WETLANDS

Wetlands are composed of physical, chemical, and biological components. They may be transitional areas between uplands and aquatic habitats, may occur as isolated depressions within uplands, may occur on slopes, or may be fringing wetlands associated with tidal or nontidal waters. In wetlands, the water table is at or near the surface of the soil during all or part of the year, creating conditions favorable for life adapted to inundated or saturated soil conditions (Cowardin et al., 1979). A regulatory, as well as an *ecological*, definition developed in response to Section 404 of the Clean Water Act of 1977 defines wetlands as:

> Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.

Wetlands generally have three ecological characteristics: wetland vegetation (hydrophytes), wetland soils (hydric soils), and wetland hydrology. Hydrophytic vegetation consists of those plant species adapted to grow under anaerobic conditions through morphological, physiological, or reproductive mechanisms. Hydric soils are those soils that develop under reducing conditions, are associated with low oxygen, and are unmodified. Wetland hydrology implies that soils are flooded or saturated with water either periodically or permanently. These three ecological characteristics are present in most wetlands and are important in wetland *identification* and *delineation*. The federal regulatory definition of wetlands incorporates the three characteristics as technical criteria in a method for determining federal wetlands jurisdiction. The identification and delineation of wetlands also rely on the use of field indicators, or conditions occurring in wetlands that help in establishing technical criteria. Both the regulatory and the scientific community recognize the interdependence of hydrophytic vegetation, hydric soils, and wetland hydrology (National Research Council, 1995).

Ecological Classification

Wetlands are classified according to their ecological characteristics for such purposes as communication among scientists, planning, and assessment. The U.S. Fish and Wildlife Service developed a classification system to provide national consistency for wetland concepts, terminology, and classification — the *1979 Classification of Wetlands and Deepwater Habitats of the United States* (commonly referred to as the "Cowardin et al. Classification System," after the authors of that publication). This system employs a hierarchical approach to classifying various wetland types. It first describes wetlands broadly by five *systems:* Marine, Estuarine, Riverine, Lacustrine, and Palustrine. Each system (with the exception of the Palustrine System) is further divided into *subsystems* based on major hydrologic characteristics. Subsystems are subdivided into *classes*, describing the general vegetative types or substrate types. The classes are then divided into *subclasses*, which describe either dominant substrate type in unvegetated areas (e.g., bedrock, rubble, cobble-gravel, sand, mud, or organic), or dominant vegetation type (e.g., persistent or non-persistent emergents, moss, lichen, or broad-leaved deciduous, needle-leaved deciduous, broad-leaved evergreen, needle-leaved evergreen, and dead woody plants). Additional modifiers describing hydrologic and soil properties, water chemistry, or physical modifications of the wetland are commonly used following the class or sub-class designation.

Four varieties of specific modifiers (Water Regime, Water Chemistry, Soil, and Special) describe particular wetland or deep-water habitats with respect to hydrologic, chemical, and edaphic (soil-influenced) characteristics and human impacts. These modifiers may be applied to class and lower levels of the classification hierarchy. Water regime modifiers describe soil inundation or saturation conditions and are distinguished as tidal and nontidal. Special modifiers describe activities affecting and effecting wetlands and deep-water habitats. Special modifiers include excavated, impounded (i.e., obstructed hydrology outflow), diked (i.e., obstructed hydrology inflow), partly drained, farmed, and artificial (i.e., materials deposited to create or modify a wetland or deep-water habitat) (DNREC, *Delaware Freshwater Wetlands Restoration*, 1992).

Of the five wetland *systems* described above, the two most prevalent in the Piedmont Basin are Estuarine (tidally influenced wetlands of salinities varying from seawater to fresh water), and Palustrine (nontidal freshwater wetlands and tidal freshwater wetlands with salinities of less than 5 parts per thousand). For example, palustrine (P), forested (FO), broad-leaved deciduous (1), temporarily flooded (A) wetlands (PFO1As) are a common nontidal wetland type. Palustrine refers to the *system*, forested indicates the *class*, temporarily flooded identifies the *water regime*, and broad-leaved deciduous is a *sub-class* that further characterizes the specific type of vegetation.

Palustrine forested wetlands are the most prevalent type of wetland in Delaware and probably in the Piedmont Basin. These wetlands are dominated by trees such as *Acer rubrum* (red maple), *Fraxinus americanus* (green ash), *Liquidambar styraciflua* (sweet gum), *Nyssa sylvatica* (black gum), *Salix nigra* (black willow), and *Quercus* (oaks).

Palustrine scrub-shrub wetlands — a less common type of nontidal wetland — is dominated by a number of water regimes and woody vegetation less than 20 feet tall. Scrub-shrub wetlands may be characterized by shrub species such as *Cephalanthus occidentalis* (buttonbush), *Salix* (willow), *Viburnum* (arrowwood), and *Cornus* (dogwood), or may be thickets dominated by native vines, such as *Smilax* (catbrier) or *Vitis* (grape), or by invasive/alien vines such as *Rosa multiflora* (multiflora rose) and *Lonicera japonica* (Japanese honeysuckle) vines. Scrub-shrub wetlands may be early successional stages of forests characterized by scattered hydrophytic tree saplings associated with a wet meadow, or they may characterize Coastal Plain ponds (Table 32). Palustrine emergent marshes are a relatively uncommon type of nontidal wetland in the Piedmont Basin and occur along ponds, seeps, streams, and rivers, or in depressions. Palustrine marshes may be characterized by *persistent* vegetation, which is biologically active year-round, such as *Typha* (cattails), or by *non-persistent* vegetation — which is perennial but dormant during the winter, such as *Peltandra* (arrow arum) and *Pontederia* (pickerelweed).

Plant Communities

DNREC's Delaware Natural Heritage Program has characterized natural plant community associations based primarily on vegetation collected by its biologists over the past decade. Tables 31 – 35 show specific examples of wetland plant communities occurring in the Piedmont Basin. They are a reflection of the Delaware Natural Heritage data base as well as preliminary natural community classifications developed respectively by Clancy (1993) and Rawinski (1989).

Hydrologic Classification

Wetland hydrologic types are important in wetland identification and delineation, restoration, and compensation efforts because hydrology is the driving force in the creation and maintenance of wetlands. The source, direction, and hydrodynamics of water are also important in understanding wetland groundwater recharge and/or discharge properties and water-quality mechanisms. In a discussion of the hydrologic characteristics and hydrologic processes that occur in wetlands, Novitiski (1989) identified four simple wetland classes that have been widely accepted as applicable to most situations (Figure 16).

Surface-water depression wetlands occur where precipitation and overland runoff collect and where water leaves primarily by infiltration and evapotranspiration. The bottoms of the depressions are above the water table most of the time. Water levels are typically high in spring (immediately after snowmelt) and decline through the rest of the year, although periodic rises may result from intense storms.

Surface-water slope wetlands occur along the margins of lakes or streams and extend to shallow but permanently flooded parts of lakes or river up-slopes to points flooded only occasionally. These wetlands receive lake or river floodwaters in addition to runoff and direct precipitation; water leaves primarily by drainage as the stage of the lake or river declines, as well as by infiltration and evapotranspiration. Water levels are controlled by the lake or river stages and are typically high in spring and decline through the rest of the year. Lake-edge wetlands differ from river-edge wetlands in that lake levels fluctuate more slowly than river stages.

Groundwater depression wetlands occur in depressions that intercept the water table and receive groundwater inflow as well as precipitation and overland flow. The amount of groundwater inflow to the wetland may be only a small percentage of its total water budget; however, since the inflow is continuous rather than seasonal, it is a determining factor in the type of plant community that develops and in the rate of soil development, in addition to other processes. Water usually leaves this wetland by evapotranspiration although it may occasionally recharge the water table. If the water table slopes toward the wetland from all sides, the wetland functions most of the time as a groundwater discharge point. In spring, when the wetland water level may rise briefly above the local water table, the local water table may decline briefly below the wetland bottom, resulting in the wetland recharging the local groundwater.

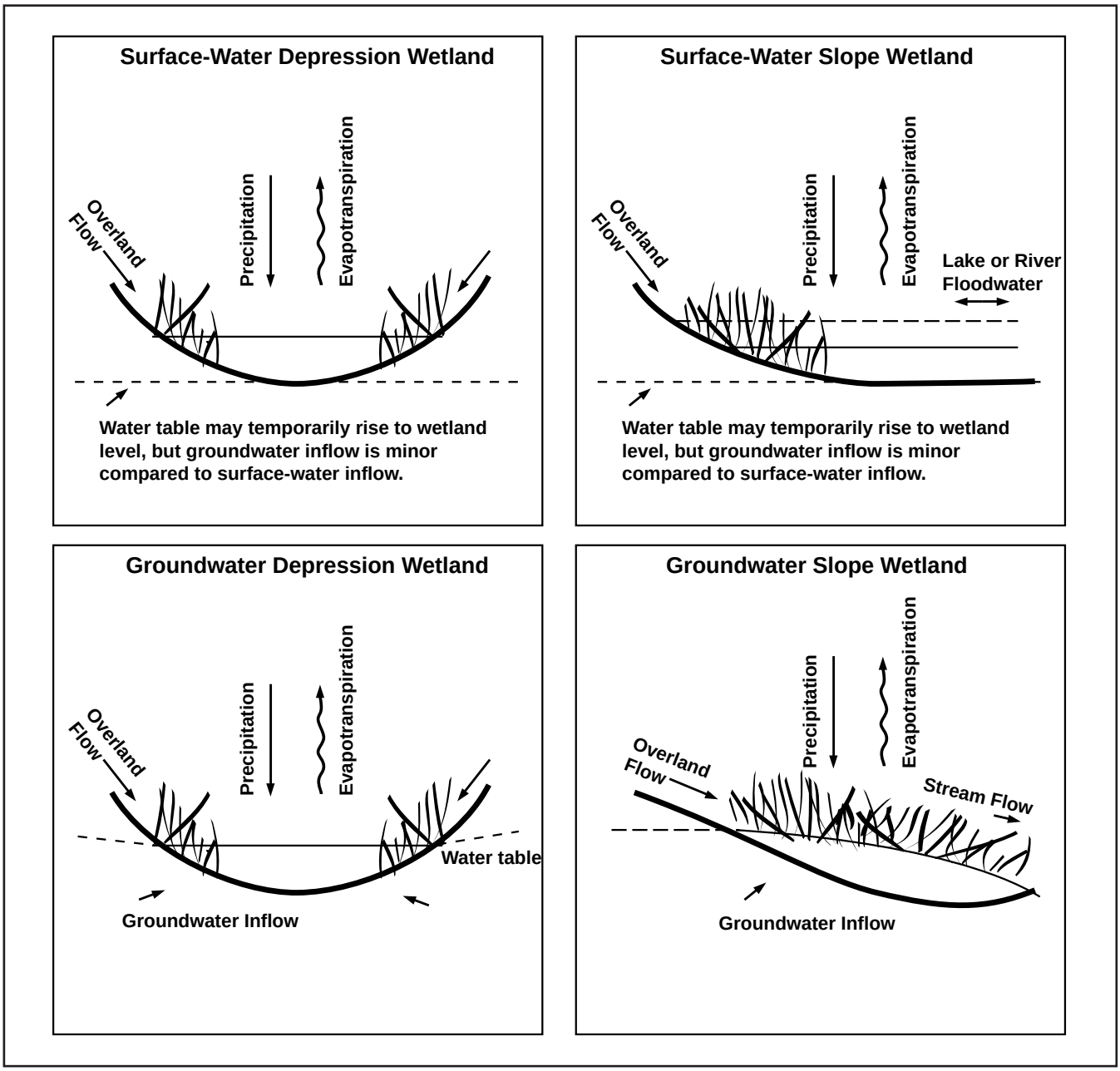
Groundwater slope wetlands occur where groundwater discharges continuously as a spring or seep at the land surface. The amount of groundwater inflow to the wetland may range from a relatively small percentage to a major portion of the total water budget, which results in wide differences among wetland plant communities and soil development rates. This type of wetland is rarely flooded because water can drain away down-slope. The water table surrounding the wetland typically is at or above (artesian) the wetland surface (Novitski, DNREC, *Delaware Freshwater Wetlands Restoration*, 1992).

Landscape Classification and Wetland Functions

In the Piedmont Basin, wetlands are associated with headwaters (upper reaches) of streams and rivers, occur as isolated depressions, occur on slopes, or are associated with tidal estuaries. Often, riparian wetlands occur within floodplains, which serve some of the same functions as jurisdictional wetlands.

Wetland functions include such physical mechanisms as flood flow alteration, water storage, and nutrient and sediment trapping. Biochemical processes include nutrient attenuation through denitrification and plant assimilation. Biological processes include food web support, habitat, and biodiversity. All wetlands provide functions, but wet-

Figure 16
HYDROLOGY OF SURFACE-WATER AND GROUNDWATER WETLANDS
(Redrawn from Noviski 1982; in Tiner, 1985)



lands in different landscape positions and with differing types and degrees of disturbance vary in their ability to perform their functions. Accordingly, one approach to classifying wetlands and describing wetland functions is based on the position of the wetland in the landscape.

Headwater riparian wetlands, for example, are important for their contribution to the maintenance of stream water quality through the removal of nonpoint source nutrients and contaminants. Sediment trapping and the seasonal or temporary uptake of nitrogen and phosphorus by wetlands associated with first-order streams may be as important as in riverine systems since headwater wetlands cumulatively represent an area comparable to second- or third-order stream floodplains (Brinson, 1988, 1991). Headwater wetlands provide important habitat for plants, fish, and wildlife through the maintenance of water quality for headwater

Table 31
WETLAND PLANT COMMUNITIES OF THE PIEDMONT BASIN

COMMUNITY TYPE	COMMUNITY CHARACTERISTICS	DISTRIBUTION
	DECIDUOUS FORESTED PALUSTRINE ASSOCIATIONS	
Scientific Designation: *Platanus occidentalis/Acer negundo/Lindera benzoin* Floodplain Forest Common designation: Sycamore–Box Elder/Spice Bush Floodplain Forest	◆ This association is found along streams of the Piedmont as far south as the Fall Line and is characterized by the canopy consisting of *Platanus, Acer negundo,* occasionally *Acer rubrum,* and *Liriodendron tulipifera. Lindera benzoin* is usually the dominant shrub. ◆ Due to the periodic disturbance from flooding and past impacts from logging/clearing — and the lack of adequate buffers, combined with very fertile soils — these wetlands provide a haven for weedy species, particularly the following: R*obinia pseudoacacia, Celastrus orbiculatus, Berberis thunbergii, Lonicera japonica, Lonicera morrowii, Pachysandra procumbens, Euonymus alatus, Hedera helix, Alliaria petiolata, Ligustrum vulgare,* and *Microstegium vimineum.* ◆ Additional woody native species often encountered include *Ulmus rubra, Acer rubrum, Fraxinus pennsylvanica, Carpinus caroliniana, Prunus serotina, Cornus florida, Viburnum dentatum var. lucidum, Toxicodendron radicans, Smilax rotundifolia, Juglans nigra,* and *Carya spp.* ◆ Herbs include *Onoclea sensibilis, Woodwardia areolata, Arisaema triphyllum, Pilea pumila, Polygonum virginianum, Polystichum acrostichoides,* and *Impatiens capensis.*	Piedmont streams and associated tributaries (e.g., Red Clay Creek, White Clay Creek) in New Castle County; frequently found at the base of narrow seepage wetlands.
Scientific Designation: *Acer rubrum* Series Common designation: Red Maple Series	◆ A palustrine forest dominated by *Acer rubrum* (which may approach 100% cover), with only scattered occurrences of associated tree taxa (e.g., *Fraxinus pennsylvanica, Nyssa sylvatica, Liquidambar styraciflua, Pinus taeda*). ◆ Floristically, the understory can be diverse or depauperate, and may consist of the following tree and shrub species: *Magnolia virginiana, Lindera benzoin, Cornus amomum (only occasional), Ilex opaca, Ilex verticillata, Clethra alnifolia, Vaccinium corymbosum, Itea virginica, Euonymus americanus, Viburnum nudum,* and *Leucothoe racemosa,* to name a few. ◆ Likewise, the herbaceous stratum can be diverse or depauperate and may consist of a combination of the following species: *Arisaema triphyllum, Osmunda regalis, Osmunda cinnamomea, Woodwardia areolata, Boehmeria cylindrica, Peltandra virginica* (though usually found in tidal occurrences), *Sambucus canadensis, Cicuta maculata, Saururus cernuus, Symplocarpus foetidus, Impatiens capensis, Mitchella repens, Viola cucullata, Lycopus spp.,* and *Carex spp.*	This series consists of the following forest community associations that are ubiquitous throughout the Coastal Plain of Delaware (including the Coastal Plain portion of the Piedmont Basin). Red maple is typically the conspicuous component of these communities, but occasionally it may be sparse.

Table 32
WETLAND PLANT COMMUNITIES OF THE PIEDMONT BASIN — CONT'D.

COMMUNITY TYPE	COMMUNITY CHARACTERISTICS	DISTRIBUTION
DECIDUOUS FORESTED PALUSTRINE ASSOCIATIONS		
Scientific Designation: *Acer rubrum* Wetland Forest Association Common Designation: Red Maple Swamp	◆ These forests may have either a low or moderately high structural complexity: low if there appears to be a uniform, singular tree stratum (suggesting that the canopy consists of an even-aged forest stand), or high where the forest stand consists of multi-layered strata. ◆ The former may have been previously clear-cut. The latter may represent a more mature and usually a higher-quality forest stand. Such communities are less common, but are represented in Piedmont Basin forested wetlands (pers. comm. between P. Emslie and K. Clancy, 1996).	Along streams or in isolated wetlands in New Castle County (as well as Kent and Sussex Counties).
Scientific Designation: *Acer rubrum – Liquidambar styraciflua – Nyssa sylvatica* Wetland Forest Common Designation: Red Maple – Sweet Gum – Black Gum Swamp	◆ This natural community type is quite abundant on the Delmarva coastal plain and is very similar to the previously described community, except that the canopy consists of two or more co-dominant species (e.g., red maple, sweet gum, black gum). ◆ *Nyssa* is usually less common than red maple or sweet gum. Overall species composition of this community may be nearly identical to the *Acer rubrum* wetland community above. ◆ Typical woody species include *Diospyros virginiana, Magnolia virginiana, Ilex opaca, Ilex verticillata, Leucothoe racemosa, Lindera benzoin, Clethra alnifiolia, Vaccinium corymbosum, Viburnum dentatum var. lucidum, Cornus amomum,* and *Viburnum nudum.* ◆ The herbaceous layer may be sparse or well developed, and includes many of the same species found in the red maple community association (see above).	Along palustrine streams in New Castle County (as well as in Kent and Sussex counties).
DECIDUOUS SCRUB PALUSTRINE		
Scientific Designation: *Cephalanthus occidentalis Scrub* Wetland Series Common Designation: Buttonbush Scrub Wetlands	◆ This wetland type — characterized by an abundance of *Cephalanthus occidentalis* — is mainly found in isolated depressional wetlands (i.e., Coastal Plain ponds or Delmarva bays), but occasionally may be present in elevated scrubby marsh areas. ◆ In Coastal Plain ponds, the occurrence of *Cephalanthus* may be quite variable. *Cephalanthus* may be densely or sparsely distributed throughout the pond or along the pond perimeter, or may be restricted to the pond center.	These ponds are most common in central Delaware (southwestern New Castle County and northwestern Kent County) in the region known for its abundance of Delmarva bays.

Table 33
WETLAND PLANT COMMUNITIES OF THE PIEDMONT BASIN — CONT'D.

COMMUNITY TYPE	COMMUNITY CHARACTERISTICS	DISTRIBUTION
	DECIDUOUS SCRUB PALUSTRINE ASSOCIATIONS	
	◆ The *Cephalanthus occidentalis* wetland basin community is significant because it may harbor rare species. (DNREC's Division of Water Resources proposed, via the Freshwater Wetlands Act, to afford greater regulatory protection to such wetlands.) Perhaps more importantly, such wetlands occur in unique geological entities known as Coastal Plain ponds or Delmarva bays. These wetlands are intermittently flooded (the degree and duration of seasonal flooding varies year to year), typically drawing down late in the growing season. ◆ Rare species known to occur in these wetlands include *Hottonia inflata, Eragrostis hypnoides, Fimbristylis perpusilla, Ambystoma maculatum, Ambystoma tigrinum, Hyla chrysoscelis,* and *Hyla gratiosa*. *Fimbristylis perpusilla* is a Federal Candidate species for listing and is only known to occur in four Delaware ponds (see also, Coastal Plain Ponds).	
Scientific Designation: *Acer rubrum* Scrub Wetland Series Common Designation: Red Maple Scrub Wetlands	◆ Very similar to the *Acer rubrum* Wetland Forest Association (see above) but with lower-statured trees (i.e., scrub size). This association may consist of many of the same species as its taller, forested counterpart. This series may either represent an early successional stage to the *Acer rubrum* Wetland Forest or may, in fact, represent a more stable climax community (e.g., for those red maple scrub habitats located along freshwater tidal streams). ◆ Typical species include scattered occurrences of small individuals of such tree taxa as *Fraxinus pennsylvanica, Nyssa sylvatica, Liquidambar styraciflua,* and *Pinus taeda*. Other species present include *Magnolia virginiana, Lindera benzoin, Cornus amomum, Rosa palustris, Ilex opaca, Ilex verticillata, Clethra alnifolia, Vaccinium corymbosum, Itea virginica, Viburnum nudum,* and *Leucothoe racemosa,* among woody species. ◆ The herbaceous layer may also be quite diverse consisting of a combination of species such as *Osmunda regalis, Osmunda. cinnamomea, Decodon verticillatus, Woodwardia areolata, Boehmeria cylindrica, Peltandra virginica, Sambucus canadensis, Sium suave, Cicuta maculata, Iris versicolor, Saururus cernuus, Impatiens capensis, Viola cucullata,* and *Carex spp.* ◆ These scrub communities may either have a low or moderately high structural complexity. Low structural complexity is anticipated if there appears to be a uniform, singular tree stratum — suggesting that the community may have developed after a recent clear-cut; high structural complexity (multiple strata) might suggest a more natural, stable, and mature community.	Frequently found along freshwater tidal streams in New Castle County (as well as in Kent and Sussex counties).

Table 34
WETLAND PLANT COMMUNITIES OF THE PIEDMONT BASIN — CONT'D.

COMMUNITY TYPE	COMMUNITY CHARACTERISTICS	DISTRIBUTION
	EMERGENT TIDAL/NONTIDAL MARSHES *General Community Description*	
Emergent herbaceous palustrine wetlands in Delaware are varied and, accordingly, the array of natural communities found in these wetlands is quite diverse. The following are examples of some of the more frequently encountered herbaceous wetlands.		
Scientific Designation: *Nuphar lutea* Emergent Wetlands Common Designation: Spadderdock Marshes	◆ Located in freshwater tidal and nontidal streams, this wetland community may be composed of pure stands of *Nuphar*. Conversely, it may be more diverse with scattered stands of *Acorus calamus, Zizania aquatica,* or *Pontederia cordata*. ◆ Other species present, but in much lower numbers, include *Peltandra virginica, Polygonum spp. (punctatum, arifolium, sagittatum), Impatiens capensis, Sagittaria latifolia,* and *Amaranthus cannabinus.*	Along edges of freshwater portions of tidal streams, in millponds or along nontidal streams above millponds, in the Nanticoke River, Delaware Bay, Atlantic Ocean, and Piedmont basins. Churchman's Marsh is an example of an extensive *Nuphar lutea* emergent marsh in the tidal freshwater portion of the Christina River.
Scientific Designation: *Acorus calamus* Emergent Wetlands Common Designation: Sweet Flag Marshes	◆ A wetland that may be composed of large, extensive, nearly mono-specific stands of *Acorus*. Or, sweet flag may form small- to medium-sized discrete colonies within other community types. ◆ Additional species that may be found (generally in low numbers) in sweet flag marshes include *Impatiens capensis, Bidens laevis, Zizania aquatica, Typha spp.*, and *Sagittaria latifolia*. (Some of these species may form other distinct communities.)	Along edges of tidal streams, in upper freshwater portions of the Nanticoke River, Delaware Bay, and Atlantic Ocean drainages (above the *Nuphar lutea* zone). An *Acorus calamus* emergent wetland in the Piedmont Basin is a privately owned site associated with a nontidal floodplain in Pike Creek Valley.

Table 35
UNIQUE WETLAND ECOSYSTEMS OF THE PIEDMONT BASIN

UNIQUE PIEDMONT STREAM VALLEY WETLAND ECOSYSTEMS *General Ecosystem Description* Preliminary surveys of Piedmont stream valley wetlands were conducted in 1993 by the Delaware Heritage Program to determine the potential for Category I (rare or unique) wetland ecosystem designation. These investigations include natural community and rare plant and animal community associations as well as observations on other ecological factors such as hydrology and soils. Two of the six unique wetland communities found statewide are represented in the Piedmont Basin.	
Piedmont Stream Valley Wetlands	◆ Two types of candidate plant communities are identified. The more frequent type is an emergent wetland characterized by herbaceous species — many are rare — with scattered shrubs and stunted trees. This graminoid-forb type of wetland is usually found at the base of a steep slope at groundwater discharge (seep) areas and is sometimes also influenced by seasonal overbank flooding. Several of these wetlands appear to be located in former stream channels or river oxbows. All but one site contains rare plants, and several of these rare species may be restricted to this wetland type (Clancy and McAvoy, 1994). ◆ Additionally, the Piedmont stream valley wetland is believed to be prime habitat for the bog turtle, a candidate species for [imminent] listing as either "threatened" or "endangered" by the U.S. Fish and Wildlife Service. Surveys by the Division of Fish and Wildlife Non-game and Endangered Species Program in 1992 have found this reptile in Piedmont stream valley wetlands of a similar description to the plant association described by the Delaware Natural Heritage Program. Piedmont stream valley wetlands are also believed to be breeding sites for Neotropical migratory songbirds (pers. comm. between P. Emslie and L. Gelvin-Innvaer, 1996).
Red Maple-Dominated Forested Floodplain Wetlands	◆ Only one example of this wetland has been identified in Delaware and is found in the Red Clay Creek watershed. This wetland is typified by its high species richness, its low number of nuisance species, and its many rare species, including the smooth white violet *(Viola macloskeyi spp. pallens)*, the only known location in the state for this species (Clancy and McAvoy, 1994).
Coastal Plain Ponds	◆ Although primarily found in concentrated areas in the Atlantic and Chesapeake basins farther to the south, some Coastal Plain ponds are represented in the more southerly portion of the Piedmont Basin. ◆ Coastal Plain ponds are unique wetlands due to a combination of interacting ecological factors including hydrogeology, soils, and plant communities. ◆ These ponds are relatively small, oval to elliptical, isolated wetlands fed primarily by seasonally fluctuating groundwater and characterized by unique plant communities. ◆ They provide habitat for state rare and endangered plant and animal species and are especially good habitat for amphibians (see Buttonbush Scrub Community). Due to their small, isolated nature, Coastal Plain ponds are vulnerable to filling from development pressures, and to indirect and cumulative impacts.

Table 36
IMPACT DESCRIPTIONS

IMPACT	DESCRIPTION
Plant Community Alteration	◆ Evapotranspiration from a wetland may be altered by altering the wetland vegetation; for example, deforestation of a forested wetland may yield an emergent wetland. Alteration of plant communities in the drainage basins of wetlands may have various effects on wetlands because of changed water regime and sedimentation. ◆ Complete removal of the transpiration process could result in considerable more water being made available for surface runoff and/or groundwater recharge. Wetlands associated with altered surface water and groundwater flow regimes may be enhanced, changed, or destroyed, depending on how the flow regime is altered.
Surface-Water Storage	◆ Surface water can be stored in reservoirs along the main stem of rivers (on-channel storage) in lowlands, or in reservoirs off the main stem (off-channel storage). [In Delaware, surface water storage is most likely to be effectuated by the creation of lakes or ponds (e.g., on-channel).] ◆ Because wetlands commonly occur in floodplains of major rivers, on-channel storage obliterates the wetlands drowned by the reservoir. ◆ Also, storage of water commonly has a negative impact on riparian wetlands downstream from the dam because the natural flow regime upon many wetlands were formed and maintained is altered.
Road Construction	◆ Can significantly effect wetlands, because road bed serves as a dam to water movement, even if culverts are used to connect the separated areas of wetland. It is not unusual to find dead vegetation on one side of a road and a living viable wetland on the other side. However, even the side with living plants undergoes change to adjust to the new condition of water flow. ◆ In the case of wetlands interacting with surface water, it is relatively easy to visualize obstruction of natural water flow by roadbeds. However, wetlands without surface water inlets and outlets and with interactions with ground water also can be significantly affected by road construction.
Surface Water and Groundwater Drainage	◆ Drainage is a common practice in regions of flat and/or hummocky topography. Because ponded water or slowly moving water enhances wetlands formation, removal of water from a wetland is detrimental. Drainage can completely destroy wetlands with little or no groundwater inflow. ◆ Drainage of any area can affect wetlands downstream. Drainage of uplands results in increased delivery of water to lowlands, streams, and lakes. This increased volume of water could drown or alter existing riparian wetlands. However, the increased delivery of water to the lowlands could enhance the formation and persistence of wetlands in the lowlands by providing additional water. ◆ Historically, road construction divides a floodplain into an area that floods more frequently and an area that almost never floods. Surface water quality parameter changes are almost exclusively restricted to those areas that flood. Sediment deposition, phosphorus retention, and turnover rates are greater in flooded areas. Extractable soil nitrates and nitrogen concentration of leaf litter can be higher in areas not flooded. There may be no differences, however, between the two areas in annual litter production rates, but rates of decomposition were higher in the non-flooded area.

Table 37
IMPACT DESCRIPTIONS — CONT'D.

IMPACT	DESCRIPTION
Recharge Alteration due to Water Removal	◆ Increasing the efficiency of water removal from areas of flat slope by ditching reduces recharge to groundwater. Not only is less water available because of the drainage, but the resulting lowered water table reduces the hydrologic head that provides the driving force for recharge. ◆ Drainage of small seasonal wetlands will eventually lower the water table enough to change the hydrologic function of lower wetlands, changing them from groundwater flow-through or groundwater discharge wetlands to recharge wetlands. The end result will be a lower water table throughout the entire area. ◆ Drainage is not the only practice that will decrease the quantity of water available for recharge. Other modifications to the landscape that will have the same effect include paving or building over extensive areas with the attendant storm runoff pulses. ◆ Other modifications to the landscape that could affect groundwater recharge, and, ultimately, the wetlands that receive that groundwater as discharge, include forest clearing, tillage, and other modifications to vegetative cover.
Groundwater Pumping	◆ Groundwater development can have an impact on surface water and wetlands. Groundwater pumping causes a lowering of hydrologic head within an aquifer that results in a cone-shaped depression of hydraulic head centered on the well. In the case of unconfined aquifers, the water table itself takes the shape of a cone centered on the well. If the cone depression extends areally to intersect a wetland, the lowered hydraulic head can cause seepage from the wetlands. ◆ From the perspective of groundwater development, the practice of pumping groundwater near wetlands is beneficial, because water that would be used to sustain plants is available to the well instead. This practice is commonly referred to by hydrologists as "salvaging evapotranspiration." ◆ From the perspective of wetland ecology, of course, groundwater pumping specifically at the expense of the wetland is extremely detrimental. But even if not specifically designed to impact the wetland, groundwater pumping anywhere within the flow field may impact surface water. Decreasing the hydraulic head by pumping, even some distance away from a wetland, will cause the flow-field configuration, in some cases enough to decrease groundwater discharge to the wetland or even to induce seepage from it.

streams and downstream habitats. Large tracts of headwater wetlands provide habitat for Neotropical migratory birds and overwintering and reproductive habitat for other birds, reptiles, and mammals.

Floodplain wetlands store floodwaters and buffer surface- and groundwater from the effects of agricultural, residential, and industrial development. Riverine floodplains are believed to interact extensively with surface- and groundwater, thereby contributing to water-quality maintenance (Brinson, 1988). The water-quality and water-storage functions of wetlands become increasingly important in the rapidly developing landscape of New Castle County. Floodplain wetlands provide food, shelter, and migratory corridors for furbearing mammals including fox, otter, mink, and beaver; for Neotropical migratory songbirds; and for many other forest species (Mitsch and Gosselink, 1986).

Isolated, depressional, or basin wetlands may be geographically located in any landscape position and are discontiguous to nontidal streams. These wetlands may serve as groundwater recharge basins for precipitation, as well as provide the functions of water storage and nutrient and contaminant trapping (Brinson, 1988). Where surrounded by urban or rural development, these isolated wetlands may be oases of habitat for wildlife in an otherwise developed landscape.

Estuarine or tidally influenced vegetated wetlands in the Piedmont Basin are primarily comprised of emergent wetlands and are found in the lower reaches of the basin watersheds. Estuarine wetlands are highly productive wet-

lands, specializing in functions such as nutrient cycling and organic matter production. They may be nutrient sinks and /or export organic matter in the form of detritus to surrounding tidal waters, providing primary production to the base of complex food webs. The role of the tidal marsh/ estuarine ecosystem as a nursery for both nearshore and offshore fisheries has been well documented. Tidal wetlands provide feeding, resting, and nesting habitat for resident waterfowl and waterbirds, and resting and feeding grounds for migratory waterfowl and shorebirds.

Trends

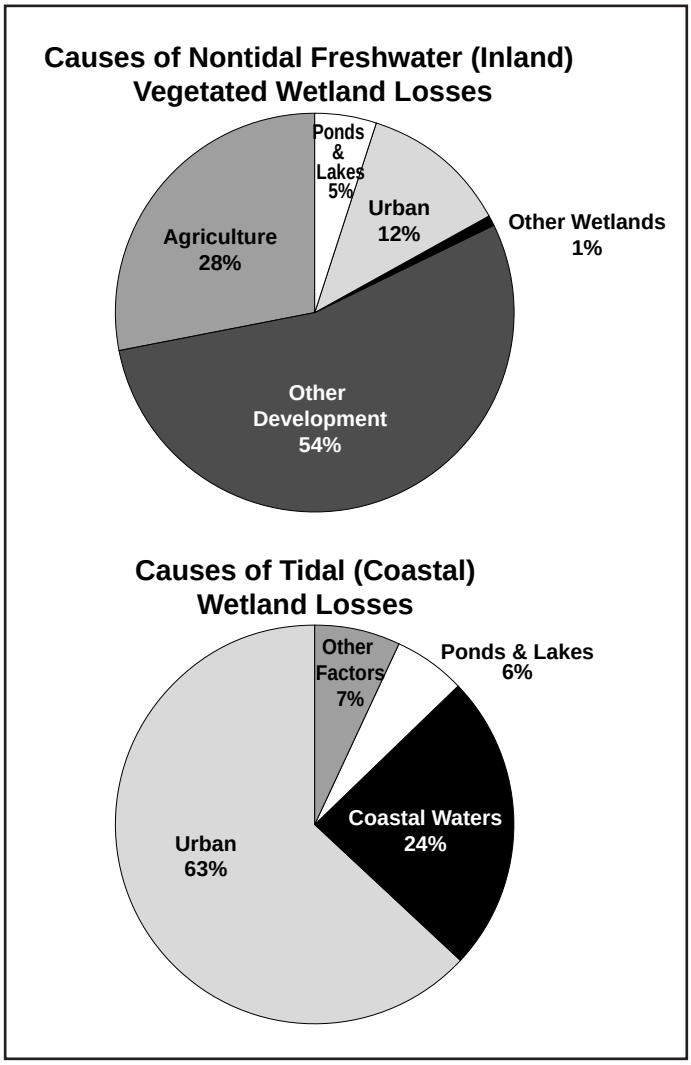
The most recent status of remaining wetland acreage in Delaware is based on the U. S. Fish and Wildlife Service's National Wetlands Inventory conducted during the late 1970s and early 1980s. This information is available by county and by wetland type in both map and digitized form in a Geographical Information System (GIS). In 1982, Delaware had approximately 215,000 acres of wetlands, representing about 17% of the state's surface area. Most of this acreage (68%) was nontidal wetlands, with forested wetlands being the predominant class (DNREC, 1996).

The National Wetlands Inventory uses color infrared imagery from the mid-1970s to the early 1980s to map wetlands using a modified version of the Cowardin Classification System described earlier. Based on the National Wetlands Inventory, wetlands comprise about 13% of New Castle County's land mass. Of this percentage, estuarine wetlands make up about 8% of the total New Castle County wetland acreage, and palustrine (primarily nontidal) wetlands make up 5% of the total wetland acreage (Tiner, 1985). The ongoing Statewide Wetlands Mapping Project will provide updated information on the location, acreage, and type of wetlands in the Piedmont Basin.

Delaware is one of 22 states that have lost approximately half their wetlands since pre-Colonial times (Dahl et al., 1991). A recent, five-state wetlands trends study conducted by the National Wetlands Inventory for the period between the mid-1950s and the early 1980s estimates wetland loss rate by wetland type for the Mid-Atlantic region and within each of the five states. Delaware experienced a 21% loss of the state's palustrine wetlands and a 6% loss of estuarine wetlands during the study period. A significant net loss of 42,000 acres of vegetated wetlands was experienced for the entire state during the period for a resultant average annual (statewide) loss of about 1,600 acres. No figures are available by basin or by county (Tiner, 1985).

Causes of inland (nontidal) wetlands losses were attributed to other development, mainly channelization and ditching projects (54%), agricultural development (28%), urban development (12%), pond and lake creations (5%), and change to other wetlands (1%). For coastal (estuarine and tidal vegetated) wetlands, losses during the period were attributed to urban development (63%), loss to coastal waters through sea-level rise and dredging (24%), coastal pond and impoundments (6%), and other factors (7%). See Figure 17 (Tiner and Finn, 1987).

Figure 17
DELAWARE WETLAND TRENDS
FOR THE PERIOD 1955 TO 1981
(Adapted from R. W. Tiner, Jr., 1987.
Mid-Atlantic Wetlands: A Disappearing Treasure)



Sources of Impact

Natural Impacts

As shown in Tables 36 and 37, both natural and human-induced threats impact wetlands. Natural threats are dynamic processes, including sea-level rise, natural succession, fluctuation of hydrologic cycles over time, sedimentation, erosion,

and fire. Sea-level rise may significantly alter tidal wetland and/or estuarine ecosystems. Changes in weather and rainfall patterns may affect the hydrologic budgets of nontidal wetlands, making them particularly sensitive to anthropogenic impacts. Erosional forces may remove wetlands, while sedimentation may result in the creation of new ones. Fire, a natural occurrence in historical times, is largely suppressed in modern-day Delaware, indirectly affecting succession and climax communities.

Other natural impacts to wetlands include flooding and wind damage from hurricanes and other severe storms. In the undeveloped landscape, beaver-dam floods in forested wetlands and uplands set the stage for an increased diversity of wetland habitats over time. In a developed landscape such as the Piedmont Basin, however, the potential impacts of beavers may be the flooding of human developments as well as natural communities. Other natural impacts (which may be exacerbated by human disturbances) include such biotic effects as invasion of non-native plant species and grazing by herbivorous waterfowl (e.g., snow geese) and mammals (e.g., muskrat) (Tiner, 1985).

Human Impacts

Human-induced threats include direct effects such as filling for residential, commercial, and industrial development; discharge of point and nonpoint source pollutants; drainage for agriculture; flooding for the creation of lakes, ponds, and waterfowl impoundments; stream channelization for flood control and navigation; and groundwater removal for drinking water, irrigation, or other purposes. These impacts have both direct and indirect as well as cumulative effects. Direct impacts completely remove or alter wetland functions. Human impacts are directly related to increasing population growth, bringing about increased alterations in the natural landscape.

The Delaware Department of Transportation undertakes highway projects of potential major impact to wetlands in the Piedmont Basin and elsewhere in the state. Permit review is led by the U.S. Army Corps of Engineers, in coordination with other federal agencies and DNREC's Division of Water Resources, Wetlands and Subaqueous Lands Section. Highway construction further fragments the landscape, resulting in the loss of wildlife habitat for species such as nesting Neotropical migratory birds.

Other impacts to Piedmont Basin wetlands include those from large public projects and smaller county and municipal projects. Of major potential impact is the ongoing Northern Delaware Water-Supply Project, where proposed alternative sites include Piedmont riparian and floodplain wetlands and tidal and nontidal freshwater marshes farther downstream in the watershed. Other, smaller potential impacts include the construction and upgrade of public facilities such as libraries, parks, and emergency facilities. The reconstruction and upgrading of utilities maintained by New Castle County are considered to be temporary impacts, but may have cumulative effects on the hydrologic functioning of floodplain wetlands. Increased paving from all forms of development increases quantities of surface-water runoff but decreases flood storage time, thereby contributing to the increase in flash-flooding in the Piedmont Basin (pers. comm. between P. Emslie and L. Jones, 1996).

Cumulative Impacts

It has become apparent that cumulative impact may threaten the integrity of wetland ecosystems within the landscape. Cumulative impact is defined by the Council on Environmental Quality as:

> The impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

Disturbances to wetlands with cumulative impacts are highlighted in Tables 36 and 37. (DNREC, *Delaware Freshwater Wetlands Restoration*, 1992).

Positive Initiatives

Regulatory Oversight

The Wetlands Act — Tidal Wetlands Regulatory Program. Since 1973, the "Wetlands Act" (Title 7, *Delaware Code*, Chapter 66) has been effective in conserving Delaware's remaining tidal wetlands. Under a concurrent review process with the Corps of Engineers and the regulatory oversight provided by the Clean Water Act, the state requires a permit for any non-exempt activity including dredging, filling, or construction in state-mapped wetlands. Proposed activities are evaluated in consideration of environmental, aesthetic, economic, and cumulative impacts. Any proposed permit action must be consistent with county zoning ordinances. Tidal wetlands jurisdiction is determined based on aerial photo-interpretive identification of specified vegetation and topography as depicted on regulatory maps. Since passage of the Wetlands Act, the loss rate of tidal wetlands has been greatly reduced. The Division of Water Resources, Wetlands and Subaqueous Lands Section implements the state wetlands regulatory program.

Freshwater Wetlands Act. In the early 1990s, DNREC developed the "Freshwater Wetlands Act" (subsequently

referred to as Substitute Senate Bill 248), to enable state regulation of nontidal wetlands. This legislation sought to achieve no-net loss of nontidal wetlands by acreage and function; to provide greater protection of the state's higher-value wetlands; and to reduce the regulatory burden to the public through improved predictability, flexibility, and responsiveness. This participatory legislative process gained the support of the vast majority of the state's constituent groups but did not pass the legislature. However, information generated as part of the development of the freshwater wetlands program has provided the state with the information to approach wetlands protection through alternative regulatory and non-regulatory means. Furthermore, the counties may incorporate freshwater wetlands program development information into their land-use planning processes and ordinances. For example, the draft New Castle County Comprehensive Development Plan (July 1996) recommends that freshwater wetlands (including higher-value wetlands such as in Coastal Plain ponds and Piedmont stream valleys) be given additional protection by the county.

Clean Water Act — Federal Programs. Current regulatory oversight of nontidal wetlands is provided by the federal government through Sections 404 and 401 of the Clean Water Act. The federal regulatory program is administered by the U. S. Army Corps of Engineers, Philadelphia District ("the Corps"). Authorization is required for the placement of "dredge and fill" material in wetlands and other "waters of the state." For projects involving significant potential wetlands impacts, an individual permit is required and involves a review by federal and state agencies. The Council on Environmental Quality specifies that mitigation be defined for the purposes of the 1972 Clean Water Act as:

- Avoiding the impact altogether by not taking a certain action or parts of an action.
- Minimizing impacts by limiting the degree or magnitude of the action and its implications.
- Rectifying the impact by repairing, rehabilitating, or restoring the affected environment.
- Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action.
- Compensating for the impact by replacing or providing substitute resources or environment (40 Certified Federal Registry 1508.20).

Section 401 of the Clean Water Act allows for broadened oversight by the states of the Corps' "dredge and fill" program, as well as a scientific basis for permit review. This law requires that states certify that issuance of a Corps individual permit will not degrade "waters of the state" including wetlands. Individual states have the prerogative to deny, certify, or issue with condition, individual and nationwide Corps permits based on potential impacts of the project to water quality. Water quality and coastal zone management consistency certificates are issued on a case-by-case basis for individual Corps permits.

These and other provisions of the Clean Water Act of 1972 are believed to have slowed the loss rate of freshwater, nontidal wetlands. However, cumulative losses of wetlands and wetland functions continue due to increasing development pressures, inadequate regulatory programs, gaps in the understanding of the science, and lack of resource management actions.

Subaqueous Lands Act. DNREC's Division of Water Resources, Wetlands and Subaqueous Lands Section regulates subaqueous lands, which include streams, ponds, and other waterways (Title 7, *Delaware Code*, Chapter 72). A permit is required for the placement of a structure, or for a non-exempt regulated activity in public, or over private, subaqueous lands. This legislation provides state regulatory oversight for activities in jurisdictional state waters. In addition, the Division of Fish and Wildlife manages certain millponds for freshwater fisheries. A "Pond Policy" guides the decision-making process in providing comments on subaqueous lands permit applications for structures and activities in millponds which may be deemed incompatible with fisheries management practices.

Wetland Development Projects

The following wetland program development projects have been undertaken by DNREC with funding from EPA Region III. The information generated through these efforts is important to the overall development of a Comprehensive Conservation and Management Plan for nontidal wetlands and to a whole basin management approach.

Identification and Preliminary Characterization of Unique Wetland Ecosystems

As part of a DNREC freshwater wetlands legislative and program development initiative between 1990 and 1994, the Division of Water Resources contracted with the Delaware Natural Heritage Program to characterize six wetland ecosystems considered to be of highest functions and values: Coastal Plain ponds (Delmarva bays); interdunal wetlands; Atlantic white cedar wetlands; bald cypress wetlands, Piedmont stream valley wetlands, and sea-level fens. These characterizations provide detailed information based on field surveys and literature review on wetland plant community profiles, associated ecological factors, and locations. Of these five rare and unique wetland ecosystems, two are found in the Piedmont Basin: the Piedmont stream valley wetland, and the Coastal Plain pond. The Coastal Plain pond, however, although present in the more southerly

portions of the Piedmont Basin (in the Inner Coastal Plain physiographic region), is represented to a greater degree in the Chesapeake Basin.

Evaluation of Remote Sensing/GIS Methodologies for Nontidal Wetlands Restoration

Wetlands compensatory mitigation may include the enhancement of existing wetlands, the restoration of former wetlands that have been converted to non-wetlands, the creation of wetlands from previously non-wetland areas, or, occasionally, the preservation of existing wetlands. Of those mitigation procedures described, wetlands restoration and wetlands creation are most consistent with stated federal and state goals of both areal no-net loss of wetlands functions and values (The Conservation Foundation, 1988). The primary difficulty in achieving these two types of wetlands establishment is associated with the pre-identification of sites that exhibit characteristics indicative of potential success. This study includes efforts by the DNREC Division of Water Resources to identify a wetlands restoration siting methodology that would advance Delaware's goal to meet federal and state wetlands compensatory mitigation mandates.

Wetlands restoration siting may also have a crucial role in the development of watershed planning initiatives, with the recent policy shift in the EPA, the Corps of Engineers, and DNREC regarding consideration of multiple environmental impacts and natural resource conservation from a landscape perspective. Appropriately sited and successful wetlands restoration projects can protect or rehabilitate watersheds where wetlands resources are lacking due to historical degradation or conversion. Toward this end, wetlands restoration siting is a potentially valuable component of the evolving Delaware Whole Basin Planning Initiative (DNREC, *An Evaluation of Three Remote Sensing/Geographic Information System Methodologies*, 1995).

Restoration/Creation/Enhancement and Compensation Banking Criteria

This report reflects the collection, review, and evaluation of literature on the wetlands restoration science with respect to natural resources and regulatory management. Delaware (and the nation's) wetlands resource base continues to decline, increasing the need to initiate actions that re-establish or expand wetlands area or functions. Three general approaches to (re)establishing wetlands are recognized:

- Wetlands Creation — involves the establishment of wetlands at a site where wetlands did not historically exist.
- Wetlands Enhancement — involves the net increase of wetlands function within an existing wetland.
- Wetlands Restoration — involves the re-establishment of wetlands at a site where wetlands historically existed but were subsequently lost.

Wetlands restoration seeks to rehabilitate damaged wetlands systems as a means to reverse historical or anticipated future losses. In principle, effective and efficient restoration ecology may (1) return functioning wetlands to sites where wetlands previously existed; (2) help maintain existing genetic integrity by protecting endangered or threatened species from extinction due to habitat loss; (3) reduce recreational and commercial pressure on more pristine ecosystems by providing alternative areas that may be more suitable but less sensitive; (4) slow or reverse destruction processes to allow time over which societal adjustments can occur; and (5) educate the public as to the costs of restoration and the true costs of environmental destruction. Thus, effective wetlands restoration may slow the rate at which, and decrease the net impact of, wetlands loss such that sustainable-use practices can be sufficiently developed. Social and political recognition must be given to ecosystem services that may not be restored more quickly than those services can be expended.

Compensatory mitigation involves the creation, restoration, enhancement — and more rarely, preservation — of wetlands to compensate for unavoidable adverse wetlands impacts. More specifically, compensatory mitigation banking involves these practices to mitigate adverse wetlands impacts associated with *anticipated* regulated activities. Compensatory mitigation banking, or "compensation banking," differs from most wetlands compensation projects in that it is established by agencies, nonprofit organizations, or private entities. Compensation banks usually provide a relatively large site to be used to collectively compensate, in advance, for one or more projects affecting wetlands. In contrast, individual wetlands compensation projects commonly involve restoration, creation, or enhancement activities concurrent with, or after, the permitted wetlands impacts (DNREC *Delaware Delaware Freshwater Wetlands Restoration*, 1992).

Comparison of Wetland Assessment Methodologies

The objective of this study is to identify, evaluate, and compare the advantages and disadvantages of three "rapid" wetland functional assessment models and a fourth method — Best Professional Judgment — to determine their applicability within the developing freshwater wetlands program. A secondary objective is to evaluate palustrine forested, Coastal Plain wetland functions and their indicators using the expertise of an interdisciplinary team of wetland scientists. The results of this study provide recommendations for the use of functional assessment methods and information on indicators of specific functions, as well as gaps in the knowledge of wetlands science. The establishment of a core set of reference wetlands provides baseline monitoring information useful for future wetlands studies (DNREC, *A Comparison of Four Wetland Assessments*, 1995).