The Hackensack Meadowlands District: Wetland Inventory and Remotely-sensed Assessment of "Natural Habitat" Integrity

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The Hackensack Meadowlands District: Wetland Inventory and Remotely-sensed Assessment of "Natural Habitat" Integrity

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Introduction

The U.S. Fish and Wildlife Service's Northeast Region is providing information to the New Jersey Meadowlands Commission on wetlands and other environmental resources within the Hackensack Meadowlands District (HMD) This work is being directed by the New Jersey Ecological Services Field Office (NJFO), Pleasantville, New Jersey. The NJFO contacted the Region's National Wetlands Inventory Program (NWI) about collecting and analyzing information on wetlands and related resources. The NWI portion of this work involved conducting an inventory of current natural resources within the District through photointerpretation techniques. Work included a wetlands inventory and an assessment of the overall extent of "natural habitat" in this area.

The typical wetlands inventory characterizes wetlands mainly by their vegetation and expected hydrology (water regime), with other modifiers used to indicate human or beaver activities (e.g., diked/impounded, excavated, partly drained, and beaver-influenced). In order to use the NWI data to predict functions (e.g., surface water detention, nutrient transformation, streamflow maintenance, and provision of fish/wildlife habitat) and get a better sense of the relationship between wetlands and waterbodies, additional information on the hydrogeomorphic characteristics of wetlands is required. The Service has developed a set of attributes to better describe wetlands by landscape position, landform, water flow path, and waterbody type (LLWW descriptors; Tiner 2003a). When added to the NWI data, the enhanced NWI data have a predictive capability regarding wetland functions (Tiner 2003b). To characterize the general status of natural resources through remote sensing techniques, the Service developed a set of remotely sensed "natural habitat integrity indices" (Tiner 2004). The land use/cover information needed for calculating these indices were collected as part of this project. This report documents the findings for the Meadowlands District.

Study Area

The Meadowlands District is located at the mouth of the Hackensack River in northeastern New Jersey (Figure 1). The District contains more than 16,000 acres (25 square miles). The Meadowlands is one of the largest urban wetlands in the state and is the largest estuarine wetland in the Newark metropolitan area. The Hackensack River is tidal in this area and most of the District’s wetlands are subject to tidal flooding on a less than daily basis. Nontidal wetlands is this urban area have been largely filled, with few remaining. Besides the Hackensack River, Berry’s Creek, Overpeck Creek, and Bellman’s Creek are the major waterways in the Meadowlands. Eight subbasins have been identified: 1) Berry’s Creek above Paterson Avenue, 2) Berry’s Creek below Paterson Avenue, 3) Hackensack River from the Amtrak bride to Route 3, 4) Hackensack River from Bellman’s Creek to Fort Lee Road, 5) Hackensack River below the Amtrak bridge, 6) Hackensack River from Route 3 to Bellman’s Creek, 7) Overpeck Creek, and 8) Lower Passaic River from Newark Bay to the 4th Street Bridge (Figure 1).

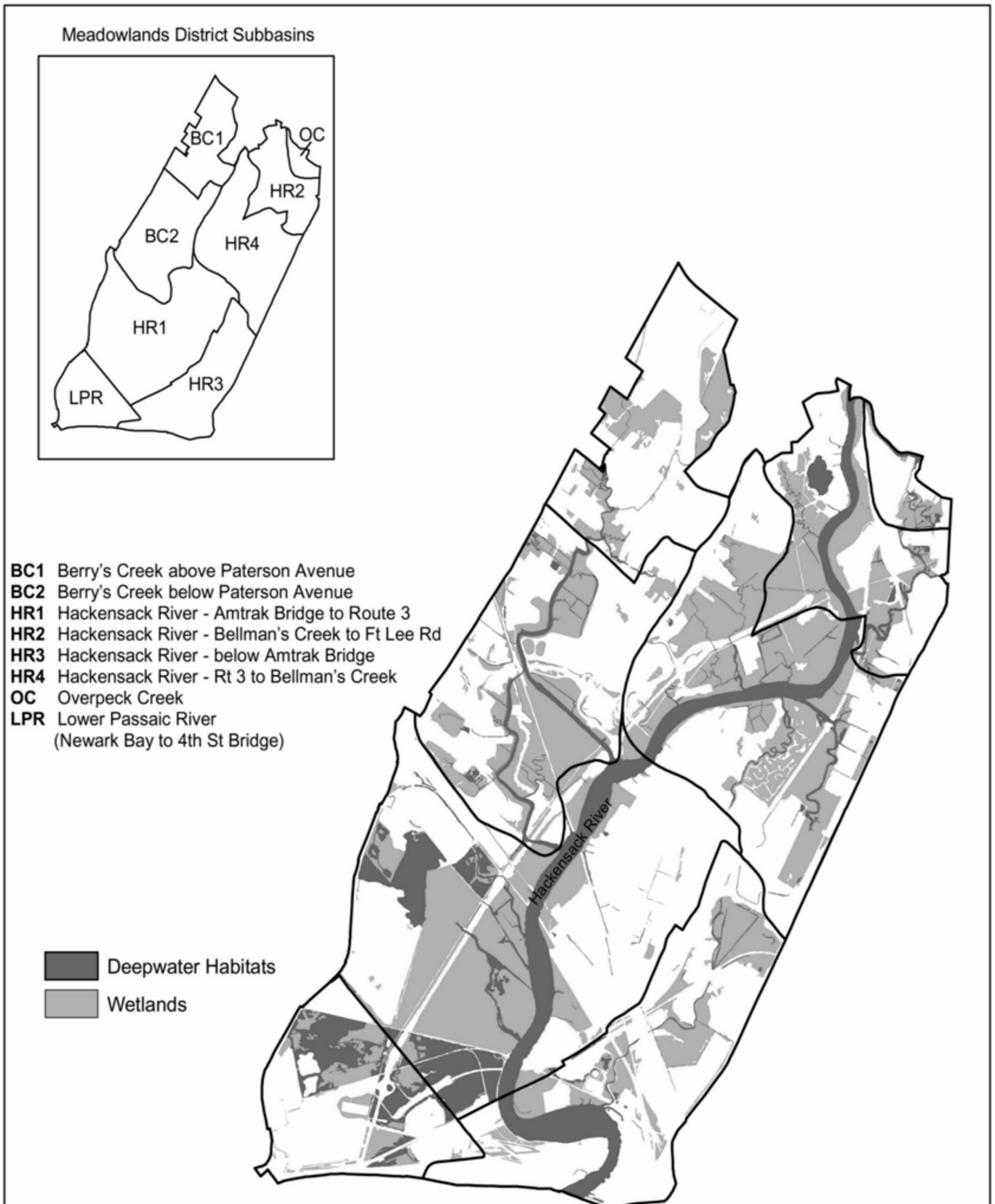

Figure1. The Meadowlands and its subbasins.

Methods

Wetland Classification and Inventory

One of the objectives of this project was to create an up-to-date inventory of wetlands and to add attributes for landscape position, landform, water flow path, and waterbody type (LLWW descriptors) to each mapped wetland and deepwater habitat, as appropriate. For the inventory, NWI data based on 1995-1:40,000 color infrared photography was updated through a heads-up (on-screen) interpretation process using 2002 color orthophotography and 2003 black and white orthophotography for the Meadowlands. The 1995 NWI data were matched to the orthophotographs and adjusted accordingly, and then updated through heads-up photointerpretation procedures. A special effort was made to map the full extent of open ditches in the District within the constraints of the aerial photography.

The predominance of common reed (Phragmites australis) and the occurrence of many impoundments and road and railroad crossings complicated wetland classification. Instead of calling the entire Meadowlands simply estuarine, we attempted to pull out areas where freshwater influence was more significant. We did this by applying the oligohaline water chemistry modifier ("6") to wetlands behind roads and highways and tidal wetlands enclosed by dikes. Such areas have reduced tidal flow (e.g., sheet flow restricted by causeways and railroad embankments, and dikes), greater freshwater influence due to these structures, and some communities were mixtures of common reed and cattail (Typha) – evidence of lower salinities than estuarine portions of the Meadowlands where smooth cordgrass (Spartina alterniflora) is establishing. Marshes along the mainstem of the Hackensack River were considered to be more brackish or saline. These interpretations provided consistent results.

After completing the basic inventory, three main descriptors (landscape position, landform, and water flow path) were applied to each wetland by interpreting available map information, and in some cases, aerial photography was consulted. "Dichotomous Keys and Mapping Codes for Wetland Landscape Position, Landform, Water Flow Path, and Waterbody Type Descriptors" (Tiner 2003a; Appendix) was initally used to classify these features. Other modifiers were added to depict features such as headwater, drainage-divide, and human-impacted wetlands.

Landscape position defines the relationship between a wetland and an adjacent waterbody if present. For the Meadowlands, four landscape positions were possible: 1) estuarine (along salt and brackish tidal waters), 2) lotic (along rivers and streams), 3) lentic (along lakes and reservoirs), and 4) terrene (typically surrounded by upland or serving as the source of a stream). Lotic wetlands may be divided into lotic river and lotic stream wetlands by their width on a 1:24,000-scale map. Watercourses mapped as linear (single-line) features on NWI maps and on U.S. Geological Survey topographic maps (1:24,000) were designated as streams, whereas two-lined channels (polygonal features on the maps) were classified as rivers. All lotic wetlands are in contact with streams or rivers. Wetlands on floodplains surrounded by upland (nonhydric soil) were classified as terrene wetlands as were nontidal wetlands completely surrounded by dryland and wetlands that were the source of streams. Lentic wetlands were divided into two categories: natural and dammed, with the latter type separating wetlands associated with reservoirs from those along other controlled lakes, when possible.

Landform is the physical form or shape of a wetland. Five landform types were recognized in the study area: 1) basin, 2) flat, 3) slope, 4) island, and 5) fringe (Table 1). Fringe wetlands are mostly associated with estuarine waters and semipermanently flooded vegetated wetlands elsewhere. Where an estuarine wetland is located behind a causeway (road or railroad) or otherwise partially cut off from the mainbody of a fringing wetland, the wetland was classified as a basin wetland. Other basin wetlands were depressional wetlands and seasonally flooded wetlands along streams. Flats are wetlands on nearly level landforms; they typically have a seasonally saturated or temporarily flooded water regime.

Water flow path descriptors characterize the flow of water associated with wetlands. Four patterns of flow were recognized for wetlands in the Meadowlands: 1) bidirectional-tidal (all tidal wetlands), 2) throughflow, 3) outflow, and 4) isolated. Throughflow wetlands have either a perennial watercourse (e.g. stream) or another type of wetland above and below it, so water passes through them (usually by way of a river or stream, but sometimes by ditches). The water flow path of lotic wetlands associated with perennial streams is throughflow. Outflow wetlands discharge water year-long or nearly so. Isolated wetlands are essentially closed depressions (geographically isolated) where water comes from surface water runoff and/or groundwater discharge. For this project, surface water connections are emphasized, since it is not possible to determine ground water linkages (especially outflow) without hydrologic investigations. Consequently, wetlands designated as isolated may have groundwater connections and may not be “hydrologically isolated.”

The headwater descriptor ("hw") was applied to wetlands along intermittent streams and first- and second-order perennial streams and to terrene wetlands that are the sources of these streams.

The pond modifer ("pd") was applied to any wetland in contact with a pond. The pond may exert influence on the wetland vegetation or may simply have little or no influence on the wetland (e.g., where a pond represents only a small portion of the wetland such as bog eyelet pond or where an artificial pond was excavated from an existing wetland). Wetlands bordering ponds that were mapped by NWI as impounded ("h") should be significantly influenced by pond hydrology.

Table 1. Definitions and examples of landform types (Tiner 2003a).

Landform Type	General Definition	Examples
Basin*	a depressional (concave) landform including artificially created ones by impoundments, causeways, and roads	lakefill bogs; wetlands in the saddle between two hills; wetlands in closed or open depressions, including narrow stream valleys; tidally restricted estuarine wetlands
Slope	a landform extending uphill (on a slope; typically crossing two or more contours on a 1:24,000 map)	seepage wetlands on hillside; wetlands along drainageways or mountain streams on slopes
Flat*	a relatively level landform, often on broad level landscapes	wetlands on flat areas with high seasonal ground-water levels; wetlands on terraces along rivers/streams; wetlands on hillside benches; wetlands at toes of slopes
Floodplain**	a broad, generally flat landform occurring on a landscape shaped by fluvial or riverine processes	wetlands on alluvium; bottomland swamps
Fringe	a landform occurring within the banks of a nontidal waterbody (not on a floodplain) and often but not always subject to near permanent inundation and a landform along an estuary subject to unrestricted tidal flow or a regularly flooded landform along a tidal freshwater river or stream	buttonbush swamps; aquatic beds; semipermanently flooded marshes; river and stream gravel/sand bars; salt and brackish marshes and flats; regularly flooded tidal fresh marsh or flat
Island	a landform completely surrounded by water (including deltas)	deltaic and insular wetlands; floating bog islands

*May be applied as sub-landforms within the Floodplain landform.
**This landform is applied only to wetlands on floodplains along “rivers” (polygonal watercourses); it is not applied to wetlands along streams because alluvial soils are not consistently mapped in these locations; the latter wetlands are classified as basins or flats.

Land Use/Cover Mapping and Geodatabase Construction

For this assessment, a geospatial database covering the entire Meadowlands District needed to be created. ARC GIS 9.0 was the format for the geospatial database. The updated NWI data and land use/cover data from the New Jersey Meadowlands Commission served as base data for this phase of the project. Coding of the latter source was simplified for our use and the classifications refined where necessary. The Anderson et al. (1976) land use and land cover (LULC) classification system was used to classify upland areas, with the following categories being among those identified: developed land, agricultural land, forests, wetlands (from NWI data), transitional land (moving toward some type of development or agricultural use, but future status unknown), and water. This update focused on major areas of land use change and, therefore, did not represent a comprehensive revision of all LULC categories. Changes between ”natural“ habitat and land use (mainly development for this study area) were emphasized.

Natural Habitat Integrity Assessment

We applied the remotely sensed indices of "natural habitat integrity" (Tiner 2004) to the geospatial dataset for the Meadowlands District. These indices were designed to meet four of the following requirements: 1) be derived from air photointerpretation and/or satellite image processing for contemporary data and from maps for historical data, 2) be suitable for frequent updating and rapid assessment, 3) consist of metrics that could efficiently and cost effectively updated for large geographic areas, 4) present a broad view of the extent of “natural habitat,” and 5) provide a historic perspective on the extent of wetlands and open waterbodies. Such indices would be coarse-filter variables for assessing the overall condition of watersheds. They were intended to augment, not supplant, other more rigorous, fine-filter approaches for describing the ecological condition of watersheds (e.g., IBIs for instream macroinvertebrates and fish and the extent of invasive species) and for examining relationships between human impacts and natural resources. While the indices were designed for use in larger watersheds, they may be applied to subbasins as they were for the Meadowlands District. The indices were calculated for each of the eight subbasins.

The variables chosen for indexing included: 1) extent of “natural” habitat, 2) condition of river and stream corridors, 3) condition of buffers around vegetated wetlands, 4) condition of pond and lake buffers, 5) present extent of wetlands relative to historic area, 6) present extent of standing waterbodies relative to historic area, 7) amount of stream channelization, 8) extent of river/stream damming, 9) the amount of wetland disturbance (i.e., drained, excavated, impounded, and farmed wetlands), and 10) the degree of habitat fragmentation by roads. While there are undoubtedly other features that can be monitored, these variables represent features important to natural resource managers attempting to lessen the impact of human development on the environment.

Eleven indices were created: six addressing habitat extent (i.e., the amount of natural habitat occurring in the watershed and along wetlands and waterbodies), four dealing with habitat disturbances (emphasizing human-induced alterations to streams, wetlands, and terrestrial habitats), and one composite index. The six “natural” habitat extent indices are “natural” cover, river-stream corridor integrity, vegetated wetland buffer integrity, pond and lake buffer integrity, wetland extent, and standing waterbody extent. The four “habitat disturbance indices“ involve dammed stream flowage, channelized stream flowage, wetland disturbance, and habitat fragmentation by roads. The last index - “composite natural habitat integrity index” - is comprised of the weighted sum of all the other indices, with the disturbance indices subtracted from the habitat extent indices to yield an overall “natural habitat integrity“ score for a watershed or subbasin. All indices have a maximum value of 1.0 and a minimum value of zero. For the habitat extent indices, the higher the value, the more habitat available. For the disturbance indices, the higher the score, the more disturbance.

For purposes of this study, ”natural habitats" are defined as areas where significant human activity is limited to activities such as nature observation, hunting, fishing, or timber harvest, and where vegetation is allowed to grow for many years without annual harvesting of vegetation or fruits and berries for commercial purposes. Natural habitats are not restricted to pristine habitats; they include managed habitats such as commercial forests and wildlife impoundments, but they are not cultivated or subjected to heavy human traffic (except perhaps along hiking trails). They are essentially plant communities represented by forests, meadows, shrub thickets, and wetlands where resident and migratory wildlife find food, shelter, and water. They are not developed sites (e.g., impervious surfaces, lawns, turf, cropland, pastures, or mowed hayfields). ”Natural habitat“ therefore includes habitats ranging from pristine wilderness to wetlands now colonized by invasive species (e.g., Phragmites australis or Lythrum salicaria) or pine plantation forests. “Natural vegetation” is the plant community growing in these habitats. Natural habitat integrity is broadly defined as conditions where “natural habitat” is typically allowed to exist for many years, without great disturbance by humans. This is quite different from the concept of biological integrity proposed by Angermeier and Karr (1994) that emphasizes conditions with little or no human influence. Clearly, the urban environment surrounding the Meadowlands has greatly reduced the amount of "natural habitat" outside of the remaining wetlands.

The indices do not include certain qualitative information on the condition of existing habitats as reflected by the presence, absence, or abundance of invasive species or the degree of forest fragmentation, for example. Fragmentation of the Meadowlands by roads is not as useful a statistic as it is in less developed watersheds, since the density of roads in some areas of the District are among the highest possible due to urban development. The level of effort required to inject more qualititative data into the analysis may preclude the rapid assessment objective for this remotely-sensed ecological assessment. For most watersheds, weighting of natural woodlands versus commercial forests may be a practical option for this type of assessment, but it was not explored. Another consideration would be establishment of minimum size thresholds to determine what constitutes a viable ”natural habitat“ for analysis (e.g., 0.04 hectare/0.1 acre patch of forest or 0.4 hectare/1 acre minimum?). Other indices may also need to be developed to further aid in water quality assessments (e.g., index of ditching density for agricultural and silvicultural lands).

Habitat Extent Indices

These indices mainly attempt to provide an assessment of the amount of “natural vegetation” or “natural habitat” that occurs in a watershed, including strategic locations important for water quality and aquatic/wetland wildlife. The following areas are emphasized: the entire watershed, stream and river corridors, vegetated wetlands and their buffers, and pond and lake buffers. The extent of standing waterbodies is also included to provide information on the quantity of aquatic habitat in the watershed relative to their historic extent.

A Note on Buffers: Before discussing the indices, a comment on what the buffer includes is relevant. The indices include assessments of the 100m buffer around vegetated wetlands and waterbodies (ponds, lakes, rivers, and streams). Vegetated buffers are recognized as important to maintaining habitat and water quality. For this project, a 100m buffer was drawn around all vegetated wetlands and the buffer of interest was the upland portion (not open water in this zone). Along waterbodies, the 100m buffer included both vegetated wetlands and uplands. For this study, buffer areas within the District's subbasins were assessed. If the buffer fell outside the District that area was not included in the analysis. If a portion of the buffer fell outside the subbasin but within another subbasin of the District, that portion of the buffer was included in the analysis for latter but not the former subbasin.

The *Natural Cover Index* (I_{NC}) is the proportion of a watershed that is wooded or "natural" open land (e.g., emergent wetlands, "old fields," or sand dunes, but not cropland, hayfields, lawns, turf, or pastures), excluding open water.

> $I_{NC} = A_{NV}/A_W$, where A_{NV} (area in "natural" vegetation) equals the area of the watershed's land surface in "natural" vegetation and A_W is the total land surface area of the watershed (excluding open water).
>
> Significance of index: provides information on how much of a watershed is not developed and may be serving as important wildlife habitat.

The *River-Stream Corridor Integrity Index* (I_{RSCI}) is derived by considering the condition of the land bordering perennial rivers and streams.

> $I_{RSCI} = A_{VC}/A_{TC}$, where A_{VC} (vegetated river-stream corridor area) is the area of the river-stream corridor that is colonized by "natural vegetation" and A_{TC} (total river-stream corridor area) is the total area of the river-stream corridor.
>
> Significance of index: provides information on the status of vegetated riparian corridors.

A 200-meter corridor (100m on each bank of the river or stream) is the recommended minimum. Note that these corridors include banks of impounded sections of rivers and streams, so that a continuous river or stream corridor is evaluated. The corridor area does not include the waterbody. It might be worthwhile to separate linear segments (streams) from polygonal segments (rivers) as the latter may be more frequently surrounded by wetland rather than upland, especially in tidal reaches. For the Meadowlands District, the index was applied to nontidal perennial rivers and streams; only a few such watercourses exist in the District.

The *Vegetated Wetland Buffer Integrity Index* (I_{VWB}) measures the condition of wetland buffers within a specified distance (e.g., 100m) of mapped vegetated wetlands for a watershed.

$I_{VWB} = A_{VB}/A_{TB}$, where A_{VB} (area of vegetated buffer) is the area of the buffer zone that is in natural vegetation cover and A_{TB} is the total area of the buffer zone.

Significance of index: provides information on vegetated buffers around wetlands that are important for wildlife and for reducing impacts to wetland water quality from surface runoff.

This buffer is drawn around all existing vegetated wetlands, therefore such wetlands are excluded from the buffer. While the buffer zone may include open water, the buffer index focuses on upland areas that are either capable of supporting free-standing vegetation or in some type of land use. For the Meadowlands District, a 100m buffer was examined.

The *Pond and Lake Buffer Integrity Index* (I_{PLB}) addresses the status of buffers of a specified width around these standing waterbodies (excluding instream impoundments that are part of the river-stream corridor integrity index):

$I_{PLB} = A_{VB}/A_{TB}$, where A_{VB} (area of vegetated buffer) is the area of the buffer zone that is in natural vegetation cover and A_{TB} is the total area of the buffer zone.

Significance of index: documents the condition of vegetation in a zone surrounding these waterbodies which is important for both water quality and aquatic life (buffer from impacts associated with adjacent urban/suburban development, agriculture, and other human actions).

Ponds are shallow waterbodies mapped as palustrine unconsolidated bottoms and unconsolidated shores by NWI. Vegetated ponds are mapped as a vegetated wetland type and their buffers are not included in this analysis, but instead are evaluated as wetland buffers. For this project, a 100m buffer was examined.

The *Vegetated Wetland Extent Index* (I_{VWE}) compares the current extent of vegetated wetlands to the estimated historic extent.

$I_{VWE} = A_{CW}/A_{HW}$, where A_{CW} is the current area of vegetated wetland in a watershed and A_{HW} is the historic vegetated wetland area in the watershed.

Significance of index: gives historical perspective on wetland loss.

The I_{VWE} is an approximation of the extent of the original vegetated wetland acreage remaining in a watershed. Farmed wetlands are included where cultivation is during droughts only, since they are likely to support “natural vegetation” during normal and wet years. Where farmed wetlands are cultivated more or less annually such as in much of the Northeast region, they are not included in the area of vegetated wetland, since they lack “natural vegetation” in most years and only minimally function as wetland at best. In most cases, hydric soil data are used to help generate the historic extent of wetlands. For the Meadowlands, we used data from a 1880s map from a prior study (Tiner et al. 2002) to determine historic wetlands.

The *Standing Waterbody Extent Index* (I_{SWE}) addresses the current extent of standing fresh waterbodies (e.g., lakes, reservoirs, and open-water wetlands - ponds) in a watershed relative to the historic area of such features.

> $I_{SWE} = A_{CSW}/A_{HSW}$, where A_{CSW} is the current standing waterbody area and A_{HSW} is the historic standing waterbody area in the watershed.
>
> Significance of index: gives perspective on changes in waterbody area (historic vs. today).

From a practical standpoint, this index is estimated. For most areas, a net gain in ponds and impoundments has occurred over time. Every national wetland trend study (Frayer et al. 1983, Tiner 1984, Dahl and Johnson 1991, Dahl 2000) has shown an increase in pond area as ponds are constructed for a multitude of purposes. For these situations, the I_{SWE} value is 1.0+ indicating a gain in this aquatic resource and no specific calculations necessary; a value of 1.0 is then used for determining the composite natural habitat integrity index for the study area. In geographic areas where significant loss of open water has occurred, an estimate will need to be derived from available sources (including historic maps).

Habitat Disturbance Indices

A set of four indices have been developed to address alterations to natural habitats. For these indices, a value of 1.0 is assigned at maximum disturbance, e.g., when all of the streams or existing wetlands have been modified.

The *Dammed Stream Flowage Index* (I_{DSF}) highlights the direct impact of damming on rivers and streams in a watershed.

> $I_{DSF} = L_{DS}/L_{TS}$, where L_{DS} is the length of perennial streams impounded by dams (combined pool length) and L_{TS} is the total length of perennial streams in the watershed (including the length of instream pools).
>
> Significance of index: reveals how much of the stream system has been dammed.

Note that the total stream length used for this index will be greater than that used in the channelized stream length index, since the latter emphasizes existing streams and excludes dammed segments. This index should be expanded to include the entire river-stream length (i.e., the Dammed River-Stream Flowage Index) or represented as two separate indices.

The *Channelized Stream Length Index* (I_{CSL}) is a measure of the extent of stream channelization within a watershed.

> $I_{CSL} = L_{CS}/L_{TS}$, where L_{CS} is the channelized stream length and L_{TS} is the total stream length for the watershed.
>
> Significance of index: documents the magnitude of stream channelization.

Since this index addresses channelization of existing streams, it focuses on the linear streams. The index will usually emphasize perennial streams, but could include intermittent streams, if desirable. The total stream length does not include the length of: 1) artificial ditches excavated in farm fields and forests, 2) dammed sections of streams, and 3) polygonal portions of rivers. Channelization of the latter may be represented by a separate index or preferably combined with this index to form a Channelized River/Stream Length Index.

The *Wetland Disturbance Index* (I_{WD}) focuses on alterations within existing wetlands. As such, it is a measure of the extent of existing wetlands that are diked/impounded, ditched, excavated, or farmed. It also includes wetlands in urban areas that are cut off from rivers by roads, causeways, and development. For the Meadowlands, all wetlands except those contiguous to the mainstem of the Hackensack River were considered disturbed and even some of the latter were classified as disturbed due to ditching and other factors. All wetlands (vegetated and nonvegetated, natural and created) were included in this index.

> $I_{WD} = A_{DW}/A_{TW}$, where A_{DW} is the area of disturbed or altered wetlands and A_{TW} is the total wetland area in the watershed.
>
> Significance of index: identifies the degree to which existing wetlands have been altered by human actions.

Since the focus of analysis is on "natural habitat," diking or excavating wetlands (or portions thereof) is viewed as an adverse action. It is recognized, however, that many such wetlands serve as valuable wildlife habitats (e.g., waterfowl impoundments) despite such alteration.

The *Habitat Fragmentation/Road Index* (I_{HF}) attempts to address habitat fragmentation by roads.

> $I_{HF} = A_R/A_W \times 16$, where A_R is the area of roads (interstates, state/county and other roads) and A_W is the total land area of the watershed.
>
> Significance of index: indicates habitat fragmentation by roads, but likely reflects degradation of water quality, and terrestrial and aquatic ecosystems from associated development.

Since road area will never equal 100 percent of a watershed, a multiplier was created to increase the index value to a level of relevance for the composite index (remotely-sensed index of natural habitat integrity). A multiplier of 16 was established based on examination of road density in a portion of Jersey City, NJ with extremely high road density (0.06 road area/city area); multiplying by 16 would yield an index value near 1.0 (the estimated maximum road area/unit area). If this multiplier yields an index value greater than 1.0, use 1.0 for the value when computing the composite index. (Note: This would only happen if an entire watershed or subbasin had higher road density than Jersey City, NJ which would be a rare situation. It is most likely to happen in very small subbasins in urban areas such as the subbasins of the Meadowlands District.)

While limited to road fragmentation, this index serves a surrogate for habitat fragmentation and degradation. Two watersheds may have the same amount of natural habitat, but one may have many roads and the other few. Although not the only human action that causes habitat fragmentation, road density is closely correlated to degraded ecosystems (Miller et al. 1996, Quigley and Arbelbide 1997, Forman and Alexander 1998, Forman 2000, and Trombulak and Frissell 2000). Moreover, adverse impacts from other development (e.g., urban and suburban) are likely related to the extent of roads, especially paved roads. More detailed assessments of habitat fragmentation, including mean patch size, patch density, edge density, and total core area, could be performed, if necessary.

In an assessment study for Delaware's Nanticoke River watershed, the following road widths were used to calculate A_R: interstates (2 lanes/direction) - 12.1m, state roads (2 lanes; 1 lane/direction) - 12.1m, county/local roads (2 lanes; 1 lane/direction) - 11.5m, and dirt roads (2-lanes) - 6.7m (Kevin Canning, Delaware Department of Transportation, pers. comm. 2003). The above numbers are estimates as actual road width depends on numerous conditions. These widths were applied to the orthophotoquad of the Meadowlands District and appeared to match up well, so no changes were necessary. Road widths were applied to road lengths to calculate area of roads for the study area; they provide perspective on the area of road surface in a watershed.

Composite Habitat Integrity Index for the District

The *Composite Natural Habitat Integrity Index* (I_{CNHI}) is a combination of the preceding indices. It seeks to express the overall condition of a watershed in terms of its potential ecological integrity or the relative intactness of “natural” plant communities and waterbodies, without reference to specific qualitative differences among these communities and waters. Variations of I_{CNHI} may be derived by considering buffer zones of different widths around wetlands and other aquatic habitats (e.g., $I_{CNHI\ 100}$ or $I_{CNHI\ 200}$) and by applying different weights to individual indices or by separating or aggregating various indices (e.g., stream corridor integrity index, river corridor integrity index, or river-stream corridor integrity index). While the weighting of the indices is debatable, the results of this analysis are comparable among the subbasins examined. The same weighting scheme must be used whenever comparisons of this index are made between and within watersheds.

For the analysis of the Meadowlands District, the following formula was used to determine this composite index:

> $I_{CNHI\ 100}$ = (0.5 x I_{NC}) + (0.125 x $I_{RSCI200}$) + (0.125 x I_{VWB100}) + (0.05 x I_{PLB100})+ (0.1 x I_{WE}), + (0.1 x I_{SWE}) - (0.1 x I_{DSF}) - (0.1 x I_{CSL}) - (0.1 x I_{WD}) - (0.1 x I_{HF}), where the condition of a 100m buffer is used throughout.
>
> Significance of index: gives an overview of the condition of the watershed relative to the existence of “natural” habitat and a measure that can be compared with other watersheds.

The indices were applied to the District’s subbasins.

GIS Analysis and Data Compilation

The geographic information system (GIS) used for this project was ARC GIS 9.0. Several GIS analyses were performed to produce wetland statistics (acreage summaries) and the remotely-sensed indices of "natural habitat integrity." Tables summarizing the results of the inventory were prepared to show the extent of different wetland types by NWI classifications and by LLWW descriptors and to portray differences among subbasins with respect to the natural habitat integrity indices.

Maps

A series of four maps was produced to show the study findings: 1) wetlands and deepwater habitats classified by NWI types, 2) wetlands and deepwater habitats classified by landscape position, 3) land use and land cover, and 4) upland land use and land cover within 100 meters of wetlands and deepwater habitats. All maps were produced at a scale of 1:30,000 for this report. A template showing subbasin boundaries is included on each map.

Results

The results are presented for the Meadowlands District as a whole and for the eight subbasins. Data are organized by the District and then for the subbasins. Maps are presented in a separate folder contained on the compact disk (CD) version of the report and are hyperlinked to the report; they are not included in the hardcopy version of this report. One set of hardcopy maps were printed and given to NJFO.

District Totals

Wetland Classification and Inventory

Wetlands by NWI Types

According to the NWI, the Meadowlands District had over 5,800 acres of wetlands (including ponds) (Table 2; Map 1). Estuarine emergent wetlands were the predominant wetland type with over 4,100 acres inventoried, accounting for 70% of the wetlands in the District. Estuarine unconsolidated shores (e.g., tidal mudflats) wetlands were next in abundance with nearly 1,200 acres, representing 20% of the wetlands. Thus, estuarine wetlands overall accounted for roughly 91% of the District's wetlands. Palustrine (freshwater) wetlands comprised the remaining 9% (540 acres).

Wetlands by LLWW Types

Most (93%) of the wetland acreage was associated with the Hackensack River estuary (Table 3; Map 2). This figure included some tidal freshwater wetland contiguous to brackish marshes of the estuary. Terrene and lotic wetlands each represented about 2.7% of the wetlands. The rest of the wetlands were ponds.

From the landform perspective, fringe and basin wetlands were most extensive, accounting for 57% and 43% of the wetland acreage, respectively. Less than 1% was made up of flat and island landforms. Wetlands along the mainstem of the Hackensack River were classified as fringe, whereas estuarine wetlands behind the New Jersey Turnpike and other highways and roads were identified as basin types.

Considering water flow path, it was no surprise that 94% of the wetland acreage had bidirectional-tidal flow. Three percent of the wetlands had throughflow, 2% outflow, and 1% isolated. These numbers include wetlands and ponds.

Table 2. Wetlands classified by NWI types for the Meadowlands District.

NWI Wetland Type	Acreage
Estuarine Wetlands	
Emergent	4,115.8
Scrub-Shrub	1.6
Unconsolidated Shore	1,186.9
Subtotal	5,304.3
Palustrine Wetlands	
Emergent	247.0
Emergent/Scrub-Shrub	27.6
Forested, Broad-leaved Deciduous	90.4
Scrub-Shrub, Deciduous	12.7
Scrub-Shrub/Emergent	7.6
Scrub-Shrub/Forested	66.0
Unconsolidated Bottom	82.4
Unconsolidated Shore	6.2
Palustrine Subtotal	539.9
GRAND TOTAL (ALL WETLANDS)	5,844.2

Table 3. Wetlands in the Meadowlands District classified by LLWW types (including ponds).

Landscape Position	**Landform**	**Water Flow**	**Acreage**
Estuarine (ES)			
	Fringe	Bidirectional-tidal (BT)	3,303.4
	Basin	Bidirectional-tidal (BT)	2,127.5
	Island	Bidirectional-tidal (BT)	14.5
	(Subtotal Estuarine)		*5,445.4*
Lotic Stream (LS)			
	Basin (BA)	Throughflow (TH)	137.2
	Flat (FL)	Throughflow (TH)	19.0
	(Subtotal Lotic Stream)		*156.2*
Terrene (TE)			
	Basin (BA)	Isolated (IS)	14.2
		Outflow (OU)	122.8
		(subtotal)	*137.0*
	Flat (FL)	Isolated (IS)	2.9
		Outflow (OU)	1.5
		(subtotal)	*4.4*
	Slope (SL)	Outflow (OU)	12.9
	(Subtotal Terrene)		*154.3*
Pond (PD)*			
		Bidirectional-tidal (BT)	46.3
		Isolated (IS)	40.1
		Outflow (OU)	2.2
	(Subtotal Pond)		*88.6*
TOTAL LLWW Types			5,844.5

*Ponds are a type of basin wetland, but have been reported separately since they typically are permanently flooded (or nearly so).

Subbasin Totals

Wetland Classification and Inventory

The results of the inventory for all subbasins are presented in Tables 4 and 5. The former summarizes findings by NWI types, whereas the latter reports acreage data by LLWW types.

Two subbasins had more than half (54%) of the District's estuarine wetlands: HR1 (Hackensack River below the Amtrak bridge) and HR4 (Hackensack River from Rt. 3 to Bellman's Creek). These subbasins had more than 1,400 acres of these wetlands. Subbasin BC2 (Berry's Creek below Paterson Avenue) also had substantial estuarine acreage (910 acres), accounting for 17% of these wetlands in the District. Fifty-seven percent of the palustrine wetlands (including ponds) in the District were associated with a single subbasin: BC1 (Berry's Creek above Paterson Avenue). Lotic and terrene wetlands each accounted for 29% of the District's freshwater wetlands, while 36% were located behind estuarine wetlands. The remaining 16% were associated with freshwater ponds.

Natural Habitat Integrity Assessment

The findings are summarized below in the following subsections and in Table 6.

Natural Cover

Values for natural cover indices ($I_{NC)}$ varied from a high of 0.46 for subbasin LPR (Lower Passaic River,(Newark Bay to 4th St. Bridge) to a low of 0.25 for the Overpeck Creek subbasin (Table 6). Other subbasins with more than 40% of their "land" area in "natural vegetation" included BC2 (Berry's Creek below Paterson Avenue) subbasin and two Hackensack River subbasins HR4 and HR2 (Route 3 to Bellman's Creek and Bellman's Creek to Fort Lee Road, respectively). Map 3 shows the distribution of "natural habitats" as well as various land uses in the District.

Freshwater River/Stream Corridors

Only three subbasins had freshwater rivers and streams (Table 6). Of these the Hackensack River subbasin from Bellman's Creek to Ft. Lee Road (HR2) and the Berry's Creek subbasin above Paterson Avenue (BC1) had river/stream corridor integrity values above 0.45. The other one (HR3) had only 11% of their corridors covered with natural vegetation. No freshwater streams or stream buffers were located in five subbasins (BC2, HR1, HR4, OC, and LPR). The I_{RSC} value for "not applicable" ("na") was evaluated two ways for comparison, since the composite values are significantly affected by the I_{RSC} value. We found that by giving "na" a value of 1.0 the composite value goes up by 0.12 or 0.13 over that generated when giving "na" a value of 0.0. Given the results, we decided that it was more appropriate to give them a value of 1.0 rather than 0.0, for the latter would suggest that all of the corridor is developed while in reality, there was none and hence no impact. Map 4 shows the condition of buffers along wetlands and deepwater habitats.

Table 4. Wetland acreage in subbasins of the Meadowlands District. Subbasins: BC1 (Berry's Creek above Paterson Avenue), BC2 (Berry's Creek below Paterson Avenue), HR1 (Hackensack River - Amtrak bridge to Route 3), HR2 (Hackensack River - Bellman's Creek to Fort Lee Road), HR3 (Hackensack River - below Amtrak bridge), HR4 (Hackensack River - Route 3 to Bellman's Creek), OC (Overpeck Creek), and LPR (Lower Passaic River -Newark Bay to 4th Street Bridge). Wetland types: US - unconsolidated shore, EM - emergent, EM-t - emergent-tidal, EM-nt - emergent-nontidal, SS – scrub-shrub, OV - other vegetated (t - tidal; nt - nontidal). % of HMD = percent of the District's wetlands (estuarine, palustrine, and total)

	Estuarine Wetlands			**Subtotal**	**Palustrine Wetlands**					**Subtotal**	**Total**
Subbasin	**US**	**EM**	**SS**	**Acreage (% of HMD)**	**UB***	**EM-t**	**EM-nt**	**OV-t**	**OV-nt**	**Acreage (% of HMD)**	**Acreage (% of HMD)**
BC1	1.0	81.2	1.5	83.7 (1.6)	3.4	108.6	51.8	52.3	92.6	308.7 (57.2)	392.4 (6.7)
BC2	1.1	908.5	--	909.6 (17.1)	26.3	6.6	0.5	4.4	0.5	38.3 (7.1)	947.9 (16.2)
HR1	776.1	655.9	--	1,432.0 (27.0)	16.3	14.7	5.6	--	0.4	37.0 (6.9)	1,469.0 (25.1)
HR2	103.7	522.7	--	626.4 (11.8)	0.7	5.6	0.1	18.6	--	25.0 (4.6)	651.4 (11.1)
HR3	0.4	529.9	--	530.3 (10.0)	18.2	40.8	6.7	--	--	65.7 (12.2)	596.0 (10.2)
HR4	291.0	1,155.3	-	1,446.3 (27.3)	1.5	4.2	--	3.9	--	9.6 (1.8)	1,455.9 (24.9)
OC	8.3	51.3	--	59.6 (1.1)	0.2	0.4	--	4.5	--	5.1 (0.1)	64.7 (1.1)
LPR	5.5	210.9	--	216.4 (4.1)	22.1	23.6	5.7	--	--	51.4 (9.5)	267.8 (4.6)

Table 5. Wetland acreage (including ponds) by LLWW types for subbasins of the Meadowlands District. See preceding table for subbasin names. FR – fringe, BA – basin, IL – island, SL – slope, TH – throughflow, IS – isolated, OU – outflow, and BT – bidirectional-tidal.

	Estuarine (ES)			**Lotic Stream (LS)**		**Terrene (TE)**					**Pond (PD)**		
Subbasin	**BA**	**FR**	**IL**	**BATH**	**FLTH**	**BAIS**	**BAOU**	**FLIS**	**FLOU**	**SLOU**	**BT**	**IS**	**OU**
BC1	95.9	--	--	123.1	33.1	3.6	119.1	--	1.5	12.9	2.1	1.3	--
BC2	902.4	18.6	--	--	--	--	--	--	--	--	21.1	5.2	--
HR1	470.1	963.1	13.5	--	--	2.3	3.7	--	--	--	9.1	7.2	--
HR2	351.7	298.9	--	--	--	0.1	--	--	--	--	0.1	0.6	--
HR3	491.6	79.9	--	--	--	3.3	--	2.9	--	--	9.2	7.0	2.0
HR4	694.4	759.0	1.0	--	--	--	--	--	--	--	0.5	0.8	0.2
OC	58.5	6.0	--	--	--	--	--	--	--	--	0.2	--	--
LPR	238.6	2.0	--	--	--	4.9	--	--	--	--	4.2	17.9	--

Table 6. Natural habitat integrity indices for subbasins of the Meadowlands District. na = not applicable (see ** below).

	Natural Habitat Extent Indices						**Disturbance Indices**				**Composite Index***
Subbasin	$\mathbf{I_{NC}}$	$\mathbf{I_{RSC}}$	$\mathbf{I_{VWB}}$	$\mathbf{I_{PLB}}$	$\mathbf{I_{VWE}}$	$\mathbf{I_{SWE}}$	$\mathbf{I_{DSF}}$	$\mathbf{I_{CSL}}$	$\mathbf{I_{WD}}$	$\mathbf{I_{HF}}$	$\mathbf{I_{CNHI}}$
BC1	0.28	0.46	0.13	0.04	0.27	1.00+	0.00	1.00	1.00	0.70	0.14
BC2	0.43	na (1.0)	0.14	0.06	0.35	1.00+	0.00 (0.0)	na	1.00	1.00	0.29**
HR1	0.28	na (1.0)	0.18	0.03	0.16	1.00+	0.00 (0.0)	na	0.67	1.00	0.24**
HR2	0.44	0.48	0.07	0.48	0.44	1.00+	0.00	1.00	0.85	0.97	0.17
HR3	0.30	0.11	0.15	0.26	0.26	1.00+	0.00	1.00	1.00	0.96	0.02
HR4	0.45	na (1.0)	0.12	0.08	0.40	1.00+	0.00 (0.0)	na	0.83	1.00	0.33**
OC	0.25	na (1.0)	0.03	0.00	0.26	1.00+	0.00 (0.0)	na	0.87	1.00	0.19**
LPR	0.46	na (1.0)	0.24	0.33	0.14	1.00+	0.00 (0.0)	na	0.99	1.00	0.32**

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* $I_{CNHI\ 100} = (0.5 \times I_{NC}) + (0.125 \times I_{RSCI200}) + (0.125 \times I_{VWB100}) + (0.05 \times I_{PLB100}) + (0.1 \times I_{VWE}), + (0.1 \times I_{SWE}) - (0.1 \times I_{DSF}) - (0.1 \times I_{CSL}) - (0.1 \times I_{WD}) - (0.1 \times I_{HF})$.

**No freshwater streams or stream buffers were located in these subbasins, composite values differ greatly depending on how the index I_{RSC} is treated; when assigned a value of 1.0 to this index for a "na", the composite value goes up by 0.12 or 0.13 vs. when the I_{RSC} for a "na" is given a value of 0.0. Given these results, it appears that assigning I_{RSC} a value of 1.0 for a "na" is better than a zero, for the latter would suggest that the entire corridor is developed while in reality, there was none. The index value for "na" under I_{CSL} is assigned a value of zero as to indicate no impact.

Vegetated Wetland Buffers

Buffers around vegetated wetlands were in poor shape (Map 4), with all index values less than 0.25 (Table 6). This means that less than 25% (one-quarter) of the 100m upland border was vegetated with "natural vegetation."

Pond and Lake Buffers

Pond and lake buffers were in the best shape in the subbasin covering the Hackensack River from Bellman's Creek to Ft. Lee Road (HR2) (Table 6). About 48% of its buffer was vegetated (Map 4). Two other subbasins had more than 25% of their pond/lake buffers covered by natural vegetation: Lower Passaic River (LPR) and the Hackensack River below the Amtrak bridge (HR3).

Historic Wetland Trends

Over 70% of the wetlands in the Meadowlands have been destroyed since the late 1800s, so there was no surprise to find rather low values regarding wetland extent. For individual subbasins, wetlands are still abundant, with both Hackensack River from Bellman's Creek to Fort Lee Road (HR2) and from Route 3 to Bellman's Creek (HR4) having index values above 0.40 (Table 6). The lowest values were recorded for the Hackensack from the Amtrak bridge to Route 3 (HR1) and the Lower Passaic River (LPR) subbasins.

Standing Waterbody Trends

Each subbasin in the District had created ponds while some had significant areas of diked open water. Consequently, the I_{SWE} for each subbasin was recorded as 1.0+.

River/Stream Damming and Channelization

No dams were located in the District and all streams were mapped as channelized, so the index values for dammed stream flowage index (I_{DSF}) are 0.0 for all subbasins, while the channelized stream length index (I_{CSL}) is 1.0 for all subbasins that had streams inventoried (Table 6). Five subbasins did not have any streams mapped (BC2, HR1, HR4, OC, and LPR), so none were channelized and their I_{CSL} was 0.0.

Altered Wetlands

Given that the Meadowlands is surrounded by one of the most densely populated metropolitan areas, the wetland disturbance index (I_{WD}) values were expected to be high. The stats for individual subbasins support this expectation (Table 6); all had index values above 0.66.

Road Fragmentation

As expected, the fragmentation by road index (I_{HF}) values is variable due to the conditions within the subbasins. Road density outside the wetlands in the District is extremely high. In all but one of the subbasins (BC1 exception), the index values were maximum (i.e., 1.0) or near maximum (>0.95) (Table 6).

Composite Index of Remotely-sensed "Natural Habitat Integrity"

Results of the composite index (I_{CNHI}) for the subbasins support our knowledge that the environment of the District is highly disturbed and stressed due to urban impacts. For reference, a pristine area would have a value of 1.0. All of the District's subbasins had composite index values at or below 0.33, with most having a value $\geq$ 0.19 (Table 6). The lowest value was recorded for subbasin HR3 (Hackensack River below the Amtrak bridge).

Discussion

The Meadowlands, Degraded but Valuable Wildlife Habitat

It seems paradoxical that a natural area can be severely degraded but still serve as valuable habitat…such is the Meadowlands. The assessment of natural habitat integrity clearly pointed out the level of destruction and degradation of wetlands, streams, and other natural habitats in the District. The results are not surprising given the amount of development that has taken place over the past 150 years in this metropolitan area. After all, the Meadowlands is only a fraction of its original size. By 1995, only 28 percent of the wetland area that occurred in the late 19th Century remained (Tiner et al. 2002).

While all subbasins have been significantly impacted by development and the value of the wetlands have been compromised, the wetlands still support significant fish and wildlife populations. The Meadowlands is the largest remaining estuarine wetland complex in northern New Jersey. Estuarine wetlands are among the nation's most valuable wetlands even when surrounded by developed upland as the tidal connection and fluctuating hydrology is the lifeblood of their ecology. The dominance of common reed (Phragmites australis) over other salt and brackish species also has likely reduced the value of this marshland to many species, yet many birds still uses the Meadowlands, especially the tidal flats and open water areas.

Common reed is widely recognized as the number one invasive plant threatening estuarine wetlands in the northeastern United States. It has replaced typical salt marsh plants in areas where tidal flow has been significantly restricted and where fill has been deposited in wetlands; both conditions apply to the Meadowlands. Common reed is a good disturbance indicator as it readily colonizes exposed soils in the coastal zone and even inland areas along highways (Marks et al. 1994). Plant diversity usually declines with the invasion of Phragmites as this species typically forms monotypic stands, especially in brackish waters (Meyerson et al. 2000). Changes in plant composition alter the habitat use by some to many species. There is general agreement that pure Phragmites stands generally yield poorer quality wildlife habitat than the marshes they replace, while they may be important habitat for some species (Roman et al. 1984; Kiviat 1987). The tall, dense reeds restrict wildlife movement and also adversely affect hydrology with negative impacts on aquatic species.

Over 50 species of birds have been found in common reed marshes (Meyerson et al. 2000). Despite this usage, there are no birds that depend solely on these wetlands. Common birds using Phragmites marshes include marsh wren, red-winged blackbird, and swamp sparrow. Ringed-necked pheasant and American bittern have been observed (R. Tiner, personal observations). The Meadowlands contains a mixture of emergent marsh types (Phragmites, cattails, and smooth cordgrass), tidal flats, and open water. The diversity and juxtaposition of these habitats and the location of the Meadowlands along the Atlantic Flyway make it an attractive habitat despite being surrounded by densely populated and highly industrialized areas. More than 265 species of birds use the Meadowlands, including numerous breeding species of concern, such as black-crowned night heron, blue-winged teal, northern harrier, common moorhen, American coot, and spotted sandpiper (U.S. Fish and Wildlife Service et al. 2000). The Meadowlands is recognized as a major link along the Atlantic Flyway for migratory species (especially shorebirds) and an important overwintering area for species including canvasback, redhead, bufflehead, lesser scaup, greater scaup, ruddy duck, hooded merganser, and common merganser. This urban wetland complex also provides significant natural aesthetics to the surrounding built-up landscape and offers opportunities to millions of people in the New York-Newark metropolitan area to see waterfowl (ducks, Canada geese, common moorhen, and American coot), wading birds (herons, egrets, glossy ibis, and occasionally the secretive least bittern), shorebirds, and numerous passerines (especially red-winged blackbird). Muskrats, raccoons, and other wildlife reside in the Meadowlands.

From the aquatic organism perspective, marsh flooding provides access for fishes and nektonic invertebrates and anything reducing this process will have a negative impact on their use of the marshes. Common reed is known to accelerate the buildup of the marsh surface and reduce drainage density by filling in small ditches and creeks (Weinstein and Balletto 1999), thereby restricting access to the marshes by fishes and transient shellfish. Reducing the frequency of tidal flooding has obvious negative consequences for aquatic species. Fish and shellfish density in Phragmites stands vary with hydrology and wetland geomorphology (Hanson et al. 2002). They noted that high stem density and litter accumulation may reduce tidal flow rates, leading to a reduction in the depth of tidal flooding. From the surface of a brackish Phragmites marsh along the Hudson River, they collected common mummichog (Fundulus heteroclitus), herrings (Alosa spp.), grass shrimp (Palaemonetes pugio), and blue crab (Callinectes sapidus). Most of the individuals were captured in the marsh near the creekbanks and only a few in the marsh interior. Depositional sites produced the most individuals and greatest biomass, but other studies have not yielded similar findings (Rozas 1992) Some studies have found a greater abundance of mummichog in Spartina (smooth cordgrass) marshes than in neighboring Phragmites marshes (Hanson et al. 2002). The Meadowlands serves as an important food source for the detritus-based food web of the New York/New Jersey Harbor Estuary ecosystem (U.S. Fish and Wildlife Service et al. 2000).

Future Considerations

Urban watersheds present an interesting challenge for assessment of natural habitat integrity given the amount and nature of development. For example, to further describe habitat fragmentation in urban watersheds, we might also want to address the actual fragmentation of designated "natural habitats" by roads and railroads in addition to reporting on the amount of road surfaces in a watershed or subbasin. This may give a better picture of the extent to which roads and railroads cross the remaining natural habitats. Different statistics could be reported for both wetlands and upland natural habitats. The extent of development in a watershed or subbasin is already characterized by the "natural cover index" which reports on the area of natural habitat relative to the land area of the watershed or subbasin. We also might want to report the size distribution of natural habitats in a given area as that statistic will provide another important property of the remaining natural habitats and likely show significance size reduction in wetlands, forests, and other natural habitats.

Our applications of the natural habitat integrity indices to date have been limited and we are still in a learning phase. Here are some lessons learned from our Meadowlands study.

1. <u>Vegetated Wetland Buffer Index</u>. To date, the buffer of vegetated wetlands has been one of our main focuses while nonvegetated wetlands were not included. This was because nonvegetated wetlands were bordered by vegetated wetland plus we wanted to treat ponds (the predominant nonvegetated freshwater wetland in the Northeast) separately and have given them their own index. In the Meadowlands, the level of disturbance with diking has created nonvegetated wetlands along uplands. For the District, the area that would be added to the buffer was minimal, so we applied the original formula that focused on the upland buffer around vegetated wetlands. However in thinking more broadly, we realize that nonvegetated wetlands also lie along uplands especially in macrotidal areas such as the Gulf of Maine, so the wetland buffer index will be modified in future studies (including the forthcoming assessment for the Hackensack River watershed) to include the upland border of all wetlands (excluding ponds) not just the vegetated wetlands. Inclusion of nonvegetated wetlands in the buffer analysis will also be important in arid regions where these wetland types are extensive. In future studies, vegetated and nonvegetated wetlands will be combined into a single data layer and then buffered for analysis. The aim of this buffer assessment is to determine the condition of the surrounding upland as certain land use practices have a significant impact on the quality of wetlands and their use by wildlife, hence the buffer should remain restricted to the upland.

The revised index will be called the *Wetland Buffer Integrity Index* (I_{WBI}) and the formula will be:

> $I_{WBI} = A_{VB}/A_{TB}$, where A_{VB} (area of upland buffer around wetlands excluding ponds) is the area of the buffer zone that is in natural vegetation cover and A_{TB} is the total area of the buffer zone.

2. <u>Pond Buffer Integrity Index</u>. As noted earlier, ponds are considered separately since in many areas of the country, ponds are artificial waterbodies constructed within agricultural or developed landscapes; a separate index addresses their buffers. In areas where there are significant numbers of both natural ponds and artificial ponds, it would be worth developing separate indices to analyze and report on the buffer around natural ponds versus that around created ponds. The current pond and lake buffer index will be separated into at least two, and possibly four indices: 1) pond buffer integrity index (with the option of separating natural from artificial ponds for analysis) and 2) lake buffer integrity index (with the option of separating natural lakes from artificial lakes/reservoirs/large impoundments).

The *Pond Buffer Integrity Index* (I_{PBI}) addresses the status of buffers of a specified width around ponds (excluding instream impoundments that are part of the river-stream corridor integrity index). In this case, the buffer will include both wetlands and uplands, but will exclude open water.

> $I_{PBI} = A_{VB}/A_{TB}$, where A_{VB} (area of vegetated buffer) is the area of the buffer zone that is in natural vegetation cover and A_{TB} is the total area of the buffer zone.

The *Lake Buffer Integrity Index* (I_{LBI}) addresses the status of buffers of a specified width around lakes. The buffer includes both vegetated wetlands that are seasonally flooded or drier and uplands. Semipermanently flooded wetlands in the lake should be considered part of the lake proper since they are in water for virtually all of the growing season and are more of an aquatic habitat than semiaquatic or terrestrial.

$I_{LBI} = A_{VB}/A_{TB}$, where A_{VB} (area of vegetated buffer) is the area of the buffer zone that is in natural vegetation cover and A_{TB} is the total area of the buffer zone.

3. <u>River/Stream Corridor Integrity Index</u>. This index has a dual purpose: 1) to identify the condition of riparian corridors ("naturally" vegetated or in some type of land use) and 2) to be able to identify wooded corridors that help moderate water temperatures as well as provide organic matter (leaf litter) for aquatic productivity. It may be best to separate stream corridors from river corridors for indexing purposes as streams and rivers represent different types of aquatic systems. It may also be worth separating tidal rivers from nontidal rivers as well as perennial from intermittent for the latter, due to ecological differences. All of this separation gives more specific information about ecologically different resources and helps pinpoint potential land use impacts that may have a negative effect on water quality and aquatic biota. Also, if desirable, impounded sections could be culled out and included in the pond/lake buffer integrity index or as a separate index (impounded river/stream corridor integrity index).

The *River Corridor Integrity Index* (I_{RCI}) is derived by considering the condition of the land bordering perennial rivers and streams.

$I_{RCI} = A_{VC}/A_{TC}$, where A_{VC} (vegetated river corridor area) is the area of the river corridor that is colonized by "natural vegetation" and A_{TC} (total river corridor area) is the total area of the river corridor. This index may be calculated separately for tidal, perennial nontidal, and intermittent nontidal rivers, if desirable.

The *Stream Corridor Integrity Index* (I_{SCI}) is derived by considering the condition of the land bordering perennial rivers and streams.

$I_{SCI} = A_{VC}/A_{TC}$, where A_{VC} (vegetated stream corridor area) is the area of the stream corridor that is colonized by "natural vegetation" and A_{TC} (total stream corridor area) is the total area of the stream corridor. This index may be calculated separately for tidal, perennial nontidal, and intermittent nontidal streams, if desirable.

See comments under #5 below regarding assigning values to corridor index when no streams (or corridors) are present in a subbasin; this would be an extremely rare situation.

4. <u>Wetland Disturbance Index</u>. Currently only wetlands classified as diked/impounded, excavated, partly drained, or farmed are included as "disturbed wetlands." In enhancing the NWI data, a fragmented code ("fg") is applied to wetlands separated by roads or railroads. The section that is separated from the main body of the wetland should be considered disturbed also. If the crossing does not cut off a small section, but simply crosses a large wetland and does not "isolate" a section of wetland, such as a road across most estuarine and lotic wetlands, the wetlands would not be designated as disturbed. Moreover, relict wetlands completely surrounded by development or nearly so should also be considered disturbed; these wetlands

may have to be culled from the database as currently they do not have a unique code. Similarly, the fragmented wetlands will also have to be reviewed, but at least they are highlighted with the unique “fg” code. If interested in knowing level of disturbance to certain types of wetlands, the analysis could be done to report on the level of disturbance to certain types. This would be in addition to reporting the wetland disturbance index and could be reported in terms of percent of acreage of a given type that is disturbed in various ways (e.g., % of lotic wetland acreage that is ditched or fragmented by roads and railroads or the % of terrene wetlands that are surrounded by development).

5. Composite Index. The Meadowlands’ subbasins were so small that five lacked freshwater streams and therefore did not have calculated values for stream corridor integrity. The composite index is not really applicable to situations where there are no values for a given subbasin or watershed, especially when doing a comparison between them. Since the composite index weights all indices for comparison among subbasins, a value needed to be developed for the “not applicable” indices. This should not be a problem in other subbasins as they are larger units and should contain at least one stream because their boundaries are in large part determined by the location of streams and their contributing area; the stream system (including rivers) is the focal point. The Meadowlands District is largely an estuarine tidal wetland complex and represented a unique set of circumstances in that no freshwater streams were mapped in five subbasins. If the I_{RSC} value (stream corridor integrity) was treated as zero, it would signify an impact and would result in lowering their composite score. If instead, the “not applicable” (na) was treated as 1.0, the composite index would be higher by 0.12 or 0.13. If this situation ever arises again, the “na” under a habitat extent index should be given a value of 1.0 (no alteration), while a “na” under a disturbance index should be rated as 0.0 (no impact).

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Appendix

Dichotomous Keys and Mapping Codes for Wetland Landscape Position, Landform, Water Flow Path, and Waterbody Type Descriptors (Tiner 2003a)

U.S. Fish and Wildlife Service

Dichotomous Keys and Mapping Codes for Wetland Landscape Position, Landform, Water Flow Path, and Waterbody Type Descriptors

September 2003

Dichotomous Keys and Mapping Codes for Wetland Landscape Position, Landform, Water Flow Path, and Waterbody Type Descriptors

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Table of Contents

Section 1. Introduction

A wide variety of wetlands have formed across the United States. To describe this diversity and to inventory wetland resources, government agencies and scientists have devised various wetland classification systems (Tiner 1999). Features used to classify wetlands include vegetation, hydrology, water chemistry, origin of water, soil types, landscape position, landform (geomorphology), wetland origin, wetland size, and ecosystem form/energy sources.

The U.S. Fish and Wildlife Service's wetland and deepwater habitat classification (Cowardin et al. 1979) is the national standard for wetland classification. This classification system emphasizes vegetation, substrate, hydrology, water chemistry, and certain impacts (e.g., partly drained, excavated, impounded, and farmed). These properties are important for describing wetlands and separating them into groups for inventory and mapping purposes and for natural resource management. They do not, however, include some abiotic properties important for evaluating wetland functions (Brinson 1993). Moreover, the classification of deepwater habitats is limited mainly to general aquatic ecosystem (marine, estuarine, lacustrine, and riverine) and bottom substrate type, with a few subsystems noted for riverine deepwater habitats. The Service's classification system would benefit from the application of additional descriptors that more fully encompass the range of characteristics associated with wetlands and deepwater habitats.

In the early 1990s, Mark Brinson created a hydrogeomorphic (HGM) classification system to serve as a foundation for wetland evaluation (Brinson 1993). He described the HGM system as "a generic approach to classification and not a specific one to be used in practice" (Brinson 1993, p. 2). This system emphasized the location of a wetland in a watershed (its geomorphic setting), its sources of water, and its hydrodynamics. The system was designed for evaluating similar wetlands in a given geographic area and for developing a set of quantifiable characteristics for "reference wetlands" rather than for inventorying wetland resources (Smith et al. 1995). A series of geographically focused models or "function profiles" for various wetland types have been created and are in development for use in functional assessment (e.g., Brinson et al. 1995, Ainslie et al. 1999, Smith and Klimas 2002).

Need for New Descriptors

The Service's National Wetlands Inventory (NWI) Program has produced wetland maps for 91 percent of the coterminous United States and 35 percent of Alaska. Digital data are available for 46 percent of the former area and for 18 percent of the latter. Although these data represent a wealth of information about U.S. wetlands, they lack hydrogeomorphic and other characteristics needed to perform assessments of wetland functions over broad geographic areas. Using geographic information system (GIS) technology and geospatial databases, it is now possible to predict wetland functions for watersheds - a major natural resource planning unit. Watershed managers could make better use of NWI data if additional descriptors (e.g., hydrogeomorphic-type attributes) were added to the current NWI database. Watershed-based preliminary assessments of wetland functions could be performed. This new information would also permit more detailed characterizations of wetlands for reports and for developing scientific studies and lists of potential reference wetland sites.

Background on Development of Keys

Since the Cowardin et al. wetland classification system (1979) is the national standard and forms the basis of the most extensive wetland database for the country, it would be desirable to develop additional modifiers to enhance the current data. This would greatly increase the value of NWI digital data for natural resource planning, management, and conservation. Unfortunately, Brinson's "A Hydrogeomorphic Classification of Wetlands" (1993) was not designed for use with the Service's wetland classification. He used some terms from the Cowardin et al. system but defined them differently (e.g., Lacustrine and Riverine). Consequently, the Service needed to develop a set of hydrogeomorphic-type descriptors that would be more compatible with its system. Such descriptors would bridge the gap between these two systems, so that NWI data could be used to produce preliminary assessments of wetland functions based on characteristics identified in the NWI digital database. In addition, more descriptive information on deepwater habitats would also be beneficial. For example, identification of the extent of dammed rivers and streams in the United States is a valuable statistic, yet according to the Service's classification dammed rivers are classified as Lacustrine deepwater habitats with no provision for separating dammed rivers from dammed lacustrine waters. Differentiation of estuaries by various properties would also be useful for national or regional inventories.

Recognizing the need to better describe wetlands from the abiotic standpoint in the spirit of the HGM approach, the Service developed a set of dichotomous keys for use with NWI data (Tiner 1997b). The keys bridge the gap between the Service's wetland classification and the HGM system by providing descriptors for landscape position, landform, water flow path and waterbody type (LLWW descriptors) important for producing better characterizations of wetlands and deepwater habitats. The LLWW descriptors for wetlands can be easily correlated with the HGM types to make use of HGM profiles when they become available. The LLWW attributes were designed chiefly as descriptors for the Service's existing classification system (Cowardin et al. 1979) and to be applied to NWI digital data, but they can be used independently to describe a wetland or deepwater habitat. Consequently, there is some overlap with Cowardin et al. since some users may wish to use these descriptors without reference to Cowardin et al.

The first set of dichotomous keys was created to improve descriptions of wetlands in the northeastern United States (Tiner 1995a, b). They were initially used to enhance NWI data for predicting functions of potential wetland restoration sites in Massachusetts (Tiner 1995a, 1997a). Later, the keys were modified for use in predicting wetland functions for watersheds nationwide (Tiner 1997b, 2000). A set of keys for waterbodies was added to improve the Service's ability to characterize wetland and aquatic resources for watersheds.

The keys are periodically updated based on application in various physiographic regions. This version is an update of an earlier set of keys published in 1997 and 2000 (Tiner 1997b, 2000).

Relatively minor changes have been made, including the following: 1) added "drowned river-mouth" modifier to the Fringe and Basin landforms (for use in areas where rivers empty into large lakes such as the Great Lakes where lake influences are significant), 2) added "connecting channels" to river type (to address concerns in the Great Lakes to highlight such areas), 3) added "Throughflow-intermittent" water flow path (to separate throughflow wetlands along intermittent streams from those along perennial streams), 4) added "Throughflow-artificial" and "Outflow-artificial" to water flow path (to identify former "isolated" wetlands or fragmented wetlands that are now throughflow or outflow due to ditch construction), 5) revised the lake key to focus on permanently flooded deepwater sites (note: shallow and seasonally to intermittently flooded sites are wetlands) and added "open embayment" modifier, and 6) revised the estuary type key (consolidated some types). This version also clarifies that a terrene wetland may be associated with a stream where the stream does not periodically flood the wetland. In this case, the stream has relatively little effect on the wetland's hydrology. This is especially true for numerous flatwood wetlands. It also briefly discusses how the term "isolated" is applied relative to surface water and ground water interactions. In the near future, illustrations will be added to this document to aid users in interpretations.

Use of the Keys

Two sets of dichotomous keys (composed of pairs of contrasting statements) are provided - one for wetlands and one for waterbodies. Vegetated wetlands (e.g., marshes, swamps, bogs, flatwoods, and wet meadows) and periodically exposed nonvegetated wetlands (e.g., mudflats, beaches, and other exposed shorelines) should be classified using the wetland keys, while the waterbody keys should be used for permanent deep open water habitats (subtidal or >6.6 feet deep for nontidal waters). Some sites may qualify as both wetlands and waterbodies. A good example is a pond. Shallow ponds less than 20 acres in size meet the Service's definition of wetland, but they are also waterbodies. Such areas can be classified as both wetland and waterbody, if desirable. However, we recommend that ponds be classified using the waterbody keys. Another example would be permanently flooded aquatic beds in the shallow water zone of a lake. We have classified them using wetland hydrogeomorphic descriptors, yet they also clearly represent a section of the lake (waterbody). This approach has worked well for us in producing watershed-based wetland characterizations and preliminary assessments of wetland functions.

Uses of Enhanced Digital Database

Once they are added to existing NWI digital data, the LLWW characteristics (e.g., landscape position, landform, water flow path, and waterbody type) may be used to produce a more complete description of wetland and deepwater habitat characteristics for watersheds. The enhanced NWI digital data may then be used to predict the likely functions of individual wetlands or to estimate the capacity of an entire suite of wetlands to perform certain functions in a watershed. Such work has been done for several watersheds including Maine's Casco Bay watershed and the Nanticoke River and Coastal Bays watersheds in Maryland, the Delaware portion of the Nanticoke River, and numerous small watersheds in New York (see Tiner et al.

1999, 2000, 2001; Machung and Forgione 2002; Tiner 2002; see sample reports on the NWI website:http://wetlands.fws.gov for application of the LLWW descriptors). These characterizations are based on our current knowledge of wetland functions for specific types (Tiner 2003) and may be refined in the future, as needed, based on the applicable HGM profiles and other information. The new terms can also be used to describe wetlands for reports of various kinds including wetland permit reviews, wetland trend reports, and other reports requiring more comprehensive descriptions of individual wetlands.

Organization of this Report

The report is organized into seven sections: 1) Introduction, 2) Wetland Keys, 3) Waterbody Keys, 4) Coding System for LLWW Descriptors (codes used for classifying and mapping wetlands), 5) Acknowledgments, 6) References, and 7) Glossary.

Section 2. Wetland Keys

Three keys are provided to identify wetland landscape position and landform for individual wetlands: Key A for classifying the former and Keys B and C for the latter (for inland wetlands and coastal wetlands, respectively). A fourth key - Key D - addresses the flow of water associated with wetlands.

Users should first identify the landscape position associated with the subject wetland following Key A-1. Afterwards, using Key B-1 for inland wetlands and Key C-1 for salt and brackish wetlands, users will determine the associated landform. The landform keys include provisions for identifying specific regional wetland types such as Carolina bays, pocosins, flatwoods, cypress domes, prairie potholes, playas, woodland vernal pools, West Coast vernal pools, interdunal swales, and salt flats. Key D-1 addresses water flow path descriptors. Various other modifiers may also be applied to better describe wetlands, such as headwater areas; these are included in the four main keys.

Besides the keys provided, there are numerous other attributes that can be used to describe the condition of wetlands. Some examples are other descriptors that address resource condition could be ones that emphasize human modification, (e.g., natural vs. altered, with further subdivisions of the latter descriptor possible), the condition of wetland buffers, or levels of pollution (e.g., no pollution [pristine], low pollution, moderate pollution, and high pollution). Addressing wetland condition, however, was beyond our immediate goal of describing wetlands from a hydrogeomorphic standpoint.

Key A-1: Key to Wetland Landscape Position

This key allows characterization of wetlands based on their location in or along a waterbody, in a drainageway, or in isolation ("geographically isolated" - surrounded by upland).

1. Wetland is completely surrounded by upland (non-hydric soils)....................................**Terrene**
1. Wetland is not surrounded by upland but is connected to a waterbody of some kind................2

2. Wetland is located in or along tidal salt or brackish waters (i.e., an estuary or ocean) including its periodically inundated shoreline (excluding areas formerly under tidal influence)...................3
2. Wetland is not periodically inundated by salt or brackish tides...4

3. Wetland is located in or along the ocean...**Marine**
Go to Key C-1 for coastal landform
3. Wetland is located in or along an estuary (typically a semi-enclosed basin or tidal river where fresh water mixes with sea water)..**Estuarine**
Go to Key E-2 for Estuary Type, then to Key C-1 for coastal landform

> Note: If area was formerly connected to an estuary but now is completely cut-off from tidal flow, consider as one of inland landscape positions - Terrene, Lentic, or Lotic, depending on current site characteristics. Such areas should be designated with a modifier to identify such wetlands as "former estuarine wetland." Lands overflowed infrequently by tides such as overwash areas on barrier islands are considered Estuarine. Tidal freshwater wetlands contiguous to salt/brackish/oligohaline tidal marshes are also considered Estuarine, whereas similar wetlands just upstream along strictly fresh tidal waters are considered Lotic.

4. Wetland is located in or along a lake or reservoir (permanent waterbody where standing water is typically much deeper than 6.6 feet at low water), including streamside wetlands in a lake basin and wetlands behind barrier islands and beaches with open access to a lake.............**Lentic**
Go to Key C-2 for Lake Type
Then *Go to Key B-1 for inland landform*

> Note: Lentic wetlands consist of all wetlands in a lake basin (i.e., the depression containing the lake), including lakeside wetlands intersected by streams emptying into the lake. The upstream limit of lentic wetlands is defined by the upstream influence of the lake which is usually approximated by the limits of the basin within which the lake occurs. The streamside lentic wetlands are designated as "Throughflow," thereby emphasizing the stream flow through these wetlands. Other lentic wetlands are typically classified as "Bidirectional-nontidal" since water tables rise and fall with lake levels during the year. Tidally-influenced freshwater lakes have "Bidirectional-tidal" flow.

Modifiers: Natural, Dammed River Valley, Other Dammed - see Key C-2 for others.

4. Wetland does not occur along this type of waterbody...5

5. Wetland is located in a river or stream (including in-stream ponds), within its banks, or on its active floodplain and is periodically flooded by the river or stream...6
5. Wetland is not located in a river or stream or on its active floodplain............................**Terrene**

Note: These wetlands may occur: (1) on a slope or flat, or in a depression (including ponds, potholes, and playas) lacking a stream but contiguous to a river or stream, (2) on a historic (inactive) floodplain, or (3) in a landscape position crossed by a stream (e.g., an entrenched stream), but where the stream does not periodically inundate the wetland.
Go to Key B-1 for inland landform

6. Wetland is the source of a river or stream but this watercourse does not extend through the wetland..**Terrene**

Modifiers: May include Headwater for wetlands that are sources of streams and Estuarine Discharge or Marine Discharge for wetlands whose outflow goes directly to an estuary or the ocean, respectively.

6. Wetland is located in a river or stream, within its banks, or on its active floodplain..................7

7. Wetland is associated with a river (a broad channel mapped as a polygon or 2-lined watercourse on a 1:24,000 U.S. Geological Survey topographic map) or its active floodplain........
....**Lotic River**
Go to Couplet "a" below
(Also see note under first couplet #3 - Lentic re: streamside wetlands in lake basins)

7. Wetland is associated with a stream (a.linear or single-line watercourse on a 1:24,000 U.S. Geological Survey topographic map) or its active floodplain...................................**Lotic Stream**
Go to Couplet "a" below
(Also see note under first couplet #3 - Lentic re: streamside wetlands in lake basins)

Note: Artificial drainageways (i.e., ditches) are not considered part of the Lotic classification, whereas channelized streams are part of the Lotic landscape position.

Modifiers: Headwater (wetlands along first-order streams and possibly second-order streams and large wetlands in upper portion of watershed believed to be significant groundwater discharge sites) and Channelized (excavated stream course).

a. Water flow is under tidal influence (freshwater tidal wetlands)..............**Tidal Gradient**

Go to Key B-1 for inland landform

a. Water flow is not under tidal influence (nontidal)..b

b. Water flow is dammed, yet still flowing downstream, at least seasonally.........................
....**Dammed Reach**

Go to Key B-1 for inland landform

Modifiers: Lock and Dammed, Run-of-River Dam, Beaver Dam, and Other Dam (see Waterbody Key B-2 for further information).

b. Water flow is unrestricted..c

c. Water flow is intermittent during the year..................................**Intermittent Gradient**

Go to Key B-1 for inland landform

c. Water flow is perennial (year-round)..d

d. Water flow is generally rapid due to steep gradient; typically little or no floodplain development; watercourse is generally shallow with rock, cobbles, or gravel bottoms; first- and second-order "streams" in hilly to mountainous terrain; part of Cowardin's Upper Perennial Subsystem...**High Gradient**

Go to Key B-1 for inland landform

d. Watercourse characteristics are not so; "stream" order greater than 2 in hilly to mountainous terrain..e

e. Water flow is generally slow; typically with extensive floodplain; water course shallow or deep with mud or sand bottoms; typically fifth and higher order "streams", but includes lower order streams in nearly level landscapes such as the Great Lakes Plain (former glacial lakebed) and the Coastal Plain, and ditches; the lower order streams may lack significant floodplain development); Cowardin's Lower Perennial subsystem....................
....**Low Gradient**

Go to Key B-1 for inland landform

e. Water flow is fast to moderate; with little to some floodplain; usually third-, fourth- and higher order "streams" associated with hilly to mountainous terrain; part of Cowardin's Upper Perennial Subsystem...**Middle Gradient**

Go to Key B-1 for inland landform

Key B-1: Key to Inland Landforms

1. Wetland occurs on a noticeable slope (e.g., greater than a 2 percent slope)........**Slope Wetland**
Go to Key D-1 for water flow path

> *Modifiers* can be applied to Slope Wetlands to designate the type of inflow or outflow as Channelized Inflow or Outflow (intermittent or perennial, stream or river), Nonchannelized Inflow or Outflow (wetland lacking stream, but connected by observable surface seepage flow), or Nonchannelized-Subsurface Inflow or Outflow (suspected subsurface flow from or to a neighboring wetland upslope or downslope, respectively).

1. Wetland does not occur on a distinct slope...2

2. Wetland forms an island...**Island Wetland**
(*Go to Key D-1 for water flow path*)

> Note: Can designate an island formed in a delta at the mouth of a river or stream as a Delta Island Wetland; other islands are associated with landscape positions (e.g., lotic river island wetland, lotic stream island wetland, lentic island wetland, or terrene island pond wetland). Vegetation class and subclass from Cowardin et al. 1979 should be applied to characterize the vegetation of these wetland islands; vegetation is assumed to be rooted unless designated by a *modifier* - "Floating Mat" to indicate a floating island.

2. Wetland does not form an island...3

3. Wetland occurs within the banks of a river or stream or along the shores of a pond, lake, or island, or behind a barrier beach or island, and is either: (1) vegetated *and* typically permanently inundated, semipermanently flooded (including their tidal freshwater equivalents plus seasonally flooded-tidal palustrine emergent wetlands which tend to be flooded frequently by the tides) or otherwise flooded for most of the growing season, or permanently saturated due to this location or (2) a nonvegetated bank or shore that is temporarily or seasonally flooded ......**Fringe Wetland**

Go to Couplet "a" below for Types of Fringe Wetlands
Then *Go to Key D-1 for water flow path*

Attention: *Seasonally to temporarily flooded vegetated wetlands along rivers and streams (including tidal freshwater reaches) are classified as either Floodplain, Basin, or Flat landforms - see applicable categories.*

> a. Wetland forms along the shores of an upland island within a lake, pond, river, or stream..b
> a. Wetland does not form along the shores of an island...d
>
> b. Wetland forms behind a barrier island or beach spit along a lake..............Lentic Barrier Island Fringe Wetland or Lentic Barrier Beach Fringe Wetland

Modifier: Drowned River-mouth

b. Wetland forms along another type of island..c

c. Wetland forms along an upland island in a river or stream..................Lotic River Island Fringe Wetland or Lotic Stream Island Fringe Wetland

c. Wetland forms along an upland island in a lake or pond..................Lentic Island Fringe Wetland or Terrene Pond Island Fringe Wetland

d. Wetland forms in or along a river or stream.........................Lotic River Fringe Wetland or Lotic Stream Fringe Wetland

d. Wetland forms in or along a pond or lake..e

e. Wetland forms along a pond shore...f

e. Wetland forms along a lake shore..Lentic Fringe Wetland

Modifier: Drowned River-mouth

f. Wetland occurs along an in-stream pond...Lotic River or Stream Fringe Pond Wetland Throughflow

f. Wetland occurs in another type of pond............................Terrene Fringe Pond Wetland

Note: Vegetation is assumed to be rooted unless designated by a *modifier* to indicate a floating mat (Floating Mat).

3. Wetland does not exist along these shores...4

4. Wetland occurs on an active floodplain (alluvial processes in effect).......................**Floodplain Wetland*** (could specify the river system, if desirable). *Go to Key D-1 for water flow path* Sub-landforms are listed below.

a. Wetland forms along the shores of a river island...................Floodplain Island Wetland

a. Wetland is not along an island..b

b. Wetland forms in a depressional feature on a floodplain.........Floodplain Basin Wetland or Floodplain Oxbow Wetland (a special type of depression)

b. Wetland forms on a broad nearly level terrace..........................Floodplain Flat Wetland

*Note: Questionable floodplain areas may be verified by consulting soil surveys and locating the presence of alluvial soils, e.g., Fluvaquents or Fluvents, or soils with Fluvaquentic subgroups. While most Floodplain wetlands will have a Throughflow water flow path; others may be designated, e.g., Inflow, Outflow, or Isolated. Former floodplain wetlands are classified as Basins or Flats and designated as former floodplain.

Modifiers: Partly Drained; Confluence wetland - wetland at the intersection of two or more streams; River-mouth or stream-mouth wetland - wetland at point where a river and stream empties into lake; Meander scar wetland - floodplain basin wetland, the remnant of a former river meander.

4. Wetland does not occur on an active floodplain..5

5. Wetland occurs on an interstream divide (interfluve)..................................**Interfluve Wetland** or specify *regional types* of interfluve wetlands, for example: *Carolina Bay Interfluve Wetland*, *Pocosin Interfluve Wetland*, and *Flatwood Interfluve Wetland* (Southeast). Sub-landforms are listed below. *Go to Key D-1 for water flow path*

a. Wetland forms in a depressional feature.................................. Interfluve Basin Wetland

a. Wetland forms on a broad nearly level terrace ....Interfluve Flat Wetland

Modifiers: Partly Drained.

5. Wetland does not occur on an interfluve..6

6. Wetland exists in a distinct depression in various positions on the landscape (i.e., surrounded by upland, along smaller rivers and streams, along in-stream ponds, along lake shores, or on former floodplains or interfluves)............ **Basin Wetland** or **Basin Wetland Former Floodplain** (including *Basin Oxbow Wetland Former Floodplain*) or **Basin Wetland Former Interfluve**. Can specify regional types: *Carolina Bay Basin Wetland* and *Pocosin Basin Wetland* (Atlantic Coastal Plain), *Cypress Dome Basin Wetland* (Florida), *Prairie Pothole Basin Wetland* (Upper Midwest), *"Salt Flat" Basin Wetland* (arid West), *Playa Basin Wetland* (Southwest), *West Coast Vernal Pool Basin Wetland* (California and Pacific Northwest), *Interdunal Basin Wetland* (sand dunes), *Woodland Vernal Pool Basin Wetland* (forests throughout the country), *Polygonal Basin Wetland* (Alaska), *Sinkhole Basin Wetland* (karst/limestone regions), *Pond Wetland Basin* (throughout country), or some type of *Island Basin Wetland* for basin wetlands on islands.

Go to Key D-1 for water flow path

Modifiers may be applied to indicate artificially created basins due to beaver activity or human actions or artificially drained basins including: Beaver (beaver-created); wetlands created for various purposes or unintentionally formed due to human activities - may want to specify purpose like Aquaculture (e.g., fish and crayfish), Wildlife management (e.g., waterfowl impoundments), and Former floodplain, or to designate former salt marsh that is now nontidal (Former estuarine wetland). Other *modifiers* may be applied to designate the type of inflow or outflow as Channelized (intermittent or perennial, stream or river), Nonchannelized-wetland (contiguous wetland lacking stream), or Nonchannelized-subsurface flow (suspected subsurface flow to neighboring wetland), or to identify a headwater basin (Headwater) or a drainage divide wetland that discharges into two or more watershed (Drainage divide), or to denote a spring-fed wetland (Spring-fed), a wetland bordering a pond (Pond basin wetland) and a wetland bordering an upland island in a pond (Pond island border). For lotic basin wetlands, consider additional modifiers such as Confluence wetland - wetland at the intersection of two or more streams; River-mouth or Stream-mouth wetland - wetland at point where a river and a stream empties into a lake. For lentic basins associated with the Great Lakes, possibly identify Drowned River-mouth wetlands where mouth extends into the lake basin. Partly drained may be used for ditched/drained wetlands.

6. Wetland exists in a relatively level area...**Flat Wetland** or specify *regional types* of flat wetlands, for example: **Salt Flat Wetland** (in the Great Basin) or flats that are fragments of once-larger interfluve flats or former floodplains: **Flat Wetland, Former Interfluve** or **Flat Wetland, Former Floodplain**.

Go to Key D-1 for water flow path

Note: If desirable, a *modifier* for drained flats can be applied (Partly drained). Other modifiers can be applied to designate the type of inflow or outflow as Channelized (intermittent or perennial, stream or river), Nonchannelized-wetland (contiguous wetland lacking stream), or Nonchannelized-subsurface flow (suspected subsurface flow to neighboring wetland). For lotic flat wetlands, consider additional modifiers such as confluence wetland - wetland at the intersection of two or more streams; river-mouth or stream-mouth wetland - wetland at point where a river and a stream empties into a lake.

Key C-1: Key to Coastal Landforms

1. Wetland forms a distinct island in an inlet, river, or embayment........................**Island Wetland**

Go to Key D-1 for water flow path

a. Occurs in a delta..Delta Island Wetland
(Could identify flood delta and ebb delta islands for tidal inlets if desirable.)

a. Occurs elsewhere either in a river or an embayment ....b

b. Occurs in a river...River Island Wetland

b. Occurs in a coastal embayment..Bay Island Wetland

1. Wetland does not form such an island, but occurs behind barrier islands and beaches, or along the shores embayments, rivers, streams, and islands..2

2. Wetland occurs along the shore, contiguous with the estuarine waterbody.......**Fringe Wetland**

Go to Key D-1 for water flow path

a. Occurs behind a barrier island or barrier beach spit...........Barrier Island Fringe Wetland or Barrier Beach Fringe Wetland [*Modifier* for overwash areas: Overwash]

a. Occurs elsewhere..b

b. Occurs along a coastal embayment or along an island in a bay.........Bay Fringe Wetland or Bay Island Fringe Wetland or Coastal Pond Fringe Wetland (a special type of embayment, typically with periodic connection to the ocean unless artificially connected by a bulkheaded inlet) or Coastal Pond Island Fringe Wetland

b. Occurs elsewhere...c

c. Occurs along a coastal river or along an island in a river................River Fringe Wetland or River Island Fringe Wetland

c. Occurs elsewhere...d

d. Occurs along an oceanic island..Ocean Island Fringe Wetland

d. Occurs along the shores of exposed rocky mainland................Headland Fringe Wetland

2. Wetland is separated from main body of marsh by natural or artificial means; the former may be connected by a tidal stream extending through the upland or by washover channels (e.g., estuarine intertidal swales), whereas the latter occurs in an artificial impoundment or behind a road or railroad embankment where tidal flow is at least somewhat restricted........**Basin Wetland**

Go to Key D-1 for water flow path

Modifiers may be applied to separate natural from created basins (managed fish and wildlife areas; aquaculture impoundments; salt hay diked lands; tidally restricted-road, and tidally restricted-railroad), and for other situations, as needed.

Key D-1: Key to Water Flow Paths

1. Wetland is periodically flooded by tides...**Bidirectional-tidal**
   See Key F-2 for additional descriptors based on tidal ranges (i.e., macrotidal, mesotidal, and microtidal).

1. Wetland is not flooded by tides..2

2. Water levels fluctuate due to lake influences or to variable river levels, but water does not flow through this wetland...**Bidirectional-nontidal**

Note: Lentic wetlands with streams running through them are classified as Throughflow to emphasize this additional water source, while lentic wetlands located in coves or fringing the high ground would typically be classified as Bidirectional-Nontidal. Similarly, many floodplain wetlands are throughflow types, while some are connected to the river through a single channel in which water rises and falls with changing river levels. The water flow path of the latter types is best classified as bidirectional-nontidal.

2. Wetland is not subject to lake influences..3

3. Wetland is formed by paludification processes where in areas of low evapotranspiration and high rainfall, peat moss moves uphill creating wetlands on hillslopes (i.e., wetland develops upslope of primary water source)..**Paludified**
3. Wetland is not formed by paludification processes...4

4. Wetland receives surface or ground water from a stream, other waterbody or wetland (i.e., at a higher elevation) <u>and</u> surface or ground water passes through the subject wetland to a stream, another wetland, or other waterbody at a lower elevation; a flow-through system....**Throughflow**, **Throughflow-intermittent***, **Throughflow-entrenched***, or **Throughflow-artificial***

> *Modifiers*: <u>Groundwater-dominated</u> throughflow wetlands can be separated from <u>Surface water-dominated</u> throughflow wetlands.
>
> *<u>Note</u>: **Throughflow-intermittent** is to be used with throughflow wetlands along intermittent streams; **Throughflow-entrenched** indicates that stream flow is through a wetland but the stream is deeply cut and does not overflow into the wetland (therefore the stream is, for practical purposes, separate from the wetland) - this water flow path is intended to be used with Terrene wetlands in this situation; **Throughflow-artificial** is used to designate wetlands where throughflow is human-caused - usually to indicate connection of Terrene wetlands to other Terrene wetlands and waters by ditches and not by streams either natural or channelized

4. Water does not pass through this wetland to other wetlands or waters....................................5

5. There is no surface or groundwater inflow from a stream, other waterbody, or wetland (i.e., no documented surface or ground water inflow from a wetland or other waterbody at a higher elevation) <u>and</u> no observable or known outflow of surface or ground water to other wetlands or waters...**Isolated**

<u>Attention</u>: *In most applications, isolation is interpreted as "geographically isolated" since groundwater connections are typically unknown for specific wetlands. For practical purposes then," isolated" means no obvious surface water connection to other wetlands and waters. If hydrologic data exist for a locale that documents groundwater linkages, such wetlands should be identified as either outflow. inflow, or throughflow with a "<u>Groundwater-dominated</u>" modifier and not be identified as isolated <u>unless</u> the whole network of wetlands is not connected to a stream or river. In the latter case, the network is a collection of interconnected isolated wetlands.*

5. Wetland is not hydrologically or geographically isolated...6

6. Wetland receives surface or ground water inflow from a wetland or other waterbody

(perennial or intermittent) at a higher elevation <u>and</u> there is no observable or known significant outflow of surface or ground water to a stream, wetland or waterbody at a lower elevation ....**Inflow**

> *Modifiers*: <u>Groundwater-dominated</u> inflow wetlands can be separated from <u>Surface water-dominated</u> inflow wetlands; <u>Human-caused</u> (usually to indicate connection of Terrene wetlands to other Terrene wetlands and waters [e.g., Inflow human-caused] by ditches and not by streams either natural or channelized).

6. Wetland receives no surface or ground water inflow from a wetland or permanent waterbody at a higher elevation (may receive flow from intermittent streams only) <u>and</u> surface or ground water is discharged from this wetland to a stream, wetland, or other waterbody at a lower elevation..**Outflow** or **Outflow-artificial***

> *Modifiers:* <u>Groundwater-dominated</u> outflow wetlands can be separated from <u>Surface water-dominated</u> outflow wetlands. Might consider separating perennial outflow (**Outflow-perennial**) from intermitttent outflow (**Outflow-intermittent**), if interested.

> *<u>Note</u>: Outflow-artificial is usually used to indicate outflow from formerly isolated wetlands resulting by ditches.

Section 3. Waterbody Keys

These keys are designed to expand the classification of waterbodies beyond the system and subsystem levels in the Service's wetland classification system (Cowardin et al. 1979). Users are advised first to classify the waterbody in one of the five ecosystems: 1) marine (open ocean and associated coastline), 2) estuarine (mixing zone of fresh and ocean-derived salt water), 3) lacustrine (lakes, reservoirs, large impoundments, and dammed rivers), 4) riverine (undammed rivers and tributaries), and 5) palustrine (e.g., nontidal ponds) and then apply the waterbody type descriptors below.

Five sets of keys are given. Key A-2 helps describe the major waterbody type. Key B-2 identifies different stream gradients for rivers and streams. It is similar to the subsystems of Cowardin's Riverine system, but includes provisions for dammed rivers to be identified as well as a middle gradient reach similar to that of Brinson's hydrogeomorphic classification system. The third key, Key C-2, addresses lake types, while Keys D-2 and E-2 further define ocean and estuary types, respectively. Key F-2 is a key to water flow paths of waterbodies. Key G-2 is for describing general circulation patterns in estuaries. The coastal terminology applies concepts of coastal hydrogeomorphology.

Besides the keys provided, there are numerous other attributes that can be used to describe the condition of waterbodies. Some examples are other descriptors that address resource condition could be ones that emphasize human modification, (e.g., natural vs. altered, with further subdivisions of the latter descriptor possible), the condition of waterbody buffers (e.g., stream corridors), or levels of pollution (e.g., no pollution [pristine], low pollution, moderate pollution, and high pollution).

Key A-2. Key to Major Waterbody Type

1. Waterbody is predominantly flowing water..2
1. Waterbody is predominantly standing water...7

Note: Fresh waterbodies may be tidal; if so, waterbody is classified as a Tidal Lake or Tidal Pond using criteria below to separate lakes from ponds.

2. Flow is unidirectional and waterbody is a river, stream, or similar channel..............................3
2. Flow is tidal (bidirectional) at least seasonally; waterbody is an ocean, embayment, river, stream, or lake..4

3. Waterbody is a polygonal feature on a U.S. Geological Survey map or a National Wetlands Inventory Map (1:24,000/1:25,000)..**River**
3. Waterbody is a linear feature on such maps..**Stream**
Go to River/Stream Gradient Key - Key B-2 - for other modifiers

4. Waterbody is freshwater...5
4. Waterbody is salt or brackish...6

5. Waterbody is a polygonal feature on a U.S. Geological Survey map or a National Wetlands Inventory Map (1:24,000/1:25,000)..**River**
5. Waterbody is a linear feature on such maps..**Stream**
Go to River/Stream Gradient Key - Key B-2 - for other modifiers

6. Part of a major ocean or its associated embayment (Marine system of Cowardin et al. 1979) ....**Ocean**

Go to Ocean Key - Key D-2

6. Part of an estuary where fresh water mixes with salt water (Estuarine system of Cowardin et al. 1979)..**Estuary**

Go to Estuary Key - Key E-2

7. Waterbody is freshwater...8
7. Waterbody is salt or brackish and tidal..10

8. Waterbody is permanently flooded and deep (>than 6.6 ft at low water), excluding small

"kettle or bog ponds" (i.e., usually less than 5 acres in size and surrounded by bog vegetation)...**Lake**

Go to Lake Key - Key C-2

8. Waterbody is shallow (< 6.6 ft at low water) or a small "kettle or bog pond" (with deeper water)..9

9. Waterbody is small (< 20 acres)...**Pond**

Separate natural from artificial ponds, then add other modifiers like the following. Some *examples* of modifiers for ponds: beaver, alligator, marsh, swamp, vernal, Prairie Pothole, Sandhill, sinkhole/karst, Grady, interdunal, farm-cropland, farm-livestock, golf, industrial, sewage/wastewater treatment, stormwater, aquaculture-catfish, aquaculture-shrimp, aquaculture-crayfish, cranberry, irrigation, aesthetic-business, acid-mine, arctic polygonal, kettle, bog, woodland, borrow pit, Carolina bay, tundra, coastal plain, tidal, and in-stream.

Note: Wetlands associated with ponds are typically either Terrene basin wetlands, such as a Cypress dome or cypress-gum pond, or Terrene pond fringe wetlands, such as semipermanently flooded wetlands along margins of pond. In-stream ponds are in the Lotic landscape position.

9. Waterbody is large (≥20 acres)..**Lake**
Go to Lake Key - Key C-2

10. Part of a major ocean or its associated embayment (Marine system of Cowardin et al. 1979) ....**Ocean**

Go to Ocean Key - Key D-2

10. Part of an estuary where fresh water mixes with salt water (Estuarine system of Cowardin et al. 1979)...**Estuary**

Go to Estuary Key - Key E-2

Key B-2. River/Stream Gradient and Other Modifiers Key

Please note that the river/stream gradient extends from the freshwater tidal zone through the intermittent reach. The limits of the latter are typically defined by drainageways with well-defined channels that discharge water seasonally. From a practical standpoint, the limits of the lotic system are displayed on 1:24,000 U.S. Geological Survey topographic maps or similar digital data. Intermittent streams, certain dammed portions of rivers plus lock and dammed canal systems may be classified as rivers using the descriptors presented in these keys. In the Cowardin et al. system, they may be classified as Riverine Intermittent Streambed or Lacustrine Unconsolidated Bottom, respectively.

1. Water flow is under tidal influence..**Tidal Gradient**

> *Type of tidal river or stream*: 1) natural river, 2) natural stream, 3) channelized river, 4) channelized stream, 5) canal (artificial polygonal lotic feature), 6) ditch (artificial linear lotic feature), 7) restored river segment (part of river where restoration was performed), and 8) restored stream segment (part of stream where restoration was performed).

1. Water flow is not under tidal influence (nontidal)...2

2. Water flow is dammed, yet still flowing downstream at least seasonally..........**Dammed Reach**

> *Type of dammed river*: 1) lock and dammed (canalized river, a series of locks and dams are present to aid navigation), 2) run-of-river dammed (low dam allowing flow during high water periods; often used for low-head hydropower generation), and 3) other dammed (unspecified, but not major western hydropower dam as such waterbodies are considered lakes, e.g., Lake Mead and Lake Powell).

2. Water flow is unrestricted...3

3. Water flow is perennial (year-round); perennial rivers and streams..4
3. Water flow is seasonal or aperiodic (intermittent); Cowardin's Intermittent Subsystem ....**Intermittent Gradient***

4. Water flow is generally rapid due to steep gradient; typically little or no floodplain development; watercourse is generally shallow with rock, cobbles, or gravel bottoms; first and second order "streams"; part of Cowardin's Upper Perennial subsystem...............**High Gradient***
4. Water flow is not so; some to much floodplain development..5

5. Water flow is generally slow; typically with extensive floodplain; water course shallow or deep with mud or sand bottoms; typically fifth and higher order "streams", but includes lower order streams in nearly level landscapes such as the Great Lakes Plain (former glacial lakebed) and the Coastal Plain (the latter streams may lack significant floodplain development); Cowardin's Lower Perennial subsystem ....**Low Gradient***
5. Water flow is fast to moderate; with little to some floodplain; usually third and fourth order "streams"; part of Cowardin's Upper Perennial subsystem.................................**Middle Gradient***

**Type of river or stream* - additional modifiers that may be applied as desired: 1) natural river-single thread (one channel), 2) natural river-multiple thread (braided) (multiple, wide, shallow channels), 3) natural river-multiple thread (anastomosed) (multiple, deep narrow channels), 4) natural stream-single thread, 5) channelized river (dredged/excavated), 6) channelized stream, 7) canal (artificial polygonal lotic feature), 8) ditch (artificial linear lotic feature), 9) restored river segment (part of river where restoration was performed), 10) restored stream segment (part of stream where restoration was performed), and 11) connecting channel (joins two lakes). Other possible descriptors: 1) for perennial rivers and streams - riffles (shallow, rippling water areas), pools (deeper, quiet water areas), and waterfalls (cascades), 2) for water depth of perennial rivers - deep rivers (≥6.6 ft at low water) from shallow rivers (<6.6 ft at low water), 3) nontidal river or stream segment emptying into an estuary, ocean, or lake (estuary-discharge, marine-discharge, or lake-discharge), 4) classification by stream order (1st, 2nd, 3rd, etc. for perennial segments), and 5) channels patterns (straight, slight meandering, moderate meandering, and high meandering).

Key C-2. Key to Lakes.

The lake designation is for permanently flooded deep waters (>6.6 feet). Some classification systems include shallow waterbodies or periodically exposed areas as "lakes." The Cowardin et al. system considers standing waterbodies larger than 20 acres to be part of the lacustrine system (regardless of water depth; shallow = wetlands; >6.6 feet = deepwater habitat), and smaller ones typically part of the palustrine wetlands. For our purposes, "shallow lakes" and "seasonal or intermittent lakes" are considered some type of terrene or lotic wetland depending on the presence and location of a stream. Lentic wetlands are associated with permanently flooded standing waterbodies deeper than 6.6 feet at low water.

1. Waterbody is not dammed or impounded..**Natural Lake**

> *Modifiers*: Main body, Open embayment, Semi-enclosed embayment, Barrier beach lagoon, Seiche-influenced, River-fed and Stream-fed descriptors. Can also use applicable modifiers listed under Pond (see Key A-2).
>
> *Can use additional modifiers listed under Pond (see Key A-2) and others (e.g., crater, lava flow, aeolian, fjord, oxbow, other floodplain, glacial, alkali, and manmade), as appropriate.

1. Waterbody is dammed, impounded, or excavated 2

2. Waterbody is dammed or impounded...3
2. Waterbody is excavated..**Excavated Lake**

3. Dammed river valley..**Dammed River Valley Lake**

> *Modifiers*: Reservoir, Hydropower, and Seiche-influenced; also River-fed and Stream-fed descriptors.

Note: When the dam inundates former floodplains and other low-lying areas, the waterbody is considered a Dammed River Valley Lake. If the dam crosses a higher gradient river and increase water depth in an channel without significant flooding of much neighboring "land," the waterbody is considered the dammed reach of a river.

3. Dammed natural lake or other landscape..**Other Dammed Lake**

Modifiers: Former natural lake, Artificial lake, River-fed and Stream-fed descriptors.

Key D-2. Ocean Key.

1. Waterbody is completely open, not protected by any feature.................................**Open Ocean**
(Can further identify open bays if desirable.)
1. Waterbody is somewhat protected..2

2. Associated with coral reef or island 3

2. Not associated with coral reef or island...4

3. Open but protected by coral reef ....**Reef-protected Waters**
3. Protected by a coral island..**Atoll Lagoon**

4. Deep embayment cut by glaciers, with an underwater sill at front end, restricting circulation; associated with rocky headlands...**Fjord**
4. Other semi-protected embayment..**Semi-protected Oceanic Bay**

Modifiers for all types above: Submerged vegetation (e.g., eelgrass or turtle-grass) or Floating vegetation (e.g., macroalgae such as kelp beds).

Key E-2. Estuary Key.

The following types should encompass most of the estuaries located in the United States. There may be estuaries that do not fit within this classification. Such types should be brought to the attention of the author.

1. Estuary is surrounded by rocky headlands and shores...2
1. Estuary is not surrounded by rocky headlands and shores..4

2. Deep embayment cut by glaciers, with an underwater sill at front end, restricting circulation

(e.g., Puget Sound)..**Fjord Estuary**
2. Not so, either open or semi-enclosed..3

3. Protected by islands.....................................**Island Protected Rocky Headland Bay Estuary**
3. Not protected by islands...**Rocky Headland Bay Estuary**

Modifiers: Open or Semi-enclosed

4. Estuary is tectonically formed (e.g., San Francisco Bay), including volcanic activity.................
....**Tectonic Estuary**

Modifiers: Fault-formed and Volcanic-formed

4. Estuary is not tectonically formed or is formed by volcanic activity..5

5. Estuary is river-dominated with very little tidal range and a delta formed at the mouth of the river where it enters the sea (e.g., Mississippi River Delta)..................**River-dominated Estuary**
5. Estuary is not river-dominated..6

6. Estuary is a drowned river valley (e.g., Chesapeake Bay)........**Drowned River Valley Estuary**

Modifiers: Open Bay, River Channel, and Semi-enclosed Bay

6. Estuary is not a drowned river valley..7

7. Estuary formed behind and is protected by sandy barrier islands or barrier beaches (spits)..**Bar-built Estuary**

Modifiers: Coastal Pond (oligohaline to saline) and Hypersaline Lagoon (hypersaline)

7. Estuary is not behind sandy barrier islands or beaches...8

8. Estuary is protected by reefs or other islands....................................**Island Protected Estuary**
8. Estuary is an open or semi-enclosed embayment...................................**Shoreline Bay Estuary**

Modifiers for all estuarine waterbodies: Inlet (includes any ebb- or flood- deltas that are completed submerged), Stabilized Inlet, Shoal (shallow water area), Submerged vegetation (e.g., eelgrass or turtle-grass) or Floating vegetation (e.g., macroalgae such as kelp beds).

Key F-2. Key to Water Flow Paths

1. Water flow is tidally influenced..2
1. Water flow is not under the influence of the tides...4

2. Tide range is greater than 4m (approx. >12 feet) ....**Macrotidal**
2. Tidal range is less than 4m 3

3. Tidal range is 2-4m (approx. 6-12 feet) ....**Mesotidal**
3. Tidal range is less than 2m (approx. < 6 feet) ....**Microtidal**

4. Water flows out of the waterbody via a river, stream, or ditch, with little or no inflow (inflow could be from intermittent streams or ground water only) ....**Outflow**

> *Modifier*: <u>Human-caused</u> for inflow via a ditch network. Might consider separating perennial outflow (**Outflow-perennial**) from intermitttent outflow (**Outflow-intermittent**), if interested.

4. Water flow is not so...5

5. Water enters waterbody from river, stream, or ditch, flows through it, and continues to flow downstream..**Throughflow** or **Throughflow-intermittent**

> *Modifier*: <u>Human-caused</u> for throughflow via a ditch network

> <u>Note</u>: Throughflow intermittent is applied to intermittent streams

5. Water flow is not throughflow...6

6. Water flows in and out of the waterbody through the same channel; it does not flow through the waterbody..**Bidirectional-nontidal**

6. Water flow is not bidirectional...7

7. Water flow enters via a river, stream, or ditch, but does not exit pond, lake or reservoir; waterbody serves as a sink for water...**Inflow**

> *Modifier*: <u>Human-caused</u> for inflow via a ditch network.

7. No apparent channelized inflow, source of water either by precipitation or by underground sources...**Isolated**

<u>Attention</u>: *In most applications, isolation is interpreted as "geographically isolated" since groundwater connections are typically unknown for specific waterbodies. For practical*

purposes then," isolated" means no obvious surface water connection to other wetlands and waters. If hydrologic data exist for a locale that document groundwater linkages, such waterbodies should be identified as either outflow. inflow, or throughflow <u>with a "Groundwater-dominated" modifier added</u> and not be identified as isolated <u>unless</u> the whole network of waterbodies is not connected to a stream or river. In the latter case, the network is a collection of interconnected isolated waterbodies.

Key G-2. Key to Estuarine Hydrologic Circulation Types

1. Estuary is river-dominated with distinct salt wedge moving seasonally up and down the river; fresh water at surface with most saline waters at bottom; low energy system with silt and clay bottoms ....**Salt-wedge Estuary**
1. Estuary is not river-dominated 2

2. Estuarine water is well-mixed, no significant salinity stratification, salinity more or less the same from top to bottom of water column; high-energy system with sand bottom...............
....**Homogeneous Estuary**
2. Estuarine water is partially mixed, salinities different from top to bottom, but not strongly stratified; low energy system ....**Partially Mixed Estuary**

Section 4. Coding System for LLWW Descriptors

The following is the coding scheme for expanding classification of wetlands and waterbodies beyond typical NWI classifications. When enhancing NWI maps/digits, codes should be applied to all mapped wetlands and deepwater habitats (including linears). At a minimum, landscape position (including lotic gradient), landform, and water flow path should be applied to wetlands, and waterbody type and water flow path to water to waterbodies. Wetland and deepwater habitat data for specific estuaries, lakes, and river systems could be added to existing digital data through use of geographic information system (GIS) technology.

Codes for Wetlands

Wetlands are typically classified by landscape position, landform, and water flow path. Landforms are grouped according to Inland types and Coastal types with the latter referring to tidal wetlands associated with marine and estuarine waters. Use of other descriptors tends to be optional. They would be used for more detailed investigations and characterizations.

<u>Landscape Position</u>

ES	Estuarine
LE	Lentic
LR	Lotic river
LS	Lotic stream
MA	Marine
TE	Terrene

<u>Lotic Gradient</u>

1	Low	
2	Middle	
3	High	
4	Intermittent	
5	Tidal	
6	Dammed	
a		lock and dammed
b		run-of-river dam
c		beaver
d		other dammed
7	Artificial (ditch)	

Lentic Type

1	Natural deep lake (see also Pond codes for possible specific types)	
a		main body
b		open empbayment
c		semi-enclosed embayment
d		barrier beach lagoon
2	Dammed river valley lake	
a		reservoir
b		hydropower
c		other
3	Other dammed lake	
a		former natural
b		artificial
4	Excavated lake	
a		quarry lake
5	Other artificial lake	

Estuary Type

1	Drowned river valley estuary	
a		open bay (fully exposed)
b		semi-enclosed bay
c		river channel
2	Bar-built estuary	
a		coastal pond-open
b		coastal pond-seasonally closed
c		coastal pond-intermittently open
d		hypersaline lagoon
3	River-dominated estuary	
4	Rocky headland bay estuary	
a		island protected
5	Island protected estuary	
6	Shoreline bay estuary	
a		open (fully exposed)
b		semi-enclosed
7	Tectonic	
a		fault-formed
b		volcanic-formed
8	Fjord	
9	Other	

Inland Landform

SL	Slope	
SLpa		Slope, paludified
IL	Island*	
ILde		Island, delta
ILrs		Island, reservoir
ILpd		Island, pond
FR	Fringe*	
FRil		Fringe, island*
FRbl		Fringe, barrier island
FRbb		Fringe, barrier beach
FRpd		Fringe, pond
FRdm		Fringe, drowned river mouth
FP	Floodplain	
FPba		Floodplain, basin
FPox		Floodplain, oxbow
FPfl		Floodplain, flat
FPil		Floodplain, island
IF	Interfluve	
IFba		Interfluve, basin
IFfl		Interfluve, flat
BA	Basin	
BAcb		Basin, Carolina bay
BApo		Basin, pocosin
BAcd		Basin, cypress dome
BApp		Basin, prairie pothole
BApl		Basin, playa
BAwc		Basin, West Coast vernal pool
BAid		Basin, interdunal
BAwv		Basin, woodland vernal
BApg		Basin, polygonal
BAsh		Basin, sinkhole
BApd		Basin, pond
BAgp		Basin, grady pond
BAsa		Basin, salt flat
BAaq		Basin, aquaculture (created)
BAcr		Basin, cranberry bog (created)
BAwm		Basin, wildlife management (created)

BAip		Basin, impoundment (created)
BAfe		Basin, former estuarine wetland
BAff		Basin, former floodplain
BAfi		Basin, former interfluve
BAfo		Basin, former floodplain oxbow
BAdm		Basin, drowned river-mouth
FL	Flat	
FLsa		Flat, salt flat
FLff		Flat, former floodplain
FLfi		Flat, former interfluve

*Note: Inland slope wetlands and island wetlands associated with rivers, streams, and lakes are designated as such by the landscape position classification (e.g., lotic river, lotic stream, or lentic), therefore no additional terms are needed here to convey this association.

Coastal Landform

IL	Island	
ILdt		Island, delta
ILde		Island, ebb-delta
ILdf		Island, flood-delta
ILrv		Island, river
ILst		Island, stream
ILby		Island, bay
DE	Delta	
DEr		Delta, river-dominated
DEt		Delta, tide-dominated
DEw		Delta, wave-dominated
FR	Fringe	
FRal		Fringe, atoll lagoon
FRbl		Fringe, barrier island
FRbb		Fringe, barrier beach
FRby		Fringe, bay
FRbi		Fringe, bay island
FRcp		Fringe, coastal pond
FRci		Fringe, coastal pond island
FRhl		Fringe, headland
FRoi		Fringe, oceanic island
FRlg		Fringe, lagoon
FRrv		Fringe, river

FRri	Fringe, river island
FRst	Fringe, stream
FRsi	Fringe, stream island

BA	Basin
BAaq	Basin, aquaculture (created)
BAid	Basin, interdunal (swale)
BAst	Basin, stream
BAsh	Basin, salt hay production (created)
BAtd	Basin, tidally restricted/road (not a management area)
BAtr	Basin, tidally restricted/railroad (not a management area)
BAwm	Basin, wildlife management (created)
BAip	Basin, impoundment (created)

Water Flow Path

PA	Paludified
IS	Isolated
IN	Inflow
OU	Outflow
OA	Outflow-artificial*
OP	Outflow-perennial
OI	Outflow-intermittent
TH	Throughflow
TA	Throughflow - artificial*
TN	Throughflow - entrenched
TI	Throughflow - intermittent
BI	Bidirectional Flow - nontidal
BT	Bidirectional Flow - tidal

*Note: To be used with wetlands connected to streams by ditches.

Other Modifiers (apply at the end of the code as appropriate)

br	barren
bv	beaver
ch	channelized flow
cl	coastal island (wetland on an island in an estuary or ocean including barrier islands)
cr	cranberry bog
dd	drainage divide
dr	partly drained
ed	freshwater wetland discharging directly into an estuary
fe	former estuarine wetland

fg	fragmented
fm	floating mat
gd	groundwater-dominated (apply to Water Flow Path only)
hi	severely human-induced
hw	headwater
li	lake island (wetland associated with a lake island)
md	freshwater wetland discharging directly into marine waters
ow	overwash
pi	pond island border
ri	river island (wetland associated with a river island)
sd	surface water-dominated (apply to Water Flow Path only)
sf	spring-fed
ss	subsurface flow
td	tidally restricted/road
tr	tidally restricted/railroad

(Note: "ho" was formerly used to indicate human-induced outflow brought about by ditch construction; now this is addressed by the water flow path "OA" Outflow-Artificial.)

Codes for Waterbodies

Besides Waterbody Type, waterbodies can be classified by water flow path (for lakes and ponds), estuary hydrologic type (for estuaries), and tidal range types (for estuaries and oceans).

Waterbody Type

RV	River		
	1	low gradient	
	a		connecting channel
	b		canal
	2	middle gradient	
	a		connecting channel
	3	high gradient	
	a		waterfall
	b		riffle
	c		pool
	4	intermittent gradient	
	5	tidal gradient	
	6	dammed gradient	
	a		lock and dammed
	b		run-of-river dammed
	c		other dammed

ST Stream
1 low gradient
a connecting channel
2 middle gradient
a connecting channel
3 high gradient
a waterfall
b riffle
c pool
4 intermittent gradient
5 tidal gradient
6 dammed
a lock and dammed
b run-of-river dammed
c beaver dammed
d other dammed
7 artificial
a connecting channel
b ditch

LK Lake
1 natural lake (*see also Pond codes for possible specific types*)
a main body
b open empbayment
c semi-enclosed embayment
d barrier beach lagoon
2 dammed river valley lake
a reservoir
b hydropower
c other
3 other dammed lake
a former natural
b artificial
4 other artificial lake

(Consider using a modifier to highlight specific lakes as needed, especially the Great Lakes, e.g., LK1E for Lake Erie or LK2O for Lake Ontario, and Lake Champlain, LK1C)

EY Estuary
1 drowned river valley estuary
a open bay (fully exposed)
b semi-enclosed bay
c river channel

2 bar-built estuary
- a coastal pond-open
- b coastal pond-seasonally closed
- c coastal pond-intermittently open
- d hypersaline lagoon

3 river-dominated estuary

4 rocky headland bay estuary
- a island protected

5 island protected estuary

6 shoreline bay estuary
- a open (fully exposed)
- b semi-enclosed

7 tectonic
- a fault-formed
- b volcanic-formed

8 fjord

9 other

Note: If desired, you can also designate river channel (rc), stream channel (sc),and inlet channel (ic) by modifiers. *Examples*: EY1rc = Drowned River Valley Estuary river channel; EY2ic= Bar-built estuary inlet channel. If not, simply classify all estuarine water as a single type, e.g., EY1 for Drowned River Valley or EY2 for Bar-built Estuary.

OB Ocean or Bay
- 1 open (fully exposed)
- 2 semi-protected oceanic bay
- 3 atoll lagoon
- 4 other reef-protected waters
- 5 fjord

PD Pond
- 1 natural
  - a bog
  - b woodland-wetland
  - c woodland-dryland
  - d prairie-wetland (pothole)
  - e prairie-dryland (pothole)
  - f playa
  - g polygonal
  - h sinkhole-woodland
  - i sinkhole-prairie
  - j Carolina bay
  - k pocosin
  - l cypress dome

m		vernal-woodland
n		vernal-West Coast
o		interdunal
p		grady
q		floodplain
r		other
2	dammed/impounded	
a		agriculture
a1		cropland
a2		livestock
a3		cranberry
b		aquaculture
b1		catfish
b2		crayfish
c		commercial
c1		commercial-stormwater
d		industrial
d1		industrial-stormwater
d2		industrial-wastewater
e		residential
e1		residential-stormwater
f		sewage treatment
g		golf
h		wildlife management
i		other recreational
o		other
q		floodplain
3	excavated	
a		agriculture
a1		cropland
a2		livestock
a3		cranberry
b		aquaculture
b1		catfish
b2		crayfish
c		commercial
c1		commercial-stormwater
d		industrial
d1		industrial-stormwater
d2		industrial-wastewater
e		residential
e1		residential-stormwater
f		sewage treatment
g		golf

h		wildlife management
i		other recreational
j		mining
j1		sand/gravel
j2		coal
o		other
q		floodplain
4	beaver	
5	other artificial	

Water Flow Path

IN	Inflow
OU	Outflow
OA	Outflow-artificial*
OP	Outflow-perennial
OI	Outflow-intermittent
TH	Throughflow
TA	Throughflow-artificial*
TI	Throughflow-intermittent*
TN	Throughflow-entrenched
BI	Bidirectional-nontidal
IS	Isolated
MI	Microtidal
ME	Mesotidal
MC	Macrotidal

*Note: OA and TA are human-caused by ditches; TI is to be used along intermittent streams.

Estuarine Hydrologic Circulation Type

SW	Salt-wedge/river-dominated type
PM	Partially mixed type
HO	Homogeneous/high energy type

Other Modifiers (apply at end of code)

ch	Channelized or Dredged
dv	Diverted
ed	freshwater stream flowing directly into an estuary
fv	Floating vegetation (on the surface)
lv	Leveed
md	freshwater stream flowing directly into marine waters
sv	Submerged vegetation

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Section 7. Glossary

Barrier Beach -- a coastal peninsular landform extending from the mainland into the ocean or large embayment or large lake (e.g., Great Lakes), typically providing protection to waters on the backside and allowing the establishment of salt marshes; similar to the barrier island, except connected to the mainland

Barrier Island -- a coastal insular landform, an island typically between the ocean (or possibly the Great Lakes) and the mainland; its presence usually promotes the formation of salt marshes on the backside

Basin -- a depressional (concave) landform; various types are further defined by the absence of a stream (isolated), by the presence of a stream and its position relative to a wetland (throughflow, outflow, inflow), or by its occurrence on a floodplain (floodplain basins include ox-bows and sloughs, for example)

Bay -- a coastal embayment of variable size and shape that is always opens to the sea through an inlet or other features

Carolina Bay -- a wetland formed in a semicircular or egg-shaped basin with a northwest to southeast orientation, found along the Atlantic Coastal Plain from southern New Jersey to Florida, and perhaps most common in Horry County, South Carolina

Channelization -- the act or result of excavating a stream or river channel to increase downstream flow of water or to increase depth for navigational purposes

Channelized -- water flow through a conspicuous drainageway, a stream or a river

Coastal Island - an island in marine and estuarine areas

Coastal Pond - pond and its associated wetlands that form behind a barrier beach and are subjected to varying tidal influence (intermittent to daily); the tidal connection for many coastal ponds has been stabilized by jetties; the ones that are only intermittently connected have low salinities

Connecting Channel - a river or stream that connects two adjacent lakes; lakes are typically close together considering their relative size; it is not any stream that occurs between two lakes in a drainage basin; perhaps the best examples are rivers connecting the Great Lakes, such as the St. Marys River connecting Lake Superior to Lake Huron, Detroit River connecting Lake St. Clair to Lake Erie, and the Niagara River connecting Lake Erie with Lake Ontario

Cypress Dome -- a wetland dominated by bald cypress growing in a basin that may be formed by the collapse of underlying limestone, forest canopy takes on a domed appearance with tallest trees in center and becoming progressively shorter as move toward margins of basin

Delta -- a typically lobed-shaped or fan-shaped landform formed by sedimentation processes at the mouth of a river carrying heavy sediment loads

Ditch – a linear, often shallow, artificial channel created by excavation with intent to improve drainage of or to irrigate adjacent lands

Drained, Partly -- condition where a wetland has been ditched or tiled to lower the ground water table, but the area is still wet long enough and often enough to fall within the range of conditions associated with wetland hydrology

Entrenched -- condition where a stream cuts through a wetland and does not periodically overflow into the wetland; the affected wetland may be a terrene wetland cut by a stream or it could be a lotic wetland along an entrenched stream (the latter would usually have to be identified in the field)

Estuarine -- the landscape of estuaries (salt and brackish tidal waterbodies, such as bays and coastal rivers) including associated wetlands, typically occurring in sheltered or protected areas, not exposed to oceanic currents

Flat -- a relatively level landform; may be a component of a floodplain or the landform of an interfluve

Flatwood -- forest of pines, hardwoods or mixed stands growing on interfluves on the Gulf-Atlantic Coastal Plain, typically with imperfectly drained soils; some flatwoods are wetlands, while others are dryland

Floodplain -- a broad, generally flat landform occurring in a landscape shaped by fluvial or riverine processes; for purposes of this classification limited to the broad plain associated with large river systems subject to periodic flooding (once every 100 years) and typically having alluvial soils; further subdivided into several subcategories: flat (broad, nearly level to gently sloping areas) and basin (depressional features such as ox-bows and sloughs)

Floodplain, active -- floodplain that is typically inundated once every 100 years by natural events

Floodplain, inactive -- floodplain that is no longer flooded once in 100 years due to human-alterations such as leveeing, diking, or altered river flow regimes or to natural processes such as changing river courses

Fringe -- a wetland occurring along a standing or flowing waterbody, i.e., a lake, pond, river, stream, estuary, or ocean, including tidal wetlands that are inundated frequently by tides, nontidal vegetated wetlands that are flooded for most of the growing season, and nonvegetated wetlands that form the banks of these waterbodies (such as cobble-gravel bars along river bends)

Ground Water -- water below ground, held in the soil or underground aquifers

Headland -- the seaward edge of the major continental land mass (North America), commonly called the mainland; not an island

High Gradient -- the fast-flowing segment of a drainage system, typically with no floodplain development; equivalent to the Upper Perennial and Intermittent Subsystems of the Riverine System in Cowardin et al. 1979

Inflow -- water enters; an inflow wetland is one that receives surface water from a stream or other waterbody or from significant surface or ground water from a wetland or waterbody at a higher elevation and has no significant discharge

Interdunal -- occurring between sand dunes, as in interdunal swale wetlands found in dunefields behind ocean and estuarine beaches and in sand plains like the Nebraska Sandhills

Interfluve -- a broad level to imperceptibly depressional poorly drained landform occurring between two drainage systems, most typical of the Coastal Plain

Island -- a landform completely surrounded by water and not a delta; some islands are entirely wetland, while others are uplands with or without a fringe wetland

Isolated -- lacking an apparent surface water connection to other wetlands and waterbodies; typically "geographically isolated" (surrounded by upland - nonhydric soils); may be connected to other wetlands and water via groundwater, but this is not known

Karst -- a limestone region characterized by sinkholes and underground caverns

Kettle -- a glacially formed depression typically created by a block of glacial ice left on the land by a retreating glacier; melting of the ice formed a kettle pond that may be quite deep, with bog vegetation frequently established along its perimeter

Lake Island - an island in a lake

Lentic -- the landscape position associated with large, deep standing waterbodies (such as lakes and reservoirs) and contiguous wetlands formed in the lake basin (excludes seasonal and shallow lakes which are included in the *Terrene* landscape position)

Lotic -- the landscape position associated with flowing water systems (such as rivers, creeks, perennial streams, intermittent streams, and similar waterbodies) and contiguous wetlands

Low Gradient -- the slow-flowing segment of a drainage system, typically with considerable floodplain development; equivalent to the Lower Perennial Subsystem of the Riverine System in Cowardin et al. 1979 plus contiguous wetlands

Marine -- the landscape position (or seascape) associated with the ocean's shoreline

Middle Gradient -- the segment of a drainage system with characteristic intermediate between the high and low gradient reaches, typically with limited floodplain development; equivalent to areas mapped as Riverine Unknown (R5) in the Northeast Region plus contiguous wetlands

Nonchannelized -- water exits through seepage, not through a river or stream channel or ditch

Outflow -- water exits naturally or through artificial means (e.g., ditches); an outflow wetland has water leaving via a stream, seepage, or ditch (artificial) to a wetland or waterbody at a lower elevation; it lacks an inflowing surface water source like an intermittent or perennial stream

Oxbow -- a former mainstem river bend now partly or completely cut off from mainstem

Paludified -- subjected to paludification, the process by which peat moss engulfs terrains of varying elevations due to an excess of water, typically associated with cold, humid climates of northern areas (boreal/arctic regions and fog-shrouded coasts)

Playa -- a type of basin wetland in the Southwest characterized by drastic fluctuations in water levels over the normal wet-dry cycle

Pocosin -- a shrub and/or forested wetland forming on organic soils in interstream divides (interfluves) on the Atlantic Coast Plain from Virginia to Florida, mostly in North Carolina

Pond -- a natural or human-made shallow open waterbody that may be subjected to periodic drawdowns

Prairie Pothole -- a glacially formed basin wetland found in the Upper Midwest especially in the Dakotas, western Minnesota, and Iowa

Reservoir -- a large, deep waterbody formed by a dike or dam created for a water supply for drinking water or agricultural purposes or for flood control, or similar purposes

River Island - an island within a river

Salt Pond -- a coastal embayment of variable size and shape that is periodically and temporarily cut off from the sea by natural accretion processes; some may be kept permanently open by jetties and periodic maintenance dredging

Salt Flat -- a broad expanse of alkaline wetlands associated with arid regions, especially the Great Basin in the western United States

Sinkhole -- a depression formed by the collapse of underlying limestone deposits; may be wetland or nonwetland depending on drainage characteristics

Slope -- a wetland occurring on a slope; various types include those along a sloping stream (fringe), those (paludified) formed by paludification -- the process of bogging or swamping of uplands by peat moss in northern climes (humid and cold), and those not designated as one of the above and typically called seeps

Stream – a natural drainageway that contains flowing water at least seasonally; different stream types: *perennial* where water flows continously in all years except drought or extremely dry years; intermittent where water flows only seasonally in most years; channelized where stream bed has been excavated or dredged

Subsurface Flow -- water leaves via ground water

Surface Water -- water occurring above the ground as in flooded or ponded conditions

Tectonic - changes in the earth's surface caused by landslides, faulting, and volcanic activity

Terrene -- wetlands surrounded or nearly so by uplands and lacking a channelized outlet stream; a stream may enter or exit this type of wetland but it does not flow through it as a channel; includes a variety of wetlands and natural and human-made ponds

Throughflow -- water entering and exiting, passing through; a throughflow wetland receives significant surface or ground water which passes through the wetland and is discharged to a stream, wetland or other waterbody at a lower elevation; throughflow may be perennial, intermittent, or associated with an entrenched stream

Tidal Gradient -- the segment of a drainage basin that is subjected to tidal influence; essentially the freshwater tidal reach of coastal rivers; equivalent to the Tidal Subsystem of the Riverine System in Cowardin et al. 1979 plus contiguous wetlands

Vernal Pool -- a temporarily flooded basin; woodland vernal pools are found in humid temperature regions dominated by trees, these pools are surrounded by upland forests, are usually flooded from winter through mid-summer, and serve as critical breeding grounds for salamanders and woodland frogs; West Coast vernal pools occur in California, Oregon, and Washington on clayey soils, they are important habitats for many rare plants and animals