Pennsylvania's Adopt-a-Wetland Program Wetland Education and Monitoring Module

Student Manual

Visit our Web Site: www.wetlands.psu.edu

Prepared by:
Ayesha Gray, Robert P. Brooks, Denice Heller Wardrop,
and Jennifer K. Perot
Penn State Cooperative Wetlands Center

Table of Contents

Introduction to the Student

When you think of a wetland you might imagine everything from the movie "Swamp Thing" to hoards of hungry mosquitoes! The variety of images and responses differs dramatically depending on who is doing the imagining. Wetlands are areas inundated with water and dominated by plants specifically adapted for wet environments. They can range from the soggy edges of a river or lake to a forested swamp to a bog.

Local, state and federal governments have become increasingly concerned with the destruction and past abuse of wetland areas in the last several decades. These wet areas have become the focus of political and environmental concerns because of the important roles they play in water quality, sediment retention, flood control and wildlife habitat.

The purpose of these chapters is to involve students in the active exploration and monitoring of these important resources. You will have an opportunity to increase your awareness and contribute to a body of data currently being gathered by the Penn State Cooperative Wetlands Center (CWC). These data are used to better understand wetlands. They will help improve the recommendations and decisions that are made regarding these fragile and valuable ecosystems. The following list of objectives will help you understand the focus of the upcoming chapters and what results you can expect from your investigations:

- identify why an area is a wetland
- learn what wetlands do in the environment
- learn the importance of wetlands to humans
- meet professional scientists and activists involved in studying and protecting wetlands
- learn to identify plants and suitable habitat for a variety of animals
- sample soils that occur in wetlands
- measure the fluctuating hydrology of a wetland or stream
- map a wetland area
- analyze data and learn about statistical calculations
- become familiar with wetland protection and regulation

As the issues regarding the use and abuse of our wetland ecosystems become more and more difficult, the importance of informed decisions concerning our water resources increases. This series of chapters is designed to help you better understand wetlands, and aid in the collection of data which will ultimately be used to help your community manage and maintain these unique ecosystems. By participating in this program you will be learning about a serious issue and also contributing to a data set that is used not only by the CWC, but by the Commonwealth of Pennsylvania as well. This is more than just "another assignment", it is actual scientific research aimed at confronting real water resource issues. As you learn more, you are helping to create a more informed community able to make wise decisions about these important ecosystems.

The readings and field work are designed to promote your understanding and stimulate your own thinking. You can use these tools as a starting point and further your studies at the library or by participating in local organizations. We hope you are prepared to learn something new and exciting and to get your feet wet! We think you will find these places more intriguing than you previously thought.

Chapter 1 - Introduction to Wetlands

Objectives

The objectives of this section are to:

- introduce the students to the concept of a wetland
- introduce the three characteristics used to define a wetland
- describe different types of wetlands and wetland classification
- introduce and compare the concepts of wetland functions and values
- describe the concept of a watershed and its delineation

Definition of a Wetland

Wetlands are so variable that their appearance and boundaries fluctuate over time (Figure 1). These dynamic changes are what makes wetlands difficult to recognize. Yet, these same characteristics are what make wetlands so productive and diverse. Wetlands are unique. They are one of the few habitats that are protected and regulated by state and federal agencies. The following definition of wetlands is used for regulatory and permitting purposes:

Figure 1.Example of a wetland Photo by R.P. Brooks

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

This definition states the three important features of wetlands. Look at the three underlined words - these define a wetland.

Water: Hydrology is the driving force in a wetland. The water in a wetland may either be contributed from above or below ground. The hydrologic evidence will necessarily be present at some time during the year, but it may not be obvious. The presence of water at or near the surface, or other indicators, such as flood debris and water stained leaves, clearly indicates that wetlands are present.

Note: Students will observe water levels during every visit.

Soils: Wet or hydric soils develop recognizable characteristics after being saturated for several weeks. A mixture of brown and gray mottles near the surface usually means the water table fluctuates during the year and may support wetland vegetation. Dark gray soils are usually very wet or hydric. Lists of hydric soils have also been developed by county offices of the National Resources Conservation Service.

Vegetation: Wetland plants, called hydrophytes, are the most obvious indicator that one is standing in a wetland area. Numerous field manuals are available to help identify wetland plants. The U.S. Fish and Wildlife Service developed a list of plants that occur in wetlands for various regions of the country. In this list, wetland plants are assigned to several categories depending on how often they are found in wet areas. For example, some species are called *obligates* because they are almost always found in standing water or saturated soils. Other species might be classified as *facultative* because they can adapt to either wet or dry conditions. (See the National Wetlands Inventory description of plant indicator status in Appendix 1).

Wetland Functions and Values

What do wetlands do? A function is a process. It is something the wetland does. Some functions can be measured or quantified, others are more difficult to measure.

Wetlands are an essential component of the environment. They are purifiers. They perform functions such as improving water quality by transforming chemicals or trapping sediment or preventing erosion. Wetlands perform a useful, free service in cleaning our waters, but these biological systems can be degraded and destroyed to the point where they are no longer able to perform these functions.

Wetlands have social and economic values associated with them. These values are something the wetland provides to humans. Some functions can also be thought of as values, such as flood control. When wetlands are destroyed, flooding is more prevalent and the costs of these floods can reach up to billions of dollars.

Shoreline Stabilization and Erosion Control

Figure 2. Soil erosion caused by livestock.
Photo by R.P. Brooks

Wetlands protect shorelines from the erosive action of waves. The dense root masses of emergent and woody hydrophytes stabilize river banks and shorelines. On banks and beaches where native vegetation has been removed or damaged by livestock grazing, the soil is quickly washed away (Figure 2). Eroded sediments carried downstream can cloud the water and smother the larvae of trout, bass, frogs, or reduce the penetration of light needed for aquatic plants.

Flood Control

Wetlands are important for flood control, acting as buffers during spring thaws and heavy rains. Wetlands adjacent to rivers and streams absorb the excess waters of floods and delay its release. By slowly releasing water, wetland basins and their associated vegetation can reduce the incidence of flooding downstream.

Sediment Trapping and Nutrient Removal

Wetlands trap pollutants and sediment that might otherwise contaminate streams and reservoirs. They can prevent toxins that have been dumped on the ground from seeping into groundwater. Plants are one of the important components of this function. Plants slow down the flow of water allowing silt to settle. Plants are also able to absorb nutrients and toxins. These nutrients are broken down and cycled through the food web as animals consume the plants. Plants use *photosynthesis* to provide food for themselves. The process supplies oxygen to the ecosystem, and the plants become food for other life forms. This is called "*primary productivity*".

Wildlife and Fisheries

Wetlands are important as breeding and spawning grounds for waterfowl, fish and amphibians (Figure 3). They provide protective cover and food for migrating birds, muskrat, moose and other wildlife species. Many species of juvenile finfish and shellfish are raised in wetlands before entering lakes and oceans. Aquatic invertebrates, such as snails, clams, crayfish and aquatic insects, are abundant in wetlands. These invertebrates are essential links in the food web that support waterfowl, furbearer and fish populations. Thus, recreational hunters, trappers, and anglers rely on wetlands, both directly and indirectly, to provide adequate numbers of harvestable species.

Figure 3. Heron. Photo by R.P. Brooks

Wetlands provide critical habitat for many threatened and endangered species. In Pennsylvania, the American bittern, king rail, Blanding's turtle, and eastern tiger salamander are but a few of the species of special concern that are dependent on wetlands.

Figure 4. Wetland plant. Photo by R.P. Brooks

Wetland Vegetation

Wetland plant communities provide the shelter and food upon which wetland fauna depend (Figure 4). Wetlands also provide homes for many species of rare plants including the spreading globe flower, whorled pogonia, carnivorous sundews and pitcher plants. In some instances, plant products are removed from wetlands. These include renewable supplies of blueberries and cranberries. Wetlands are also used as sources of timber and peat. The commercial production of berries, timber, or peat will invariably alter the hydrology of the system.

Recreation and Education

Wetlands provide a host of recreational and educational activities. They are living classrooms ready to teach lessons in plant and animal diversity. They are places of scientific research and artistic inspiration. Birders, photographers, musicians, students, hunters and anglers are all people that have benefited from the natural beauty of wetlands.

Types of Wetlands

(adapted from Wetlands and Wildlife, Brooks et al. 1993)

The term *wetlands* is actually an all-encompassing name for a very diverse and variable group of habitats (Figure 5). This variety is due to regional and local differences in climate, soils, topography, hydrology and water chemistry. These factors control to a large extent the amount and kind of vegetation in the area. *Can you name a type of wetland?*

Figure 5. Emergent wetland. Photo by R.P. Brooks

U. S. Fish and Wildlife Classification

In the 1970's the U.S. Fish and Wildlife Service (USFWS) designed a classification scheme to assist in a new effort called the National Wetlands Inventory. This new product, commonly called Cowardin classification (Cowardin et al. 1979), has become the most widely recognized and commonly used detailed classification for wetland ecosystems in the United States (Figure 6). The five major wetland systems recognized are: marine, estuarine, lacustrine, riverine and palustrine.

The marine system includes open ocean and coastlines, and is generally limited to beaches, rocky shores, and deep, saltwater habitats. Estuarine wetlands are coastal brackish areas such as tidal salt marshes, intertidal mudflats and coastal rivers. Lacustrine wetlands include deep freshwater areas such as lakes and reservoirs and the fringing wetlands. The Riverine system includes freshwater rivers, stream channels, and immediately adjacent wetlands. The Palustrine (meaning "marshy") system contains the majority of vegetated freshwater wetlands including marshes, swamps, bogs and wet meadows.

Emergent, Shrub, and Forested Wetlands

Wetlands are further characterized by either the amount of water in the area (nonvegetated wetlands) or the type of dominant plants in the area (vegetated wetlands). Types of nonvegetated wetland include the open water portions of lakes, ponds, rivers and streams. Vegetated wetlands can be broken into three main types: emergent wetlands, shrub wetlands and forested wetlands (Figure 6).

Emergent wetlands, commonly called marshes and meadows, are dominated by herbaceous (nonwoody) plants such as grasses, sedges, and forbs (broad-leaved plants) that “emerge” from the water. Shrub wetlands, commonly called shrub swamps or thickets, are dominated by low, woody plants such as willow, alder, buttonbush and meadowsweet. Forested wetlands,

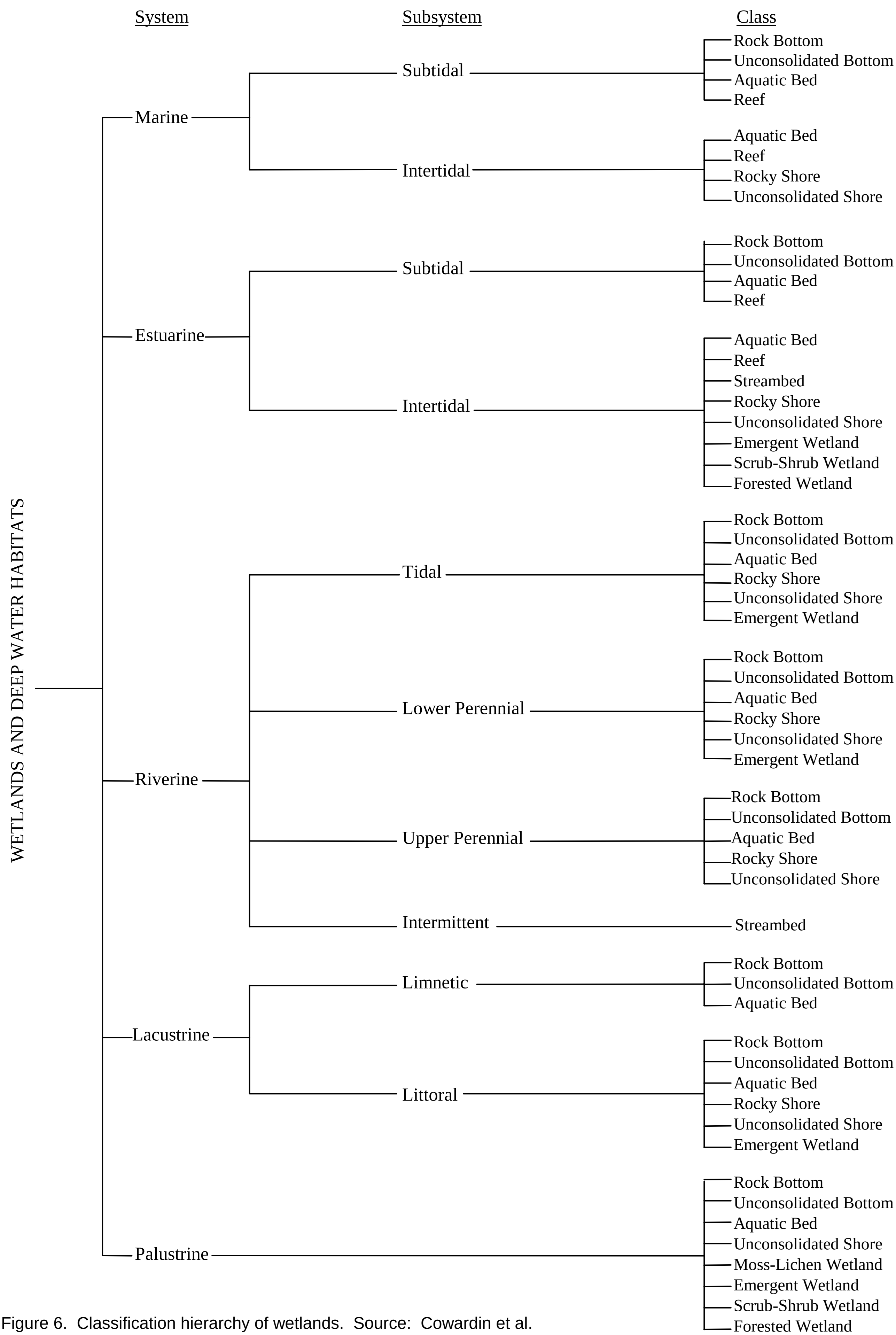


Figure 6. Classification hierarchy of wetlands. Source: Cowardin et al. 1979. The Palustrine System does not include deepwater habitats.

known as wooded swamps or bottomland forests, are dominated by large trees over 6 meters (20 feet) tall. These trees include species such as red and silver maple, willow, pin oak, black ash, slippery elm, eastern hemlock, spruce and tamarack.

Many inland wetlands are a mosaic of several wetland types. Indeed, it is rather common to find nonvegetated and vegetated wetlands adjacent to each other. Emergent wetland communities are often present as fringing wetlands along lakes and other water bodies, or may include clumps of woody plants.

Bogs

Bogs are a unique mosaic of wetland types found in the northeastern and northwestern corners of Pennsylvania. Most of these originated during the last ice age when small, round "kettle ponds" were formed. Large blocks of ice were left behind as the glaciers retreated northward. Bogs do not have flowing water, but may have open water depending on how far succession has progressed. Plants associated with bogs include sphagnum moss, cranberry, blueberry, pitcher plant, leather-leaf, sheep laurel, black spruce and tamarack (Figure 7)

Figure 7. Bog. Photo by R.P. Brooks

Hydrogeomorphic Classification

Hydrogeomorphic (HGM) classification is a promising new classification method developed by Dr. Mark Brinson from East Carolina University in Greenville, NC. This system classifies wetlands based on three characteristics: geomorphic setting (location of the wetland within the surrounding landscape), water source and transport (precipitation, surface and near-surface water flow and groundwater discharge), and hydrodynamics (direction and strength of water flow within the wetland). These characters are responsible for maintaining many of the functions performed by wetland ecosystems (Brinson 1993). This systems focuses on the abiotic factors that influence such functions as chemistry of water, habitat maintenance, and water storage and transport (Brinson 1993). The Cowardin classification system relies primarily on the structure and composition of the vegetative cover. The HGM approach does not mean to disregard the importance organisms play in the ecosystem, but rather intends to develop a better understanding of the relationship between organisms and the environment (Brinson 1993). Wetland functions are closely tied to HGM class.

Wetlands classified into different HGM classes perform different functions and have different structures; wetlands in the same HGM class should have similar functions. Each wetland is different, but if they are grouped based on functions they perform we can focus on the processes fundamental to the sustained existence of these ecosystems. Developing a method to classify wetlands based on what they do will also lend a greater understanding to the relationship between ecosystem structure and function. Using both the Cowardin and HGM classification systems is very useful in distinguishing among wetland types.

The diagram (Figure 8) shows the subclasses, different types of wetlands, in Pennsylvania. This classification for Pennsylvania wetlands was developed using the HGM approach and a set of 63 reference wetlands by the CWC. The purpose of this classification system is to categorize actual wetland sites based on the idealized characteristics and functions of model wetlands, which are based in part on data collected from reference wetlands (Brooks et al. 1996). The HGM classification can be used to describe a subclass such as headwater floodplain (HF) and then the Cowardin system can further describe the vegetation type of that area. For example, a riverine headwater-floodplain (HF) could be dominated by shrubs (SS for scrub-shrub) or trees (FO for forest) or both (SS/FO).

Riparian depressions are often located at the juncture of hillside slopes and the valley floor, along rivers. The water in these depressions often flows into streams, but the source is more often groundwater than water flooding over the banks of the river or stream. Headwater floodplains are found along small tributaries in the watershed. These wetlands receive most of their water from overland flow during spring runoff and rainfall, and occasionally flooding. Mainstem floodplain wetlands are found along larger streams and rivers, and most of their water comes from overbank flow during floods. Slope systems are found along elevational gradients, some that are very gentle. The water for these systems can either come from a groundwater or surface water source. Figures 9 and 10 provide a schematic of the HGM subclasses of wetlands in Pennsylvania.

Wetlands and Watersheds

A watershed is all the land area that contributes runoff to a particular body of water. It is a catch basin that guides all the precipitation and runoff into a specific river system. A watershed is the geographic locus of a water-driven dynamic that affects all living and nonliving things within its boundaries (Aquatic Project WILD 1992). *Do you know what watershed you live in?*

A watershed is a landscape unit formed around a network of streams (Figure 11). All the water in a watershed flows out at a single point and into another watershed. Watersheds are also called river basins, catchments or subwatersheds. Watersheds form a natural unit upon which to focus efforts aimed at understanding wetlands protection and restoration. Watersheds are constrained within identifiable boundaries and the primary defining factor, water, is measurable. Along the stream network, headwater and riparian wetlands form important buffers between landscape activities (such as development, agriculture and mining) and in-stream effects (such as acid mine drainage, erosion and runoff).

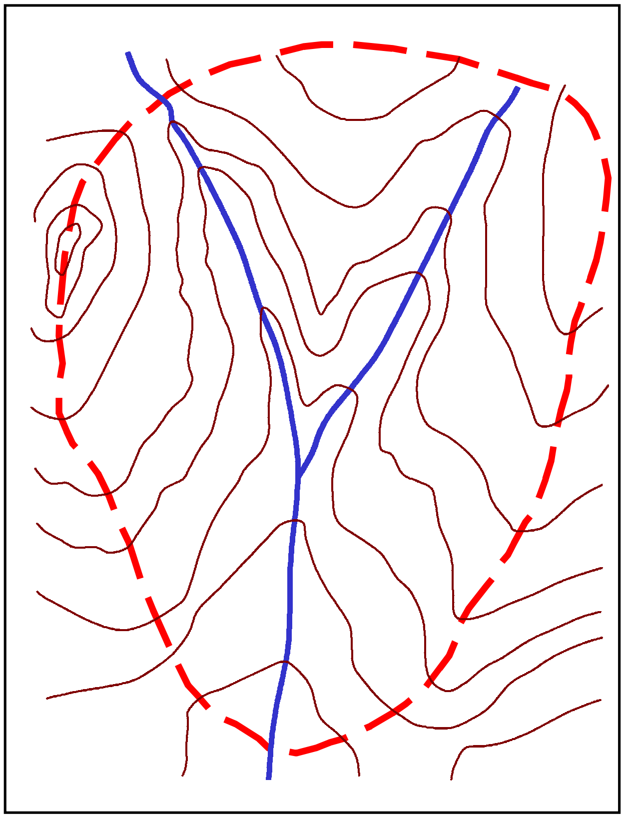


Figure 11. Example of a watershed.

Figure 8. Key for hydrogeomorphic classification of wetlands into classes and subclasses in Pennsylvania. Underlined items are HGM subclasses. Source: Cole et al. 1997.

1. Wetland associated with a stream or river.. Floodplain or depression 2
1. Wetland not associated with a stream or river................................ Fringing, slope, or depression 14

2. Wetland located within defined banks or channel of stream or river .... <u>Floodplain in-stream</u>
2. Wetland does not occur within defined banks or channel of stream or river.. 3

3. Equivalent stream order is 1st or 2nd order Floodplain, headwater (H) 4
3. Equivalent stream order is 3rd or larger Floodplain, mainstem (M) 9

4. Wetland is impounded............................... <u>Headwater Impoundment</u> (HI) 5
4. Wetland is not impounded... 6

5. Wetland impounded by beaver activities........................... Beaver, HI
5. Wetland impounded by human activities........................... Human, HI

6. Wetland has evidence of recent flooding .... <u>Headwater floodplain</u>
6. Wetland has no evidence of recent flooding 7

7. Wetland located on a topographic slope with unidirectional flow of water... <u>Slope</u>
7. Wetland located in a topographic depression...... Depression, headwater (H) 8

8. Wetland located in a topographic depression with discernable inlets or outlets where primary source is groundwater .... <u>Riparian depression</u> (H)
8. Wetland located in a topographic depression with discernable inlets or outlets and with organic soil .... <u>Organic depression</u> (H)
8. Wetland located in a topographic depression with discernable inlets and outlets and where primary sources of water are overland flow or interflow .... <u>Surface water depression</u> (H)

9. Wetland is impounded............................... <u>Mainstem impoundment</u> (MI) 10
9. Wetland is not impounded.. 11

10. Wetland impounded by beaver activities............................ Beaver, MI
10. Wetland impounded by human activities............................ Human, MI

11. Wetland has evidence of frequent flooding .... <u>Mainstem floodplain</u>
11. Wetland has no evidence of frequent flooding 12

Figure 8 (continued). Key for hydrogeomorphic classification of wetlands into classes and subclasses in Pennsylvania. Underlined items are HGM subclasses. Source: Cole et al. 1997.

12. Wetland located on a topographic slope with unidirectional flow of water .... <u>Slope</u>
12. Wetland located in a topographic depression .... Depression, mainstem (M) 13

13. Wetland located in a topographic depression with discernable inlets or outlets and where primary source is ground-water .... <u>Riparian depression</u> (M)
13. Wetland located in a topographic depression with discernable inlets or outlets and with organic soil .... <u>Organic depression</u> (M)
13. Wetland located in a topographic depression with discernable inlets or outlets and where primary sources of water are overland or interflow .... <u>Surface water depression</u> (M)

14. Wetland associated with a lake, reservoir, or large pond .... <u>Fringing</u>
14. Wetland not associated with a lake, reservoir, or large pond 15

15. Wetland located on a topographic slope with unidirectional flow of water .... <u>Slope</u>
15. Wetland located in a topographic depression without discernable surface water inlets or outlets .... <u>Isolated depression</u> (I) 16

16. Wetland located in a topographic depression without discernable surface water inlets or outlets and with organic soil.................................... <u>Organic depression</u> (I)
16. Wetland located in a topographic depression without discernable surface water inlets or outlets where primary sources of water are overland flow or interflow........................... <u>Surface water depression</u> (I)

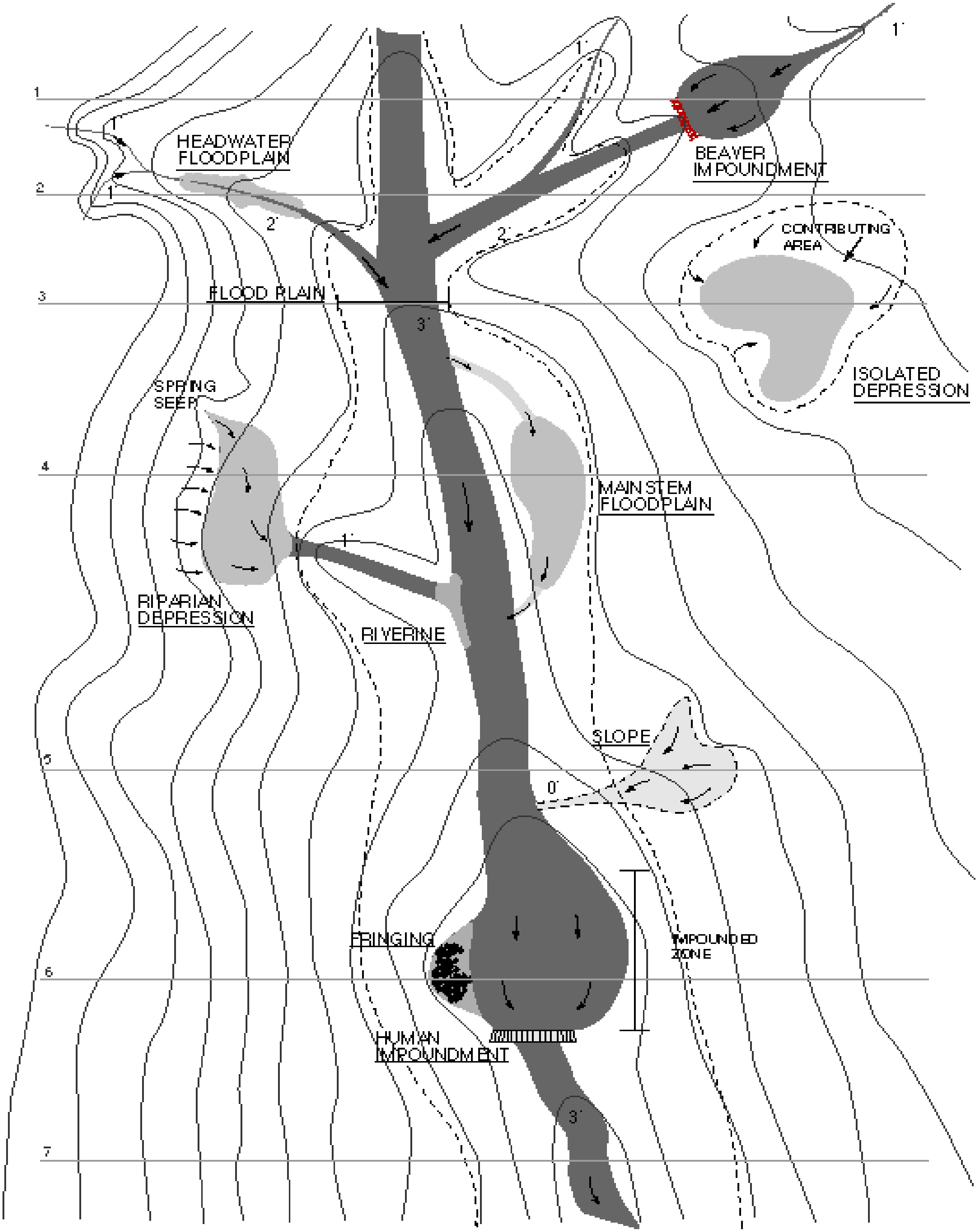
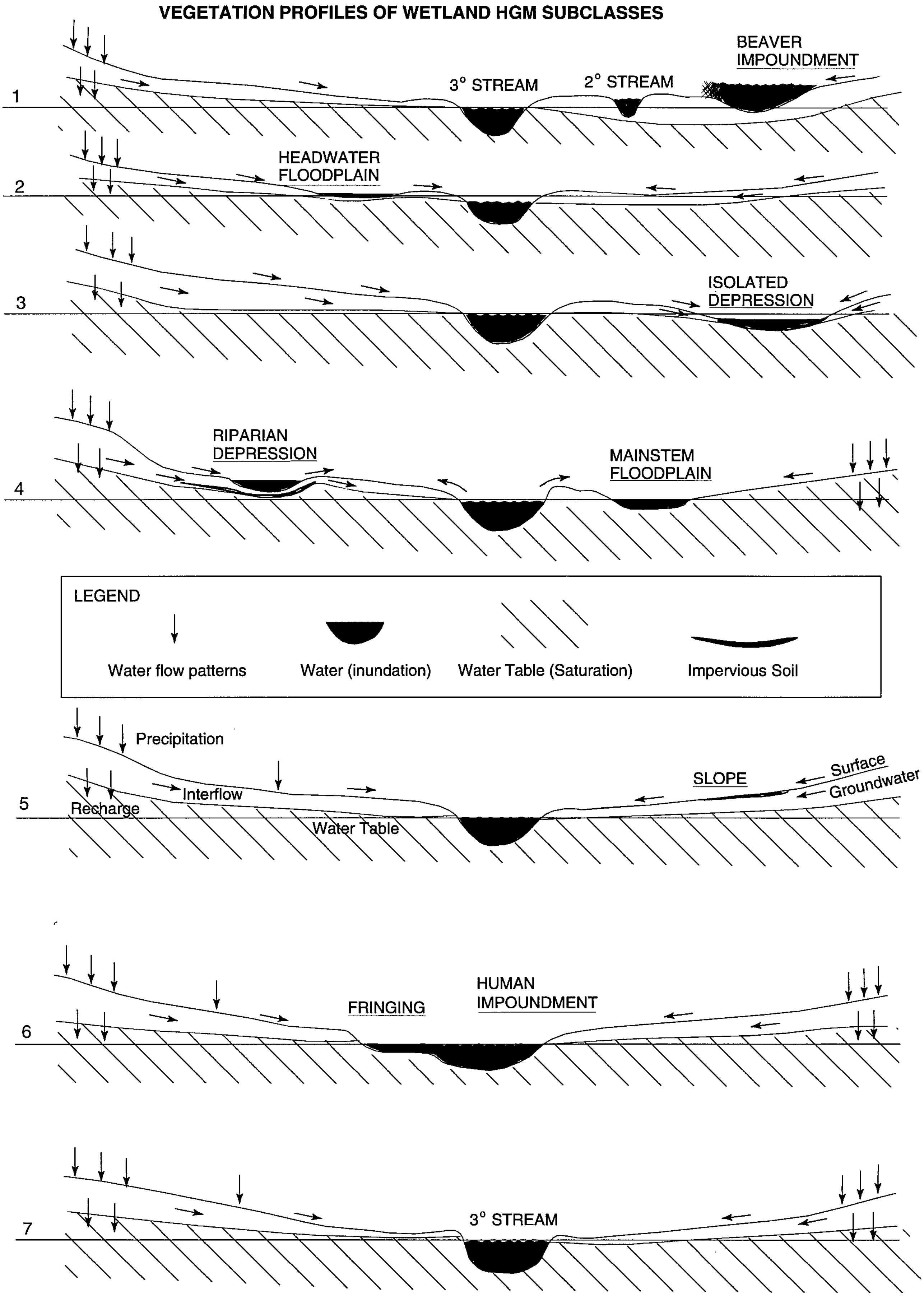


Figure 9. Schematic of Hydrogeomorphic (HGM) Subclasses of Wetlands in Pennsylvania.

Figure 10.


VEGETATION PROFILES OF WETLAND HGM SUBCLASSES
1
3° STREAM
2° STREAM
BEAVER
IMPOUNDMENT
2
HEADWATER
FLOODPLAIN
3
ISOLATED
DEPRESSION
4
RIPARIAN
DEPRESSION
MAINSTEM
FLOODPLAIN
LEGEND
Water flow patterns
Water (inundation)
Water Table (Saturation)
Impervious Soil
5
Precipitation
Interflow
Recharge
Water Table
SLOPE
Surface
Groundwater
6
FRINGING
HUMAN
IMPOUNDMENT
7
3° STREAM

Determining the boundary of a watershed can be a challenging task and is normally done through the use of topographic maps and field surveys. The boundary of a watershed usually consists of topographic features, such as ridges, which direct the water flow in a certain direction. No surface water will flow across a watershed boundary and all flow within the boundary will drain to the watershed outlet (flow outside the boundary will be associated with a different watershed) (Ward 1995). Remember, water flows downhill!

Everything exists within a watershed, including wetlands. Since wetlands largely influence water quality, the quality of water within a watershed can be drastically affected by the number of wetlands existing within that watershed. To guard against water quality degradation, wetland protection efforts should take into account the larger watershed-scale. This is sometimes referred to as a landscape perspective and is simply a means of looking beyond the boundaries of the wetland of interest.

Perhaps the single most important thing to remember about watersheds is that they are hierarchical systems, connected to other watersheds as they are traced downstream. What affects a watershed in one place eventually affects other sites downstream. Damage often accumulates as water proceeds downstream. Most scientists feel it is far more economical to prevent contaminants from entering water systems than to clean up pollution after it takes place (Aquatic Project WILD 1992).

The internet is a tremendous resource for exploring topics on wetlands and watersheds. Appendix 2 provides a short list of web site addresses to help you get started on exploring different topics.

Chapter 2 - Legislation and Conservation

Objectives

The objectives of this section are to:

- address the current distribution of wetlands
- address the current trends in wetland destruction
- review historical and current legislation
- address both public and private wetland protection efforts

Wetland Distribution and Trends

(adapted from Wetlands and Wildlife, Brooks et al. 1993)

Pennsylvania currently has approximately 200,000 hectares (500,000 acres) of inland wetlands which account for around 2 percent of its surface area. This acreage can be further divided as 174,000 hectares (431,000 acres) of vegetated wetlands and 27,000 hectares (67,000 acres) of nonvegetated wetlands, mostly in ponds.

Wetlands are not evenly distributed throughout the state. In fact, the northeastern and northwestern corners of the state account for nearly one-half of Pennsylvania's wetlands. These two areas were on the southern fringe of the last ice age. Past glaciers have left their mark on many northern states and have resulted in an abundance of wetlands (Figure 12)

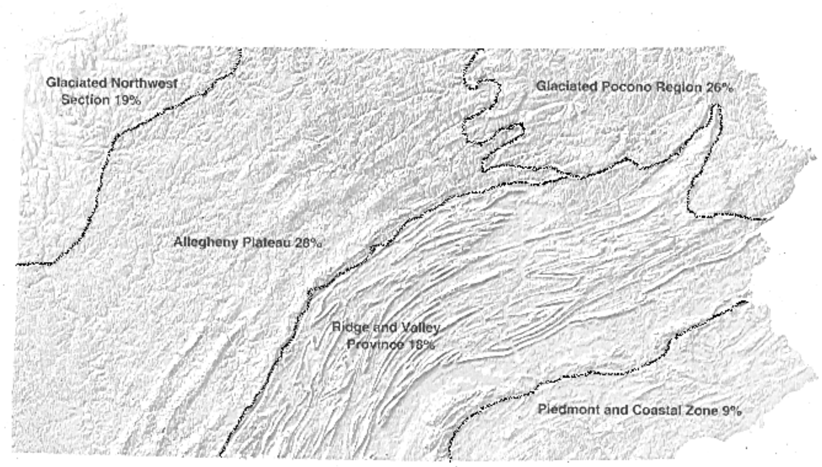


Figure 12. Wetland distribution in Pennsylvania. Source: Brooks et al. 1993.

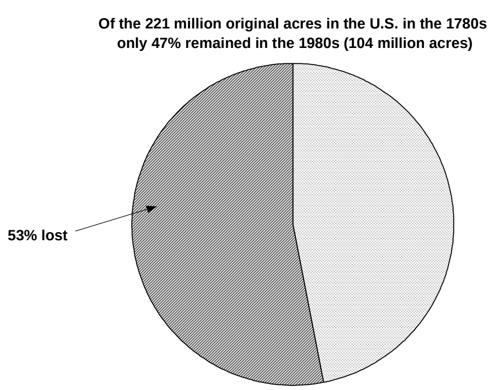


Figure 13. Original and remaining acreage of wetlands in the conterminous United States. Source: Brooks et al. 1993.

Wetlands were originally protected because of their function and value as breeding and feeding habitats for the ever-popular waterfowl. Many National Wildlife Refuges were established in the early 1900s to protect and enhance habitat for waterfowl and other waterbirds. Sine that time, scientists and managers have identified many other values of wetlands. This recognition has vaulted the concern for wetland loss and degradation to an issue of national and international prominence. *Why are wetlands valuable beyond wildlife habitat?*

By the late 1970's we had already lost more than one-half of the wetlands present before European settlement (Figure 13). Drainage of wetlands for agricultural purposes has been and continues to be a major factor in wetland loss, although it has been less important in wetland loss in Pennsylvania than nationally. More recently, expanding human activities and land development have put additional pressure on our wetland resources. A recent inventory by the National Wetlands Inventory attributes wetland losses in Pennsylvania to factors such as conversion to ponds and lakes, development and agriculture (Figure 14).

Not all wetland types have been equally affected. Vegetated wetlands, such as emergent marshes, have declined in number, but wetlands dominated by open water such as farm ponds, reservoirs and stormwater basins have increased in abundance. The ecological significance of shifting wetland types from those dominated by vegetation to those dominated by open water is not precisely known. However, a significant change in habitat value for wildlife and a shift in ecological functions is likely.

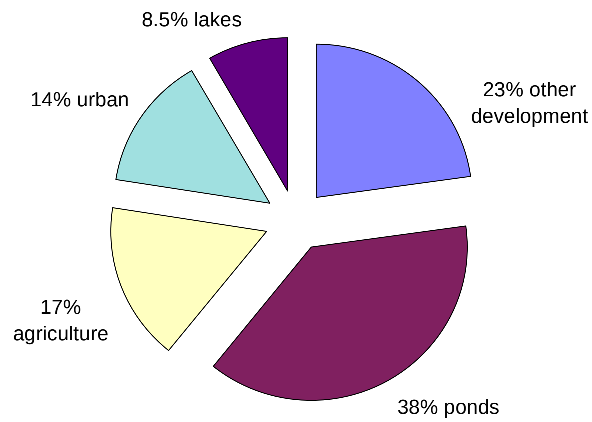


Figure 14. Causes of inland vegetated wetland losses in Pennsylvania. Source: Brooks et al. 1993.

Declining wetland numbers are a cause for concern but equally alarming is the degradation of existing wetlands. Wetlands are being influenced by many sources including pollutants such as acid mine drainage, toxic substances in urban runoff, nutrient runoff, and even subtle sources such as acid rain. As human populations continue to expand into new areas and to increase their use of natural resources such as wetlands, we should examine opportunities to protect existing wetlands, to enhance degraded ones and to create new wetlands. The latter effort can begin to reduce the state and national trends in wetland loss.

Wetland Protection

Pennsylvania has lost substantial wetland acreage over the last several centuries, only about two percent of the surface area is covered by wetlands today. Trends show a continual decline, especially in certain types such as emergent wetlands. Wetland protection has been provided by public and private sectors for some time. The protection of our wetlands is a large task needing the involvement of everyone. Government agencies alone cannot accomplish the job. Private organizations and individuals must assist in the effort. It is up to all of us to protect or wisely manage our valuable wetland resources.

Public Protection

Wetland protection and legislation in Pennsylvania are addressed by a variety of federal and state public agencies including the U. S. Army Corps of Engineers, the U. S. Environmental Protection Agency, the U. S. Fish and Wildlife Service, National Resources Conservation Service, the Pennsylvania Department of Environmental Protection, the Pennsylvania Game Commission and the Pennsylvania Fish and Boat Commission.

The federal government is involved in wetland protection through land management, economic incentive programs and regulation. The federal government manages a vast acreage of lands in the United States and perhaps the most important of these holdings in terms of wetlands is the National Wildlife Refuge system. These areas were originally purchased to aid waterfowl and have also benefited many other species. The federal government provides economic incentives to industrial and private landowners for further wetland protection. For example, landowners who donate or sell wetlands to a government agency can claim the transfer as a charitable deduction under the federal tax code. The federal government recently moved to discourage the conversion of wetlands to other land uses, by removing cost-share or benefit programs that destroyed these resources. A good example is the *Swampbuster* provision of the 1985 Food Security Act, which was further strengthened in 1990 and 1995. The 1985 Act also established the *Conservation Reserve Program* which resulted in the protection and enhancement of 100,000's hectares (250,000's acres) of wetlands. Perhaps the most important program involving wetland protection by the federal government is the regulation of activities in wetlands. Section 404 of the Clean Water Act establishes the federal authority to regulate certain activities in waters of the United States, including wetlands. This law provides that the discharge of dredged material or fill material into wetlands of the U. S. requires a permit from the Army Corps of Engineers.

Wetland protection is also provided by state law in Pennsylvania. The Dam Safety and Encroachment Act and accompanying Chapter 105 regulations provide for the protection of wetlands at a state level. These regulations require that a permit be obtained from the Department of Environmental Protection prior to the construction of any obstruction or encroachment on any watercourse, floodway, or body of water, including wetlands.

This means that in Pennsylvania both federal and state permits are required before certain activities are allowed in wetlands. To avoid confusion and duplication of effort, the Pennsylvania Department of Environmental Protection (DEP) in conjunction with the Army Corps of Engineers, has developed a *joint permit application* for activities in, along and across waters

History of Major Wetland Regulations in the United States

1991	Wetlands Reserve Program
1989	North American Wetlands Conservation Act
1988	No Net Loss Policy
1986	Emergency Wetland Resources Act
1985	"Swampbuster" provisions in the Food Security Act
1977	Floodplain Management- Executive Order 11988
1977	Protection of Wetlands- Executive Order 11990
1972	Coastal Zone Management Act
1972 - 1982	Federal Water Pollution Control Act, amended to become the Clean Water Act Section 404-dredge and fill permits Section 402-pollution discharge elimination system Section 401-water quality certification Section 303-water quality standards Section 208-water quality planning
1969	National Environmental Policy Act
1968	Land & Water Conservation Fund Act
1967	Fish & Wildlife Coordination Act
1934	Migratory Bird Hunting Stamp Act
1929	Migratory Bird Conservation Act
1918	Migratory Bird Treaty Act
1899	Rivers & Harbors Act

(and wetlands) of the Commonwealth. Once a joint permit is submitted to DEP, it is considered *on record* for both state and federal agencies.

The Pennsylvania Game Commission and the Pennsylvania Fish and Boat Commission also participate in wetland protection. Both agencies assist with expertise, and comment to DEP during permit reviews. The Game Commission manages over 526,000 hectares (1.3 million acres) of state gamelands containing many wetlands, particularly some vital areas managed for waterfowl. The Fish and Boat Commission, by its nature and statues, has a key role in maintaining and managing the Commonwealth's aquatic resources. Other public entities involved in wetland protection are local governments. Wetland protection on a local level usually takes the form of ordinances or zoning restrictions. Activities such as subdivisions, building codes, sanitary codes, and land-use zoning are regulated by local governments. These activities have the potential to affect wetland resources.

Most government agencies at federal, state and local levels enforce wetland protection regulations to some degree. In addition, all levels of government inform and educate the public on the values, functions, and regulations of wetlands. Ultimately, a well-informed public is the best form of wetland protection. *In what ways can a well-informed public influence regulatory decisions regarding natural resources?*

Private Protection

The private sector is involved in wetland protection in a variety of ways. Government in the United States is based on citizen concerns and attitudes. An informed and involved citizenry will do more for wetland protection than any other action. The public will dictate the present and future fate of our wetlands.

Conservation organizations have long been involved in wetland conservation either through acquisition, education or volunteer activities. Organizations such as The Nature Conservancy, Ducks Unlimited, the National Audubon Society and the National Wildlife Federation have been and continue to be strong advocates of wetland protection. These organizations and others have been actively involved in efforts to conserve wetlands on national, state and local levels, and often stimulate governments to take action.

Public support and participation in government wetland programs is crucial to wetland protection. Citizens should report suspected violations regarding wetland encroachments to proper authorities. The public should also support initiatives for wetland protection by public agencies. When the public works in unison with government agencies, wetland protection is strengthened substantially, often by voluntary means rather than environmental regulations.

Private landowners with wetlands on their property have a vital role in wetland protection. The majority of wetlands in Pennsylvania are in private ownership. Landowners should be encouraged to manage their lands to ensure that wetlands are not destroyed or degraded. It is up to all of us to spread the word on the values and benefits gained from our wetland resources. Talk to your family, friends, neighbors, colleagues, and community leaders about wetlands and their role in our environment. Together, we can make a difference and help protect our *un-common wealth* of wetlands.

Chapter 3 - Exploring Wetlands

Objectives

The objectives of this section are to:

- introduce students to different kinds of wetlands
- teach students to identify the plants and animals that inhabit wetlands
- teach students how to apply a "Habitat Suitability Index"
- teach students how to identify hydric soils

Wetland Creatures

(adapted from Wetlands and Wildlife, Brooks et al. 1993)

Wetlands provide important and sometimes critical habitats for many plants and animals. An estimated one-third or more of all endangered or threatened species in the United States depend on wetlands for survival. Wetland ecosystems provide important nesting, wintering, and feeding sites for many wildlife species. In fact, wetland ecosystems are one of the most productive wildlife habitats in Pennsylvania.

Most people associate species such as waterfowl, herons, beavers, muskrats and river otters with wetlands. These species are termed *obligate* wetland species because they depend on or are obligated to inhabit wetlands for survival. Many other species of wildlife use wetlands. Some do so extensively. Because, these species are not as dependent on wetlands for their survival, we call this group of animals *facultative* wetland species. Good examples of facultative species include the black bear who use Pocono wetlands extensively and ring-necked pheasants who use wetlands as escape areas when available.

Birds

An estimated 150 species of birds are wetland dependent or obligate wetland species in the United States. Countless others use wetlands or are facultative wetland species (Figure 15).

Waterfowl

The waterfowl category includes ducks, geese and swans. Waterfowl have long been the symbols of wetlands in this country. Because of their economic, recreational, and aesthetic values, waterfowl have received a great deal of attention over the years. Our knowledge of waterfowl habits far exceeds our understanding of other waterbirds.

Figure 15. Song Sparrow. Source: Cole et al. 1996.

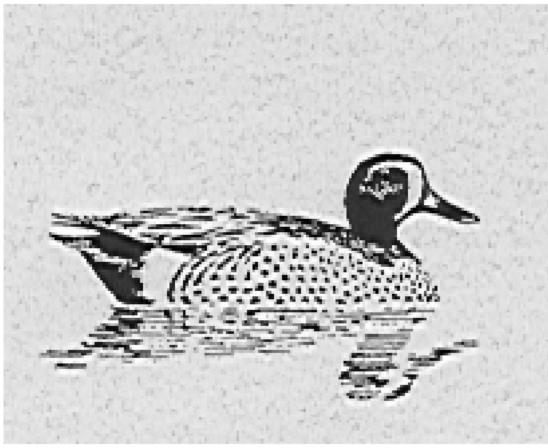


Figure 16. Blue-winged Teal. Source: Cole et al. 1996.

Ducks can be divided into three groups based on similarities in ecological requirements: dabbling ducks, diving ducks and sea ducks (Figure 16). Dabbling ducks get their name from the way they feed in wetlands. Dabblers generally are surface-feeding ducks that display the unique tipping or dabbling for their food. They also sit high in the water and are able to burst into flight without running on the water surface. Pennsylvania's most abundant dabblers are mallards and black ducks. In contrast, diving ducks are so named because of their ability to dive and swim underwater in search of submerged plants or animals for food. Diving ducks sit low in the water and have large powerful legs that are situated far back on their bodies. This positioning of their legs makes them excellent swimmers, but it also means they are awkward on land and must run on the water surface before they can fly. Familiar diving ducks in Pennsylvania include the common and hooded mergansers, buffleheads and the less abundant goldeneyes, redheads and ruddy ducks. Sea ducks, such as scoters and eiders, spend most of their time in coastal wetlands.

Two species of geese found in Pennsylvania are Canada and Snow geese. Canada geese are the best known and the most abundant. Canada geese are the birds people think of when envisioning V-shaped flocks flying in formation and foretelling the changing seasons. Canada geese nest throughout the state; whereas, snow geese are only migrants on their way to either their breeding or wintering grounds. Canada geese are very sociable, and readily land in fields where flocks can feed on pastures and croplands.

Tundra swans are our only native swan and are considered migrants in Pennsylvania. They are magnificent. Large flocks winter on the Chesapeake Bay, which brings their flight pattern through our state. Tundra swans are basically surface feeders; their long necks enable them to reach surface plants as well as submerged plants.

Shorebirds and Wading Birds

Shorebirds and wading birds display unique adaptations for feeding and breeding. Both shorebirds and wading birds feed by walking along and visually stalking their prey in shallow waters or along the edges of lakes, ponds, rivers or wetlands (Figure 17).

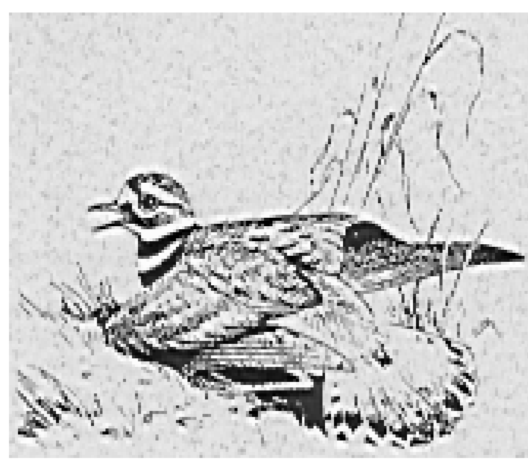


Figure 17. Killdeer. Source: Cole et al. 1996.

Few shorebirds nest in Pennsylvania, although many migrate through the state. In fact, shorebirds are more migratory than any other group of North American birds. Shorebirds include species such as plovers (including the common killdeer), rails, and sandpipers. Migrant shorebirds move frequently to exploit food sources, escape predators and to continue their migratory treks.

The wading birds in Pennsylvania are mainly represented by the heron family, which includes egrets, herons and bitterns. Unlike shorebirds, many wading birds nest in Pennsylvania. In fact, species such as the great egret, great blue heron, black-crowned night heron and yellow-crowned night heron nest in colonies. Most wading birds consume fish, frogs and insects in shallow emergent wetlands or along riparian shores.

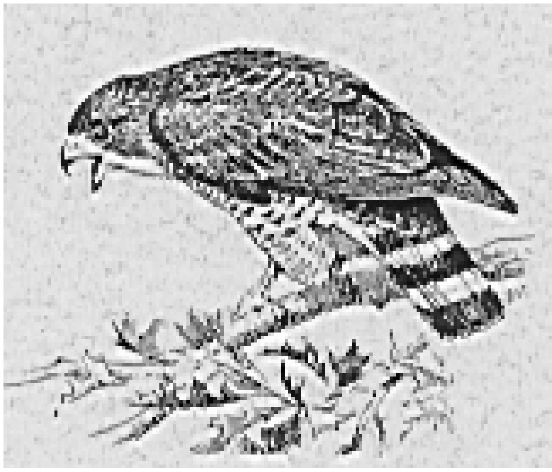


Figure 18. Broad-winged Hawk. Source: Cole et al. 1996.

Songbirds and Raptors

Wetland dependent songbirds and raptors include the red-winged blackbird, marsh wren, Louisiana waterthrush, song sparrow, swamp sparrow, belted kingfisher, northern harrier (marsh hawk), osprey, bald eagle and others (Figure 18).

Wetland and riparian ecosystems can be important to species not normally thought of as wetland dependent. These food rich sites are quite valuable for temporary residents or commuters. Wet grasslands, for instance, support robust populations of meadow mice that in turn attract harriers, short-eared owls and barn owls.

Gamebirds

Gamebirds is a term refers to birds pursued recreationally in hopes of harvesting for consumption (Figure 19). The four most important species in Pennsylvania are: American woodcock, ruffed grouse, wild turkey and ring-necked pheasant. These four species are good examples of facultative wetland species with recreational and economic value.

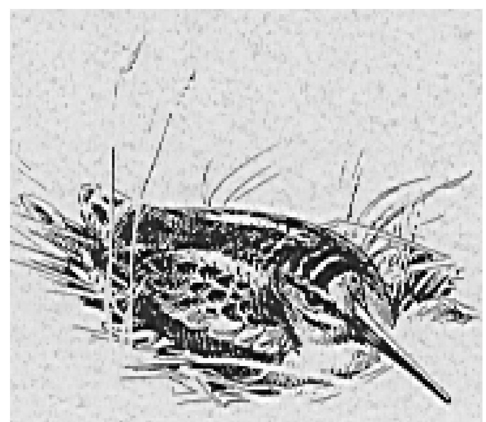


Figure 19. American Woodcock. Source: Cole et al. 1996.

The American woodcock has perhaps the best link with wetlands. The woodcock uses its long bill to probe the soil and turn leaves to find earthworms and other soft-bodied organisms. Woodcock favor wooded feeding areas which include damp or wet soils where earthworms are likely to be found close to the surface.

Ruffed grouse, the Pennsylvania state bird, are predominantly birds of brush-stage forests. Good year-round grouse range contains at least three habitat types: brushy and low-growing ground cover for feeding young birds and for supplying summer and fall foods; mature deciduous woodlands for nesting and providing fall, winter and spring foods; and low-growing evergreens such as spruce, hemlock and mountain laurel for winter cover. Wetlands sometimes provide several of the habitat types needed by grouse. Alder thickets provide brushy areas and food, and wet meadows provide a good insect source to feed young poults. Forested and shrub wetlands that contain conifers provide excellent winter cover and contribute many valuable foods.

The eastern wild turkey is the largest of Pennsylvania gamebirds and generally is considered a forest species, but two wetland habitat types are frequently used by turkeys. The first is wet meadows. Turkeys, especially young poults, use wet clearings containing grasses and forbs because these sites have herbaceous foods and an abundance of protein-rich insects. The second most frequently used habitat is spring seeps. Temperatures of the groundwater flowing from the seeps are above freezing, and the areas remain open throughout the winter. Vegetation and insect life found in these seeps provide the critical foods during a stressful time of year.

The ring-necked pheasant is not native to Pennsylvania. Since first released in 1915, they have, until recently, inhabited much of the state. Pheasants, considered chiefly as a farmland wildlife species, use available wetlands for both food and cover. Insects are an important food source for pheasants, as well as for turkeys and grouse. Wet meadows, when available, are good sources of this nutrition. Wetlands become especially important during the fall and winter season because they provide excellent escape and thermal cover as well as food.

Mammals

Five familiar species of medium-sized furbearing mammals use wetlands and other aquatic resources extensively in Pennsylvania. Four of these can be considered obligate species (beaver, muskrat, mink and otter). These species have adapted their anatomy, physiology and behavior to a life in and around water. The fifth species, raccoon, is often associated with wetland and riparian areas, but can survive in upland habitats. All of these species produce valuable fur, and thus are sought by trappers. However, due to low population numbers, there is (since 1952) a closed season on river otter in the state. Restoration activities for the river otter are taking place. Wetland furbearers have fascinating life histories which make them enjoyable to observe and study.

Beavers

Few species other than humans are able to manipulate their environment like the beaver. They cut trees, create openings, build dams and dig canals (Figure 20). Dams are designed to provide ample water for safety, food, transportation and storage. The entire complex is called a beaver flowage. Flowages abandoned by beavers evolve into beaver meadows. In effect, a colonizing beaver is the beginning of a new wildlife community characterized by elements of wetland, riparian and upland habitat.

Figure 20. Beaver Dam. Photo by R.P. Brooks.

The lodge and dam are good basking areas for snakes and turtles, and frog and salamanders breed in shallow waters. Mink, raccoons and green herons search for frogs, crayfish and other prey along marshy and riparian edges. Insects above the water attract swallows and flycatchers by day and bats at night. Dead trees harbor insects that are fed upon by woodpeckers. Holes made by woodpeckers are potential nesting sites for a variety of cavity-nesting birds. Some kinds of birds like the alder flycatcher, Louisiana waterthrush and wood duck are closely tied to beaver flowages.

Bordering the dam, small meadows resulting from felled trees provide habitat for deer, rabbit and hares. Turkey and grouse hens lead their young through such clearings in search of insects. These sunlit clearings have a rich herbaceous layer that supports high density populations of meadow voles, and certain other small mammals. In turn, these popular prey species are sought by hawks and owls, and ground-born predators like red and gray foxes. Thus, the beaver creates habitat that is used by a variety of wetland and upland wildlife species.

Muskrats

Muskrats, another rodent with construction skills, builds two types of shelter, depending on the characteristics of the ecosystem. Houses, or lodges, are constructed in shallow water (less than half a meter [2 feet] deep) surrounded by the emergent vegetation found in marshes and backwater coves. The second type of shelter, burrows, are dug when suitable banks (clay soils) are available along streams and the edges of marshes, ponds and lakes.

Mink, River Otter and Raccoon

Mink, a member of the weasel family, are found in a variety of wetland and riparian habitats that remain relatively undisturbed by human activities. They use logjams, root masses and rock crevices along shorelines for their dens. Mink hunt along the edges of waterbodies for almost any kind of vertebrate animal, including muskrats, small mammals, birds, reptiles, amphibians and fish.

River otter populations have declined from historic levels. Trapping (prior to 1952 when the season was closed), water pollution and habitat loss contributed to this decline. Only the northeastern Pocono region supported a healthy population. This large, carnivorous weasel prefers undisturbed riparian and lake habitats where it can find fish and crayfish, its primary food items. Recent reintroduction efforts have returned river otters to several other watersheds throughout the state.

Raccoons feed on many of the small vertebrates (frogs, fish, mice) and large invertebrates (crayfish, mussels, grasshoppers) found along the shores of wetlands, streams and ponds. However, their diet is more omnivorous because they also eat berries, nuts, corn and other types of plant foods. Raccoons tolerate disturbances by humans more so than other wetland furbearers. They can survive successfully in suburban and urban developments.

Other Wetland Mammals

Other species of mammal that use wetlands are not as well known. The water shrew is at home in the water and along streambanks. Another insectivore, the semi-aquatic star-nosed mole, searches for food both in water and in underground tunnels that penetrate saturated soils. The southern bog lemming, despite its name, is not restricted to bog-like environments. It can be found in old fields, forest clearings and young-growth forests.

Certain small rodents are most abundant within or near wetlands. They include the red-backed vole (Figure 21), meadow vole, rock vole, meadow jumping mouse and woodland jumping

Figure 21. Red-backed vole. Photo by R.P. Brooks.

mouse. The widely distributed meadow vole is capable of reaching densities in excess of 490 individuals per hectare (200 individuals per acre) in wet meadows. These rodents thrive on lush herbaceous vegetation, seeds and insects. They serve as prey for numerous avian and mammalian predators.

The edges of wetland and riparian areas are preferred habitat for long-tailed weasels, ermine and gray fox. Black bear, bobcat and snowshoe hare seek shelter in dense, forested and shrub wetlands like those of the Pocono region where intrusion by humans is infrequent.

Reptiles and Amphibians

Virtually all amphibians require access to water and wetlands during their breeding cycle. Their delicate jelly-like eggs must be kept moist during development. This dependence on water for breeding can be traced back to their ancient beginnings as amphibious fish that colonized the land. In addition to requiring water for breeding, many species, particularly frogs, live in water year round.

Figure 22. Salamander. Photo by R.P. Brooks.

Salamanders are a particularly diverse group in Pennsylvania and other Appalachian states (Figure 22). Dozens of species have evolved in the isolated valleys of the geologically old Appalachian mountains.

Although reptiles evolved primarily on drier lands, some species have reverted back to dependence on aquatic habitats. Species such as the painted turtle and northern water snake live in water, but lay their eggs high and dry on land. Thus, reptiles and amphibians differ in their use of wetlands. Both groups rely on wetlands and other water bodies for survival. Even the smallest of temporary ponds (sometimes called vernal ponds), only 3 meters (10 feet) in diameter, that are dry for much of the year, are critical habitat for these species. *How do you think the loss of wetlands in Pennsylvania has impacted these species?*

Fish

About 30 species of fish are known to use inland, freshwater wetlands in Pennsylvania some time during their life cycle. Fish such as sunfish and catfish will nest in the shallow open-water areas of wetlands, ponds and reservoirs. Other species such as bass, pickerel and pike require vegetated habitats with dense stands of emergent and submergent plants on which to lay their eggs and raise their young.

Wetlands connected to other water bodies, such as streams, lakes and estuaries, are more likely to contain a variety of fish species, particularly those that move to and from deep waters and shallow waters for feeding and breeding. The salt marshes along estuaries and the floodplains along larger rivers are among the most productive habitats in the world because they serve as spawning and nursery areas for many commercially important species of finfish and shellfish. Tides and floods continually replenish the nutrients used by plants, invertebrates and fish dwelling in these wetlands. Nutrients in short supply can reduce the kinds of species that can live in small, inland wetlands.

Invertebrates

Invertebrates are the most abundant and varied of all wetland animals, at least those that we can see without the aid of a microscope. Invertebrates inhabit both aquatic and terrestrial environments. From an ecological point of view, invertebrates are associated with nearly all other animals as food, predators, parasites and/or competitors for available resources or space.

Aquatic invertebrate fauna have an important role in the decomposition of dead plant and animals material in wetlands. Crane fly larvae and earthworms are two examples. Invertebrates are also important pollinators of plants, such as wetland orchids. Microscopic invertebrates provide food for larger invertebrates called macroinvertebrates. In turn, these macroinvertebrates such as crayfish, mayflies, dragonflies, damselflies, caddisflies and stoneflies are major staples in the diets of other wetland wildlife such as fish, amphibians, shorebirds, songbirds, waterfowl and insectivorous mammals. Invertebrates are integral parts of any food web (Figure 23).

Wetland Plants

Figure 23. Food web. Source: N. Obel

Many familiar plants grow in wetlands. Blueberries and cranberries are examples of wetland plants that we favor. You already know that wetlands have been classified according to the dominant plant types found there. You also know the importance of plants in wetland functions such as chemical transformation. Plants are able to uptake nutrients and toxins and transform them. The plants in a wetland are the basis for all other life forms which exist there. They offer shelter and food to insects, birds, mammals, fish, reptile and amphibians. They are the primary producers. Animals that feed on them are called secondary consumers. Plants are the base of any food web (Figure 23).

Some wetland plants only occur in wet areas and others may occur in wet or dry areas. There is a special classification system for plants which assigns an indicator status (OBL - obligate; FAC - facultative; etc.) to each species depending on how often they are found in wet areas (see Appendix 2).

Many wetland plants have special adaptations that enable them to live in water. Because the sediments in many wetlands become anaerobic (low in oxygen), the roots of some wetland plants have evolved air spaces, called aerenchyma, which allow oxygen molecules to move from the emergent portions of the plant to the underwater roots (Figure 24). Trees, such as the bald cypress of southern swamplands, have evolved prop roots with pores called lenticels. The prop roots are above the tidal or flood zone and supply oxygen to the submerged roots. Oxygen diffuses to the roots and can cause soil oxidation around the root producing a rust color in the soil horizon. Some wetland plants produce seeds during the dry season and others may produce buoyant seeds which can float to the banks to take root.

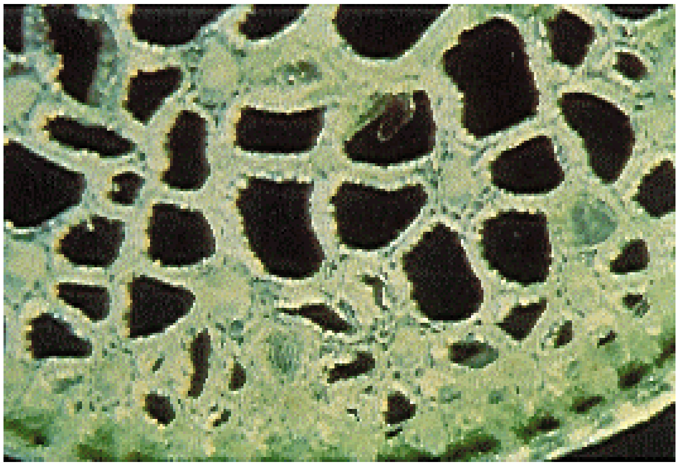


Figure 24. Aerenchyma. Source: Tiner 1998. Reprinted with permission.

Life form of vegetation and bottom substrate features determine the suitability of breeding, feeding, and resting habitat for wildlife. Some species of wildlife require several different life forms or substrates during their life cycle. The following list gives examples of the types of vegetative life form. Remember, there are an infinite number of possible combinations of these forms that can occur in a given wetland (Figure 25), so this listing of examples is only provided for reference.

Submergent and floating plants: pondweeds, wild celery, water milfoil, fanwort, water lilies, water shield, yellow pond lily, duckweed (common animals: deer, swan, coots, grebes, newts, bass and tadpoles).

Emergent plants: cattail, woolgrass, reed canary grass, sedges, rushes, bulrushes, pickerel weed, burreed (common animals: muskrat, small mammals, dabbling ducks, bitterns, rails, sparrows, frogs and tadpoles).

Shrubs: alder, high bush blueberry, viburnums, rhododendrons, dogwoods (common animals: beaver, bear, otter, snowshoe hare, woodcock, common snipe, green heron, waterthrushes, and other warblers).

Trees: elms, green and black ash, swamp white oak, hemlock, black spruce, red and silver maple (common animals: bear, raccoon, woodduck, black duck, osprey, wood turtle, wood frog, red-backed salamanders).

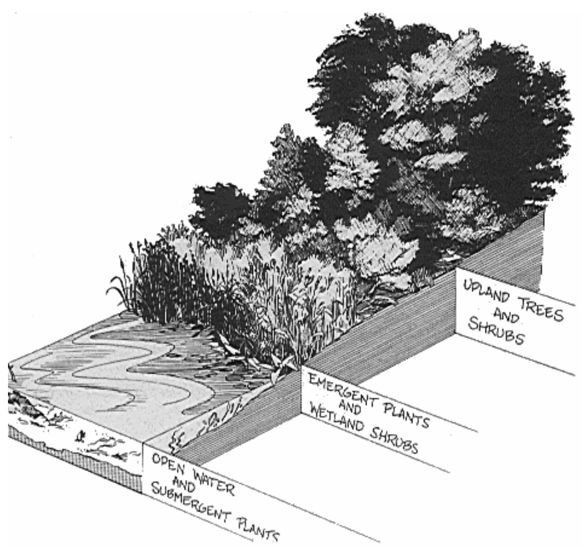


Figure 25. Types of vegetative lifeform. Source: Cole et al. 1996.

Wetland or Hydric Soils

Figure 26. Munsell soil color chart. Munsell Color 1992. Courtesy of GretagMacbeth, LLC. Reprinted with permission.

Wetland soil is both the medium in which many of the wetland chemical transformations take place and the primary storage area of available chemicals for most wetland plants (Mitsch and Gosselink 1993). The Natural Resources Conservation Service (NRCS) defined wetland soil, or hydric soil, as "a soil that is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions in the upper part". There are two types of soils you might find in a wetland, ones with a high organic content and ones with a high mineral content. Organic soils develop in wetlands that are covered in water for a significant portion of the year. Plant decomposition is slowed under the anaerobic conditions and results in the accumulation of organic materials such as peat. Soils with a high mineral content are found in wetlands that are inundated by surface waters carrying sediments for part of the year. Oxygen diffuses into these soils to hasten decomposition. Thus, the organic matter decomposition in these areas occurs at a rate even with the accumulation, leaving the minerals behind. These soils can be identified based on color using a standard color chart, such as a Munsell Color Chart (Figure 26). These soils are characteristically gray, greenish, or blue-gray as a result of a process called gleying which is the result of the chemical reduction of iron, a common element in soils. Soils that are seasonally flooded, or alternately wet and dry, develop a mottled appearance. Mottles are often orange/reddish-brown or dark reddish-brown/black and are formed because of the oxidized spots of iron and manganese oxides in an otherwise reduced environment.

Another characteristic of wetland soils is the presence of *oxidized rhizospheres*, or root channels, which form when oxygen transported to the roots of wetland plants diffuses from the roots to the surrounding soil, forming deposits of oxidized iron along the small roots (Mitsch and Gosselink 1993). When looking at a soil sample you will also notice the wetness of the soil. Is it dripping with water? Does it stick together when you pinch it or does it crumble apart? Some hydric soils also have a sulfurous (rotten egg) smell from the presence of hydrogen sulfide (H_2S). Hydric soils develop under wet conditions and support the growth of hydrophytic vegetation.

Lesson: Habitat Suitability Models

(adapted from Brooks and Prosser 1995)

The purpose of this lesson is to acquaint students with the use of habitat suitability models, so they will be able to employ them in the field. These models are designed as a way to score wetland sites based on their suitability for 10 wetland-dependent species. The models are not designed to predict the abundance of a species at a particular site, just whether it *might* occur there or not. Each site is scored based on a list of characteristics essential to a particular species. The scores range from 0.0 to 1.0, unsuitable to optimal, respectively. In each test, a final equation determines the overall habitat suitability. These models have been modified for Pennsylvania and use with students. The models are easy to use and give relatively accurate predictions of the suitability for each species.

The 10 species were chosen to represent a wide range of taxa, feeding levels and habitat uses that span the plant composition and degree of disturbance found in the wetlands of the northeastern U.S. Selected species include: bullfrog (Rana catesbeiana), muskrat (Ondatra zibethicus), meadow vole (Microtus pennsylvanicus), red-winged blackbird (Agalaius phoeniceus), American woodcock (Philohela minor), common yellowthroat (Geothlypis thrichas), green heron (Butorides striatus), wood duck (Aix sponsa), wood frog (Rana sylvatica) and southern redback vole (Clethriononmys gapperi). The species have been arranged in order according to preferred vegetative cover type (Table 1). See Appendix 3 for the habitat suitability model for each species. After completing the suitability models for each species, the students can develop a wildlife community profile. This profile can be used to compare sites and produce a visual representation of the wildlife community at each site (Figure 27).

The students should break into groups of three. Each group will be given a model to score based on pictures and description of an ecosystem. Enough information will be available in the description of the wetland so the students will be able to score each factor. This in-class exercise is intended to acquaint the students with these models so they will be prepared to use them in the field when following the CWC protocol.

Procedures:

1) At least three observers should independently score each site. The score for each variable will be calculated as an average of the independent scores of each observer. If the score difference is greater or equal to 0.3 units, observers must discuss that variable and reduce the difference to a value that is equal to or less than 0.3 before averaging their scores.

2) Each model contains an equation to calculate overall HSI value.

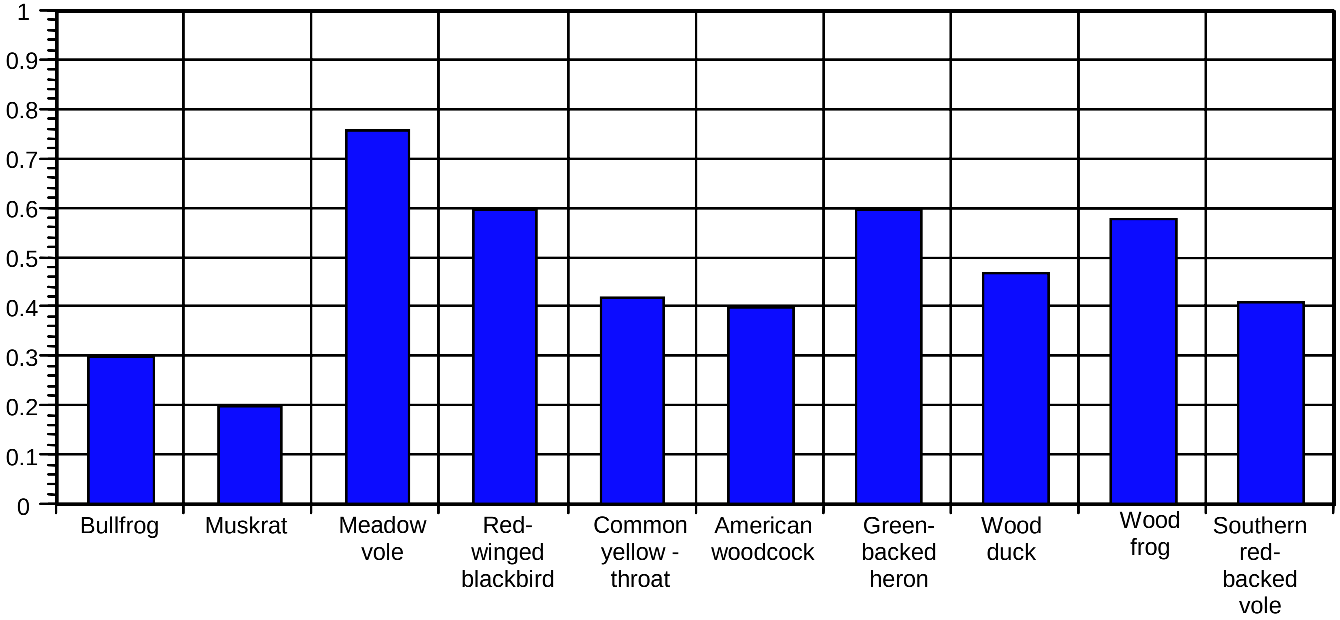
3) A site may be ranked from multiple perspectives, depending on the species model being used. Consider, for example, an open water site with grass-like herbaceous vegetation along the shore. When ranking the model for the meadow vole, focus mainly on evaluating the grassy shore rather than the open water (because the meadow vole would not be found in the open water). The wood duck, on the other hand, will use both the open water and vegetated shore, therefore focus on all portions of the site. Life history information is included at the beginning of each model.

4) It is important to score all species for each site. After the scores are computed for each species, a graph can be produced to display the relative ranking.

Table 1. Ten wildlife species used as models to evaluate wetland habitats.

COMMON NAME	SCIENTIFIC NAME	TAXONOMIC GROUP	TROPHIC LEVEL
OPEN WATER (WITH SOME EMERGENT ALLOWED)			
Bullfrog	Rana catesbeiana	amphibian	carnivore
Muskrat	Ondatra zibethicus	mammal	herbivore
EMERGENT (WITH SOME OPEN WATER OR SHRUBS ALLOWED)			
Meadow vole	Microtus pennsylvanicus	mammal	herbivore
Red-winged blackbird	Agelaius phoeniceus	bird	granivore
SCRUB-SHRUB (WITH SOME EMERGENTS OR FORESTED WETLAND ALLOWED)			
American woodcock	Philohela minor	bird	invertivore
Common yellowthroat	Geothlypis thrichas	bird	insectivore
Green-backed heron	Butorides striatus	bird	carnivore
FORESTED WETLAND (WITH SOME SHRUBS OR EMERGENTS ALLOWED)			
Wood duck	Aix sponsa	bird	herbivore
Wood frog	Rana sylvatica	amphibian	carnivore
Southern redback vole	Clethriononmys gapperi	mammal	herbivore

Figure 27. Example of a Wildlife Community Habitat Profile for a reference emergent wetland.



Chapter 4 - Scientific Method

(adapted from A Handbook of Biological Investigations, Ambrose and Peckham Ambrose 1981)

Objectives

- to understand and apply the scientific method by following procedures of a sampling protocol for wetlands
- to learn methods for data collection, analysis and interpretation
- to be introduced to issues of data accuracy, sampling bias, and data management

What is Scientific Investigation?

Science is the investigation of rational concepts capable of being tested by observation and experimentation. The analytical method involves a pattern of observation, experimentation and both inductive and deductive logic. The process of acquiring scientific investigation employs postulating and testing hypotheses. Hypotheses are possible explanations of observed phenomena. Scientists use deductive (if…then) logic to make and test predictions on the basis of their hypotheses. All science advances by the rejection of hypotheses. Good scientific research produces results from which you can draw conclusions and eventually make generalizations. Research begins with a good experimental design. Development of a good scientific design begins with a library search to find out what is already known and then a brainstorming session to determine all possible explanations of a certain phenomena. The experiment should be designed to examine one variable at a time, if possible, each time testing and accepting or rejecting a possible hypothesis.

Scientific information is gathered by asking and answering questions. After determining what the question is a researcher must determine what information is needed in order to answer that question. In other words, to find an answer, data gathered must be relevant to the question. *What questions can you think of to ask about your adopted wetland? What data would you need to gather or otherwise obtain to answer those questions?*

Statistical Analysis

1) The best scientific experiments may not require statistics to explain their results; the evidence presented is compelling enough to draw convincing conclusions.
2) However, the interpretation of environmental data is frequently hindered by the complexity of interactions occurring between the physical and biological aspects of the environment.
3) Statistics are a tool used to see relationships, such as correlations and differences within and between data sets. By knowing which statistical methods to use for certain kinds of data a researcher can determine whether they have a statistically significant cause to reject a hypothesis. The usefulness of these tests depends on the integrity of the experimental design; a poorly designed experiment may yield statistical differences that have no actual meaning.

Following the Sampling Protocol

The CWC has designed and tested the sampling protocol which will be used on each school's adopted wetland. It is important to follow the procedures in the protocol *exactly* to obtain good results. Small errors in field measurements or calculations can translate to data that is not descriptive of the actual conditions. As part of the research team, each participant must carefully and conscientiously take all measurements to insure the highest quality of data. As data accumulate over time, it may be used by you or others to test hypotheses that help us understand wetlands better. By participating in this project with commitment, you will contribute to the compilation of a reliable set of data.

Chapter 5 - Field Study

Objectives

- to collect data on the biological, chemical and physical characteristics of wetlands and adjacent streams for making comparisons among natural reference sites and between reference sites and mitigation projects
- teach students to follow a scientific protocol and to analyze these data collected
- raise student's level of awareness about the importance and protection of wetlands

Field Day

Today is the day everyone has been waiting and preparing for. Before students begin field work, assisted by CWC staff members, the class should be broken into five groups. There is much to investigate in this wetland study. Sharing the various topics in a cooperative way will enable all data to be acquired within the time constraints of the class and the student's level of expertise. In certain instances, the student groups will need to cooperate, for example the cartographers will record the elevation of the wells after they have been placed by the hydrologists. After all the data is gathered, the groups can then form a team to analyze and prepare the data for a final report that will be sent to the CWC, and eventually used in the student forum.

We suggest the following groups:

Botanists: This group will be responsible for selecting plots and sampling the percent plant cover of each species in each plot. They will also record the height and approximate the crown coverage of the five shrubs or trees closest to the plot, and diameter breast height (dbh) of trees. They will work with the cartographers to map the major subclasses of the plants using Cowardin et al (1979).

Soil Scientists: This group will be responsible for taking all soil samples. They will dig soil pits to describe the soil profile. They will determine the dominant matrix and mottle colors for each sample which will be taken from the same randomly selected plots as the vegetation samples, and determine approximate wetness from soil samples. Soil samples will be collected in zip lock bags and returned to the lab for analysis of organic content and texture. This group will also install the sedimentation pads in the selected plots.

Zoologists: This group will be responsible for using the HSI models to determine the habitat suitability for each of the 10 species. This group will also be responsible for recording any sightings of animals while in the field.

Chemists/Hydrologists: This group will be responsible for following the water quality sampling procedures. They will test for temperature, pH and specific conductance. This group will also be responsible for the installation of the wells.

Cartographers: This group will be responsible for determining the jurisdictional boundary, drawing the base map, laying down the baseline and transects and working with the surveyor to measure the microtopography. These students will also be responsible for taking photographs of the site.

Because this is a real project and the data collected during this field work will be used in the CWC reference wetland database, many of the baseline measurements will be conducted by or supervised by CWC personnel with student assistance. During the site visit to acquire these data, we will require that duplicate measures be taken by the students. Dual data sheets will be maintained, and checked frequently by CWC staff for agreement. Disparate data will be remeasured. At the end of the day or sampling period, the dual data sheets must agree. One copy will remain with the students, one will return to Penn State with CWC staff.

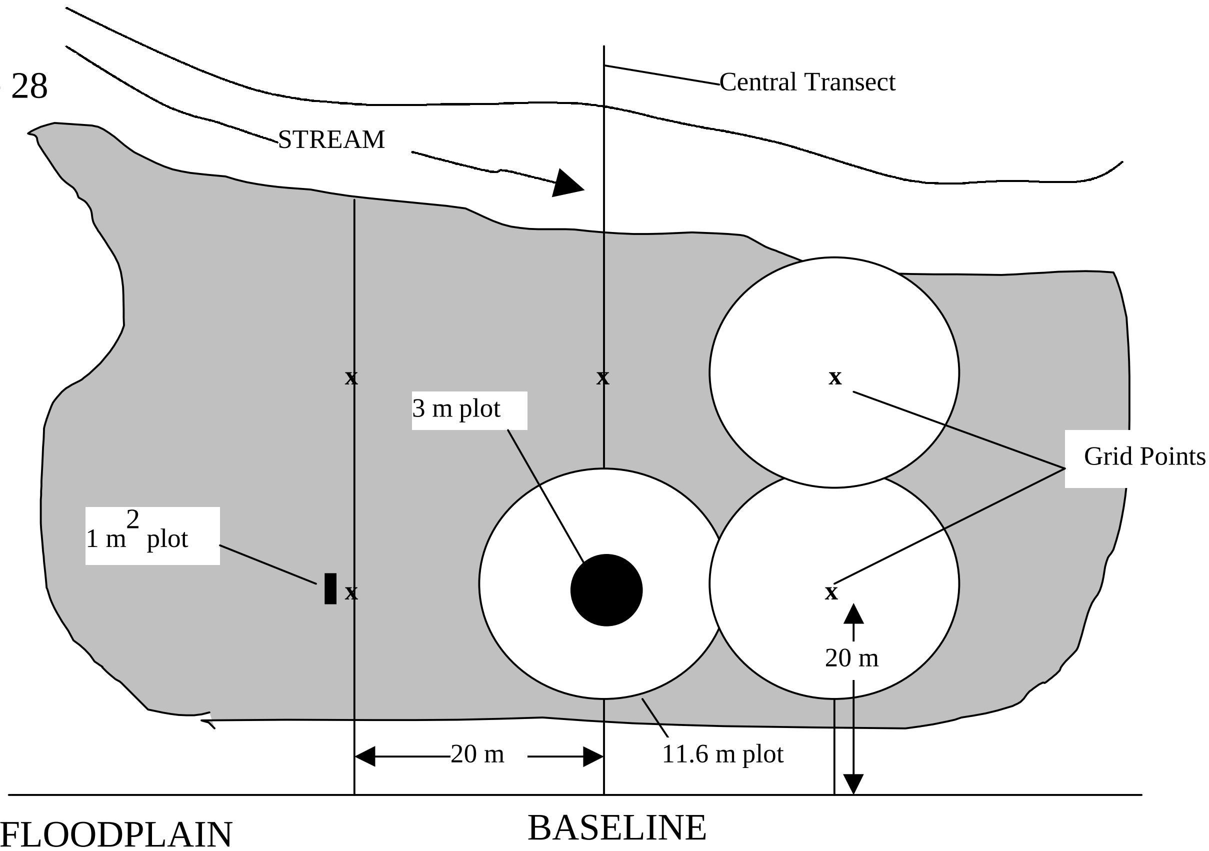
The students, with oversight from teachers, will take the hand-written data sheets and enter the data into a spreadsheet program (Microsoft Excel). They will be required to check it, and then send it via disk or Internet to the CWC. Once received at the CWC, the data will be checked against a second copy of the original data sheets. Inquiries to the students will be made regarding any detected errors. Once approved, the data will be entered into the CWC database. Teachers will be notified when data have been accepted.

Sampling Protocols

This sampling protocol was developed by the Penn State Cooperative Wetlands Center (CWC) and has been adapted for use by the high school Adopt-a-Wetland program. Modifications in the protocol will be made as needed based on its effectiveness in this pilot program.

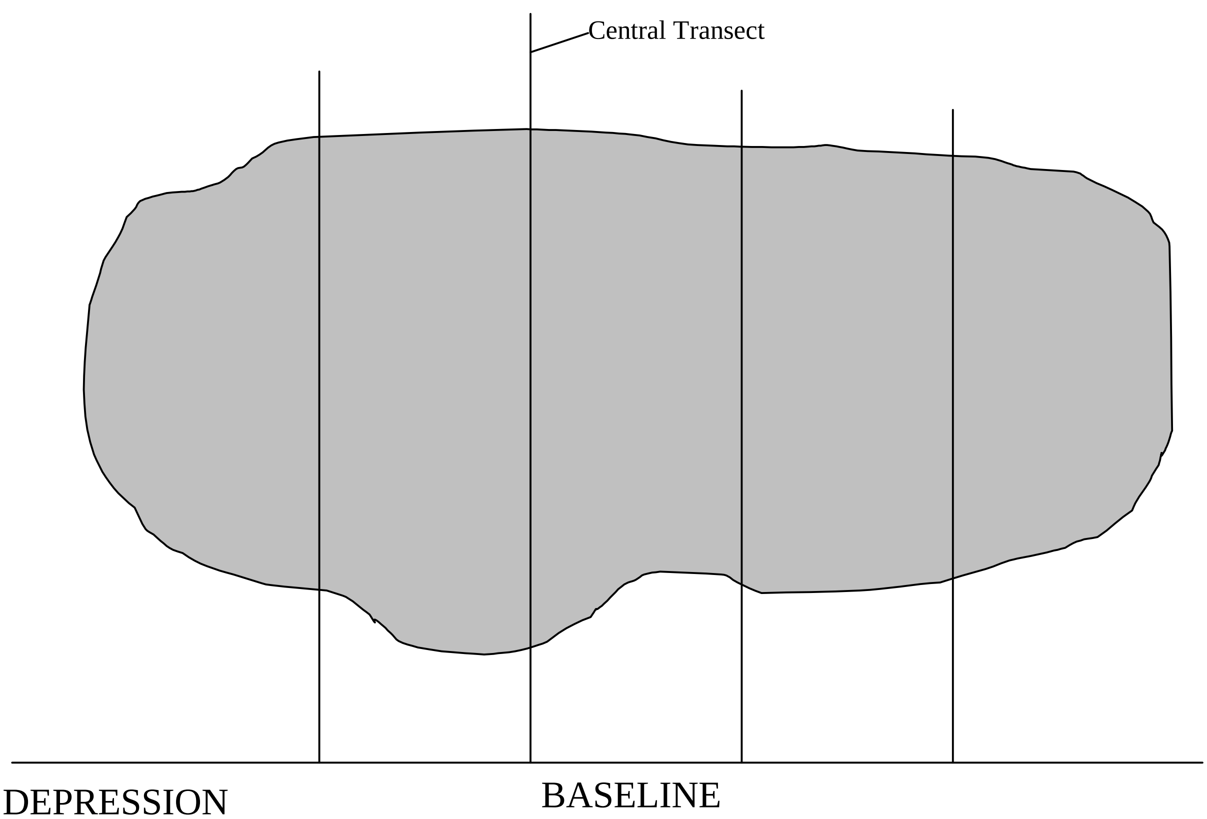
This protocol is intended for characterization of wetlands approximately 0.4 ha (1 acre) in size; the protocol may be altered to accommodate wetlands larger or smaller in size. The general approach is illustrated in Figure 28. All information is gathered along a series of transects on which grid points are evenly spaced at 20 m (65.5 ft) intervals. A minimum total transect length of 100 m (328 ft) is suggested. In order to adequately characterize a wetland of this size, 8 to 12 plots (grid points) should be established. An absolute minimum of six plots should be characterized. If the wetland is smaller than 0.4 ha (1 acre), grid points can be spaced at 10 m (32.8 ft) intervals to achieve the minimum of six grid points. If the wetland is significantly larger, grid points can be spaced at 30 m (98.4 ft) or 40 m (131.2 ft) intervals. See Appendix 5 for help converting to metric. The orientation of the transects is discussed in more detail in subsequent sections. If the wetland is located adjacent to a stream, at least one transect should cross the stream itself in order that stream topography can be characterized.

Figure 28



FLOODPLAIN

EXAMPLE



DEPRESSION

EXAMPLE

Field Sampling (all measurements to be in metric units, English units provided for comparison only)

Cartographer Student Group (5 - 7 students)

I. Baseline, Base Map, and Jurisdictional Boundary

1) Establish baseline in an obvious and convenient location parallel to the long axis of the wetland allowing some upland area between baseline and expected wetland area. Under some conditions, it may be necessary to establish baseline in the wetland (e.g., for reasons of visibility, etc.)

2) Starting and ending points should be marked with a reinforcing rod (rebar) or other obvious permanent marker. Note position on map. If an accurate base map is not available, a sketch map may be created.

3) One of the CWC staff members will help the students record the azimuth of the baseline on created sketch map of site.

4) Record length of baseline (to nearest m or ft) on map.

5) If an accurate base map is not available, one may be created. Using basic surveying methods (transit, plane table, stadia rod recommended), map the expected wetland (project area)

6) Using practices from standard delineation manuals, mark with flags the approximate boundary of the current jurisdictional wetland. Use the internal plots for documenting wetland occurrence. Add 2-3 upland plots as necessary to document upland conditions. Questionable areas can be determined after additional plots are measured during the procedures described below. Map the jurisdictional boundary. Elevations for the perimeter of the wetland and interior points can be obtained at this time using a stadia rod.

7) At this time, wetland vegetative communities that can be differentiated should be roughly mapped. The smallest unit of concern is 0.1 ac (0.04 ha).

II. Transects

1) Using random number generator/table, select end point of first transect (to nearest 0.1 m or ft) on baseline. Transects traverse entire expected wetland area into upland on far side, or to edge of study area. If wetland is adjacent to a stream, at least one transect should traverse the stream. Transects are perpendicular to baseline.

2)The remaining transects are established at uniform intervals along baseline (typically 20 m [65.6 ft], 5 m [16.4 ft] or 10 m [32.8 ft] can be used on small sites or 40 m [131.2 ft] on large sites). Number of transects depends on area of wetland. For each transect, record starting point on baseline.

3) Choose a transect that traverses a representative portion of the wetland as a center transect; it should have a maximum length of 100 m (328 ft).

III. Plots

1) Using the same intervals as the intervals between each transect, mark grid points (plot centers) along each transect with flags or stakes. Sampling plots are located at grid points along each transect. Label as T1-1 (Transect 1- Plot 1), T1-2, T1-3, …, T2-1 (Transect 2 - Plot 1), etc.

Note: Sampling of additional soil pits and plant quadrats along the wetland-upland boundary may be necessary to establish jurisdictional boundaries.

IV. Stream Map (when applicable)

A 100 m stream section is walked, and all inlets and outlets noted and recorded on a rough sketch of the stream/wetland complex.

V. Wetland Morphometry

1) Estimate the expected wetland area (nearest 0.0 ha or ac). When jurisdictional boundaries are determine, compute new area.

2) Record a yes/no measure of outlets for all macrotopographic depressions within the floodplain, if applicable. Macrotopographic depressions are defined as areas greater than the depression left by a large tree windfall, or about 10 m^2 (108ft^2) within the floodplain.

3) Create a detailed microtopographic profile of the wetland by recording elevations taken every meter on the center transect with 100 m (300 ft) tape and transit and stadia rod (or comparable method). The location of the transect profile should be recorded on the map. Measure and record the elevation and location of the lowest observed point on the site (usually the discharge point or a depression) and any outlets using a transit and stadia rod.

Botanical Student Group (3 - 4 students)

VI. Plant Sampling

Plots are typically located on the left side of the transect to avoid trampling during characterization activities. Three sizes of plots are used to record various measures of the plant community: a 1 m^2 plot, a circular plot with a radius of 3 m (10 ft), and a circular plot with a radius of 11.6 m (38 ft). The plots are “nested”, meaning that the 1 m^2 plot is inside the circular plot with a radius of 3 m (10 ft), and this plot is inside the circular plot with a radius of 11.6 m (38 ft). The activities in each plot are described separately as follows:

1 m^2 Plot

1) Within each plot (2 m x 0.5 m; 6.5 x 1.5 ft), visually estimate the percent cover to the nearest 5% for dominant species (up to 5 herbaceous, up to 5 woody species). Record % and species name on data sheet. CWC staff will help students identify plant species.

3 m-radius Plot

1) To gather data about additional species for species richness, note any other vascular plants observed within a 3 m (10 ft) radius plot centered on the plot point. Record in field notes for later tally of total number of species and species list.

2) Estimate the percent aerial cover of downed leaf and small woody material (less than 1 cm in diameter) in 3 m (10 ft) radius plot centered on plot point.

3) Measure the height and a circular projection of cover (crown) for all shrubs in a 3 m (10 ft) radius plot centered on the plot point. A shrub is defined as single stemmed woody plant

less than 3 m (10 ft) tall, or a multi-stemmed woody plant regardless of height (e.g., rhododendron).

11.6 m-radius Plot

1) In reference forested wetlands, or where mature trees are present (natural, planted, volunteer) in the wetland, determine basal area (use angle gauge or prism plotless method) from center of each plot. Record diameter at breast height (dbh) to nearest 0.1 cm and species of all individuals tallied within a 11.6 m (38 ft) radius circle centered on plot (note: dbh is defined as the stem diameter 1.3 m [4.24 ft] above ground surface). Estimates of crown closure are necessary and can be made visually.

2) Estimates of percent herbaceous cover within a 11.6 m (38 ft) radius circle centered on plot are made visually and recorded.

3) As the team proceeds to the next grid point, count occurrences of downed woody material that crosses the transect. Downed material should be tallied by size class; size classes are the following:

SIZE CLASS	MIDPOINT	# OF OCCURRENCES
Branches & Fallen Saplings (1-12 cm; 0.4-4.7 in. diameter.)	6 cm (2.3 in)	
Trees (>12-40 cm; 4.7-15.6 in. diameter.)	26 cm (10.1 in)	
Large Trees (>40 cm; 15.6 in. diameter.)	Actual Measure	

4) As the team proceeds to the next grid point, identify and count macrotopographic depressions encountered along transect. Macrotopographic depressions should be tallied by depth classes; depth classes are the following:

Depth Classes (cm)	Count
0-15	
15-30	
30-45	
45-60	

Soil Scientists Student Group (2 - 3 students)

VII. Soil Sampling

1) After transects and plots are mapped, select every other plot along each transect for locating soil pits. A minimum of 3 soil pits in the wetland should be characterized plus additional soil pits in the upland (as necessary for wetland delineation). Dig soil pit to at least 0.5 m (18 in) within 2 m (6 ft) of plot. Describe the soil profile in the pit (make sketch on data sheet of characteristics associated with the varying depths to nearest 1 cm or 1 in). Record the dominant matrix and mottle colors on the data sheet according to the Munsell Color Chart. Determine the relative wetness of soil and record. Describe any other hydrologic or hydric soil characteristics observed (see Appendix 4). An observation of the soil texture (sand; loamy sand; sandy loam & loan; silt loam & finer) and soil consistence (loose; friable; firm-extra firm; cemented) should be made at a depth of 20 to 30 cm (8 to 12 in) below the surface using standard field method (see Appendix 4). Presence of indicators of anaerobic activity, such as gaseous emissions, strong gleying, or presence of histosols should be noted. Record direct observation of redoxymorphic features. Record estimated percent organic matter utilizing observations of the cumulative thickness of the Oi, Oe and Oa horizons cross referenced with A horizon soil indicators according to the following table:

CUMULATIVE THICKNESS OF O, Oe, and Oa HORIZONS					
A Horizon		=/< 5 cm (2 in)	5-10 cm (2-4 in)	10-20 cm (4-8 in)	>20 cm (8 in)
Matrix color, value and/or chroma=/>3	---	0.1	0.5	0.75-	1.0
Matrix color value and chroma <3	=/<15 cm (6 in)	0.1	0.5	0.75	1.0
Matrix color value and chroma <3	>15 cm (6 in)	0.5	0.75	1.0	1.0
Mucky Modifier	<10 cm (4 in)	0.75	0.75	1.0	1.0
Mucky Modifier	=/>10 cm (4 in)	1.0	1.0	1.0	1.0

2) Collect soil samples for texture analysis and organic content from the sides of the pit at (not to exceed) 5 cm (2 in) and 20 cm (8 in) depths. Fill at least half of a one quart Ziploc bag (250 ml [8 oz.] minimum) and label by date, site, and plot. Send to the CWC for analysis.

Chemists and Hydrologists Student Group (3 - 4 students)

VIII. Hydrologic Sampling

See Appendix 6 in student manual for instructions on well installation.

Zoological Student Group (4 - 6 students)

IX. Photographs

1) Establish at least three, numbered, permanent photo stations per wetland. One should be a general overview of the site from an accessible vantage point. Another must be a view of typical vegetation in the study area. The third photograph should be taken of the central transect from the instrument. Additional photographs of: typical plots, examples of hydrologic indicators, unusual and problem areas, aerial photographs, etc. are recommended. Mark photo stations on the map, including a directional arrow.

2) Use a 35 mm camera, 50 mm lens (or equivalent), ASA 200 (or >) color print film and/or slides. Develop promptly and label the photographs, negatives, and slides by Site#, Station#, and Date. Use of video to pan site and identify areas in need of remediation is encouraged, but is optional.

X. Faunal Sampling

1) Record direct and indirect observations of wildlife, fish, and macroinvertebrates during the course of site visits (e.g., animals, tracks, scat).

2) Using a suite of 10 modified habitat models (which together form a Wildlife Community Habitat Profile, Brooks and Prosser 1995), assess the suitability of habitat for vertebrate species in late summer or by the end of the growing season. Model species include the bullfrog, muskrat, meadow vole, red-winged blackbird, common yellowthroat, american woodcock, green-backed heron, wood duck, wood frog, and southern red-backed vole. Assess all species for each site, even if a species is not likely to be found at that particular wetland. Two individuals must evaluate the habitat independently. If their values are greater than 0.3 units apart, they must negotiate the difference. The average of their values will be recorded. Values are standardized on a 0.0 - 1.0 scale. See Appendix 3 for HSI models.

3) In the classroom, the students will determine the HSI scores for each species and create a graph of these scores.

Glossary

abiotic. Not living.
accretion. Growth in size or extent, especially referring to the accumulation of sediment in a wetland.
aerenchyma. Air spaces in the roots and stems of wetland plants that allow for the transfer of oxygen from plant parts in aerobic conditions to plant parts in anaerobic conditions.
azimuth. Bearing in the horizontal plane, usually expressed as an angle (used when surveying).
baseline. Any line used as a point of reference.
bog. A wetland formed when large blocks of ice, left behind at the end of the last ice age, melted forming a water filled depression. Over thousands of years, the depression filled in with plants forming a place with wet, spongy ground and soils composed mainly of partially decayed vegetable matter. The soils in a bog are usually acidic (low pH).
Clean Water Act. A legislative act established in 1977 implementing new laws and regulations concerning water quality and wetlands.
community. Life in association with others. A group of organisms living together in a common environment.
correlation. Corresponding relationship between organisms in processes, qualities or structures.
dbh. Diameter Breast Height. The diameter of a tree at chest level.
depression. A low elevational point in the landscape.
dichotomous key. A tool used in the identification of organisms.
emergent. An aquatic plant with vegetative growth mostly above the water.
erosion. The wearing away of soil or rock by the influence of water, ice, winds and other forces of nature.
estuary. The wide mouth of a river as it flows into a larger water body. An estuary is influenced by water from the river and from the larger water body.
facultative. Organisms which may or may not depend on wetlands for survival.
fauna. A collective term for the animals or animal life particular to an environment.
fen. A wetland type characterized by soil with a high pH and plants specially adapted for that soil type.
floodplain. Level land along the course of a river or stream that is prone to flooding.
flora. A collective term for the plants particular to an environment.
beaver flowage. The entire complex of canals and dams constructed by a beaver which alter the hydrology of wetlands.
food. Any substance taken into and assimilated by a plant or animal to keep it alive and enable it to grow and repair tissue.
forbs. An herb, other than a grass. A flowering plant.
function. Normal activity or actions that occur in wetland ecosystems. The things that wetlands do.
geology. The science that deals with the physical history and structure of the earth, especially as recorded in rocks and rock formations.
gleying. The development of gray or sometimes greenish or blue-gray color of hydric mineral soils that are semipermanently or permanently flooded. The process, gleization, is caused by the chemical reduction of iron.
habitat. The natural locality of a plant or animal.
headwater. The part of a river near its source. The tributaries at or near the source of a river.
hectare. A unit of surface area equal to 10,000 square meters or 2.47 acres.

hydric soil. Soils that have been inundated with water for several weeks and acquire a typical gray or blue-gray color.
hydrodynamics. Pertaining to the force, pressure or motion of water.
hydrology. The science dealing with the properties, laws, and distribution of water underground, on the surface and in the earth's atmosphere.
hydrophyte. A plant which lives and grows in water or very wet soil.
lacustrine. Deep freshwater habitats such as lakes and reservoirs.
lenticels. A pore in the bark of woody stems through which the exchange of gases occurs.
levee. An embankment preventing the overflow of a stream or river.
marine. Open ocean and coastline systems, generally limited to deep, saltwater habitats.
macroinvertebrates. Animals lacking a backbone which can be seen without the aid of a microscope.
microtopography. The elevational changes which occur in a relatively small area.
mitigate. To diminish in severity by replacement or compensation.
model. A standard for comparison.
morphology. The study of form or structure without regard to function.
morphometry. The measurement of form or structure.
obligate. Organisms which require wetlands for survival.
oxidation. The act or process of uniting with oxygen.
palustrine. Marshy, referring to the majority of freshwater wetland habitats including marshes, bogs, swamps and wet meadows.
piezometer. An instrument for measuring compressibility and pressure.
poults. A young fowl.
primary productivity. The transformation of chemical or solar energy to biomass. Most primary production occurs through photosynthesis, whereby green plants convert solar energy, carbon dioxide, and water to glucose and eventually to plant tissue.
quadrats. A one meter by one meter sampling space.
reduction. The lowering of oxygen content.
riverine. Freshwater rivers and stream channels
riparian. Pertaining to or situated on the bank of a stream or river.
subclasses. A subdivision of a class, related to the HGM classification method.
swamp. A wetland type that is usually constantly inundated with water and forested.
taxonomy. The classification of plants and animals into established groups or categories on the basis of their natural relationship.
topography. Elevational changes across the landscape.
transect. A sampling area consisting of a line running across the area of interest.
value. The significance of wetland functions to society or individuals.
watershed. The area drained by a network of streams and rivers.
wetland. An ecosystem type which is at some point in the year inundated with water, has hydric soils and supports predominantly hydrophytes.

Citations

Ambrose, H.W. and K. Peckham Ambrose. 1981. A Handbook of Biological Investigations. Hunter Publishing Company, Winston-Salem, North Carolina. ISBN 0-89459-148-7.

Aquatic Project WILD. 1992. Western Regional Environmental Education Council, Bethesda, Maryland.

Brinson, M.M. 1993. A Hydrogeomorphic Classification for Wetlands. U. S. Army Corps of Engineers, Waterways Exp. Stn, Tech. Rep. WRP-DE-4, Washington, D. C. 79 pp. +app.

Brooks, R.P. et al. 1996. Wetlands, Wildlife, and Watershed Assessment Techniques for Evaluation and Restoration (W3ATER). Pennsylvania State University, Environmental Resources Research Institute, University Park, PA, 16802.

Brooks, R.P., D.A. Devlin, J.D. Hassinger. 1993. Wetlands and Wildlife. Pennsylvania State University, College of Agricultural Science, University Park, Pennsylvania. 56 pp. Available for $4 (Checks payable to Pennsylvania State University), Agricultural Publication Distribution Center, 112 Agricultural Administration, University Park, PA, 16802.

Brooks, R.P. and D.J. Prosser. 1995. Habitat Suitability Index Models and Wildlife Community Habitat Profiles For Use in Pennsylvania Wetlands. Penn State Cooperative Wetlands Center, University Park, PA. Rep. No. 95-1. 27 pp.

Cole, C.A., R.P. Brooks, and D.H. Wardrop. 1997. Wetland Hydrology as a Function of Hydrogeomorphic (HGM) Subclass. Wetlands 17:456-467.

Cole, C.A., T.L. Serfass, M.C. Brittingham, and R.P. Brooks. 1996. Managing Your Restored Wetland. Pennsylvania State University. College of Agricultural Sciences Cooperative Extension, University Park, Pennsylvania. 44pp.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. USDI, U. S. Fish and Wildlife Service. FWS/OBS-79/31. 131 pp.

Mitsch, W.J., and J.G. Gosselink. 1993. Wetlands. Van Nostrand Reinhold, New York, New York. 722pp. ISBN 0-442-00805-8

Munsell Color. 1992. Munsell Soil Color Charts. Revised Edition. Macbeth, Division of Kollmorgen Instruments Corp. Newburgh, New York.

Obel, N. 1997. Posters are available from The Penn State University, the College of Agricultural Sciences, Agricultural Publications Distribution Center, 112 Agricultural Administration Building, University Park, PA 16802.

Tiner, Ralph W. 1998. In Search of Swampland: A Wetland Sourcebook and Field Guide. Rutgers University Press, New Brunswick, New Jersey.

Ward, A.D. and W.J. Elliot. 1995. Environmental Hydrology. Lewis Publishers, Boca Raton, FL. P. 404-407.

Additional References which may be helpful

Brinson, M. M. 1995. The HGM approach explained. National Wetlands Newsletter 18(1):10-16.

Conservation Foundation. 1988. Protecting America's Wetlands: An Action Agenda. Washington, DC. 69 pp.

Dahl, T. E. 1990. Wetland losses in the United States, 1780s to 1980s. U. S. Department of Interior, Fish and Wildlife Service, Washington, DC. 21 pp.

Kusler, J. A. 1983. Our national wetland heritage: A protection guidebook. Environmental Law Institute, Washington, DC. 167 pp.

Majumdar, S. K., R. P. Brooks, F. J. Brenner, and R. W. Tiner, Jr. 1989. Wetland ecology and conservation: Emphasis in Pennsylvania. Pennsylvania Academy of Science, Easton, PA. 395 pp.

National Wetlands Newsletter. Environmental Law Institute, Washington, DC. 1978-current.

Newcomb, Lawrence. 1977. Newcomb's Wildflower Guide. Little, Brown and Company, Boston, Massachusetts.

Niering, William A. 1984. Wetlands. Audubon Society Nature Guides. Alfred A. Knopf, Inc., New York, NY. 638 pp. ISBN 0-394-73147-6

USDA Soil Conservation Service. 1985. Hydric soils of the United States. Washington, DC.

WOW! The Wonder of Wetlands: An Educator's Guide. 1995. Environmental Concern, Inc., St. Michael's, Maryland and The Watercourse, Montana State University, Bozeman, Montana. ISBN 1-888631-00-7

Wetland Journal. Environmental Concern, Inc. 1993-current.

World Wildlife Fund. 1992. Statewide wetlands strategies: A guide to protecting and managing the resource. Island Press, Washington, DC. 268 pp.

Appendix 1:

National Wetlands Inventory - Plant Indicator Status

National Wetlands Inventory - Plant Indicator Status

The wetland plant indicator status indicates the estimated probability (likelihood) of a species occurring in wetlands versus non-wetlands for a certain region. The regional indicator assignments are not based on the results of a statistical analysis of the occurrence of these species in wetlands. The indicator assignments are the best approximation of wetland affinity for these species based upon a synthesis of submitted review comments, published botanical manuals, and literature and field experience. If a regional panel was unable to reach a unanimous decision on a species, NA (no agreement) was recorded. An NI (no indicator) was recorded for those species for which inefficient information was available to determine an indicator status or that were not considered by the Regional Panel. The positive sign indicates a frequency toward the higher end of the category (more frequently found in wetlands). A negative sign indicates a frequency toward the lower end of the category (less frequently found in wetlands).

Indicator Categories

- *Obligate Wetland (OBL).* Occur almost always (estimated probability >99%) under natural conditions in wetlands.
- *Facultative Wetland (FACW).* Usually occur in wetlands (estimated probability 67%-99%), but occasionally found in non-wetlands.
- *Facultative (FAC).* Equally likely to occur in wetlands or non-wetlands (estimated probability 34%-66%).
- *Facultative Upland (FACU).* Usually occur in non-wetlands (estimated probability 67%-99%), but occasionally found in wetlands (estimated probability 1%-33%).
- *Obligate Upland (UPL).* Occur in wetlands in another region, but occur almost always (estimated probability >99%) under natural conditions in non-wetlands in the region specified.

The wetland indicator categories should not be equated to degrees of wetness. Many Obligate Wetland species occur in permanently or semipermanently flooded wetlands, but a number also occur and some are restricted to wetlands that are only temporarily or seasonally flooded. The Facultative Upland species include a diverse collection of plants that range from weedy species adapted to a number of environmentally stressful or disturbed sites (including wetlands) to species in which a portion of the gene pool (an ecotype) always occur in wetlands. Both the weedy and ecotype representatives of the facultative upland category occur in a variety of wetland habitats, ranging from the driest wetlands to semipermanently flooded wetlands.

The actual frequency of occurrence of a specific species in wetlands may be anywhere within the frequency range of the indicator category. For example, some species assigned to the Facultative Upland indicator category may actually have a frequency toward the lower end of the category whereas other species may actually have a frequency toward the upper end of the category.

Definitions of terms were obtained directly from the NWI 1996 Introduction accompanying the National List of Vascular Plant Species that Occur in Wetlands which was developed by the U.S. Fish and Wildlife Service. The list is available for downloading on the World Wide Web http://www.nwi.fws.gov/ecology.htm. A copy of the first page of the list is presented below.

National List of Vascular Plant Species that Occur in Wetlands: 1996 National Summary

Indicator by Region and Subregion

Scientific Name/ Subregion	Northeast	Southeast	North Central	North Plains	Central Plains	South Plains	Southwest	Inter-mountain	Northwest	California	Alaska	Caribbean	Hawaii	National Indicator Range
Abies amabilis (Dougl. ex Loud.) Dougl. ex Forbes									FACU	FACU	UPL			UPL,FACU
Abies balsamea (L.) P. Mill.	FAC		FACW											FAC,FACW
Abies concolor (Gord. & Glend.) Lindl. ex Hildebr.	NI				NI		NI	NI	NI	UPL				UPL
Abies fraseri (Pursh) Poir.	FACU	FACU												FACU
Abies grandis (Dougl. ex D. Don) Lindl.									FACU-*	NI				FACU-*
Abies lasiocarpa (Hook.) Nutt.				NI	NI		FACU+	FACU-	FACU	FAC	UPL			UPL,FAC
Abies magnifica A. Murr.	NI							UPL	NI	FACU				UPL,FACU
Abildgaardia ovata (Burm. f.) Kral		FACW+										FAC+		FAC+,FACW+
Abutilon theophrasti Medik.	UPL	FACU-	FACU-	UPL	UPL	UPL	UPL	UPL	NI	NI				UPL,FACU-
Acacia choriophylla Benth.		FAC*												FAC*
Acacia farnesiana (L.) Willd.		FACU					NI			NI*		NI	NI	FACU
Acacia greggii Gray						UPL	UPL	FACU		FACU				UPL,FACU
Acacia macracantha Humb. & Bonpl. ex Willd.		NI										FAC		FAC
Acacia minuta ssp. minuta (M.E. Jones) Beauchamp							FACU							FACU
Acaena exigua Gray													OBL	OBL
Acalypha bisetosa Bertol. ex Spreng.												FACW		FACW
Acalypha virginica L.	FACU-	FACU-	FAC-	FACU-	FACU-	FACU*								FACU-,FAC-
Acalypha virginica var. rhomboidea (Raf.) Cooperrider	FACU-	FAC-	FACU	FACU-	FACU-	FACU*								FACU-,FAC-
Acanthocereus tetragonus (L.) Humm.		FAC*				NI						NI		FAC*
Acanthomintha ilicifolia (Gray) Gray										FAC*				FAC*
Acanthus ebracteatus Vahl													OBL	OBL
Acer circinatum Pursh									FAC-	FAC	NI			FAC-,FAC
Acer glabrum Torr.				FAC	FAC		FAC	FACU	FACU*	FAC	FACU			FACU*,FAC
Acer grandidentatum Nutt.					NI	NI	NI	FACU	NI					FACU
Acer macrophyllum Pursh									FACU	FAC				FACU,FAC
Acer negundo L.	FAC+	FACW	FACW-	FAC	FAC	FACW-	FACW-	FAC*	FAC+	FACW				FAC*,FACW
Acer nigrum Michx. f.	FACU*	UPL	NI	NI	NI									UPL,FACU*
Acer pensylvanicum L.	FACU	FACU-	FACU											FACU-,FACU
Acer platanoides L.	UPL	NI	NI											UPL,FACU*
Great Lakes Plain	*FACU**													
Acer rubrum L.	FAC	FAC	FAC			FAC								FAC,FACW
Coastal Plain		*FACW*												

Appendix 2:

Web Resources

Web Resources

Pennsylvania Organizations

Pennsylvania Department of Conservation and Natural Resources
http://www.dcnr.state.pa.us

Pennsylvania's Department of Environmental Protection
http://www.dep.state.pa.us

Pennsylvania Fish and Boat Commission
http://www.fish.state.pa.us

Pennsylvania Game Commission
http://www.state.pa.us/PA_Exec/PGC/index.htm

Pennsylvania Natural Resources Conservation Service
http://www.pa.nrcs.usda.gov

Pennsylvania Spatial Data Access (PASDA)
http://www.pasda.psu.edu

Pennsylvania State University Center for Watershed Stewardship
http://www.larch.psu.edu/watershed/watershedstewardship.html

Pennsylvania Trout Unlimited
http://www.patrout.org

EPA Region 3 Water Protection Division
http://www.epa.gov/reg3wapd

U.S. Fish and Wildlife Service - Pennsylvania Field Office
http://www.fws.gov/r5fws/pa/pennfo.htm

National Organizations

Alliance for the Chesapeake Bay
http://www.acb-online.org

American Rivers
http://www.amrivers.org

Center for Watershed Protection
http://www.pipeline.com/~mrrunoff/

Chesapeake Bay Foundation
http://www.cbf.org

Chesapeake Bay Program
http://www.chesapeakebay.net/bayprogram

Ducks Unlimited
http://www.ducks.org

Environmental Concern, Inc.
http://www.wetland.org

EPA Office of Wetlands
http://www.epa.gov/owow/wetlands/

EPA Office of Water
http://www.epa.gov/owow

EPA Surf Your Watershed
http://www.epa.gov/surf

National Wetlands Inventory Homepage
http://www.nwi.fws.gov

National Wetland Research Center
http://www.nwrc.gov

The Nature Conservancy
http://www.tnc.org

River Network
http://www.rivernetwork.org

Society of Wetland Scientists
http://www.sws.org

Trout Unlimited
http://www.tu.org

USDA Forest Service Home Page
http://www.fs.fed.us

The Wetlands Regulation Center
http://www.wetlands.com

Wetland Science Institute
http://www.pwrc.usgs.gov/wli

Appendix 3:

Habitat Suitability Models

PAM HEP HSI MODEL

Species: Bullfrog (Rana catesbeiana)
Cover Types: Palustrine Emergent, Scrub/Shrub, and Forested Wetlands

Revised models 1994

Life History:

Eggs are deposited as a thin film on the water surface usually around plant material. Tadpoles require shallow water with protective cover along the water's edge for larval transformation. Permanent water must be available for one year to complete the larval life stage.

Bullfrogs eat a wide variety of vertebrate and invertebrate foods although insects, crayfish and amphibians form the bulk of their diet. They are opportunistic feeders, feeding on whatever is most available. Tadpoles feed mainly on diatoms and other algae with small amounts of animal food. Juvenile frogs are largely insectivorous.

Permanent water with both shallow and deep water and submergent vegetation provide optimal bullfrog habitat. Bullfrogs are generally found along the water's edge where there are overhanging tree branches, tall grasses or debris, snags, etc., on the ground. Although frequently associated with dense emergent plant growth such as pickerel weed, lilypads, cattails, and sedges, bullfrog populations also occasionally occur along open shallow edges of reservoirs, cattle ponds, wells and intermittent streams.

Juvenile bullfrogs in Illinois selected very shallow water with abundant short emergent growth vegetation and debris for cover. Density of mature frogs was dependent on the amount of dense cover. Because of their territorial behavior, adult frogs were spaced out further in more open areas. Bullfrogs use deeper water as escape cover. Survival of larval and adult frogs was reduced in mud bottom ponds lacking debris or vegetation.

Bullfrogs prefer larger bodies of water than most frogs. They will use both standing water habitat and slow moving portions of streams. Small streams are used when more optimal habitat is not available. Bullfrogs require permanent water.

Life Requisite Factors:

Factor	Conditions	Value
Breeding	1. Water: (limiting factor)	
	No surface water	0.0
	Seasonal water > 45cm (18”)	0.0
	Seasonal water < 45cm (18”)	0.0
	Permanent water > 45cm (18”)	0.8
	Permanent water < 45cm (18”)	1.0
	2. Water Current:	
	Fast flowing water (>1m/sec)	0.0
	Moderately fast (0.6-1m/sec)	0.3
	Moderately slow (0.15-0.6m/sec)	0.7
	Still water or slow (<0.15m/sec)	1.0

Cover	3. Percent herbaceous canopy cover, debris, snags, overhanging brush, etc., along shore and in the littoral zone	
	0%	0.0
	25%	0.3
	50-75%	0.7
	>75%	1.0
	4. Wetland cover type	
	Open water	1.0
	Emergent	1.0
	Field	0.7
	Shrub/scrub	0.5
	Forested	0.0

HSI Determination: [(V1+V2+V3)/3]V4
Limiting Factor: V1 (if V1 is 0, then HSI is 0)

References: WELUT Draft Model, Bullfrog, April 1980

Developed by: Richard W. McCoy, March 15, 1985, USFWS, State College, PA
Revised by: Robert P. Brooks, Diann J. Prosser, July 1994, Penn State Cooperative Wetlands Center, Forest Resources Laboratory, Pennsylvania State University, University Park, PA 16802.

PAM HEP HSI MODEL

Species: Muskrat (Ondatra zibethicus)

Cover types: Emergent wetlands
Riparian wetlands
Lacustrine wetlands

Revised model, 1994

Life History:

Good muskrat habitat is characterized by permanent, slow-moving water, emergent vegetation, and suitable bank den sites. Home range size averages approximately 60 m (200 ft) in diameter in marshes and to 305 m (1,000 ft) of shoreline in stream environments.

Although young muskrats may be found in either lodges or burrows, studies in Massachusetts, New York, and Pennsylvania indicate muskrat productivity is directly related to the availability of suitable bank burrows.

The primary foods of muskrats are stems, leaves, and rootstocks of emergent vegetation. When present, cattail is usually the dominant food species. In marshes, emergent vegetation should constitute a minimum of 5% of the area, with the optimum amount being 67% or more. In streams, herbaceous bank vegetation and riparian shrub thickets are utilized as important food sources.

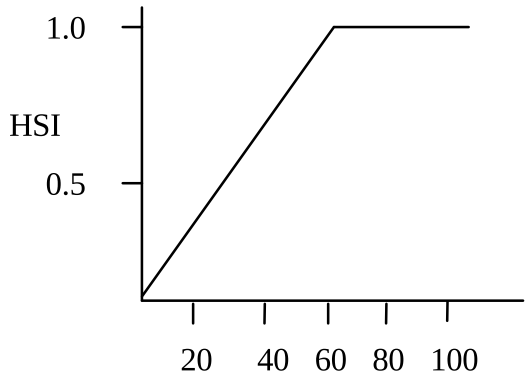
In marshes, cover is provided by dense stands of emergent vegetation supplemented by logs, trees, and shrubs. In stream environments, cover is provided by the same areas that provide food.

Optimum water values are provided by permanent water flowing very slowly. Semi-permanent water and/or water flowing at a faster rate will be utilized by muskrats, but there will be a decreased degree of suitability.

Life Requisite Factors:

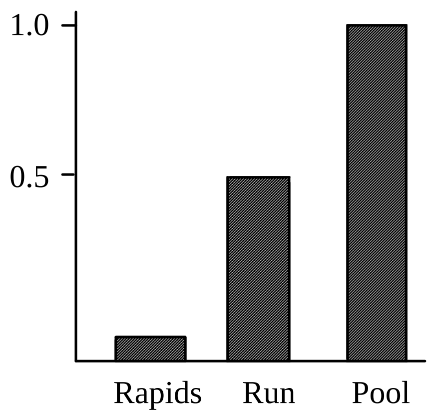
STREAM CONDITIONS:

Factor	Conditions	Value
Water Permanence	1. No permanent water	0.0
	Permanent water ≤ 15cm (6")	0.2
	Permanent water > 61cm (24")	0.7
	Permanent water 15-61cm (6-24")	1.0
Riparian bank	2. Percent herbaceous vegetation within 10m of stream	
	0%	0.0
	30%	0.5
	≥60%	1.0
	(see graph)	



Percent herbaceous vegetation

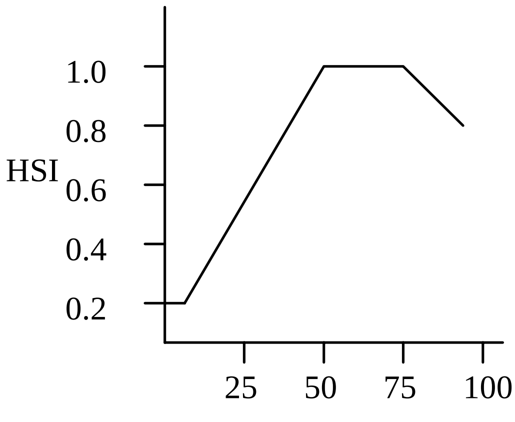
Stream class	3. Rapid / riffles dominate	0.1
	Run	0.5
	Pool / backwater	1.0



Bank Characteristics	4. (average of both sides)	
	≤ 20cm (8") ht., ≤10% slope <u>or</u> badly eroded	0.0
	20-50cm (8-20") ht., 10-20% slope with moderate erosion	0.3
	20-50cm (8-20") ht., 10-20% slope with stable banks	0.5
	> 50 cm ht., > 20% slope and moderate erosion	0.7
	> 50 cm ht., > 20% slope and stable banks	1.0
	5. Distance to emergent vegetation	
	Emergent veg. negligible or > 300m (985') of site	0.2
	Emergent veg. moderately abundant and within 200m (655') of site	0.5
	Emergent veg. abundant and within 100m (330') of site	1.0

MARSH CONDITIONS (NO STREAM):

Factor	Conditions	Value
	1. Percent herbaceous vegetation cover (vs. OW or woody cover)	
	≤5%	0.2
	25%	0.5
	>75%	0.8
	50-75%	1.0



	2. Interspersion	
	Open water with negligible herbaceous veg or herbaceous veg with negligible open water or both are negligible	0.2
	Herbaceous veg is 5 - 50% and open water is 25% of total area	0.5
	Herbaceous veg in a few large patches is 50-100% of area	0.8
	Herbaceous veg in numerous scattered patches is 50-75% of total area	1.0
	3. Water permanence (limiting factor)	
	No permanent water	0.0
	Permanent water ≤15cm (6")	0.2
	Permanent water > 61cm (24")	0.7
	Permanent water 15-61cm (6-24")	1.0

HSI Determination

STREAM CONDITIONS: [(V2 + V3 + V4 + V5) / 4] x V1
MARSH CONDITIONS: [(V1 + V2) / 2] x V3

Revised by Robert P. Brooks, Diann J. Prosser, July 1994, Penn State Cooperative Wetlands Center, Forest Resources Laboratory, Pennsylvania State University, University Park, PA 16802.

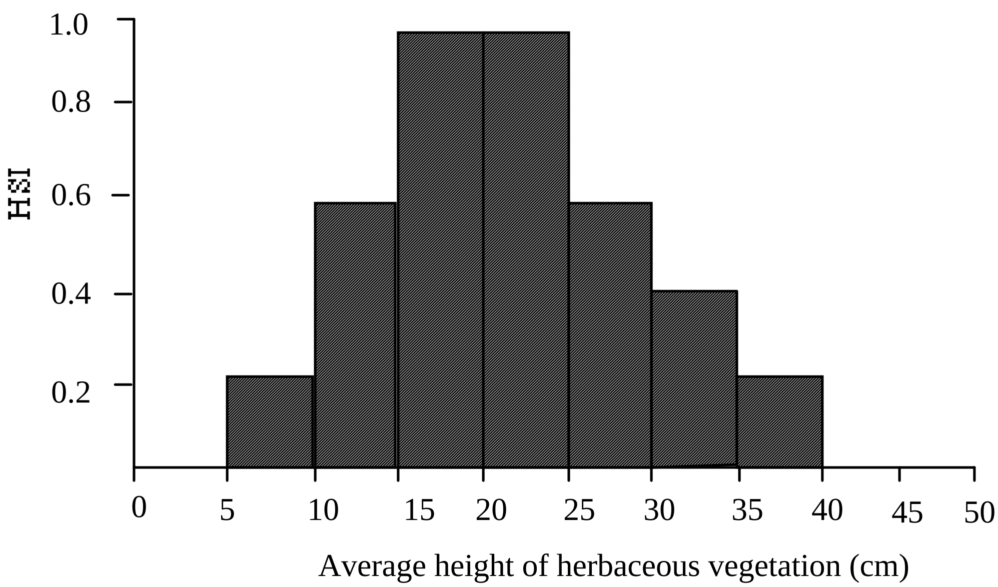
PAM HEP HSI MODEL

Species: Meadow Vole (Microtus pennsylvanicus)
Cover types: Emergent wetland
Revised model, 1994
Life History:
Meadow voles inhabit grassy areas, preferably moist, and all life requisites can be provided by a single cover type. Home range size varies widely and may be density dependent.
Breeding - The young are born above ground in grassy nests or in pockets connected with underground burrows.
Food - Grass species are the major food eaten by meadow voles. A small amount of insects are also consumed. Food preference is generally determined by plant species availability. During the winter, meadow voles still eat bark from trees and shrubs.
Cover - Meadow voles inhabit moist grassy areas along streams, lakes, and swamps. They will also live in grassy old fields, orchards, fence rows, right-of-ways, pasture, and haylands. The primary cover requirement is the availability of dense grassy vegetation. Voles have been found, in various studies, to be most abundant when herbaceous cover in 80% or greater, grasses or grass-like species comprise 50% or more of the herbaceous cover, and the vegetation height is between 10 and 30 cm (4" and 9"). Wooded areas are avoided. Runways are constructed from herbaceous vegetation to enhance cover for travel. Voles may also use underground burrows.
Water - Voles prefer moist areas but have no specific water requirements.

Life Requisite Factors:

Factor	Conditions	Value
Breeding	Not a limiting factor. Needs met by food/cover requirements	
Food/Cover	1. Percent herbaceous crown cover (do not include moss)	
	0%	0.0
	40%	0.5
	≥ 80%	1.0

2. Average height of herbaceous vegetation (avg. annual conditions)

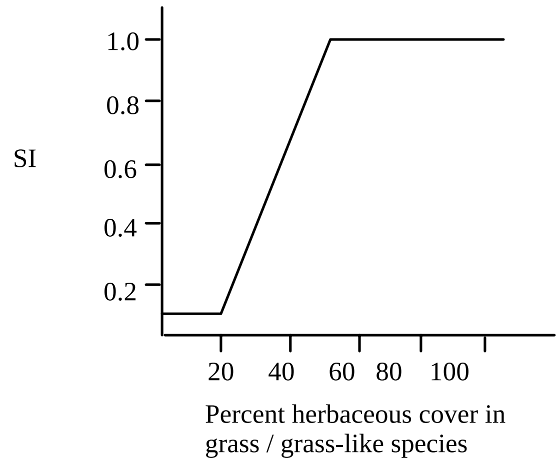


3. Density of herbaceous vegetation

sparse	0.0
moderate	0.7
dense	1.0

4. Percent herbaceous crown cover in grass or grasslike species

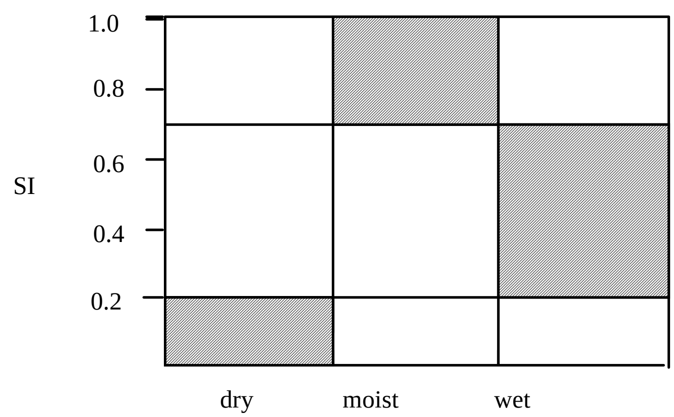
20%	0.1
35%	0.5
50% or more	1.0



5. Soil moisture (average conditions)

Hard or powdery dry soils	0.1
Wet soils with presence of standing water	0.5
Moist soils with no standing water	1.0

(see graph)



<u>HSI Determination</u>:

Food / Cover SI = $[V1 + (V2 \times V3 \times V4)^{1/3} + V5] / 3$

Note: 0.0 SI values for V1 and V2 are limiting and the resulting Food/Cover SI will be 0.0.
Water is not a limiting factor. Needs met by food/cover requirements

<u>Reference</u>: WELUT Draft Model, Meadow Vole, June 1979. <u>Revised</u>: February 1985, Richard W. McCoy, Fish and Wildlife Biologist, USFWS. October 30, 1987, J. Hugh Palmer, Game Biologist, PAGC. August 1994, Robert P. Brooks, Diann J. Prosser, Penn State Cooperative Wetlands Center, Forest Resources Laboratory, Pennsylvania State University, University Park, PA 16802.

PAM HEP HSI MODEL

Species: Red-winged Blackbird (Agelaius phoeniceus)

Cover types: Emergent wetland
Shrub-Scrub wetland*
Forested wetland*
* These wetland types are evaluated only if they contain a significant emergent component .

Revised model, 1994

Life History:

The red-winged blackbird is both a summer and winter resident in Pennsylvania. They occur in a diversity of habitat types including shrub and herbaceous wetlands, old fields, grain and hay fields, and pasture.

Red-winged blackbirds prefer wetland habitat for nesting, but can also successfully nest in upland habitats. Optimal wetland nesting is in broad-leafed monocotyledons (primarily Typha spp. and Carex spp.), 30 to 60 cm (1 - 2') tall located over water that is deeper than 25 cm (10").

An additional requirement for nesting habitat is the presence of elevated song perches needed in territory selection and establishment. Territory size ranges from 0.15 to 0.20 ha (0.37 to 0.50 ac) in wetlands.

Food is generally not a limiting factor if breeding/nesting and cover requirements are met. Red-winged blackbirds are opportunistic feeders and consume vegetative matter (herbaceous fruits including grain, softwood and hardwood fruits), animal matter (insects, arthropods, worms, snails, crustaceans, and other invertebrates), and grit.

If breeding/nesting requirements are met, then cover will not be a limiting factor.

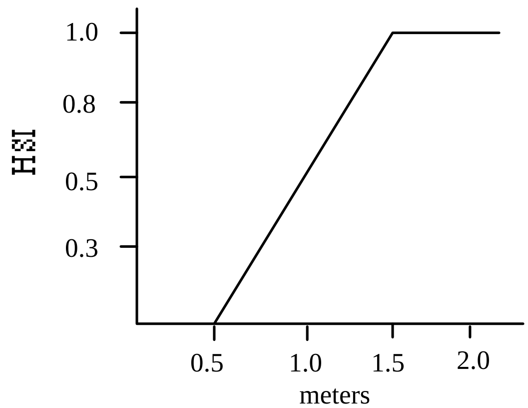
Water is a factor which enhances breeding potential and decreases the degree of predation, and is considered as a function of the breeding/nesting requirements. Drinking water is not a limiting factor.

Life Requisite Factors:

Factor	Conditions	Value
Breeding/ Nesting	1. Area in herbaceous canopy cover	
	0% of area in herbaceous canopy cover	0.0
	15% of area in herbaceous canopy cover	0.5
	30% -50% of area in herbaceous canopy cover, especially dense stands that would readily support nests	0.7
	50% or more " "	1.0

2. No surface water present during breeding season 0.1
   Standing surface water present during **early** breeding season 0.5
   Standing surface water present during **entire** breeding season, or adjacent perennial stream present **< 15cm (6")** in depth 0.8
   Standing surface water present during **entire** breeding season, or adjacent perennial stream present ≥ **15cm (6")** in depth 1.0

3. Average height of herbaceous canopy cover during breeding season



Breeding/nesting SI = (V1+ V2+V3) / 3

Note: 0.0 value for V1 is limiting and resulting Breeding/Nesting SI will be 0.0

Food is not a limiting factor
Cover is integrated with Breeding/Nesting requirements
Water is integrated with Breeding/Nesting requirements

<u>HSI Determination</u>: HSI is equal to Breeding/Nesting SI

<u>References</u>: WELUT HSI model, Red-winged Blackbird, April 1980.
PA Fish and Wildlife Database.

Developed: April 12, 1983, by Calvin DuBrock, Data Base Manager, PAGC.
Revised December 10, 1987, by J. Hugh Palmer, Game Biologist, PAGC.
Revised April 1991, by Robert P. Brooks, Associate Professor of Wildlife Science, and Mary Jo Croonquist, Research Technologist, School of Forest Resources, Pennsylvania State University.
Revised August 1994, by Robert P. Brooks, Diann J. Prosser, Aug. 1994, Penn State Cooperative Wetlands Center, Forest Resources Laboratory, Pennsylvania State University, University Park, PA 16802.

PAM HEP HSI MODEL

Species: Common Yellowthroat (*Geothlypis trichas*)

Cover types: Emergent (persistent) wetland, Shrub/Scrub wetland

Revised model, 1994

Life History:
The common yellowthroat inhabits grass - shrub communities of old fields and forest edges near water, marshes, or swamps. The yellowthroat feeds by gleaning among leaves (Willson, 1974). The bird's diet includes beetles, grubs, larvae, butterflies, moths, flies, ants, spiders, plant lice, leafhoppers, leaf rollers, and cankerworms (Bent, 1953).

No drinking water requirements were found in the literature. Yellowthroats prefer areas bordering marshes, swamps, springs, and small brooks (Bent, 1953). This may be related to a preference of the vegetation present in these areas rather than a water requirement (Kendeigh, 1945).

Dense low vegetation is used for cover (Bent, 1953). The most suitable habitat for the yellowthroat has moist to wet soil with trees and thickets 0.91 to 4.2m (3 to 15') tall and dense tangled vegetation less than 0.91m (3') high.

Nest are built up to 0.91m (3') from the ground (Preston and Norris, 1947) in tangled vegetation along brooks, margins of swamps, woodlands, or in grasses and sedges near marshes (Bent, 1953).

No special habitat requirements were found in the literature.

The territory size of the yellowthroat is 0.32 to 0.73 ha (0.8 to 1.8 ac) with an average size of 0.5 ha (1.26 ac) (Stewart, 1953). Suitable habitat for yellowthroats includes brush, old fields, and early successional stages near permanent water or marshes.

Brown-headed cowbirds are sometimes nest parasites on this species (Stewart, 1953).

Life Requisite Factors:

Factor	Conditions	Value
Food	1. Percent of shrub crown cover	
	0 - 25%	0.1
	26 - 50%	0.5
	51 - 75%	1.0
	76 - 100%	0.7
	2. Average height of shrubs	
	1 - 2 m (3-7')	1.0
	2 - 4 m (7-14')	0.5
	> 4 m (14')	0.2
	no shrubs, or < 1m	0.0

Breeding/Nesting	3. Same as V1	
	4. Same as V2	
	5. Percent herbaceous cover (relative to other veg cover; i.e. not including herbaceous cover under shrubs).	
	< 25%	0.7
	25 - 50%	1.0
	51 - 75%	0.5
	>75%	0.1
	6. Percent of grass or grass-like plants of the herbaceous cover	
	20%	0.2
	50%	0.5
	100%	1.0
Special value	7. Soil moisture	
	dry soil; no permanent water	0.0
	dry soil; permanent water	0.5
	moist	1.0
	wet	1.0
	open water	1.0

HSI Determination

Food value: $(V1 \times V2)^{1/2}$
Breeding/Nesting: $[(V3 \times V4)^{1/2} + (V5 \times V6)^{1/2}] / 2$
Special value: V7
The HSI score is the lowest of the 3 above values.

References:
Bent, A.C. 1953. Life Histories of North American Wood Warblers. Bull. 203. U.S. Gov't. Printing Office, Washington, D.C. 734 pp.
Kendeigh, S.C. 1945. Community selection by birds on the Helderberg Plateau of New York. Auk 62: 408 - 436.
Preston, F.W., and R.T. Norris. 1947. Nesting heights of breeding birds. Ecology 28: 241 - 273.
Stewart, R.E. 1953. A life study of the yellowthroat. Willson Bull. 65 (2): 99-115.
Willson, J.F. 1974. Avian community organization and habitat structure. Ecology 55: 1017-1029.
Additional References:
USDA-Forest Service. 1971. Wildlife habitat management handbook. Southern Region.
Audyk, W.D., and K.E. Evans. 1975. In: Symposium on management of forest and range habitats for nongame birds. USDA-Forest Service. Gen. Tech. Rep.WO-1, 343 pp.

Developed: June 1978 by WELUT HSI Model
Revised by: Robert P. Brooks, Diann J. Prosser, July 1994, Penn State Cooperative Wetlands Center, Forest Resources Laboratory, Pennsylvania State University, University Park, PA 16802.

PAM HEP HSI MODEL

Species: American woodcock (Philohela minor)
Cover types: Young deciduous forests, Shrub/Scrub wetlands, Forested wetlands, Lowland hardwood, Old fields

Revised model, 1994

Life History:

The woodcock is dependent on moist soils for feeding. About 30-95% of their diet consists of earthworms. They also eat insects, and occasionally seeds. Earthworms are consumed in scrub land thickets. Soil texture is important; sandy-loam or loamy soils preferred.

Woodcocks use wooded areas for diurnal coverts and open fields for night time roosting. The best stands were less than 25 years old and deciduous. They seem to avoid conifers. Lowland areas dominated by alders are preferred in summer and fall.

Woodcocks use open areas of herbaceous vegetation for singing grounds. Nests are on the ground in woody or brushy areas usually within 50 yards of the singing grounds.

Life Requisite Factors:

Factor	Conditions	Value
Breeding	1. Herbaceous canopy cover > 80%	0.2
	Herbaceous canopy cover 60-80% or < 15%	0.5
	Herbaceous canopy cover 15 - 60%	1.0
	2. Average height of herbaceous canopy > 45cm (18")	0.0
	Average height of herbaceous canopy 30-45cm (12-18")	0.5
	Average height of herbaceous canopy < 30cm (12")	1.0
	3. Canopy coverage of trees or shrubs >60%	0.0
	Canopy coverage of trees or shrubs 0-15 or 40-60%	0.5
	Canopy coverage of trees or shrubs 15-40%	1.0
Food	4. % ground covered by litter 0-10%	0.0
	% ground covered by litter 10-20%	0.5
	% ground covered by litter 20-100%	1.0
	5. Soil coarse to moderately coarse, sandy; fine grained	0.2
	Soil fine textured, clay, loam-clay; soft and sticky	0.5
	Soil medium textured, loams, silt-loams and silt	1.0
	6. Soils dry - crumbles when compressed	0.2
	Soil damp - forms a cast when compressed	0.7
	Soil wet - drips when compressed	1.0

	7. Soil not possible to penetrate	0.0
	Soil difficult to penetrate	0.4
	Soil easily penetrated	1.0
Cover	8. If tree cover is < 15%, then V8 is ignored; use V9 only.	
	Overstory forest age class >25cm (10")	0.0
	Overstory forest age class 15-25cm (6-10")	0.5
	Overstory forest age class 15cm (<6")	1.0
	9. Shrub crown cover	
	Dominated by evergreen shrubs **or** deciduous shrub cover 0 - 15%	0.2
	Deciduous shrub cover 15-40%	0.5
	Deciduous shrub cover >40%	1.0

Water - not limiting except in droughts

HSI determination: 1) average each factor separately (breeding, food, cover)
2) take the lowest average of breeding, food, or cover

For small sites (< 1 ha) the HSI score may be lower because surrounding conditions are not taken into consideration. The breeding factor can be examined separately if necessary.

Reference: WELUT HSI Model, April 1980.

Revised by: Robert P. Brooks, Diann J. Prosser, July 1994, Penn State Cooperative Wetlands Center, Forest Resources Laboratory, Pennsylvania State University, University Park, PA 16802.

PAM HEP HSI MODEL

Species: Green-backed heron (Butorides virescens)
Cover types: Emergent wetland, Shrub/Scrub wetland, Forested wetland

Revised model, 1994

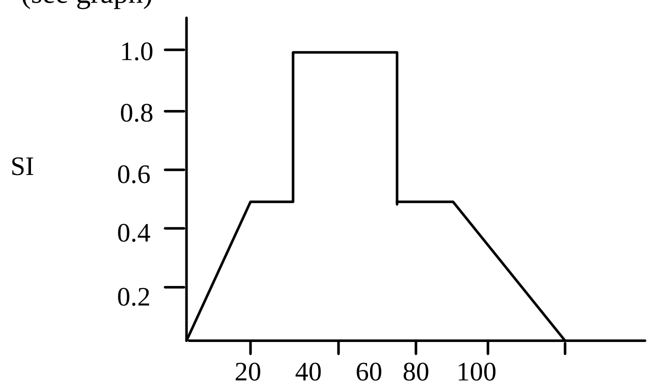
Life History:
Green-backed herons are wading birds that inhabit a wide range of aquatic environments. They are somewhat adaptable and general in their habitat preferences. Breeding cover is provided by woody material capable of supporting a nest in proximity of suitable feeding areas. Optimum breeding habitat is provided with suitable clumps of deciduous shrubs/trees within 0.4 km (0.25 mi). There must be some breeding cover within 1.6 km (1.0 mi).

Herons forage in openings, among emergent vegetation, and along soft, muddy borders of shallow water. Good feeding cover requires a muddy or sandy bottom, water less than 25cm (10") deep, and a moderate amount of vegetative cover. Cover is not generally limiting and is provided by the breeding and food requirements.

Green-backed herons require water. Permanent water provides the optimum value while semi-permanent will receive some utilization.

Life Requisite Factors:

Factor	Conditions	Value
Breeding	1. No shrubs	0.0
	Shrubs on - site or immediate adjacent but majority not overhanging water	0.5
	Shrubs on - site or immediate adjacent with majority overhanging water	1.0
	2. Percent of water surface covered by emergent vegetation, woody vegetation, logs, or trees:	
	35 - 60%	1.0
	20 - 35 or 60 - 75%	0.5
	0 or 100	0.0
	(see graph)	



Percent of water surface covered by emergent vegetation, woody vegetation, logs, or trees.

Water limiting factor	3. No surface water	0.0
	Seasonal water > 25cm (10") (majority)	0.3
	Seasonal water < 25cm (10")	0.5
	Permanent water > 25cm (10")	0.8
	Permanent water < 25cm (10")	1.0
	("Seasonal" water is considered to be surface water present for only part of the year, and "permanent" water is considered to be surface water present year - round). limiting factor	

HSI Determination: (V1+V2+V3) / 3 (if V3=0, then HSI=0)

Limiting Factor: V3

References: WELUT HSI Model, April 1980
PAMHEP HSI Model, Exton Bypass, October 1982

Developed by: J.H. Palmer, PAGC, April 13, 1982

Revised by: Robert P. Brooks, Diann J. Prosser, July 1994, Penn State Cooperative Wetlands Center, Forest Resources Laboratory, Pennsylvania State University, University Park, PA 16802.

PAM HEP HSI MODEL

Species: Wood duck (Aix sponsa)
Cover types: Emergent (persistent) wetland, Scrub/Shrub wetland, Forested Wetland (deciduous or mixed)

Revised model, 1994

Life History:
Wood ducks are primarily herbivores and forage on the ground or in shallow water. Daily foraging radius for flighted birds may be as much as 40 km (25 mi).

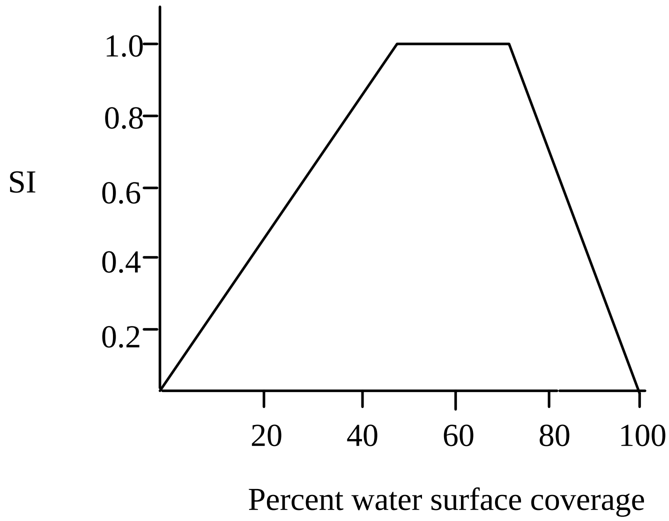
Breeding habitat is provided by suitable nest cavity sites within 0.8 km (0.5 mi) of suitable brood cover. A suitable nest cavity site is a tree cavity with an opening 8 cm (3") or more in diameter, 1.8 m (6') or more above ground level, and with a dbh of 40 cm (16") or more. Optimum nest cavity density is 5 or more cavities per acre of brood habitat. The cavity requirement may be met substituting maintained, predator-proof nest boxes for natural cavities at a ratio of 2:5.

Brood cover is provided by water areas with a combination of living and dead emergent vegetative surface cover. Optimum value is reached when from 50 to 75% of the water surface has such cover. A mixture of shrub and herbaceous cover is preferred to either type individually. Optimum cover includes buttonbush (Cephalanthus occidentalis). Minimum measured brood home range is 0.8 ha (2 ac). Brood areas smaller than 0.8 ha will be utilized if separated from other such areas by 46m (150') or less of terrestrial habitat, or connected by 0.4 km (0.25 mi) or less of riverine or lacustrine habitat.

Food and cover are not limiting factors. These requirements are provided by the breeding and water requirements. Wood ducks require water during the breeding season with the optimum value being provided by permanent water.

Life Requisite Factors:

Variable	Conditions	Value
V1	Nest cavities	
	No nest cavities with 0.8 km (0.5 mi) of brood habitat	0.0
	2.5 natural nest cavities (1 nest box) per acre of brood habitat within 0.8 km of such habitat	0.5
	5.0 natural nest cavities (2 nest boxes) per acre of brood habitat within 0.8 km of such habitat	1.0
V2	Water surface coverage	
	0% or 100% of water surface covered by emergent vegetation, woody vegetation, logs and trees.	0.0
	25% or 87% of water surface covered by emergent vegetation, woody vegetation, logs and trees.	0.5
	50% to 75% of water surface covered by emergent vegetation, woody vegetation, logs and trees.	1.0
	(see graph)	



V3	Vegetative cover	
	Vegetative cover primarily forested	0.2
	Vegetative cover provided primarily by either herbaceous or shrub species	0.4
	Vegetative cover provided by a mixture of herbaceous and shrub species	0.7
	Vegetative cover provided by a mixture of herbaceous and shrub species including buttonbush	1.0
V4 limiting factor	Water (If no permanent water, HSI is 0)	
	Permanent 1st or 2nd order stream	0.0
	Permanent 3rd order stream or river	0.7
	Permanent lake or marsh	1.0
V5	Landscape	
	Wet, forested / shrub	1.0
	Wet, emergent, open water	1.0
	Upland, forest / shrub	1.0
	Upland field / urban / agriculture	0.5

<ins>HSI Determination</ins>: [(V2 + V3 + V4) / 3] x V5
Breeding V1 - consider separately as a limiting factor (i.e. do not consider with overall HSI score)

<ins>References</ins>:

WELUT Draft Model, Wood Duck, March 1980.
PAM HEP HSI Model, Wood Duck, Loyalhanna Lake, Sept. 1982.
PAM HEP HSI Model, Wood Duck, Jacobs Creek, April 1983.
WELUT HSI Models, Wood Duck, July 1983

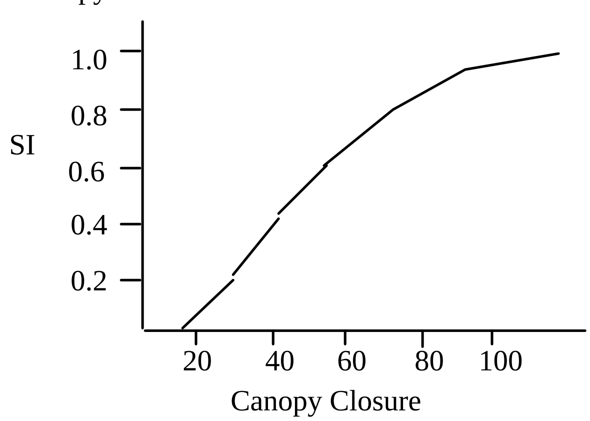
<ins>Developed</ins>: February 1, 1985, by Hugh Palmer, Game Biologist, PA Game Commission.
<ins>Revised by</ins>: Robert P. Brooks, Diann J. Prosser, July 1994, Penn State Cooperative Wetlands Center, Forest Resources Laboratory, Pennsylvania State University, University Park, PA 16802.

Species: Wood frog (Rana sylvatica)
Cover types: Deciduous Forest, Forested Wetland, Shrub/Scrub wetland
Revised model, 1994

Life History:
The wood frog occurs in cool moist upland and lowland hardwood forests. Forest margins of bogs are prime habitat. Ants are the most important food item. Other food includes beetles, spiders, and flies. Wood frogs tend to stay along the edge of permanent water. As pools dry up, they will bury in leaf litter for cover. In moist forested areas they are restricted to shaded areas or along stream borders. They require permanent or semi-permanent water during early spring (snow melt - June).

Life Requisite Factors:

Factor	Conditions	Value
Breeding	1. Water: (limiting factor)	
	Rapid/Riffles dominate	0.0
	Run dominates	0.3
	Pool / Backwater (≥25% of water), or temporary pond	1.0
	Large open water dominates	0.5
	No water	0.0
	Note: if no water even during breeding season, then entire HSI is 0.0.	
Cover	2. Soil moisture	
	Dry soil: crumbles when compressed; no cast	0.0
	Wet soil: drips water when compressed	0.5
Moist soil: forms cast when compressed; moldable		1.0
	3. Leaf litter	
	No leaf litter - bare ground	0.0
	Sparse leaf litter: 2.5cm (1") deep	0.5
	Abundant leaf litter: >2.5cm (1") deep	1.0
	4. Tree canopy closure	



HSI Determination: (V1 + V2 + V3 + V4) /4
References: WELUT Model, June 1978
Developed by: Richard W. McCoy, U.S. Fish and Wildlife Service, State College, PA.
Revised by: Robert P. Brooks, Diann J. Prosser, July 1994, Penn State Cooperative Wetlands Center, Forest Resources Laboratory, Pennsylvania State University, University Park, PA 16802.

PAM HEP HSI MODEL

Species: Southern Red-backed vole (Cleithrionomys gapperi gapperi)

Cover types: Evergreen, deciduous, and mixed forests; clearcuts within either forest type.

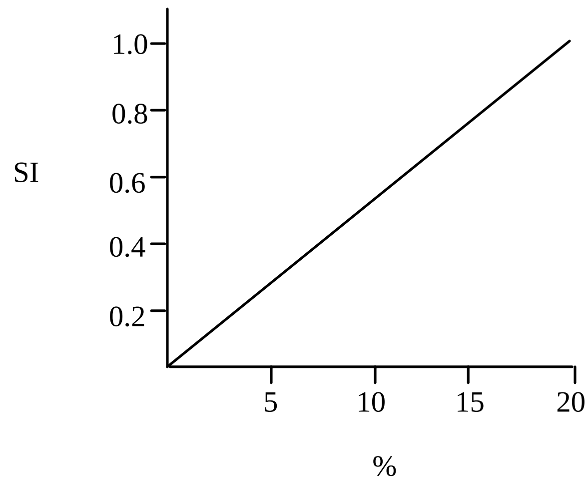
Geographic area: Pennsylvania and the Northeastern U.S.

Season: Year-round habitat
Modification of the U.S. Fish and Wildlife Service HSI model for the Southern Red-backed Vole in the western U.S. (Cleithrionomys gapperi), created by Arthur W. Allen.
Revised model, 1994

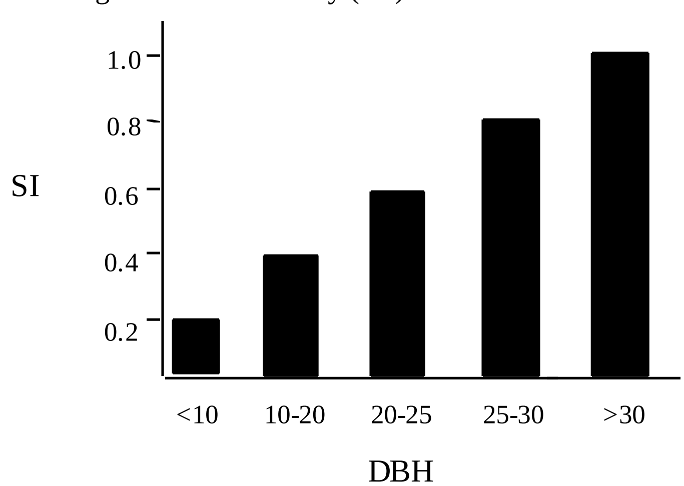
Life Requisite Factors:

Variable	Conditions	Value
V1	1. Forest type. Forested area must be ≥ 2 ha (5 ac). (includes surroundings).	
	no forest	0.0
	dry, deciduous forest	0.1
	wet, deciduous forest	0.6
	mesic, evergreen forest	0.8
	wet, evergreen forest	1.0

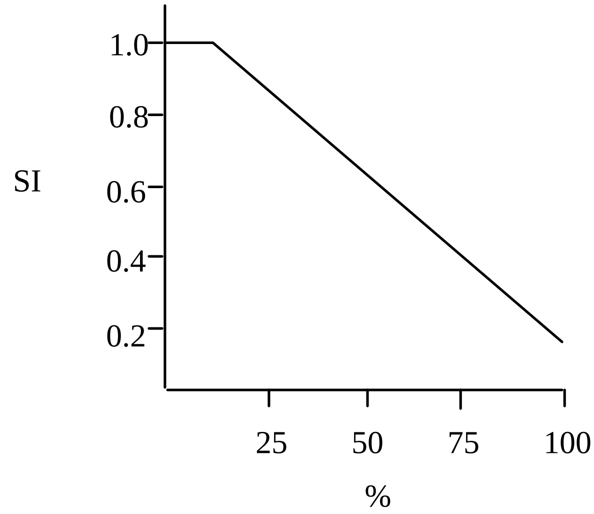
V2 2. Percent of ground surface covered by downfall ≥ 7.6 cm (3") in diameter (same as SI for western U.S.)



V3 3. Average DBH of overstory (cm)



V4 4. Percent Grass Canopy Cover
(Same as SI for western U.S.)



The same life requisites (food and cover) were adopted for both C. gapperi and C. gapperi gapperi. As long as the food and cover requirements are met, breeding requirements are assumed to be met. The above habitat variables relate to the food and cover requirements.

HSI Determination: [$(V2xV4)^{1/2}$ + V1 + V3] /3

References:

Getz, L.L. 1967. Influence of water balance and microclimate on the local distribution of the redback vole and white-footed mouse. Ecology 49:276-286.

Kirkland, G.L., Jr. 1977. Responses of small mammals to clearcutting of northern Appalachian forests. J. Mamm. 58:600-609.

Kirkland, G.L., Jr. 1978. Initial responses of small mammals to clearcutting of Pennsylvania hardwood forests. Proc. Pennsylvania Acad. Sci. 52:21-23.

Kirkland, G.L., Jr. 1990. Survey of the statuses of the mammals of Pennsylvania. J. Penna. Acad. Sci. 64:33-45.

Kirkland, G.L. Jr. 1991. Personal communication.

Merrit, J.F. 1981. Cleithrionomys gapperi. Mammalian Species 146: 1-9.

Merritt, J.F. 1987. Guide to mammals of Pennsylvania. University of Pittsburgh Press, Pittsburgh. 408pp.

Revised by:

Mary Jo Croonquist and Robert P. Brooks, 1990,School of Forest Resources, Penn State University, University Park, PA.

Robert P. Brooks, Diann J. Prosser, July 1994, Penn State Cooperative Wetlands Center, Forest Resources Laboratory, Pennsylvania State University, University Park, PA 16802.

Appendix 4:

Indicators of Wetland Hydrology, Plants and Soils

INDICATORS OF HYDROLOGY

The following hydrologic indicators can be assessed quickly in the field. Although some are not necessarily indicative of hydrologic events during the growing season or in wetlands alone, they do provide evidence that inundation or soil saturation have occurred at some time. One should use good professional judgment in deciding whether the hydrologic indicators demonstrate that the wetland hydrology criterion has been satisfied. When considering these indicators, it is important to be aware of recent extreme flooding events and heavy rainfall periods that could cause low-lying nonwetlands to exhibit some of these signs. It is, therefore, best to avoid, if possible, field inspections during and immediately after these events. If not possible, then these events must be considered in making a wetland determination. Also, remember that hydrology varies seasonally and annually as well as daily, and that at significant times of the year (e.g. late summer for most of the country) the water tables are at their lowest points. At these low water periods, signs of soil saturation and flooding may be difficult to find in many wetlands.

1). **Visual observation of inundation** - The most obvious and revealing hydrologic indicator may be simply observing the areal extent of inundation. However, both seasonal conditions and recent weather conditions should be considered when observing an area because they can affect whether surface water is present on a nonwetland site.

2). **Visual observation of soil saturation** - In some cases, saturated soils are obvious, since the ground surface is soggy or mucky under foot. In many cases, however, examination of this indicator requires digging a hole to a depth of 18 inches and observing the level at which water stands in the hole after sufficient time has been allowed for water to drain into the hole. The required time will vary depending on soil texture. Saturated soils may also be detected by a "squeeze test," which involves taking a soil sample within 18 inches (actual depth depends on soil permeability) and squeezing the sample. If free water can be extracted from the soil sample (indicating soil saturation), both the season of the year and the preceding weather conditions should be considered.

3). **Oxidized channels (rhizospheres) associated with living roots and rhizomes** - Some plants are able to survive saturated soil conditions (i.e., a reducing environment) because they can transport oxygen to their root zone. Look for iron oxide concentrations (orangish or reddish brown in color) forming along the channels of living roots and rhizomes as evidence of soil saturation (anaerobic conditions) for a significant period during the growing season.

4). **Water marks** - Water marks are found most commonly on woody vegetation but may also be observed on other vegetation. They often occur as stains on bark or other fixed objects (e.g., bridge pillars, buildings, and fences). When several water marks are present, the highest usually reflects the maximum extent of recent inundation.

5). **Drift lines** - This indicator is typically found adjacent to streams or other sources of water flow in wetlands and often occurs in tidal marshes. Evidence consists of deposition of debris in a line on the wetland surface or debris entangled in above-ground vegetation or other fixed objects. Debris usually consists of remnants of vegetation (branches, stems, and leaves), sediment, litter, and other water-borne materials deposited more or less parallel to the direction of water flow. Drift lines provide an indication of the minimum portion of the area inundated during a flooding event; the maximum level of inundation is generally at a higher elevation than that indicated by a drift line.

6). **Water-borne sediment deposits** - Plants and other vertical objects often have thin layers, coatings, or depositions of mineral or organic matter on them after inundation. This evidence may remain for a considerable period before it is removed by precipitation or subsequent inundation. Sediment deposition on vegetation and other objects provides an indication of the minimum inundation level. When sediments are primarily organic (e.g., fine organic material and algae), the detritus may become encrusted on or slightly above the soil surface after dewatering occurs.

7). **Water-stained leaves** - Forested wetlands that are inundated earlier in the year will frequently have water-stained leaves on the forest floor. These leaves are generally grayish or blackish in appearance, darkened from being underwater for significant periods.

8). **Surface scoured areas** - Surface scouring occurs along floodplains where overbank flooding erodes sediments (e.g., at the bases of trees). The absence of leaf litter from the soil surface is also sometimes an indication of surface scouring. Forested wetlands that contain standing waters for relatively long duration will occasionally have areas of bare or essentially bare soil, sometimes associated with local depressions.

9). **Wetland drainage patterns** - Many wetlands (e.g., tidal marshes and floodplain wetlands) have characteristic meandering or braided drainage patterns that are readily recognized in the field or on aerial photographs and occasionally on topographic maps. (CAUTION: Drainage patterns also occur in upland areas after periods of considerable precipitation; therefore, topographic position also must be considered when applying this indicator.)

10). **Morphological plant adaptations** - Many plants growing in wetlands have developed morphological adaptations in response to inundation or soil saturation. Examples include pneumatophores, buttressed tree trunks, multiple trunks, adventitious roots, shallow root systems, floating stems, floating leaves, polymorphic leaves, hypertrophied lenticels, inflated leaves, stems or roots, and aerenchyma (air-filled) tissue in roots and stems. As long as there is no evidence of significant hydrologic modification, these adaptations can be used as hydrologic indicators. Moreover, when these features are observed in young plants, they provide good evidence that recent wetland hydrology exists.

INDICATORS OF WETLAND PLANTS

There are hundreds of plant species that can grow and survive in aquatic environments. The identification of many of these species requires technical training in botany and related fields. However, there are some obvious plant species that are useful for making initial decisions that wetlands may be present on a given site. The classification system of the USFWS uses vegetative life forms as the primary means to categorize wetland types. Familiarity with the life forms of hydrophytes is a useful field tool. Brief descriptions of life forms and other wetland plant indicators are listed below:

Wetland Plant Life Forms

submergent - hydrophytes that require complete immersion, and are generally rooted in the bottom; require stable water levels, and most require relatively clear, unpolluted waters; examples include - pondweeds, wild celery, elodea, water milfoil, and fanwort.

floating - hydrophytes that are either free-floating on the surface (duckweed) or rooted in the bottom with major leaves floating on the surface; water levels can vary somewhat, but must be sufficiently deep during the growing season; water quality also can vary as they are more tolerant of nutrient loads than submergent species; examples include - yellow pond lily, water lily, and watershield.

emergent - rooted hydrophytes where most of the plant material is above the water surface; water levels must fluctuate for proper growth and seed germination (usually during drawdown in late summer); both persistent species (cattails, sedges, some rushes) and non-persistent species (burreed, arrowhead, pickerel weed) occur with the persistent types remaining upright and robust after frost and death in the fall.

herbs and forbs – broad-leaved herbaceous plants that typically grow either in the shallow water edges of wetlands, ponds, and streams, or in the drier areas of wetlands; examples include sunflowers, jewelweed, mints, and cardinal flower.

vine – a woody stemmed plant that typically grows on other plants or objects to obtain support; examples include grapes and poison ivy.

shrub – woody hydrophytes that usually prefer seasonally flooded conditions; defined by USFWS as plants less than 20 feet tall with single or multiple stems; species can be broad-leaved deciduous, or broad-leaved evergreen; examples include dogwoods, viburnums, and bog shrubs like leather leaf.

tree – woody hydrophytes that dominate forested wetlands; defined by USFWS as greater than 20 feet tall; species can be any combination of broad- or narrow-leaved, and/or deciduous or evergreen; examples include willows, green and black ash, pin and swamp white oak, black spruce, and most commonly, red maple.

Other plants, such as ferns, mosses, and algae commonly occur in wetlands, but are usually harder to identify with certainty. Plants have been categorized as to their likelihood of being found growing in wetlands by botanical experts brought together by the USFWS. The following conventions are used in the wetland plant lists: degree of wetland dependence according to Reed (1988) and Tiner (1988); OBL = obligate (>99% occurrence in wetlands), FACW = facultative wet (67-99%), FAC = facultative (34-66%), FACU = facultative upland (1-33%), UPL = upland (<1%).

Field Indicators of Wetland Plants

According to the federal jurisdictional manual, an area is considered wetland when the dominant plants (in terms of cover, number of stems, or visual estimate) are facultative or wetter types. That is, the prevalent vegetation has been positively identified such that the indicator status of these dominant species can be determined from the accepted USFWS plant lists (http://www.nwi.fws.gov/ecology.htm), and that there is more coverage by facultative, facultative wet, or obligate wet species than others preferring drier conditions. This determination requires strict adherence to the manual's criteria, and positive identification of the plants in question.

There are other characteristics and structural adaptations found on individual plants that indicate they have been exposed to saturated or flooded conditions over a long period of time (repeated time periods during the growing season, usually 7 continuous days or more).

Buttressed (swollen) tree trunks
Multiple trunks
Pneumatophores ("knees")
Adventitious roots (arising from stem above ground)
Shallow roots (often exposed at the surface)
Hypertrophied lenticels (larger than normal "bumps" on the stems)
Aerenchyma (air-filled tissue) in roots and stems
Polymorphic leaves (many or unusual shapes)

This collective information is used to identify and delineate jurisdictional wetlands. If any of these indicators appear to dominate a particular site, or portion of a site, then it is likely that wetlands are present. Experienced personnel that are familiar with wetland delineation methods should be called in to make a jurisdictional determination, and to delineate the boundaries of the wetland, if present.

INDICATORS OF WETLAND SOILS

There are many indicators that may be used to determine whether or not wetland soils are present on a given site. Any of these indicators may be used as the basis for a positive determination that wetland soils are present. The indicators presented below may be useful for quick field identification of wetland soils, but a soils scientist or wetland scientist should perform jurisdictional determinations or detailed field studies.

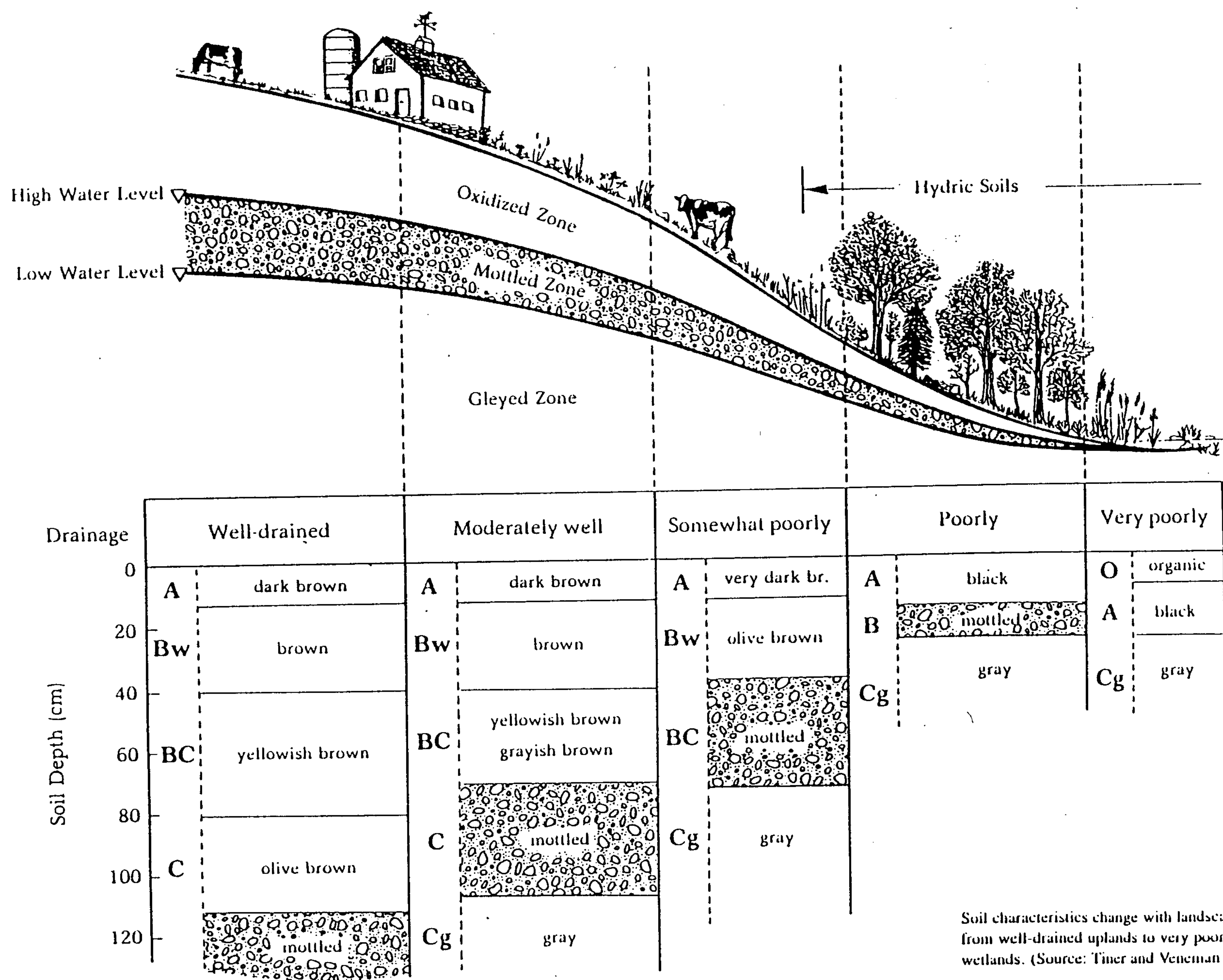
1) **Hydric soils –** A hydric soil is a soil that is saturated, flooded or ponded long enough during the growing season to develop anaerobic conditions in the upper part. Hydric soils are defined locally by the Soil Conservation Service, but a field determination must be made to be certain.

2) **Organic soils –** A soil is classified as an organic soil if: (a) more than half of the upper 80 cm (32 in.) of soil is composed of organic material; or (b) organic soil material of any thickness rests on bedrock. Organic soils are saturated with water for long periods and are commonly called peat or mucks. These types of soils make poor building sites because they are characteristically wet and unstable.

3) **Soil gleying –** Gleyed soils are developed under conditions of poor drainage resulting in reduction of iron and other elements which produces gray soil colors. The anaerobic conditions that occur in “water-logged” soils result in the predominance of reduction processes. Iron is one of the most abundant elements in soils. Under anaerobic conditions, iron is converted from the oxidized (ferric) state to the reduced (ferrous) state and thereby produces the bluish, greenish, or grayish colors associated with the gleying effect. Soils gleyed immediately below the surface layer give an indication of saturation and/or inundation for long periods and are considered to be wetland soils.

4) **Mottles with a chroma of 2 or less –** Soil color is the most widely used indicator under normal field conditions. Mottled means that the soil is marked with spots of contrasting color. If a soil layer has a matrix color of gray and a few spots of red and brown, then the spots are referred to as mottles. Chroma refers to the strength (departure from neutral) of a color, and value refers to lightness. Soils that have mottles, and with chromas of 2 or less are generally saturated for some time during the growing season. Wetland or hydric soils should have a dominant matrix with a chroma of 2 or less a few inches below the surface. Munsell color charts are used to rank soil chroma and value.

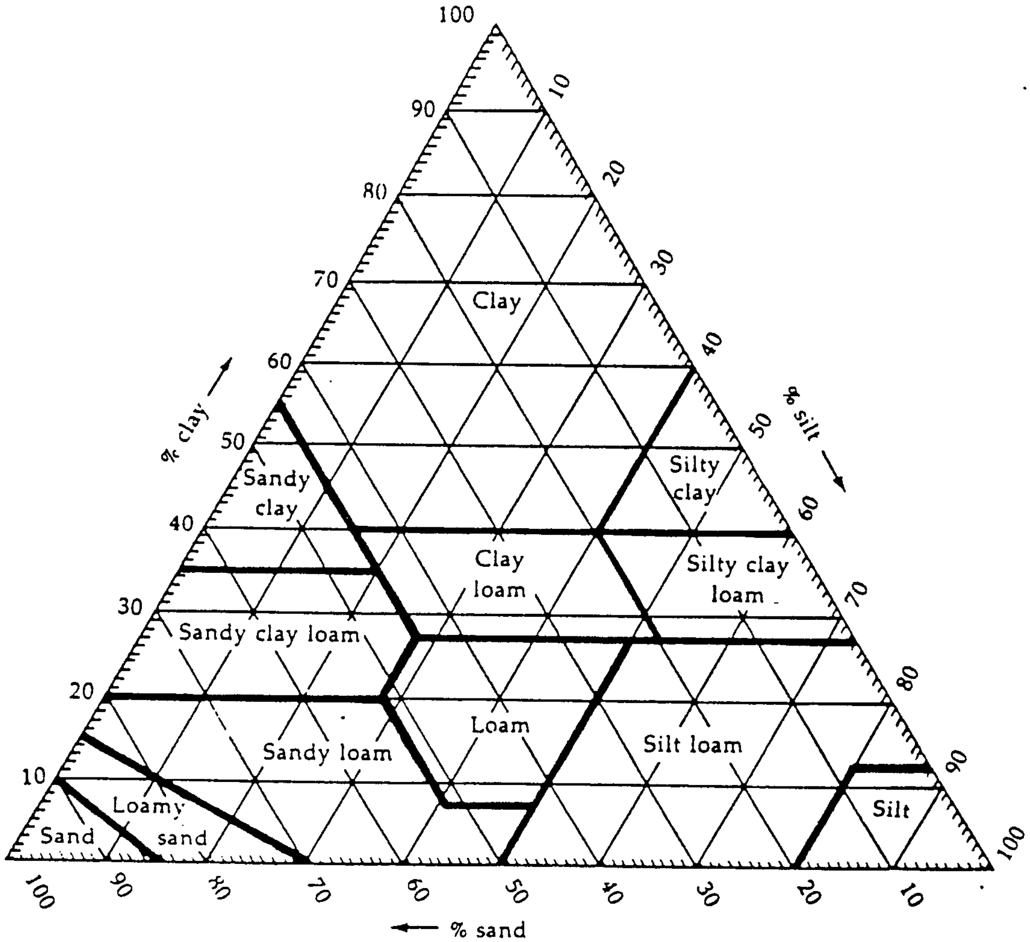
5) **Sulfidic material –** Water-logged mineral or organic soils sometimes contain 0.75 percent or more of sulfur. These soils usually have sulfidic material near the mineral soil surface and are permanently saturated at or near the soil surface. This can be detected by the “rotten egg” or sulfur dioxide odor.



Soil characteristics change with landscape position from well-drained uplands to very poorly drained wetlands. (Source: Tiner and Veneman 1989)

Tiner 1998. Reprinted with permission.

GUIDE FOR TEXTURAL CLASSIFICATION IN SOIL FAMILIES



COMPARISON OF THREE MAJOR SCHEMES OF PARTICLE SIZE DISTRIBUTION IN MILLIMETERS

International

Stones	Gravel	Coarse sand	Fine sand	Silt	Clay
20·0	2·0	0·2	0·02	0·002	

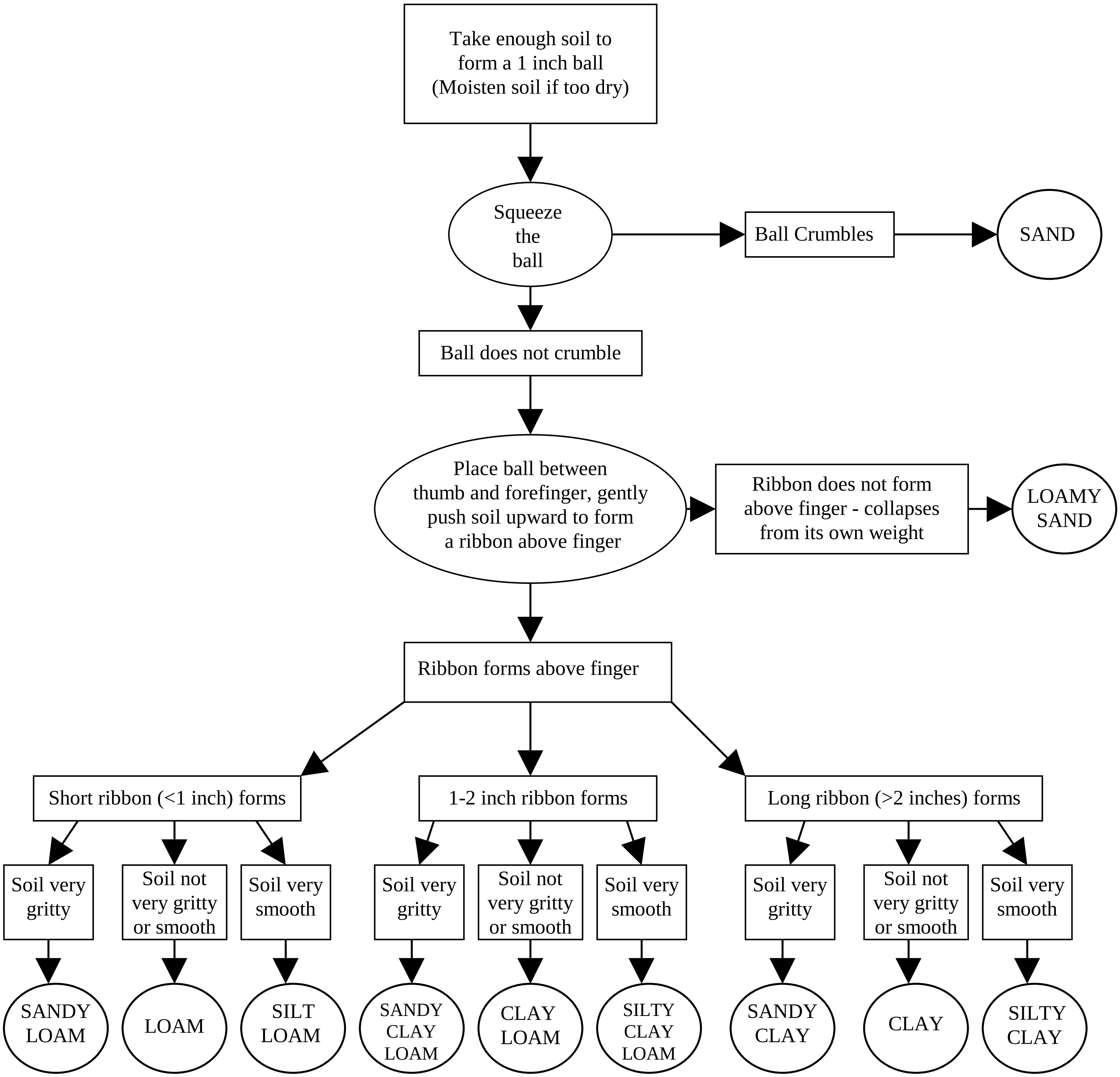
U. S. D. A.

Stones	Gravel	Very coarse sand	Coarse sand	Med. sand	Fine sand	V. fine sand	Silt	Clay
75·0	2·0	1·0	0·5	0·25	0·1	0·05	0·002	

U. S. S. R.

Stones	Gravel	Coarse sand	Med. sand	Fine sand	Coarse silt	Med. silt	Fine silt	Coarse clay	Fine clay	Colloidal clay
3·0	1·0	0·5	0·25	0·05	0·01	0·005	0·001	0·0005	0·0001	

STEPS FOR TEXTURING SOIL



Source: Adapted from Thien 1979; Tiner 1998. Reprinted with permission.

Appendix 5:

Metric Conversions

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

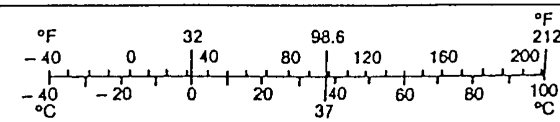
Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
	AREA			
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
	VOLUME			
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
	MASS			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
	AREA			
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
	VOLUME			
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
	MASS			
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
	TEMPERATURE (exact)			
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F



* SI is the symbol for the International System of Measurement

(Revised April 1989)

Appendix 6:

Procedures for Wetland Surface and Ground Water Monitoring Wells

PROCEDURES FOR WETLAND SURFACE AND GROUND WATER MONITORING WELLS

By Diann Prosser
Penn State Cooperative Wetlands Center

I. PURPOSE

1. To provide a standard and inexpensive method of determining the source of hydrology (surface or ground water) in reference wetlands and mitigated projects.
2. To facilitate the process of measuring water quality above and below ground level (pH, and conductivity).
3. To provide a means of obtaining hydroperiod data to form a hydrograph.

II. INTRODUCTION

This set of instructions is written for researchers and environmental consultants in the wetland field. General knowledge of wetland hydrology is assumed

Instructions are divided into 5 parts: Theory, Materials, Installation Procedures, Use and Monitoring of Wells, and Data Analysis. Section V describes methods for installing and using one well plot. To obtain useful data, however, more than one plot must be installed and monitored. Simply repeat these methods for each of the other plots you wish to establish.

> Note: Section V.E (Taking Elevations) is the only section which requires more than one person. If an extra person cannot be present at the tine of well installation, you can return to the plot within a day, with that person, to take the elevations.

In order to be efficient and successful, read these instructions in their entirety, then gather your materials. Just to be safe, bring this document to the site with you in case you need to refer to it.

III. THEORY

Wetland hydrology depends on partial or total soil saturation during various parts of the year. This saturation depends on depth to the free water table (surface water). We can measure the surface water level by inserting a slotted PVC pipe into the ground. The reason the pipe is slotted is to allow for free flow of water at this level.

Ground water is normally separated from the surface water by a confining layer of clay. As ground water follows a decreasing slope, confined by the clay layer, water pressure will build (Fig. 1.a). We can provide ourselves with a window to measuring ground water by inserting a solid PVC pipe (acting as a piezometer) through the surface water area, through the confining layer, into the ground water area. As this pressure builds, the water will find an "escape" (the pipe) through the confining layer. As the water is forced up the pipe, it forms a "head". This means that the water inside the pipe is forced, by pressure, to a level above ground surface (Fig. l.b).

Naturally, the free water table parallels the slope of the ground surface of a wetland. The ground water table also parallels this slope, but at a greater depth.

What does all this tell us? If the measured water depths are the same, then the wetland is supported by both ground and surface water. If there is a "head" in the piezometer, then the wetland is mainly supported by ground water. Finally, if water is found in the slotted pipe but not the peizometer, then the wetland is surface water fed.

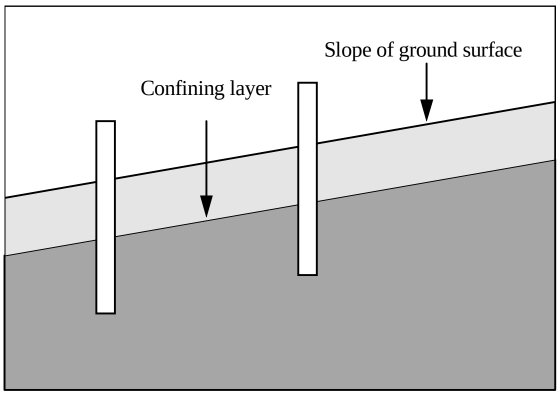


Figure 1.a

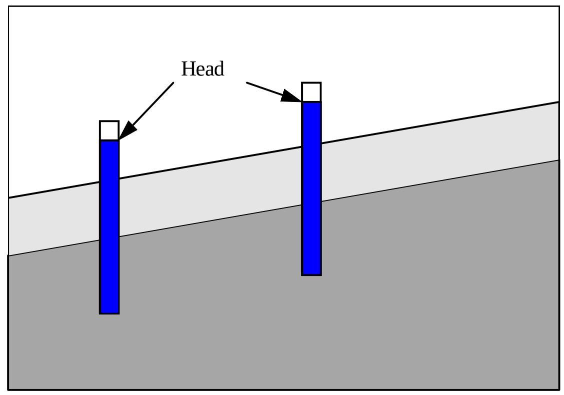


Figure 1.b

IV. MATERIALS

This method is designed to be effective as well as inexpensive. All materials can be purchased at the average hardware store. Total cost should not exceed $100 (costs will be much less if you have access to tools such as an auger, pocket knife, bow saw, transit, and stadia rod).

Supplies (single well plot)

1) slotted PVC pipe*
2) solid PVC pipe*
3) 2 PVC caps
4) 10 lb. bag of coarse sand
5) 20 lb. of bentonite clay
* 2 inches in diameter, 5 ft. in length

Tools

6) bucket auger, 2.5" diameter
7) bow saw
8) transit and stadia
9) carpenter's ruler
10) pocket knife
11) permanent marker

V. INSTALLATION PROCEDURES

A. CHOOSING LOCATION OF WELL PLOTS

1. Well plots should be established parallel to the hydrologic gradient (dark circles in Fig. 2). The number of plots depends on the size of the wetland. Spacing of 50 to 100 feet is usually sufficient. If resources allow, more than one transect can be established (lighter circles in Fig. 2).

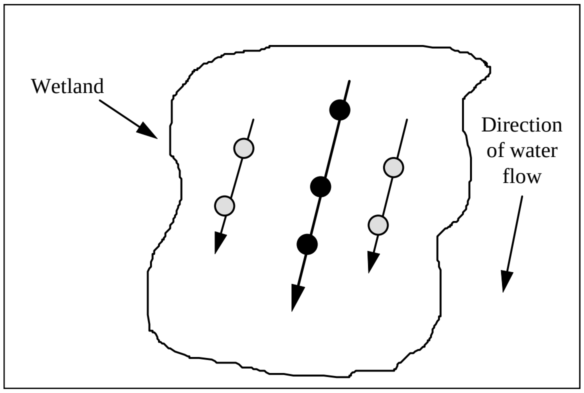


Figure 2

B. EXCAVATING HOLES

1. Use the 2.5" auger to dig a hole for each well (one for the slotted well, and one for the piezometer). Well holes should be placed within 2 feet of each other (Fig. 3.a). Keep the soil in a neat pile for later use.

   Note: Oftentimes large rock hinder the excavation process. Be sure the holes are at least 2 ft. deep; 4 ft. is the preferred depth. If you cannot dig at least 2 ft. deep, shift the well site over until the desired depth is reached (Fig. 3.b).

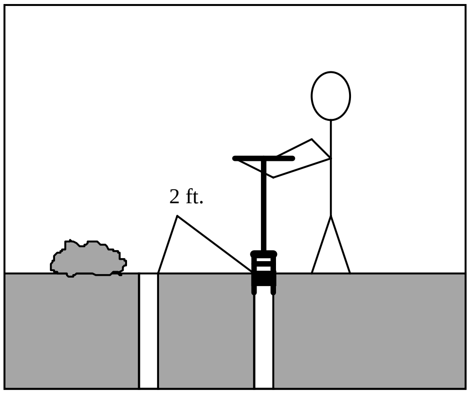


Figure 3.a

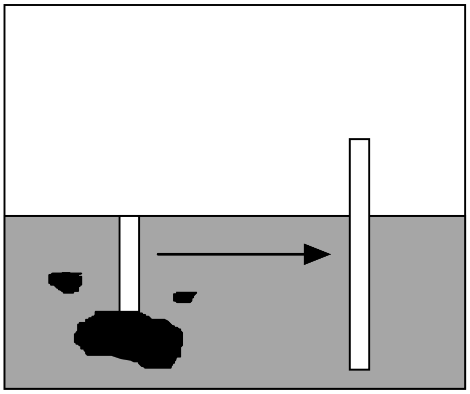


Figure 3.b

C. PREPARING FOR INSERTION OF PIPE

1. Add about 1 to 2 cups of sand to the bottom of each hole (this prevents the accumulation of soil or clay from clogging the bottoms of the wells) (Fig. 4.a).
2. Insert one well into each hole (if one hole is deeper, use it for the piezometer).
3. Place a mark on the pipe one foot above ground surface (Fig. 4.b).
4. Cut the pipes with the bow saw. Shave the edges of pipes with the pocket knife, until smooth (this helps keep the caps from becoming stuck on the pipes) (Fig. 4.c).

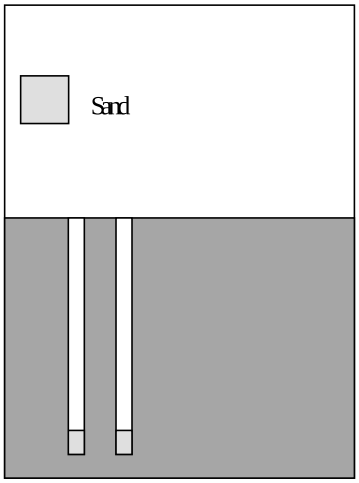


Figure 4.a

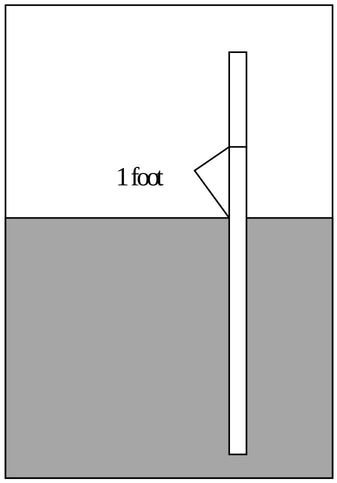


Figure 4.b

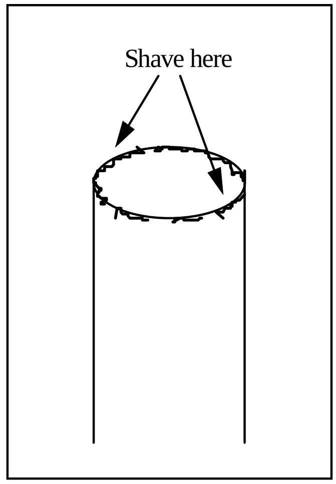


Figure 4.c

D. INSERTING WELLS

1. Reinsert the wells.
2. Fill excess space of the solid well with bentonite clay.
3. Fill excess space of the slotted well with sand (the sand allows for easy flow of water from the soil medium through the pipe, Fig. 5)

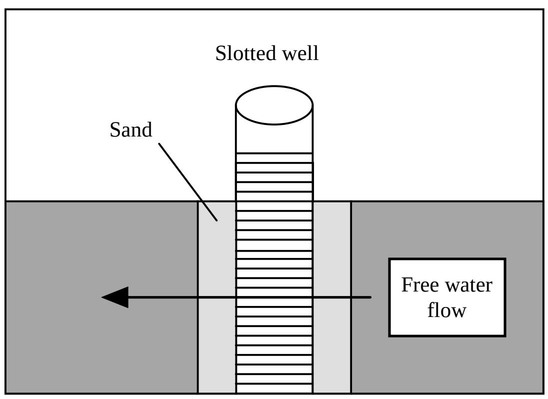


Figure 5

4.
5. Use soil extracted from digging to form a slight mound around the well to counter settling and avoid flow of excess surface water into the well (Fig. 6)
6. Place one cap **lightly** on each well to prevent rainwater and debris from entering the well.
   Note: Caps can be difficult to take off if put on too tightly

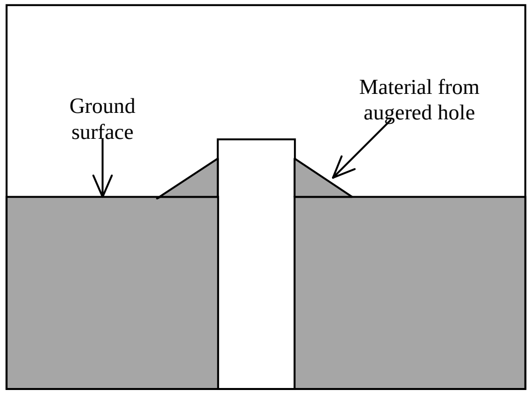


Figure 6

E. TAKING ELEVATIONS OF GROUND SURFACE

1. Take caps off the wells
2. Have person 1 hold the stadia rod on top of the **uncapped** slotted well (Fig. 7.a). Person 2 can read the elevation through the transit.
3. Have person 1 measure the distance from the top of the well to ground surface. Subtract the distance from the transit reading to obtain the elevation of the ground surface. Do the same for the solid well. Note: Place the ruler to the side of the mound of soil surrounding the well base. This will give you a more accurate reading of the ground surface (Fig. 7.b).

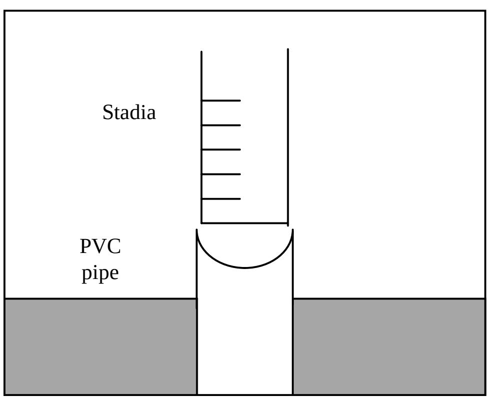


Figure 7.a

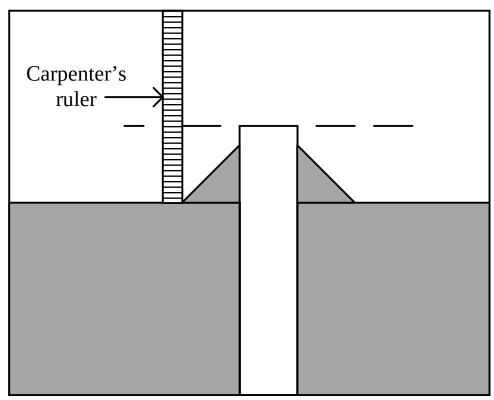


Figure 7.b

VI. USE AND MONITORING OF WELLS

The monitoring schedule depends on how fine you want your hydrograph to be. Water depths can be measured daily to monthly. Regardless, water depths should be measured throughout the different hydrologic seasons (wet through dry) in order to plot an accurate hydrologic graph.

Note: Schedule your monitoring trips at set increments (daily, biweekly, monthly, etc. This will provide even information for your graph).

A. MEASURING WATER LEVELS

1. Take the caps off of each well.
2. Using the carpenter's ruler, measure the distance from the top of the well to the water. (An easy ways to tell when you've reached the water is by watching for the reflection of daylight, or a flashlight, to ripple as the ruler touches the water, Fig 8.a).
3. Subtract the distance of the top of the well to ground surface (recorded in step V.E.3) from this distance. This value gives you the distance of the water level to ground surface (Fig 8.b).

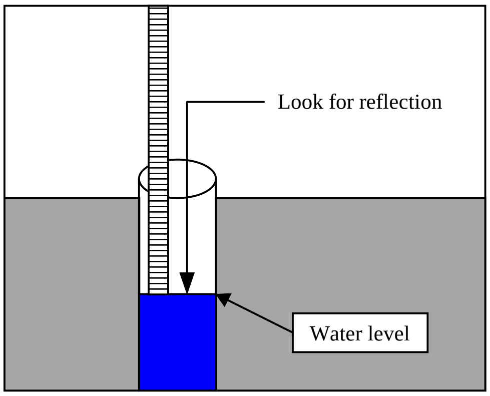


Figure 8.a

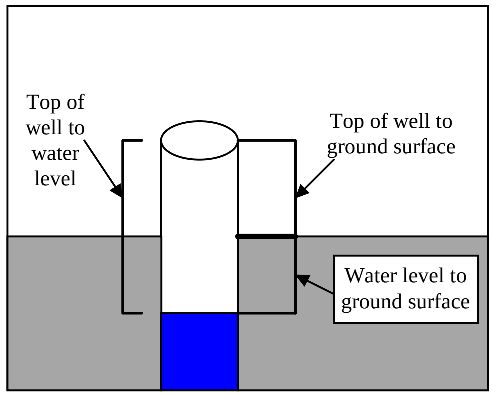


Figure 8.b

VII. DATA ANALYSIS

There are many ways to analyze your data. One of the main purposes of installing monitoring wells is to produce a hydrograph. You can do this by hand, or by computer. A simple graph can be set up by labeling "Depth to Water" (calculated in VI.A.3) as the y-axis and your time intervals on your x-axis. Plotting data for both slotted and solid wells on the same graph makes it easy to compare.