparian areas[1] are increasingly recognized as dynamic, functionally unique components of wetland buffers (*e.g.*, Naiman and Descamps, 1997). Riparian areas typically comprise a small percentage of the landscape, harbor a disproportionately high number of wildlife species, perform disparate ecological functions when compared to most upland cover types (*e.g.*, biogeochemical cycling), and have become a major focus in the restoration and management of landscapes (Knopf *et al.*, 1988; Naiman and Descamps, 1997; Allan, 2004).

The extent to which riparian and other buffer areas affect wetland functioning and biodiversity varies with buffer and wetland characteristics (*e.g.*, Castelle *et al.*, 1994; Weller *et al.*, 1998). Buffer width and extent, wetland hydraulics, the vegetative community, and other features affect the retention and discharge of sediment and nutrients into wetlands. For example, buffer widths between 5 and 50 m are often identified as critical to maintaining water quality (*e.g.*, Lynch *et al.*, 1985; Lowrance, 1992); however, buffer widths between 100 and 500 m are identified as critical to sustaining biodiversity (*e.g.*, Keller *et al.*, 1993; Whittaker and Montevecchi, 1999; Fischer and Fischenich, 2000). Thus, the Service recommends that restoration planning include identification of buffer widths and other features necessary to protect water quality and provide habitats for key species (*e.g.*, amphibians, reptiles such as diamondback terrapin, migratory birds, and mammals such as muskrat) in the Meadowlands ecosystem and throughout the HRW.

Preliminary assessments employing 100-m-wide buffers indicate that buffers throughout the watershed, and especially in the HMD, are in poor condition (Tiner and Bergquist, 2005; Tiner *et al.*, 2005). Approximately 35 percent of the wetland-buffer area throughout the HRW is vegetated; however, only 13 percent of the wetland-buffer area in the HMD is vegetated (Figure 56; Table 28). (For perspective, the extent of buffers in subbasins of the Nanticoke River, Delaware watershed, which is considered heavily impacted by agricultural activities, averages approximately 40 percent [Tiner, 2004]). Buffers around wetlands in all subbasins throughout the HMD have little vegetation; most buffer areas in the HMD are developed (Figure 56). Transitional lands (mostly landfill) also occupy a considerable portion of the wetland buffers; this indicates the importance of remediating and restoring transitional areas to prevent further degradation of water quality and provide habitat for fish and wildlife. Vegetation covers roughly 35 percent of the 100-m-wide corridor along each side of non-tidal rivers and streams throughout

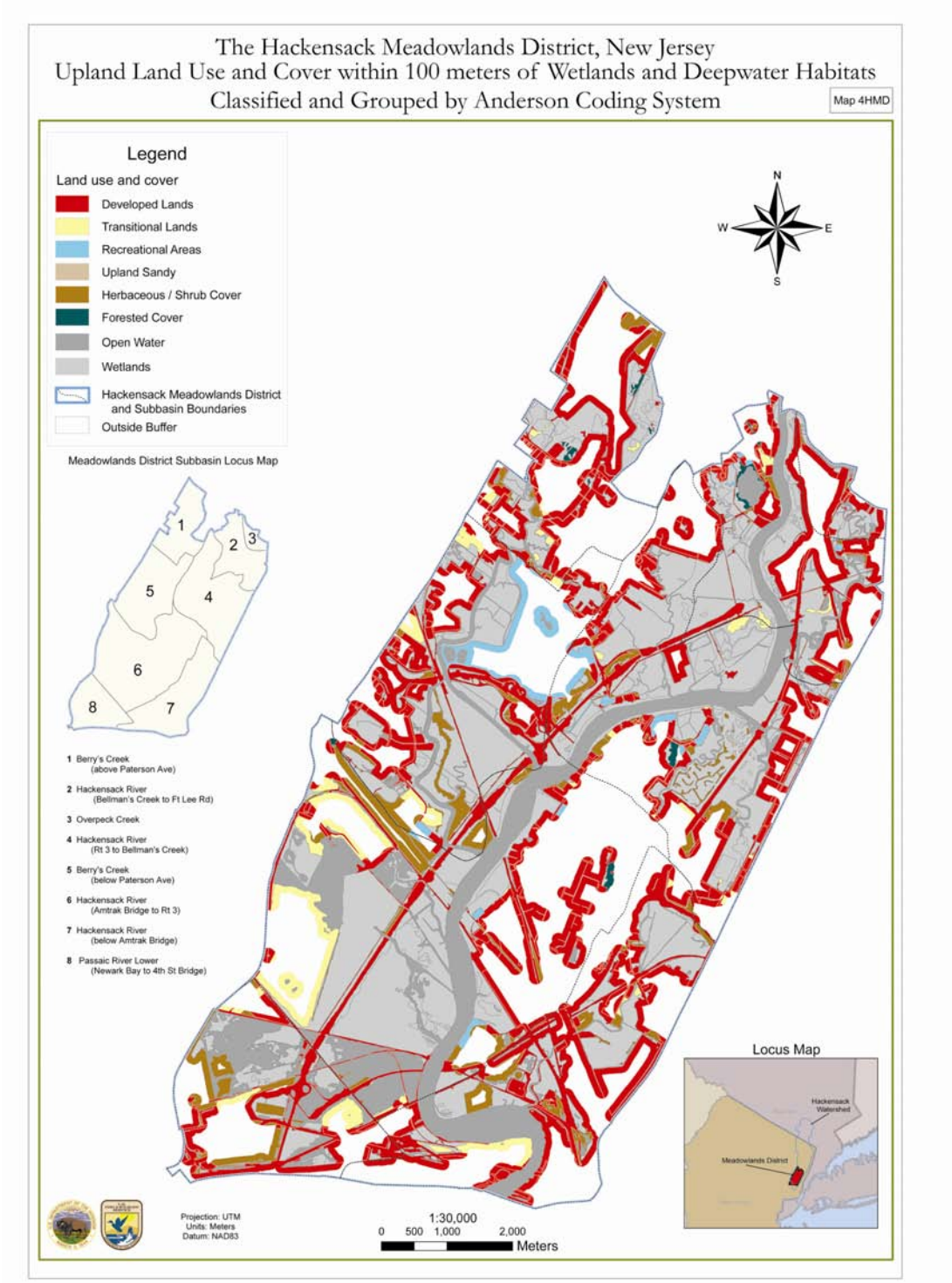
[1] Riparian areas- vegetated areas adjacent to streams, rivers, lakes, reservoirs, and other inland aquatic systems that affect or are affected by the presence of water

the HRW; however, few basins in the HMD have such non-tidal buffers (Table 28). In addition to wetland buffers, the extent of buffers around ponds and lakes is greater in the watershed (37 percent) than in the HMD (16 percent). The only extensively vegetated pond/lake buffer in the HMD occurs around Mehrhof Pond; this high-quality buffer contributes to the high Pond and Lake Buffer Index for the Hackensack River subbasin from Bellman's Creek to Fort Lee Road (Table 28). The poor condition of all buffers undoubtedly contributes to poor water quality and other adverse impacts upon biodiversity in the HMD.

Table 28. Wetland, river and stream, and pond and lake buffers for subbasins (ID number as per Figure 43) in the Hackensack Meadowlands District (HMD) and elsewhere in the Hackensack River watershed (HRW; from Tiner and Bergquist, 2005 and Tiner *et al.*, 2005). Indices of: (1) vegetated wetland buffers (I_{VWB} = area of 100-m buffer around wetlands that is vegetated / total area of the 100-m buffer around wetlands), (2) of river and stream buffers (I_{RSC} = area of 100-m buffer around rivers and streams that is vegetated / area of the 100m-buffer around rivers and streams), and (3) of pond and lake buffers (I_{PLB} = area of 100-m wide buffer around ponds and lakes that is vegetated / total area of the 100-m buffer around ponds and lakes). The low indices reflect the limited extent of vegetation in most buffer areas, and suggest impaired ecosystem functioning and reduced capacity to support biodiversity throughout the watershed.

Hackensack Meadowlands District (Subbasin ID number)	I_{VWB}	I_{RSC}	I_{PLB}
Berry's Creek above Paterson Ave. (16)	0.13	0.46	0.04
Berry's Creek below Paterson Ave. (17)	0.14	--	0.06
Hackensack River, Amtrak Bridge to Rt. 3 (18)	0.18	--	0.03
Overpeck Creek (14)	0.03	--	0.00
Hackensack River, Bellman's Creek to Ft. Lee Rd. (13)	0.07	0.48	0.48
Hackensack River, Rt. 3 to Bellman's Creek (15)	0.12	--	0.08
Hackensack River below Amtrak Bridge (19)	0.15	0.11	0.26
Lower Passaic River (20)	0.24	--	0.33
HMD averages	0.13	0.35	0.16
Hackensack River Watershed (Subbasin ID number)			
Coles Brook/Van Saun Mill Brook (12)	0.11	0.18	0.15
De Forest Lake (1)	0.51	0.44	0.56
Dwars Kill (8)	0.56	0.64	0.68
Hackensack-Nauranshaun Confluence (3)	0.47	0.41	0.56
Hackensack River, Ft. Lee to Oradell Gage (11)	0.11	0.33	0.07
Hackensack River, above Tappan Zee Bridge (5)	0.61	0.45	0.45
Hackensack River, Oradell to Tappan Zee Bridge (6)	0.50	0.47	0.54
Hirshfeld Brook (10)	0.11	0.12	0.08
Pascack Brook above Westwood Gage (4)	0.26	0.41	0.39
Pascack Brook below Westwood Gage (7)	0.19	0.35	0.27
Tenakill Brook (9)	0.29	0.27	0.33
Upper Pascack Brook (2)	0.49	0.08	0.36
HRW averages	0.35	0.35	0.37

Figure 56. Wetland buffers in the Hackensack Meadowlands District (HMD; from Tiner *et al.*, 2005). Land-use activities in the 100-m-wide area surrounding wetlands were characterized for the entire HMD and for each hydrologic subbasin. Only 13 percent of the buffer areas surrounding the HMD's wetlands are vegetated; the poor condition of buffers likely contributes to poor water quality, impaired ecosystem functions, and low biodiversity.



Buffer requirements throughout much of New Jersey have recently changed as part of the State's new stormwater regulations (*i.e.*, Phase II New Jersey Pollutant Discharge Elimination System Stormwater Regulation Program Rules [N.J.A.C. 7:14A] and the Stormwater Management Rules [N.J.A.C. 7:8]) to increase buffer width (up to 300 feet in certain areas) to provide better protection of wetlands and waterways, especially where water quality is good. Within the HMD, the buffer requirements are established by the NJMC's Zoning Regulations. Because land-use and runoff effects on water quality vary considerably (Pitt, 2003), the Service recommends that the NJMC evaluate the effects of its buffer requirements on water quality and modify the regulations as needed to reduce impairments to water quality in the Hackensack River and its tributaries (See Section IV.B for additional information about stormwater effects.).

3. Upland Corridors

Landscape connectivity generally enhances population sustainability for many species (*e.g.*, Meffe and Carroll, 1997; Primack, 2002). Certain human land-use activities (*e.g.*, wetland filling, transportation development, urbanization) are recognized as severing connectivity between wetland and upland landscapes. As a result, retaining, enhancing, and creating habitat corridors have been widely advocated as means of sustaining biodiversity, and consequently, as important to conservation planning (*e.g.*, Fahrig and Merriam, 1994; Beier and Noss, 1998; Rosenberg *et al.*, 1998). However, demonstrating the utility of corridors has been difficult due to experimental and statistical problems (Beier and Noss, 1998). For example, connecting two areas with a corridor may be no more effective than simply increasing the size of one of the areas. In addition, corridors may: (1) promote the spread of pathogens and invasive species, (2) increase mortality; and (3) have high acquisition costs in comparison with acquisition costs of other natural areas (*e.g.*, Hobbs, 1992; Simberloff *et al.*, 1992; Haddad *et al.*, 2000; Levey *et al.*, 2005). Also, unless distinct travel corridors have been closely identified and observed, there is no assurance that such corridors will actually be used.

Despite the potential problems noted above, corridors are increasingly recognized as useful for conservation of invertebrate, amphibian, reptile, bird, and mammal species, including species inhabiting wetlands and adjoining riparian areas (*e.g.*, Dunning *et al.*, 1995; DeGraaf and Yamasaki, 1999; Marsh and Trenham, 2001; Martin, 2002; Gibbons, 2003; Levey *et al.*, 2005). For example, the entire Meadowlands is important for birds migrating along the Atlantic flyway (Dunne *et al.*, 1989); moreover, most open space, including forested, grassland (mostly landfill), and wetland habitats in the Meadowlands are important refugia to migrating birds (Kane and Githens, 1997). Animal behavior (*e.g.*, predator or edge responses), corridor features (*e.g.*, width, quality), and landscape structure (*e.g.*, the mix of habitats surrounding the corridor) clearly affect corridor use by different animal species (*e.g.*, Lima and Zollner, 1996; Fagan *et al.*, 1999; Nathan *et al.*, 2003). For example, some animals may not enter narrow corridors, whereas animals may not progress far in wide corridors due to cross-directional movements (*e.g.*, Andraesson *et al.*, 1996).

To date, the extent to which open space in the Meadowlands ecosystem or the HRW is connected has not been thoroughly investigated. Wetlands in the HMD are more contiguous than wetlands in upper portions of the HRW; however, some forested and other upland open space (*e.g.*, active agricultural lands) is located in the upper Hackensack River watershed. Stakeholders should

explore acquisition, protection, and restoration of those areas that potentially serve as corridors (*i.e.*, improve connectivity in remaining open space) to sustain biodiversity in the Meadowlands, based upon actual observations of movements in certain areas and similar kinds of sites. Commitments need to be made to monitor such corridors closely for effectiveness as well as potential problems and to utilize adaptive management accordingly. The Service also recommends that initial stakeholder efforts regarding the potential use of corridors focus on landscape structures, corridor features, and the behavior and habitat requirements of rare and priority species (*e.g.*, State-listed birds, Service Birds of Conservation Concern).

E. SUMMARY

Historical human uses of the Meadowlands, other wetlands in HRW, and adjoining uplands in this densely populated area have resulted in substantial losses of wetlands and uplands, altered and fragmented remaining natural landscape, and disrupted the Meadowlands ecosystem and its capacity to sustain fish and wildlife populations. More than 70 percent of the total wetlands that once existed in the HMD (20,045 acres, which included most but not all wetlands in the Hackensack Meadowlands) have been destroyed by human activities, mostly filling. Approximately 40 percent of wetlands elsewhere in the watershed also have been lost to filling and other activities such as construction of water-storage reservoirs. Wetland types in the Meadowlands have changed extensively over the past 100 years, and continue to change as a result of increasing saltwater intrusion and other factors in the lower Hackensack River.

Currently, approximately 9,650 acres of wetlands remain in the HRW. There is a pronounced difference in the types, condition, functioning, and risks to wetlands in the HMD and the upper HRW. Wetlands in the HMD are primarily estuarine, and fairly homogeneous in their NWI inventory type and vegetative cover (predominantly common reed). Many wetlands in the HMD are relatively large and contiguous in comparison with wetlands elsewhere in the watershed. The lower Berry's Creek subbasin, which is heavily contaminated, lies between the two subbasins that contain the most extensive wetland acreage in the HMD. Wetlands in the upper watershed are almost entirely palustrine and generally small and not contiguous, yet they represent more diverse NWI wetland types (*e.g.*, lentic, lotic, terrene).

Estuarine wetlands in the HMD are extensively fragmented by roads and other rights-of-way and have been highly disturbed by human activities such as ditching and diking that have adversely impacted the land and the flows of tidal and fresh water. As a result, wetlands in the HMD are impaired for certain (*e.g.*, streamflow maintenance) but not all wetland functions. Estuarine wetlands also appear at risk of conversion to deepwater habitats due to SLR and other factors such as dredging and restoration. As a result of their type, size, and isolation, palustrine wetlands in the upper watershed remain vulnerable to adverse impacts from surrounding land-use changes and at increasing risk of development. Nonetheless, palustrine wetlands in the upper watershed help maintain and improve water quality and sustain biodiversity in the lower watershed. Thus, Meadowlands stakeholders must focus greater attention than has been given in the past to protecting wetlands and adjoining uplands in the upper HRW. Such efforts should include partnerships with agencies and NGOs in New York.

Landscape cover throughout the HRW and the HMD has been altered extensively to accommodate human land uses that are typical of the heavily populated northeastern United States. Natural upland areas that serve as buffers around wetlands and water bodies are in poor condition throughout the HRW, and especially distressed within the HMD. The Meadowlands is recognized as a corridor for migratory birds; however, natural lands throughout the watershed are heavily fragmented and poorly connected. Better assessment and an improved understanding of fragmentation-, buffer-, and corridor-effects appear essential to sustaining the fish and wildlife resources of the Meadowlands. Concerted restoration and planning efforts provide an opportunity for stakeholders to reverse and rectify historic, adverse land-use impacts on the Meadowlands ecosystem and its biodiversity.