Wetlands Management I – Determination and Delineation

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NCSR curriculum modules are designed as comprehensive instructions for students and supporting materials for faculty. The student instructions are designed to facilitate adaptation in a variety of settings. In addition to the instructional materials for students, the modules contain separate supporting information in the "Notes to Instructors" section, and when appropriate, *PowerPoint* slides. The modules also contain other sections which contain additional supporting information such as assessment strategies and suggested resources.

Acknowledgements

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NCSR *Wetland Ecology and Management Series*
Introduction

Wetlands are among the most productive ecosystems on earth, and as such, provide countless ecological and economic benefits to humans. Management of this valuable resource is complex and represents an opportunity to approach the nature and management of a natural resource from several different perspectives in natural resource or environmental science programs. The NCSR *Wetland Ecology and Management Series* is designed to support the instruction of wetlands topics at the undergraduate level. It is modular in nature and instructors can pick and choose some topics for coverage and de-emphasize or ignore others. Thus, these curriculum materials are designed to meet a variety of instructional needs and strategies. The NCSR *Wetland Ecology and Management Series* is comprised of the following modules:

- ***Wetlands – An Introduction***

This module characterizes the wetlands resource and introduces students to wetlands as ecosystems and to the rationale for wetlands management. Wetland functions and values are also described.

- ***Wetlands – Then and Now***

This module describes the current status of wetlands and compares that to their place in history. Wetland types, classification schemes and causes for wetland loss and degradation are also discussed.

- ***Wetlands Management I – Determination and Delineation***

This module introduces wetlands management and describes wetland determination and delineation as first steps in wetland management projects. A field activity is included that engages students in the essential elements of wetland determination and delineation.

- ***Wetlands Management II – Compensatory Mitigation***

This module introduces the concept of compensatory mitigation and evaluates its effectiveness as a strategy for managing the wetland resource. A wetland mitigation field activity is included that describes how instructors can identify appropriate local wetland mitigation sites and how to organize a mitigation tour.

- ***Wetlands and Climate Change***

This module describes the complex relationship between wetlands and climate change.

- ***Wetlands and Hurricanes***

This module examines the impact of hurricanes on wetlands as well as the role of wetlands in the protection of coastal areas.

- ***Wetland Restoration in the Everglades***

This module uses restoration efforts in south Florida as a case study of wetland restoration.

Each module includes a lecture outline, *PowerPoint* presentation and detailed instructor notes. Modules with field-based activities also include student handouts, detailed procedures, data sheets and notes to instructors. In addition to the presentations and field activities described above, complete citations and brief summaries of relevant web, print and video resources are provided that can be used to:

- Enhance existing lecture topics
- Develop lectures on new topics
- Develop geographically relevant case studies
- Update wetlands statistics
- Select articles for student reading
- Access video and photos for presentation purposes

Intended audience

The NCSR *Wetland Ecology and Management Series* is intended to provide instructional support for undergraduate education at the freshman/sophomore level. Technical programs that include wetlands topics such as Wetlands Management, Civil Engineering and Biological Technician programs will find the modules to be a useful introduction to wetlands science and management. The materials are not designed to provide the training that is required by individuals to become certified wetland delineators or other types of wetlands technicians, as these curriculum materials and mechanisms for their delivery are available elsewhere. Also, NCSR wetlands materials are not designed for K-12 as a number of efforts have addressed wetlands for this level. In addition to providing background for those who will work with wetlands in their profession, NCSR materials also provide the background and context for students in other undergraduate programs. The materials may generate interest in some to pursue wetlands management as a career, but more importantly will result in an informed citizenry on wetlands issues. It is hoped that a more informed public will gather support for wetland conservation efforts as they occur in their local communities and help build a greater understanding of their importance.

The need for an undergraduate wetlands curriculum

Recent interest in wetlands as a valuable and dwindling resource has resulted in a large and growing volume of wetlands-related curriculum. However, the vast majority of these wetlands education resources target audiences other than first- and second-year college students. The K-12 audience, for example, has been well-served by efforts such as Project WET (Slattery and Kesselheim, 2003). The demand for training of wetlands delineators and those with expertise in wetland mitigation has driven the development of a number of continuing education classes that teach this material. The intended audience is those who are in the wetlands profession who seek the proper certification to conduct these activities. Examples include:

The Ohio State University
Olentangy River Wetland Research Park
www.swamp.osu.edu

North Carolina State University
Forestry and Environmental Outreach Program (FEOP)
http://www.ces.ncsu.edu/nreos/forest/feop/

Portland State University
Environmental Professional Program
http://epp.esr.pdx.edu/

The Swamp School
www.swampschool.org

Some degree programs at 4-year colleges and universities include courses in wetland ecology and management. However, the majority are taught at the graduate level and curriculum materials are not widely available for use outside of those institutions.

Thus, there appears to be a lack of classroom-ready materials and resources available for **undergraduate courses** that include some coverage of wetlands topics and form a bridge between the various wetlands curriculum materials described above. The NCSR *Wetland Ecology and Management Series* is designed to fill that void.

Guidelines for use

The manner in which instructors use the modules in this series will depend upon:

- The course in which the module will be used

The wetland mitigation modules are most appropriate for inclusion in undergraduate courses such as *Environmental Science, Introduction to Natural Resources, Wetlands Ecology* and *Introduction to Wetlands Management*. Parts of the modules may also have application in courses with a broader scope such as *General Ecology* and *General Biology*.

- The background of the students

The wetland mitigation modules assume some basic understanding of basic ecology including populations, communities and ecosystem structure and function. The treatment of ecology in either a college- or high school-level general biology course should be sufficient. Instructors may need to provide additional background to students who are not familiar with this material.

- The time that will be dedicated to the study of wetlands

There is sufficient information and resources in the wetlands mitigation modules to present anything from a single one-hour lecture to a significant portion of a full semester-long or quarter-long course. Instructors may select from the various components depending on course objectives and the amount of time allocated for wetlands topics.

A note on wetland field and laboratory experiences

The NCSR *Wetland Ecology and Management Series* emphasizes lecture support for instructors who are looking for wetlands material to insert into their courses. Although classroom lectures and discussions are a necessary element of a course that deals with wetlands issues, field and laboratory experiences enhance the learning experience and allow the instructor to explore topic areas that are not easily covered in the classroom. Additionally, students are more likely to become engaged in the topic when they can experience it firsthand.

Field activities may include a wide variety of experiences ranging from "tours" of various wetland types and restoration or mitigation projects to investigative experiences where students are actively engaged in the "scientific process."

Types of field activities (adapted from Baldwin, 2001):

- Field identification of wetland plants
- Preparation of plant collections using standard herbarium techniques
- Field identification of wetland animals
- Estimates of animal diversity and abundance (e.g., collection of invertebrates in soil litter samples, mammal livetrapping, amphibian surveys)
- Vegetation sampling methods (e.g., qualitative, line-intercept, transect, quadrat sampling)
- Analysis of wetland plant diversity and abundance
- Determination of hydric soils indicators
- Determination of site hydrology

Details of these methods are beyond the scope of this series and have been well-documented elsewhere in field and laboratory manuals designed for college-level courses. See resources below for some examples.

RESOURCES

Baldwin, A.H. 2001. Got mud? Field-based learning in wetland ecology. Journal of College Science Teaching 31:94-100.

O'Neal, L.H. 1995. Using wetlands to teach ecology and environmental awareness in general biology. American Biology Teacher 57:135-139.

Slattery, B.E. and A.S. Kesselheim. 2003. WOW! The wonders of wetlands: An educator's guide. Environmental Concern, Inc., St. Michaels, MD and The Project WET International Foundation, Bozeman, MT. 348 pp.

Wetlands Management I – Determination and Delineation

Module Description

This instructional guide is designed to provide instructors with lecture and laboratory materials that introduce the concepts and practices of wetland determination and delineation. Student objectives, a general lecture outline and a more detailed *PowerPoint* presentation with instructor notes are provided. Criteria for the identification of wetlands and accepted delineation methods as established by the U.S. Army Corps of Engineers are reviewed including field indicators of hydric soils, hydrology and wetland vegetation. Various sources of archived information commonly used in wetland determination and delineation are also described. A combination laboratory/field exercise is also fully described that guides students through a hands-on experience to illustrate how determinations are performed and how the boundaries of a wetland are defined.

Instructors who are looking for videos or additional print and web-based resources on the topics covered here should consult the resources list provided at the end of this module where these resources are summarized and cited.

Objectives

Upon successful completion of this module, students should be able to:

1. Distinguish between “wetland determination” and “wetland delineation”
2. Describe the need for wetland identification and delineation in wetland management
3. Identify current and archived sources of information that could be accessed to perform a wetland determination or delineation
4. Describe field indicators of wetlands based on soils, hydrology and vegetation criteria

Wetlands Management I – Determination and Delineation

General Lecture Outline

I. Introduction
    A. The need for wetland determination and delineation
    B. Wetland definitions
    C. Definitions of “determination” and “delineation”
    D. The *Wetland Delineation Manual*
II. Wetland Determination Criteria
    A. Hydric soils
        1. Biological and chemical processes
        2. Changes in soil chemistry
            a. Iron and manganese
            b. Hydrogen sulfide and methane
            c. Organic matter accumulation
    B. Hydrology
        1. Sources of water
        2. Hydrology indicators
    C. Wetland vegetation
        1. Definitions
        2. Wetland plants as indicators
III. The Tools of Wetland Determination and Delineation
    A. Preliminary research of archived information
        1. Web Soil Survey
        2. Topographic maps
        3. *Google Earth* and historical aerial photographs
        4. National Wetland Inventory maps
        5. Local Wetland Inventories
        6. Floodplain maps
        7. Site-specific information from the landowner
    B. Field evaluation
        1. Hydrology
        2. Hydric soils
        3. Wetland vegetation
    C. Final products

PowerPoint Presentation with Instructor Notes

Wetlands Management I - Determination and Delineation

By Wynn W. Cudmore, Ph.D.

Northwest **C**enter for **S**ustainable **R**esources

DUE # 0757239

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See notes slide 2 (page 12)

Photo credit: Becca Cudmore

Notes slide 2 (page 12)

Early wetland policy was driven by the perception of wetlands as wastelands that should be drained and filled to better accommodate human uses such as agriculture and urban development. This view of wetlands led to the elimination of over half of the total wetlands in the lower 48 states by the end of the 20th century. As our understanding of the ecological role of wetlands grew, a change in the perception of wetlands occurred. Along with this change, legislation was enacted that protected wetlands and made it more difficult to destroy them.

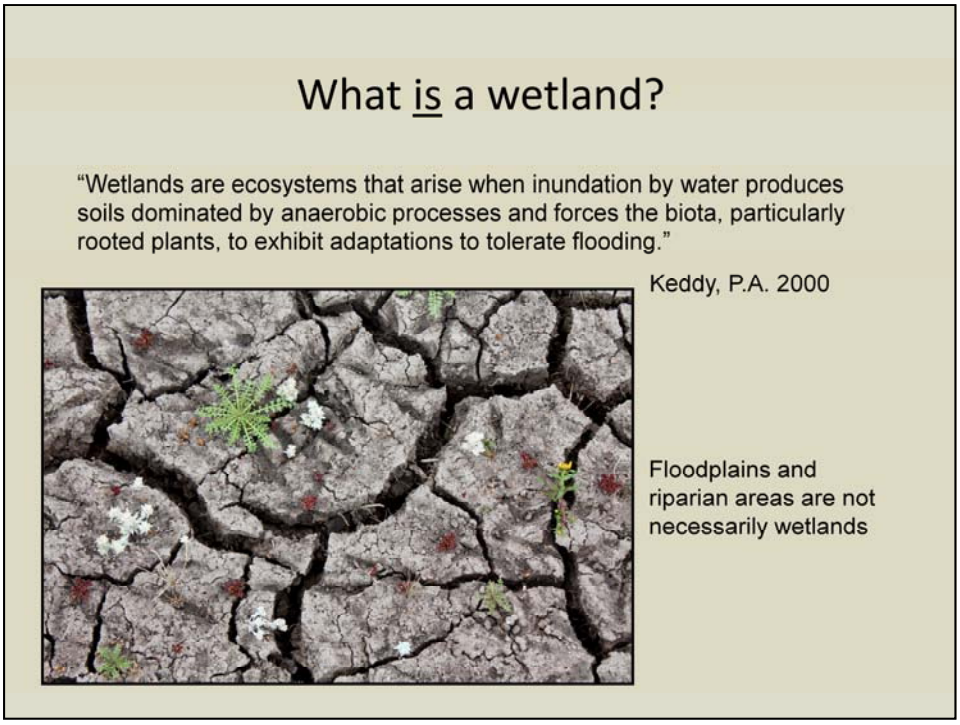
Implementation of this legislation required answers to questions that had not previously been considered. What is a wetland and what criteria should be used to distinguish wetlands from non-wetlands? How much wetland is on a given property? Where is the boundary between "wetland" and "non-wetland?" This is the realm of wetland identification (determination) and delineation (determining the borders).

Several elements of society now have compelling reasons to identify and delineate wetlands. Environmental groups may use these methods to identify ecologically significant wetlands to be protected as a park or preserve or to ensure that planned development does not encroach on a wetland. Financial institutions may require an assessment of wetlands on a property before a loan is granted. Landowners, developers and planners may need to have wetlands delineated prior to developing a site plan so as to avoid impacting wetlands or to determine the cost for mitigating unavoidable impacts. Governments at local, state and federal levels may require assessments of wetlands as infrastructure such as new roads, bridges or utilities are being planned that may impact wetlands. The U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, and Environmental Protection Agency are among those federal agencies commonly involved.

This photo of a wetland-upland boundary in an Oregon county park illustrates one setting in which these questions may have to be answered.

Is wetland present on this site? Yes - as indicated by the presence of wetland plants (rushes and others) in the left half of the photo.

Where is the boundary between "wetland" and "non-wetland?" The approximate boundary can be seen along a line roughly vertical between green wetland vegetation on the left and brown upland grasses and forbs on the right.



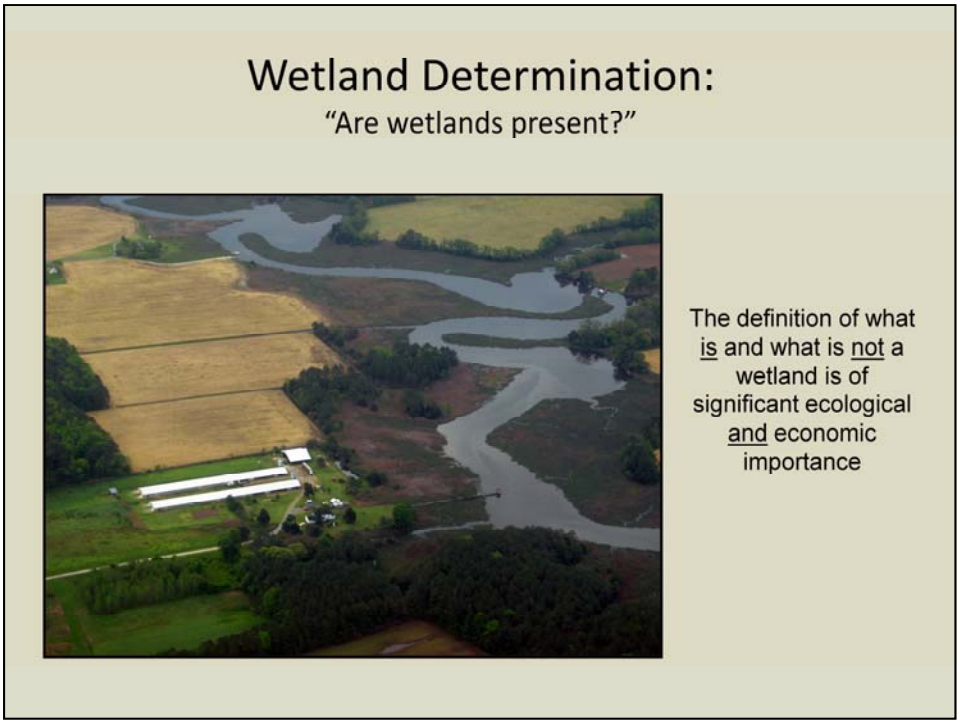
Wetlands occupy a transitional zone between well-drained uplands and permanently flooded deepwater habitats; examples include swamps, salt marshes and bogs. Many wetlands are permanently or intermittently flooded with shallow water; others are characterized by water tables that are at or near the surface. Therefore, most wetlands are not permanently inundated with water.

Formal definitions of wetlands have been proposed since the 1950s. The evolution of wetland definitions and the associated contention are discussed in detail in the NCSR module*Wetlands – An Introduction*. Most formal definitions, like this one from a wetlands ecology text, identify three major criteria that are present in wetlands – hydrology, soils and wetland-adapted vegetation.

Floodplains and riparian areas may include wetlands, but not necessarily. A floodplain can be expected to flood after heavy rains and snow melt, but many are not flooded frequently enough or long enough to meet wetland criteria. Riparian areas are vegetated corridors along streams. Many, however, have well-drained soils that do not remain saturated for prolonged periods and, therefore, do not meet wetland criteria.

Photo: Close-up of cracked soil and a variety of wetland plants as indicators of a wetland at Baskett Slough Wildlife Refuge, Polk Co., Oregon.

Photo credit: Becca Cudmore

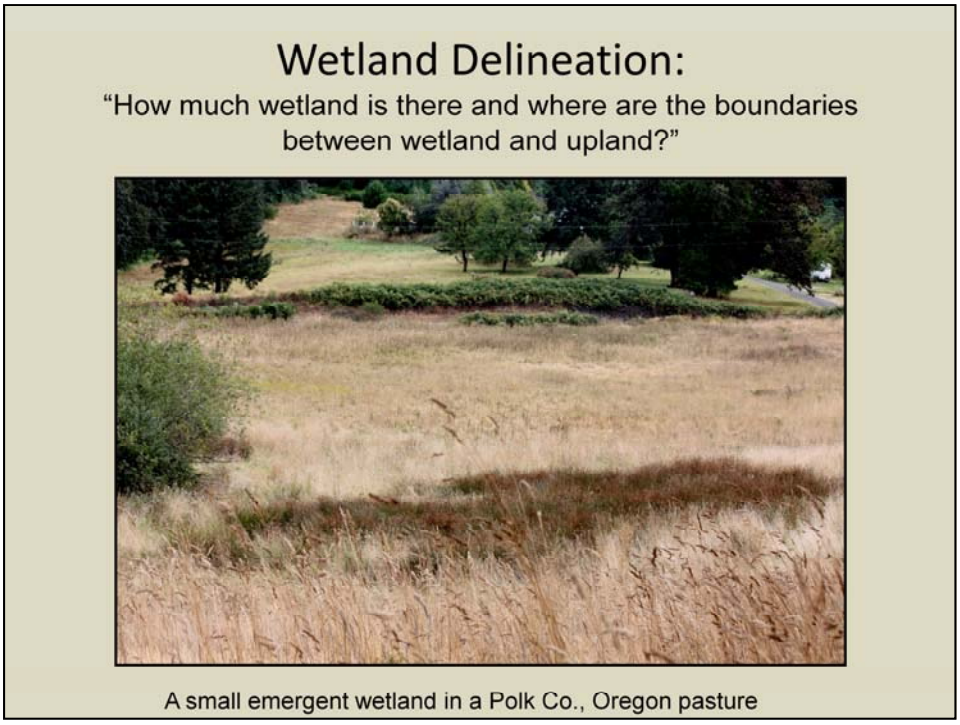


The definition of what is and what is not a wetland is not simply an academic exercise. Landowners who plan to develop wetlands must meet requirements set forth in state and federal laws. Alterations to development plans may be required in order to avoid or minimize impacts on wetlands. If this is not possible, landowners must compensate for those wetlands that are lost due to the development. Mitigation for lost wetlands may occur on-site, at a nearby location or by purchasing credits in a mitigation bank. Any of these actions are likely to come at great financial expense to the landowner or developer.

With the designation of wetlands as "waters of the United States" under Section 404 of the Clean Water Act of 1972, wetlands gained status as a protected entity under the laws of the United States. Consequently, a "wetlands industry" has emerged comprised of regulators, environmental lawyers, wetland engineers, and wetland consultants that are engaged in various aspects of wetlands management and conservation. These individuals are involved in the identification and delineation of wetlands, the design of mitigation projects to compensate for their loss and the development and enforcement of wetland regulations and policy. Therefore, the determination of whether or not wetlands are present is of concern to a wide variety of interests.

Mitigation bank – a wetland site that is restored, created or enhanced for the sole purpose of providing compensatory mitigation prior to authorized impacts to similar wetland resources (see NCSR module *Wetland Management II – Compensatory Mitigation* for more detail).

Photo credit: Emily Nauman, IAN Image Library (ian.umces.edu/imagelibrary)

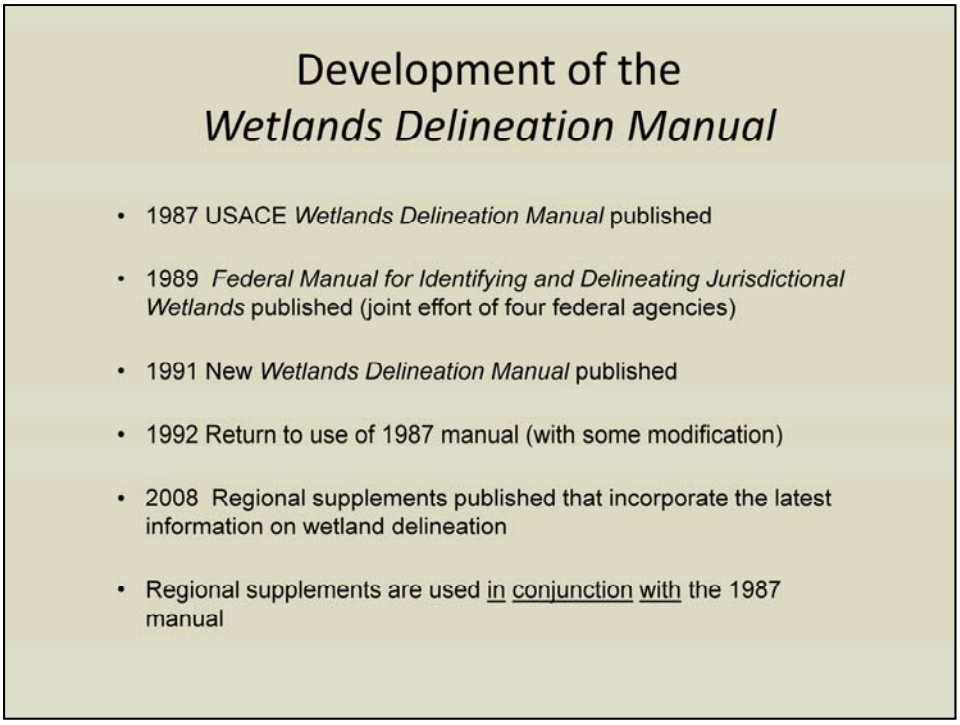


Once the determination has been made that wetlands are present, the most common next concern is "How much wetland is there and where are the boundaries?". This question is answered by the process of wetland delineation.

Identification of the boundaries of a particular wetland – i.e., where does wetland stop and upland begin. Procedures for wetland delineation have been as contentious as the definition for what a wetland is and what is not and are not as straight-forward as one might expect. Several federal agencies and some state agencies (e.g., Department of State Lands – Oregon) have had a role in establishing wetland delineation protocols and the process continues to evolve.

Wetland delineations are inherently difficult due to the often gradual transition from upland to wetland (i.e., our attempt to define a sharp boundary in a continuum), seasonal and annual variation in the extent of flooding and the influence of human land uses such as development or agricultural practices that can alter soils, vegetation and hydrology.

Photo credit: Becca Cudmore



Criteria for the identification of wetlands, the accepted methods for evaluating wetland criteria and wetland delineation methods have largely been established by the U.S. Army Corps of Engineers.

History of the development of the Wetlands Delineation Manual:

1. 1987 U.S. Army Corps of Engineers (USACE) *Wetlands Delineation Manual* published

Shortly thereafter, other federal agencies with wetland management authority (Environmental Protection Agency, U.S. Fish and Wildlife Service, Natural Resource Conservation Service) published their own manuals to reflect their authority and responsibilities.

2. A single federal manual was published in 1989 as a joint effort among 4 different federal agencies – *Federal Manual for Identifying and Delineating Jurisdictional Wetlands*

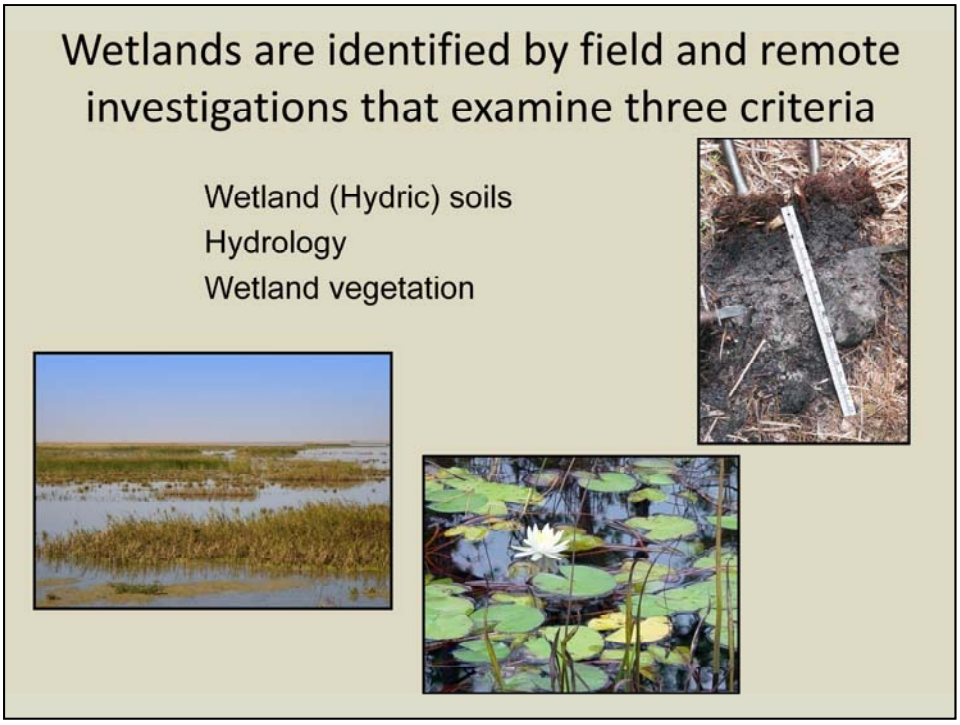
Developers, farmers and industrial interests heavily criticized the 1989 manual for being overly burdensome to development interests.

3. In response, the 1991 Wetlands Delineation Manual was published, but was quickly criticized for its lack of scientific credibility and was abandoned in 1992.

4. In 1992, it was decided to return to use of 1987 manual (with some modifications). This was seen as a political middle ground; that is, a compromise between conservation and development interests.

5. More recently (2008), the Army Corps of Engineers has published Regional Supplements (see resources for citations) that are designed to incorporate the latest information on wetland delineation that are specific to particular regions of the country. The regional supplements are designed to be used in conjunction with the 1987 manual.

Jurisdictional wetlands – wetlands that meet the criteria established in the *Wetlands Delineation Manual* and therefore subject to regulation.



Wetland identification criteria

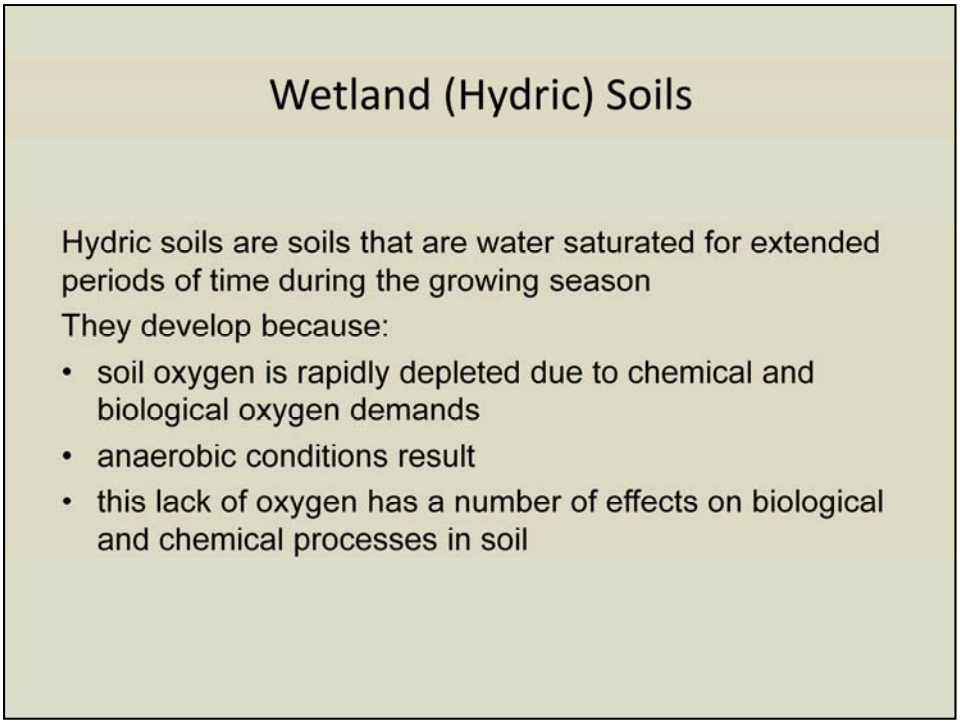
Wetland identification (determination) and delineation now determined by field and remote investigations that allow a professional to identify the presence of indicators of the 3 main components of wetlands:

Wetland (Hydric) soils
Hydrology
Wetland vegetation

Each of these will be discussed in detail.

Note that these three criteria are included in the legal definition of wetlands as “areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions.”

Photo credits:
Left – hydrology: USDA Natural Resources Conservation Service
Top right – soils: USDA Natural Resources Conservation Service
Bottom - vegetation: Ben Fertig, IAN Image Library (ian.umces.edu/imagelibrary/)



Hydric soils are defined as soils that are water saturated for extended periods of time during the growing season. Soils that are "waterlogged" will often demonstrate characteristics that distinguish them from non-hydric soils. In non-hydric soils, oxygen is trapped in the many spaces between soil particles. This oxygen is used by plants to carry out **respiration** – the metabolism of sugars to obtain energy. In hydric soils however, this soil oxygen is rapidly depleted due to chemical and biological oxygen demands and anaerobic conditions result. This lack of oxygen has a number of effects on the biological and chemical processes in soil.

For example, since plants require oxygen in the soil to carry out respiration, if anaerobic conditions persist for just a few weeks during the growing season, most upland plants will perish or show signs of stress. As discussed in the NCSR module *Wetlands - An Introduction*, wetland plants have special adaptations that provide them with an advantage over most other plants in low oxygen conditions.

Changes in Soil Chemistry

1. Iron/manganese reduction, movement and accumulation
2. Hydrogen sulfide and methane production
3. Organic matter accumulation

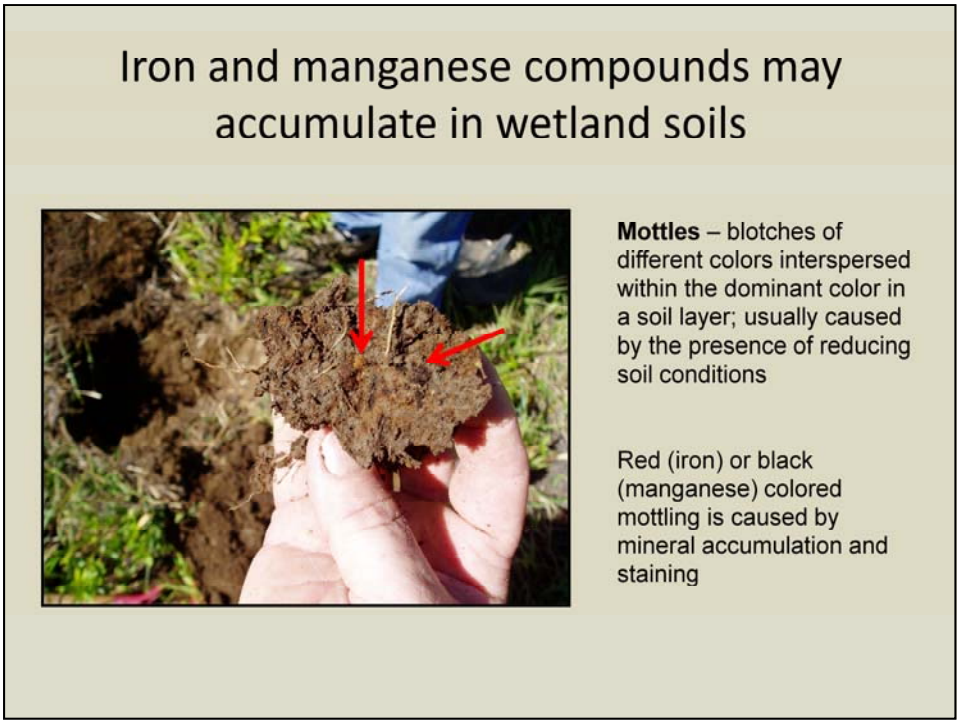
Soil profile from a wetland created in a beaver impoundment area in Ohio

Soil chemistry changes dramatically in the absence of oxygen, thus wetland soils differ chemically from aerated soils. In wetlands, soils commonly alternate seasonally between aerobic and anaerobic conditions with soil chemistry changing as well. When a soil becomes aerated after being saturated, the remnants of the anaerobic conditions can often be detected and are used to identify hydric soils (specific methods are discussed later). For example, sulfur, phosphorus and nitrogen change their compositional forms in anaerobic conditions and iron and manganese change their oxidation states.

Three main categories of chemical changes occur in hydric soils (listed here). These will be more fully described in the slides that follow.

Photo: Holly silt loam in an old beaver impoundment area in Ohio. Soil profile illustrates several characteristics of wetland soils.

Photo credit: Mark DeBrock, USDA NRCS

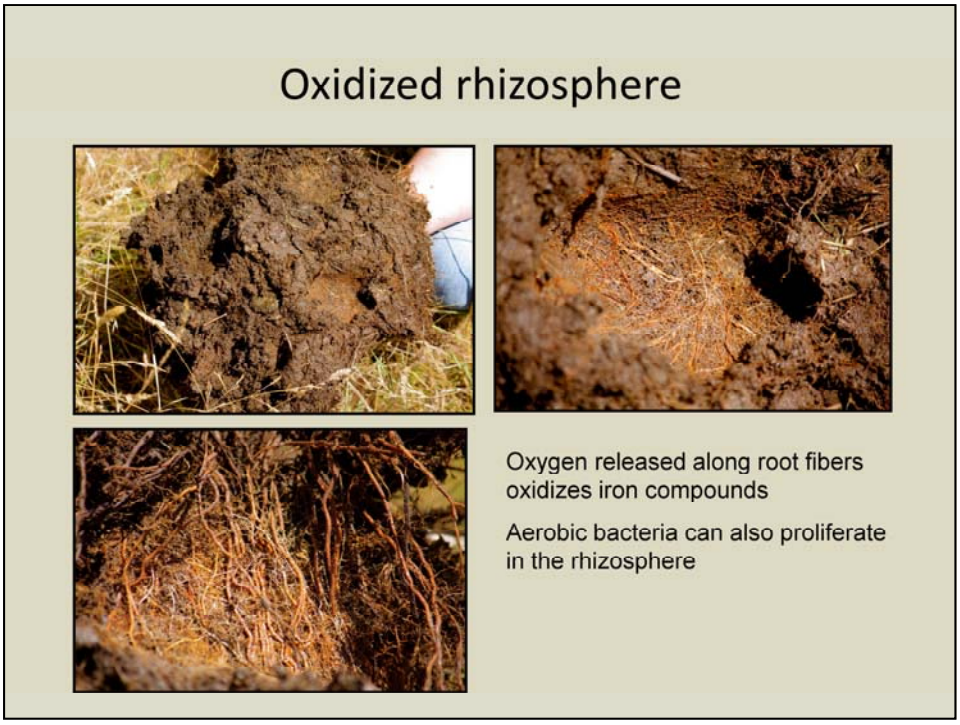


Under saturated anaerobic conditions, usually insoluble iron compounds become soluble. Iron ions become available and form various iron compounds. When these soils dry out and return to an aerated condition, these iron compounds oxidize forming iron oxides, which are deposited in the spaces between soil particles. The result is an irregular distribution of rusty-colored mottled areas, an indicator of hydric soils.

Manganese undergoes a similar conversion under saturated conditions and if soils remain in an anaerobic state for long periods of time, irregular inclusions called manganese concretions (MnO_x) may form. These, usually black, inclusions are also a possible indicator of a hydric soil.

Both iron and manganese mottles can be seen in this soil sample from an emergent wetland in Marion Co., Oregon.

Photo credit: Becca Cudmore

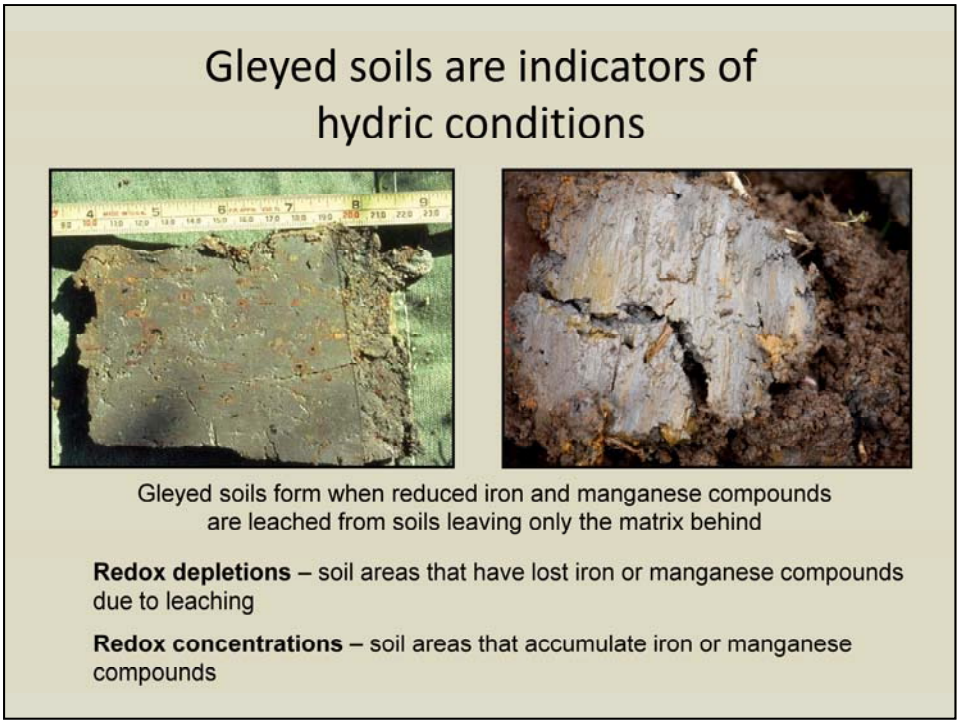


Iron oxides will also appear along root fibers in hydric soils since oxygen is released along the length of the root, oxidizing iron compounds. This results in an oxidized rhizosphere indicated in these photographs by the orange coatings on individual root fibers.

Oxidized areas along plant roots (the rhizosphere) are caused by release of oxygen from roots; these areas are high in oxygen and minerals are oxidized in their vicinity causing color changes – e.g., iron oxide producing rust-like color; also aerobic bacteria can function here so their activities can create a soil that appears different for soils outside the rhizosphere.

Photos illustrate an oxidized rhizosphere in soils collected from an emergent wetland in Marion Co., Oregon.

Photo credit: Becca Cudmore



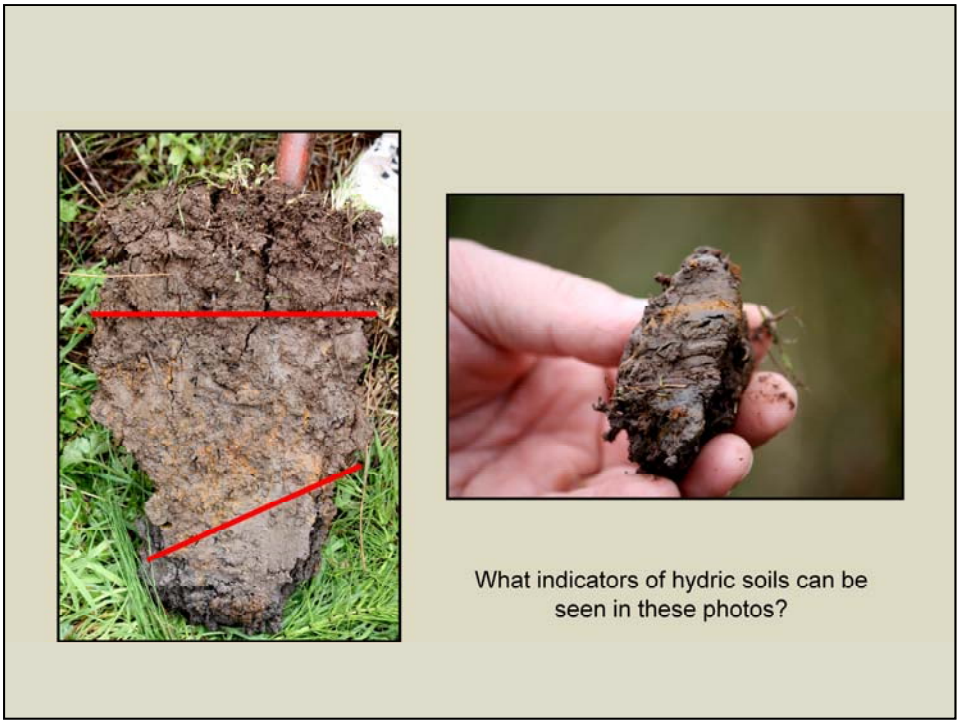
When soils are not saturated with water, iron oxides are the principal compounds that give soil its typical red, brown, yellow or orange color. Manganese oxides give the soil a black color. However, in soils that are constantly waterlogged or flooded, soil bacteria reduce both iron (from ferric to ferrous form) and manganese (from the manganic to the manganous form) into more soluble forms. These more soluble forms of iron and manganese can be leached out of the soil, leaving only the parent material (the **matrix**) behind. These loose, usually gray-colored (can be greenish-blue-gray) soils are called **gleyed soils** and they can be also used as indicators of wetland soils.

Soil areas that have lost iron or manganese develop characteristic blue-gray, green-gray or reddish-gray colors – these areas are called **redox depletions**. If oxygen returns to a soil layer (or a portion of the layer) the iron that is in solution will oxidize and become concentrated in patches, along root channels and other pores in the soil – these areas are called **redox concentrations**.

Left photo: A gleyed matrix with reddish orange redox concentrations occur along the pores of living roots.

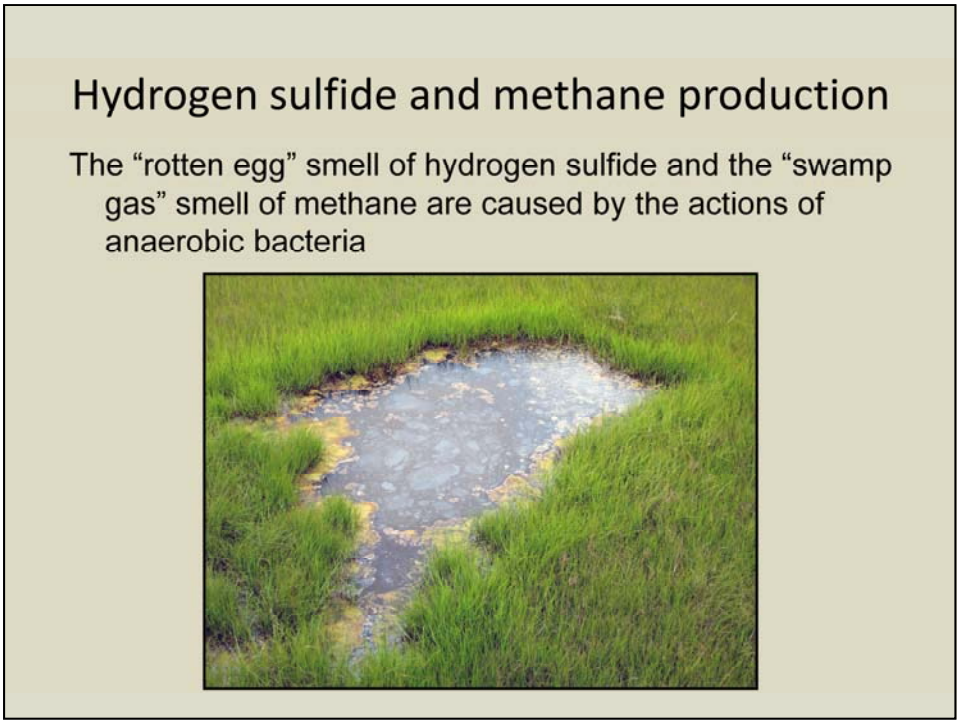
Right photo: A gleyed matrix with orange redox concentrations from a small emergent wetland in Polk Co., Oregon

Photo credits:
Left - United States Department of Agriculture, Natural Resources Conservation Service. 2006. Field Indicators of Hydric Soils in the United States, Version 6.0. G.W. Hurt and L.M. Vasilas (eds.). USDA,NRCS, in cooperation with the National Technical Committee for Hydric Soils.
Right - Becca Cudmore



To summarize, saturation and anaerobic conditions create changes in soil chemistry that can be used to distinguish wetlands from uplands. The soil profile on the left (approximately 16 inches) was taken from a small emergent wetland in Polk County, Oregon. The top layer (brown) has a high organic content; the layer below contains orange redox concentrations; the bottom layer has a uniform gray color indicating a gleyed matrix. The soil sample on the right shows a close-up of an iron oxide redox concentration ("mottle").

Photo credit: Becca Cudmore



Long-term saturation of soils can also result in the formation of reduced forms of carbon and sulfur. The resulting compounds are among those responsible for the characteristic odor often associated with some types of wetlands - for example, the "rotten egg" smell of hydrogen sulfide and other sulfur compounds and the "swamp gas" smell of methane.

The chemistry of wetland soils is complex and comprehensive treatment is beyond the scope of this module. However, in general, when soils are inundated or saturated, anaerobic (or "reduced") conditions result, transforming the chemical elements of soils into their reduced form:

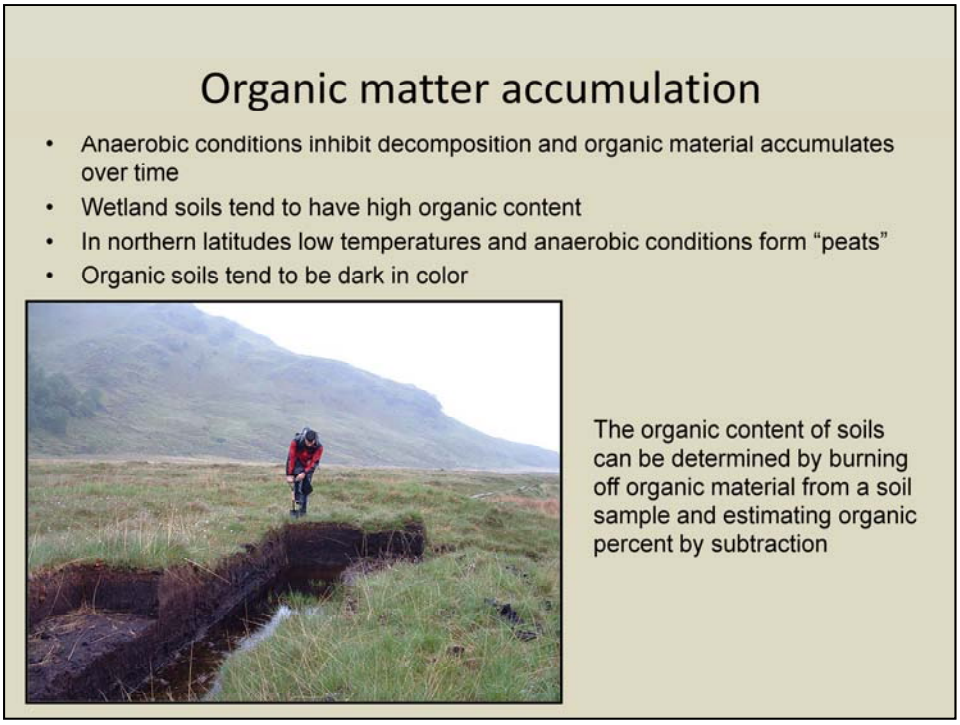
Element	Oxidized Form	Reduced Form
N	NO_3^- (nitrate)	N_2O, N_2, NH_4^+
Mn	Mn^{4+} (manganic)	Mn^{2+} (manganous)
Fe	Fe^{3+} (ferric)	Fe^{2+} (ferrous)
S	SO_4^{-2} (sulfate)	S^{-2} (sulfide)
C	CO_2 (carbon dioxide)	CH_4 (methane)

Methane and hydrogen sulfide are produced under these reducing conditions by anaerobic bacteria that are able to carry out these reactions:

$$CO_2 + 2H_2O \rightarrow CH_4 + 2O_2$$

$$SO_4^{-2} + 4H_2 \rightarrow H_2S + 2H_2O + 2OH^-$$

Photo credit: Jane Thomas, IAN Image Library (ian.umces.edu/imagelibrary/)



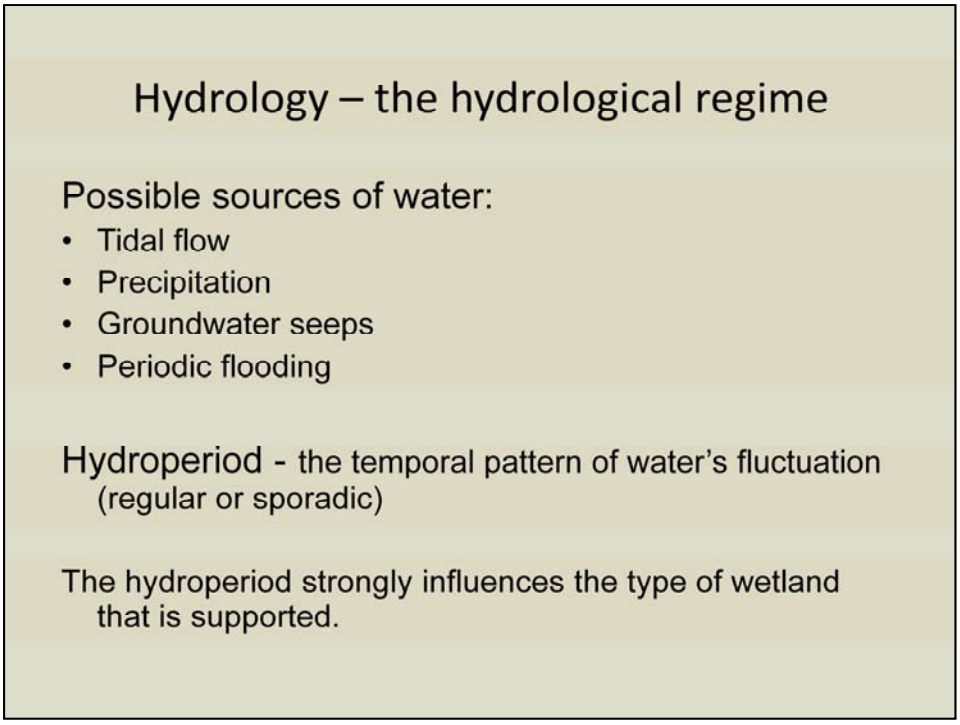
Anaerobic conditions also inhibit decomposition and thus decomposition is slowed in wetland soils (approximately one fourth the rate in aerated soils). Over long periods of time photosynthesis produces organic material, which accumulates over time. Wetland soils therefore, tend to have high organic content and, in some, organics accumulate to the point that the majority of the soil is organic. These so-called peat soils are especially common in northern latitudes where low temperatures and anaerobic conditions both slow decomposition. Organic soils tend to be dark in color and acidic and this characteristic is often used to identify wetland soils.

Organic material accumulates creating soils with a characteristic dark coloration and staining (e.g., peats and mucks). Organic content can also be measured using a method that burns off any organic material and estimates % organic content by subtraction. Organic soils are those with >12% organic content by weight.

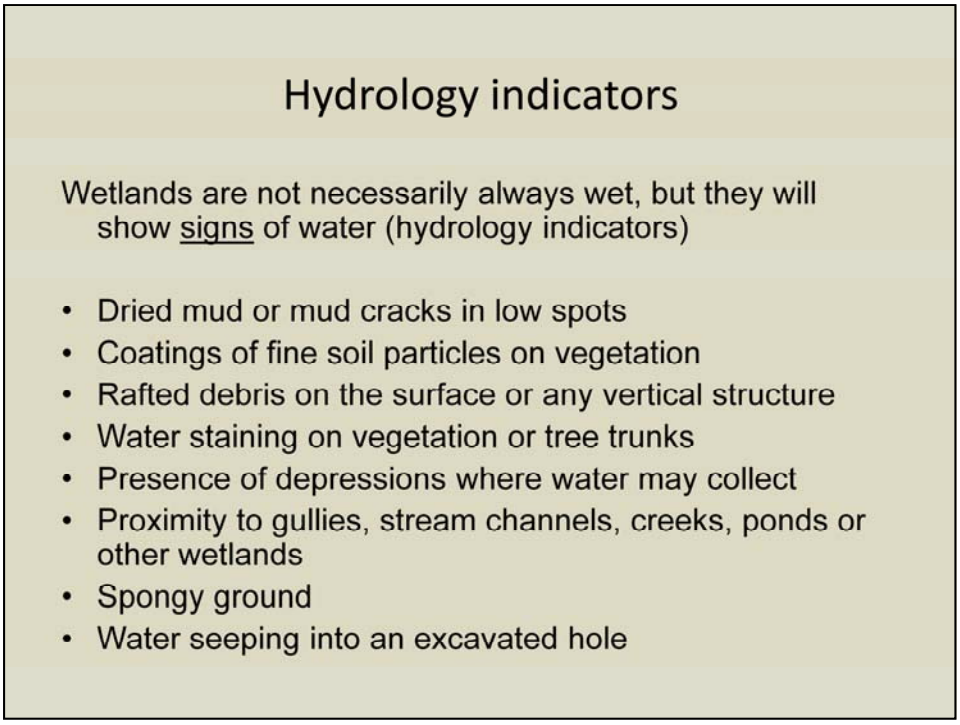
Specific criteria used for analysis of wetland soils vary from region to region and can be quite complex. The indicators described have been chosen because they occur broadly and are relatively easy to identify in the field. See Resources section at the end of this module for more detail on hydric soil indicators.

There are approximately 2000 named soils in the U.S. that are considered hydric. Soil surveys produced for every county in the U.S. by the Natural Resource Conservation Service (NRCS) include lists of those soils that are considered to be hydric (see Resources section at the end of this module).

Photo credit: Natural Resource Conservation Service. Peat soils in Richland County, Wisconsin. Ho Chunk Nation of the Winnebago Tribe of Wisconsin



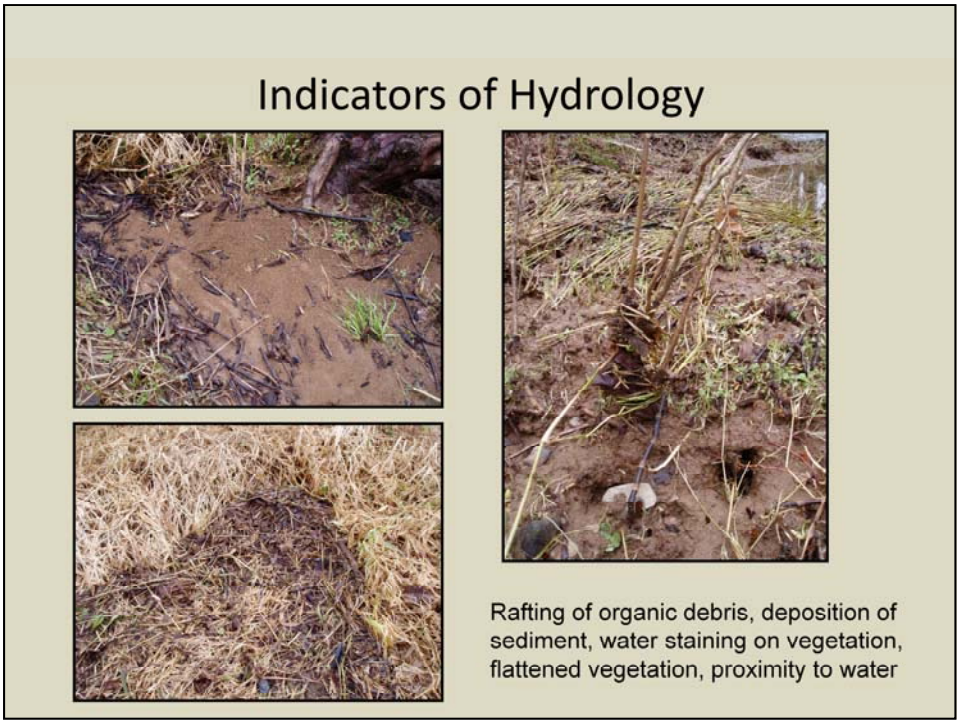
The amount and pattern of water presence determines a wetland. Water is often at or just below the surface creating saturated conditions that favor wetlands plants. Sources of water may vary with time of day (e.g., tides), season and from year to year and may include ebb and flow of tides (including salt water intrusion), rainfall, ground water seeps, or periodic flooding. Occasionally, wetlands appear due to water sources that are manmade or influenced (e.g., long-term leaking water lines or water diversions). In many wetland types, water accumulates above a poorly drained soil layer. Many wetlands are seasonal in nature and are dry during one or more seasons every year. The hydroperiod is the pattern in time of water's fluctuation and may be regular (as in tides or the onset of a predictable rainy season) or sporadic (as in flooding). The hydroperiod has a strong influence on the type of wetland that is supported. Different wetland plants and animals have different adaptations to slight differences in hydroperiod.



Wetlands are not necessarily always wet, but they will show signs of water (**hydrology indicators**) even if it is not present at the time. Commonly used indicators of past flooding or soil saturation include:

- Dried mud or mud cracks in low spots
- Coatings of fine soil particles (silt or clay) on vegetation
- Rafted debris on the surface or suspended on any vertical structure such as trees, logs, fence posts, etc.
- Water staining on vegetation or tree trunks
- Presence of depressions where water may collect
- Proximity to gullies, stream channels, creeks, ponds or other wetlands
- Spongy ground
- Water seeping into a dug hole

A more extensive list of hydrology indicators can be found in the Resources at the end of this module.



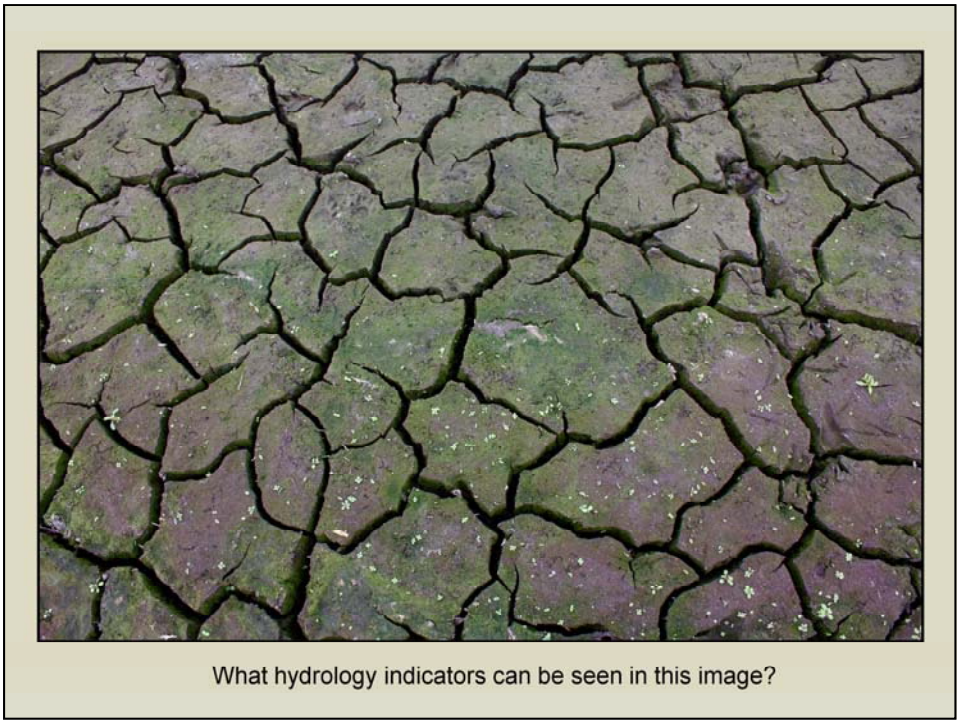
Several indicators of hydrology can be seen in these photos:

Upper left – rafting of organic debris, deposition of sediment indicating flooding

Lower left – water staining on vegetation, rafting of organic debris, flattened vegetation

Right – rafting of organic debris, proximity to body of water (creek)

Photo credits: Wynn Cudmore



What hydrology indicators can be seen in this image taken at Baskett Slough Wildlife Refuge, Polk Co., Oregon

Algal mat – green film on surface

Cracked soil

Raccoon tracks in right half of image are not hydrology indicators, but are interesting nonetheless.

Photo credit: Becca Cudmore

Vegetation – Wetland Plants

California pitcher plant or cobra lily (*Darlingtonia californica*) in Florence, Oregon

Hydrophytic plants are adapted to growing in hydric soils

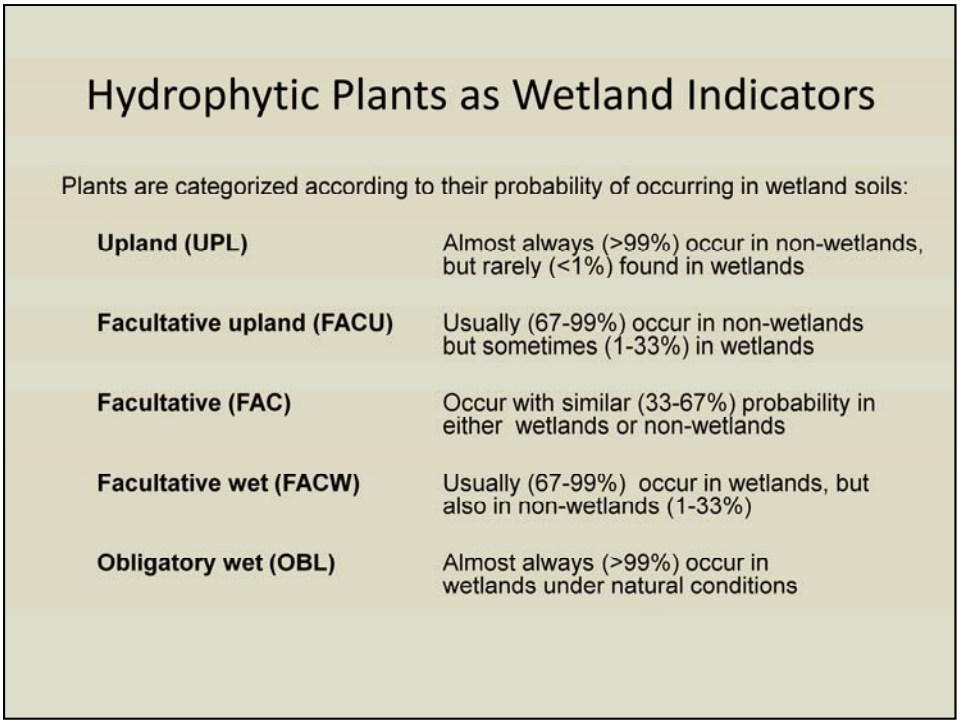
Nearly 7000 U.S. species – cattails, sedges, rushes, cordgrass, mangroves, water plantains

Wetland plants have specific adaptations that allow them to outcompete upland plants in saturated soils

In addition to the criteria described above (hydric soils and hydrology), wetlands are distinguished from uplands by having an abundance of plants adapted to growing in wet soils. Wetland plants are hydrophytic and have adaptations that allow them to occupy saturated, anaerobic soils. There are nearly 7000 plant species (6728 on "1988 National List" published by U.S. Fish and Wildlife Service) in the United States that may occur in wetlands – cattails, sedges, rushes, cordgrass, willows, mangroves and water plantains are common examples. While non-wetland plants take in oxygen through the roots and distribute it to the stems and leaves, in saturated soils wetland plants must use other strategies. Having these adaptations affords a great adaptive advantage to wetland plants over non-wetland plants in these environments. As a result, wetland plants outcompete other plants in these environments.

Details on structural and physiological adaptations of wetland plants are discussed in the NCSR module – *Wetlands – An Introduction*.

Photo credit: David Lonsdale, Chemeketa Community College



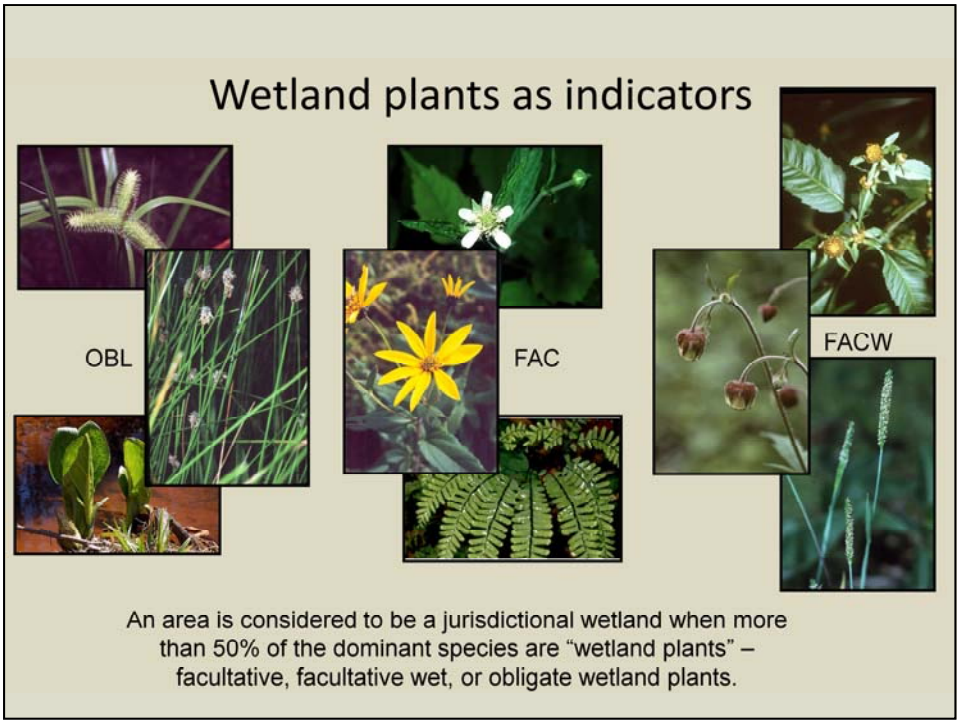
For the purposes of wetland identification, plants are categorized according to their probability of occurring in wetland soils. Five widely-used categories have been developed by the U.S. Army Corps of Engineers.

Obligate wetland (OBL)	Almost always (>99%) occur in wetlands under natural conditions
Facultative wetland (FACW)	Usually (67-99%) occur in wetlands, but also in non-wetlands (1-33%)
Facultative (FAC)	Occur with similar (33-67%) probability in either wetlands or non-wetlands
Facultative upland (FACU)	Usually (67-99%) occur in non-wetlands, but sometimes (1-33%) in wetlands
Obligate upland (UPL)	Almost always (>99%) occur in non-wetlands, but rarely (<1%) found in wetlands

To add greater detail to the 5 designations given above, some states add “+” or “-” designation to each of the categories to indicate that a plant is at the high or low end of the range of probabilities.

Facultative – optional or discretionary; in this context, plants that are “facultative” (FAC) are those that have about an equal probability of appearing in wetlands and uplands. FACU plants can survive in either, but are more likely to be in uplands. FACW plants are more likely to be in wetlands.

Obligatory – required; in this context, plants that are OBL are found only in wetlands.



See notes slide 22 (page 33)

Photo credits:

Obligate (OBL)
(Carex comosa) - Robert H. Mohlenbrock @ USDA-NRCS PLANTS Database / USDA SCS. 1989. *Midwest wetland flora: Field office illustrated guide to plant species*. Midwest National Technical Center, Lincoln.
(*Eleocharis palustris*) - Robert H. Mohlenbrock @ USDA-NRCS PLANTS Database / USDA SCS. 1989. *Midwest wetland flora: Field office illustrated guide to plant species*. Midwest National Technical Center, Lincoln.
(*Lysichiton americanum*) - Robert Shallenberger/U.S. Fish and Wildlife Service

Facultative (FAC)
(Geum canadense) - Robert H. Mohlenbrock @ USDA-NRCS PLANTS Database / USDA SCS. 1991. *Southern wetland flora: Field office guide to plant species*. South National Technical Center, Fort Worth.
(Helianthus tuberosus) - Jennifer Anderson @ USDA-NRCS PLANTS Database
(Adiantum pedatum) - Robert H. Mohlenbrock @ USDA-NRCS PLANTS Database / USDA NRCS. 1992. *Western wetland flora: Field office guide to plant species*. West Region, Sacramento.

Facultative Wet (FACW)
(Bidens frondosa) - Robert H. Mohlenbrock @ USDA-NRCS PLANTS Database / USDA SCS. 1989. *Midwest wetland flora: Field office illustrated guide to plant species*. Midwest National Technical Center, Lincoln.
(Geum rivale) - Lee Casebere @ USDA-NRCS PLANTS Database / USDA NRCS. 1995. *Northeast wetland flora: Field office guide to plant species*. Northeast National Technical Center, Chester.
(Alopecurus carolinianus) - Robert H. Mohlenbrock @ USDA-NRCS PLANTS Database / USDA SCS. 1989. *Midwest wetland flora: Field office illustrated guide to plant species*. Midwest National Technical Center, Lincoln.

Notes slide 22 (page 33)

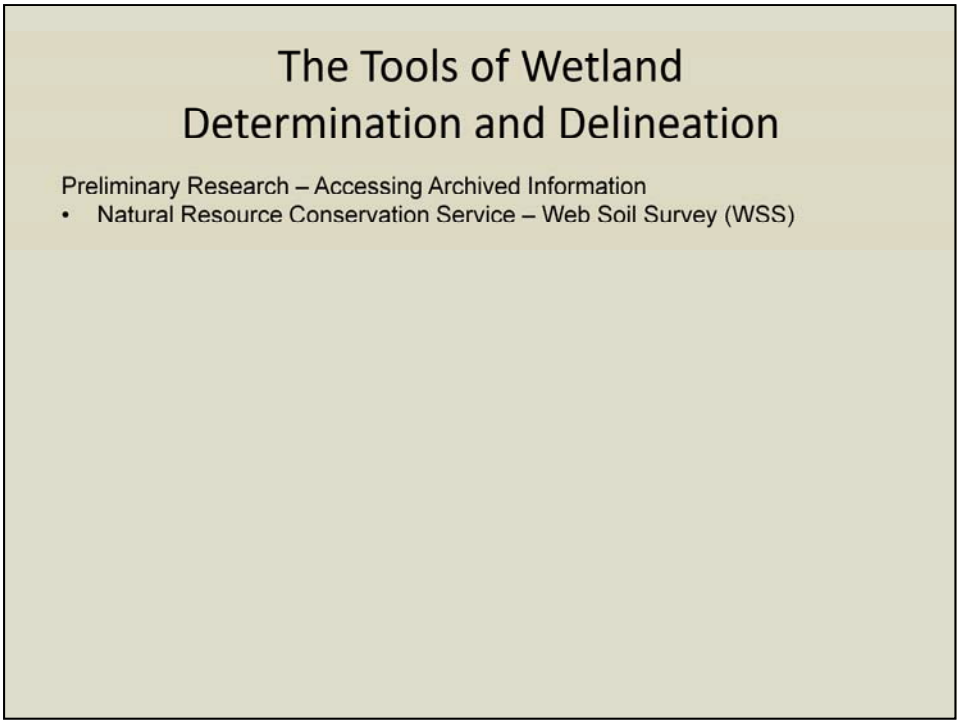
An area is considered to be a jurisdictional wetland when more than 50% of the dominant species are “wetland plants” – facultative, facultative wet, or obligatory wetland plants.

Examples of plant species in each of these categories are shown here. Note that some plant species may be categorized differently in different regions of the country. Chives (*Allium schoenoprasum*), for example, could be “FACU” or “FACW+” depending on where it is found.

Obligate (OBL)
Carex comosa - longhair sedge
Eleocharis palustris common spikerush
Lysichiton americanum - skunk cabbage

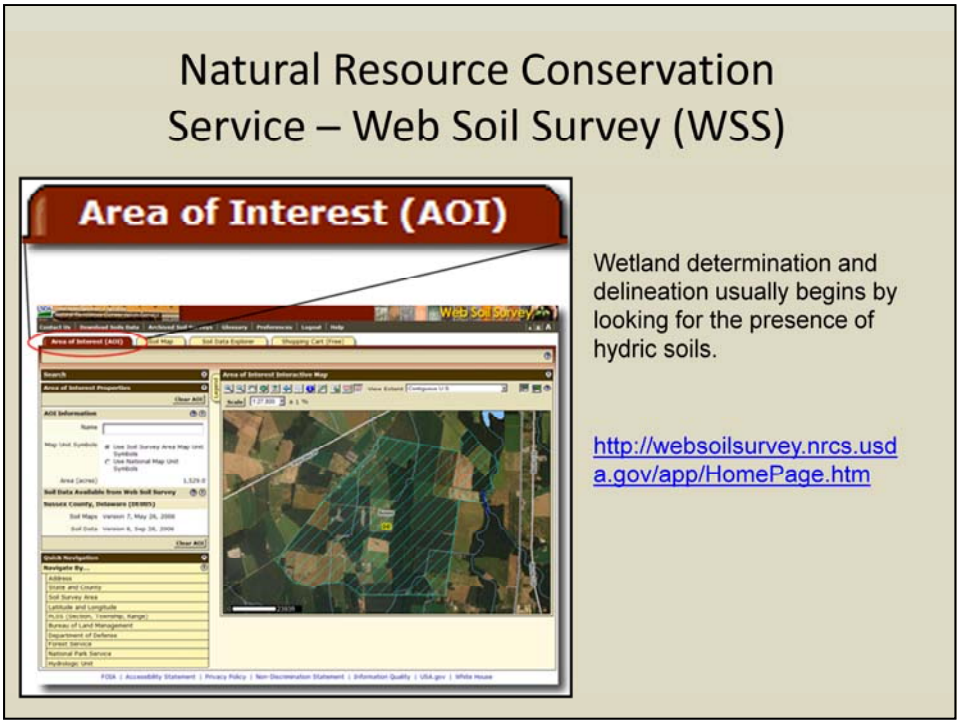
Facultative (FAC)
Geum canadense - white avens
Helianthus tuberosus - Jerusalem artichoke
Adiantum pedatum - maidenhair fern

Facultative Wet (FACW)
Bidens frondosa - devil's beggartick
Geum rivale - purple avens
Alopecurus carolinianus - Carolina foxtail



As indicated earlier, wetland determination and delineation usually requires both the preliminary examination of archived information and a field evaluation.

Prior to a field visit, a wealth of information concerning a potential wetland site can be determined from archived sources. One of these sources is the “Soil Survey.”

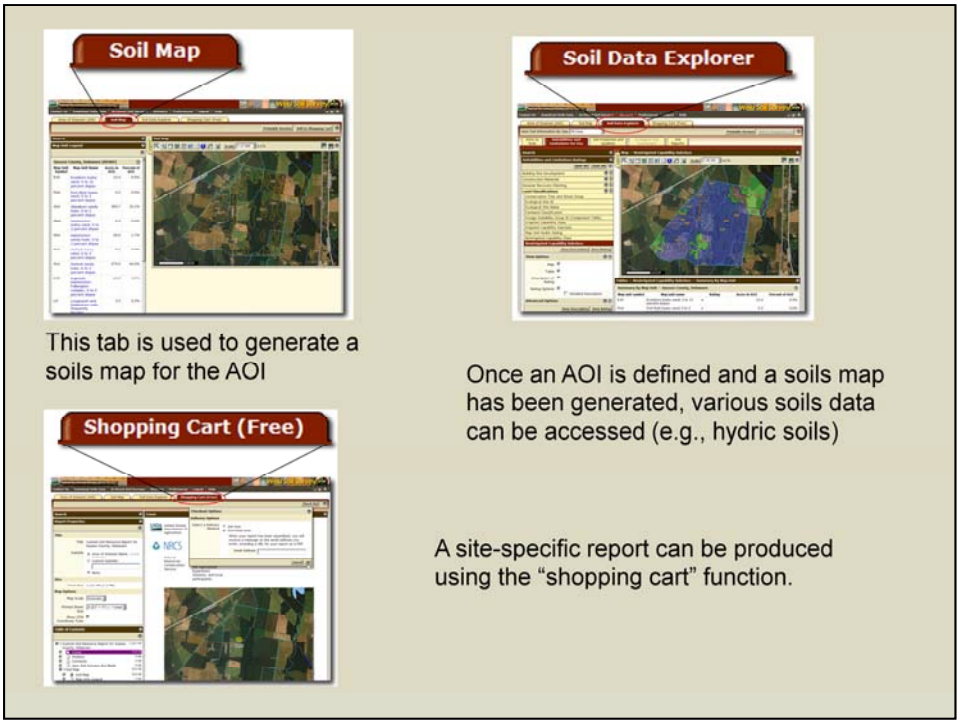


Examination of a soil survey to determine whether or not the soils at the study site have been identified as being hydric is a common first step in wetland delineation. Soil types at the site are identified and then compared to a hydric soils list. Soil surveys, once only available in hard copy, are now available for most areas in the U.S. on-line. The Web Soil Survey (WSS) provides soil data and information produced by the National Cooperative Soil Survey. It is operated by the USDA Natural Resources Conservation Service (NRCS) and provides access to the largest natural resource information system in the world. NRCS has soil maps and data available on-line for more than 95 percent of the nation's counties and anticipates having 100 percent in the near future. The site is updated and maintained on-line as the single authoritative source of soil survey information.

Detailed instructions on the use of the Web Soil Survey are provided on the NRCS web site. Instructors may find it useful to view the tutorial prior to using this resource. The following is a brief overview:

1. The study site is first located on a base map and an "area of interest" (AOI) is defined by the user as an overlay on this map. Several options are provided that allow you to navigate to the study site such as the site's street address, state and county, latitude/longitude coordinates, legal description (section, township, range), etc. An area of interest is defined by selecting the AOI tool and dragging in a box that establishes borders around the desired area.

Image credit: USDA Natural Resource Conservation Service

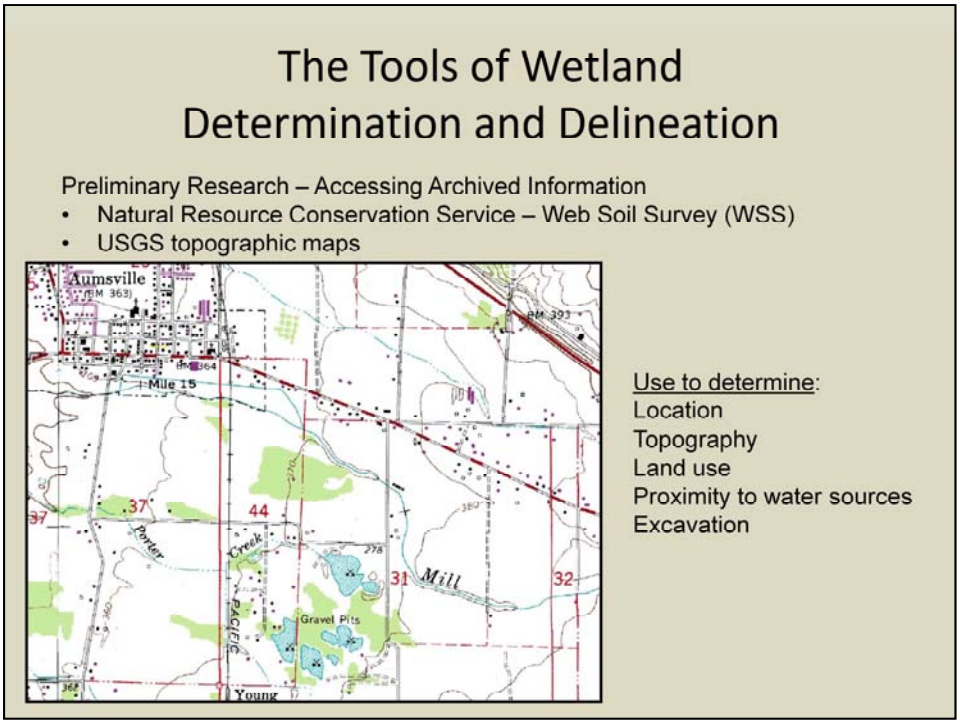


2. Once an area of interest is defined, the "Soil Map" tab can be selected to superimpose a soils map over the AOI. Different soil types are designated by map unit symbols. The map unit name and the area of each soil type within the AOI are given in a table to the left of the soils map.

3. Various soils data can be accessed by clicking on the "Soil Data Explorer" tab. The presence of hydric soils is determined by opening the "Suitabilities and Limitations for Use" tab and then the "Land Classification" link and then the "Hydric Rating by Map Unit" link. Click on "View Rating" to generate the color-coded hydric soils map. The "Legend" tab on the left margin of the map defines each of the colors used in the map.

4. The Web Soil Survey automatically generates a site report as a .pdf file. A template that includes a title, an explanatory narrative, a soils map, etc. is provided. The user can add any other element to the report by selecting the "Shopping Cart" tab while viewing that element. For example, if you would like to add a hydric soils map to the report, simply select the "Shopping Cart" tab after you have generated that map. When all desired elements have been added, select "Check out." A site-specific report will be generated that can be printed or saved. Unlike almost any site where "Shopping Cart/Check Out" functions are used, you will not be asked to enter your credit card number. The service is free.

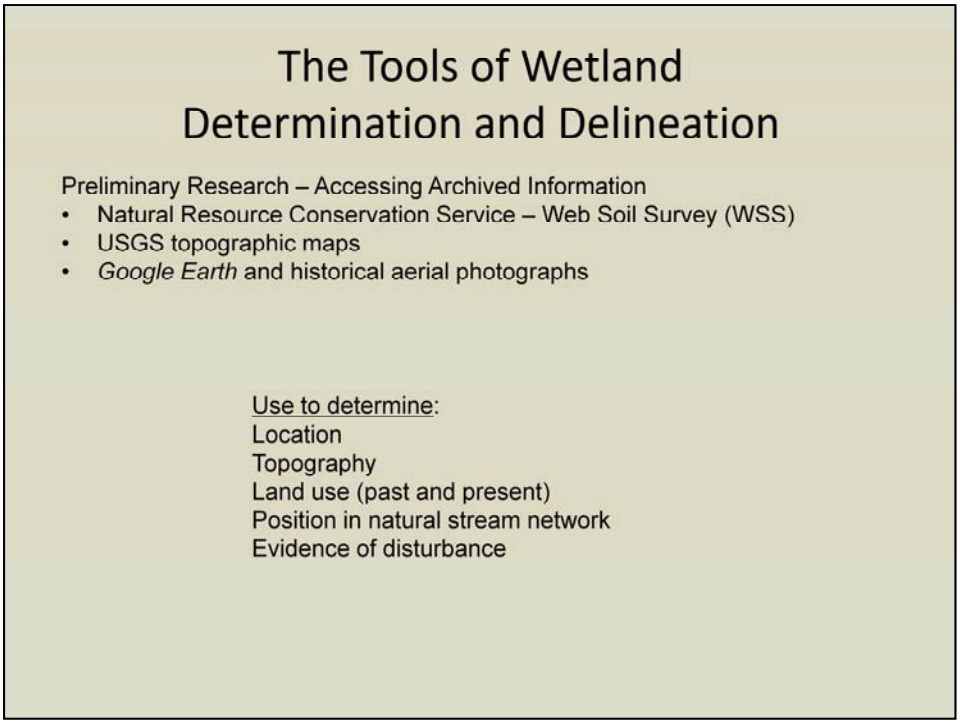
Image credit: USDA Natural Resource Conservation Service



USGS Topographic maps can be used to determine:

1. Location
2. Topography – flat, position on slope, etc. – identification of depressions or the bases of slopes where water may accumulate
3. General land use of site and surrounding area (urban, forested, agriculture, etc.)
4. Position of study site relative to natural stream network (proximity to other water sources such as streams, ponds, drainage ditches, other wetland areas) – identification of drainage patterns that may bring hydrology to the site
5. Excavated or not (look for mining symbol on map) – excavated areas create depressions that may accumulate water and support wetlands

Image credit: U.S. Geological Survey



Google Earth and historical aerial photographs (or other remote sensing imagery) can be used to determine:

1. Location
2. Topography – flat, position on slope, etc.
3. Land use of site and surrounding area (past and present)
4. Position of study site relative to natural stream network
5. Evidence of disturbance

Historical *Google Earth* imagery is now available for many locations across the United States. This imagery can sometimes be used to determine any land use change that has occurred on the site. The drawback of this resource is that it does not go back very far in time (early 1990s for most locations).

For some sites, U.S. Army Corps of Engineers historical imagery may also be available.

This slide and the two that follow are provided as examples of *Google Earth* historical imagery of wetland sites. This 1994 image shows a constructed wetland wedged between three large commercial buildings and a parking lot on the left and an active construction site on the right.

Image credit: Google Earth

This 2005 image shows a new industrial site and baseball field to the right of the wetland.

Image credit: Google Earth

This 2008 image shows the addition of a housing development below the wetland. Series of images such as these can be used to evaluate changes in the wetland itself over time as well as potential impacts on the wetland (e.g., altered hydrology, impaired water quality, invasive species, etc.) due to development.

Image credit: Google Earth

The Tools of Wetland Determination and Delineation

Preliminary Research – Accessing Archived Information

- Natural Resource Conservation Service – Web Soil Survey (WSS)
- USGS topographic maps
- *Google Earth* and historical aerial photographs
- National Wetland Inventory maps

See notes slide 32 (page 44)

Image credit: U.S. Fish and Wildlife Service, National Wetlands Inventory

Notes slide 32 (page 44)

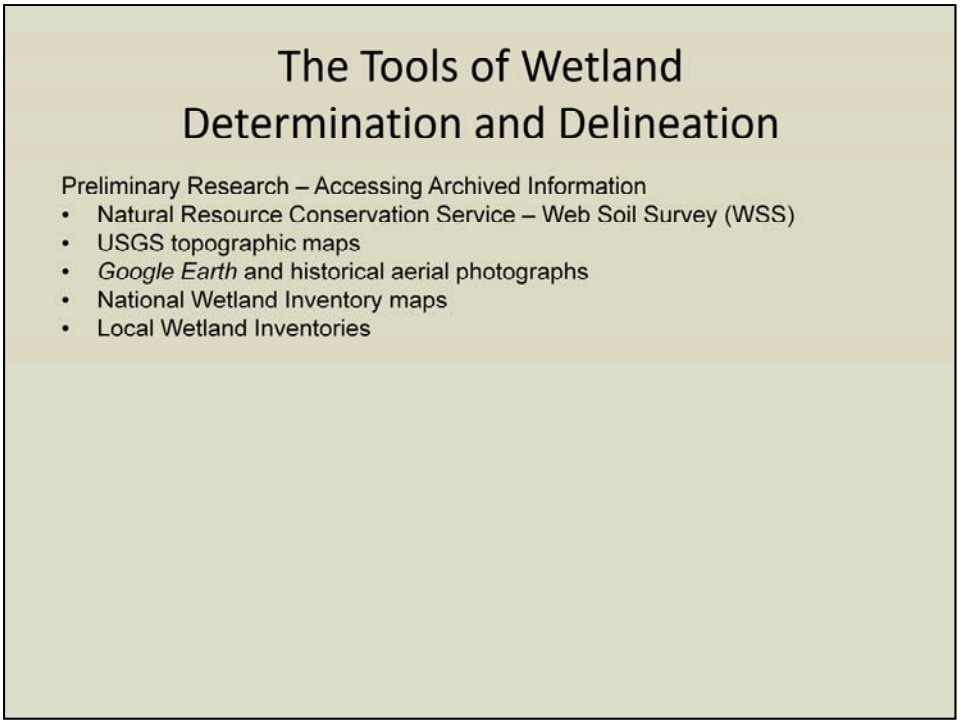
The National Wetland Inventory (NWI) Program was established by the U.S. Fish and Wildlife Service in 1974. Its primary objective is to conduct a national inventory of U.S. wetlands to assist wetland conservation efforts. Wetlands in the program are categorized according to the classification scheme developed by Cowardin, et al. (1979), which is described in the NCSR module *Wetlands – An Introduction.* Wetland maps are generated from aerial photography and digital satellite imagery and are digitized for GIS applications. NWI data are displayed with a tool called the "Wetlands Mapper" shown here with wetland types (indicated by their abbreviations) overlaying a *Google Earth* image of an area on the Central Oregon Coast.

The NWI also periodically releases reports on the status of the nation's wetlands. The most recent is entitled, "Status and Trends of Wetlands in the Conterminous U.S. 1998 to 2004." A more recent report, originally scheduled for release in 2010 had not been completed at the time this module was published.

NWI maps provide one of our best tools to assess the extent of and monitor changes in the wetlands of the United States. However, since aerial imagery is the primary data source for the maps, there are some limitations. Small areas, for example, are not well-mapped due to the resolution of the imagery and are often missed. If available, local wetland inventories are more likely to include these wetlands. Also, it should be noted that only wetland coverage is measured, not the ecological condition of wetlands. Future efforts will include developing methods for monitoring wetland condition in addition to wetland extent.

With the degradation and loss of wetlands continuing, NWI maps are used routinely to identify and estimate the extent of wetland impacted by development. In addition to this traditional use, NWI maps are also being used to:

1. Assess potential impacts of global climate change – for example:
    - Predict the impacts of sea level rise in coastal areas
    - Analyze carbon sequestration in wetlands
2. Assist in various conservation efforts, such as:
    - Wetland restoration planning projects
    - Watershed-level or landscape-level assessments
    - Identification of areas suitable for acquisition as national wildlife refuges
    - Threatened and endangered species management
    - Invasive species control programs



Local Wetland Inventories:

For some areas, more detailed inventories of wetlands may be available. Local wetland inventories are systematic surveys of wetlands that are conducted using aerial photos, soils maps and field observations. They are usually done within cities and maintained by local government agencies (e.g., county land use, city planning).

The availability of LWIs is highly uneven across the country. However, if one is available for the study area, smaller wetlands that would not show up on NWI maps can be identified. LWI maps are generally much more detailed and accurate than NWI maps, but not as detailed as a wetland delineation.

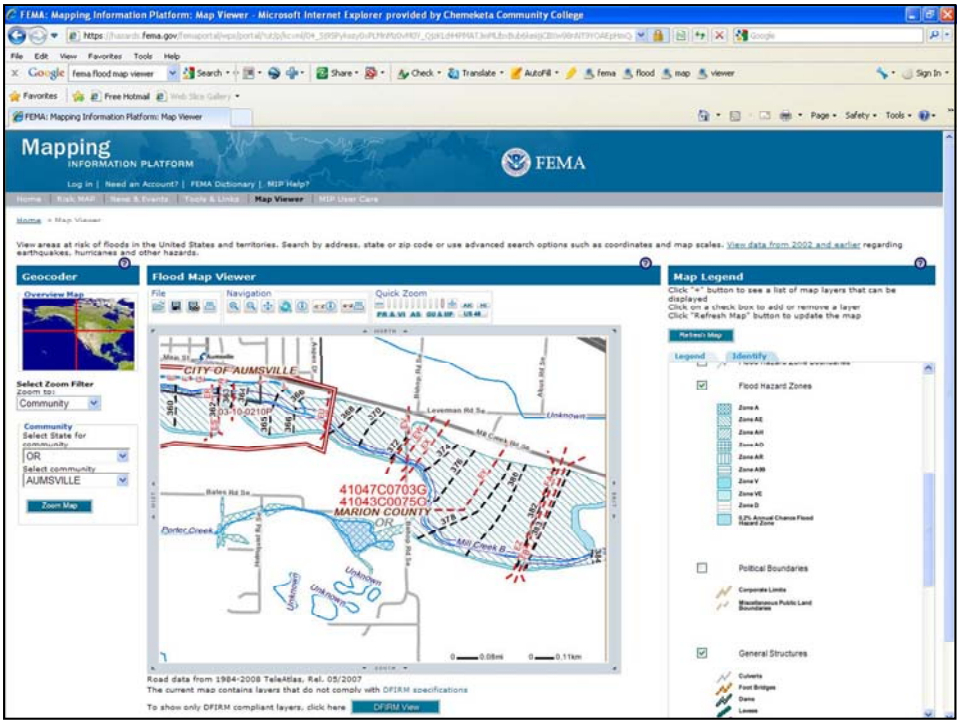
LWI maps can be difficult to find. They are most commonly available through state wetland regulatory agencies and city planning offices.

Image credit: Oregon Department of State Lands

The Tools of Wetland Determination and Delineation

Preliminary Research – Accessing Archived Information

- Natural Resource Conservation Service – Web Soil Survey (WSS)
- USGS topographic maps
- *Google Earth* and historical aerial photographs
- National Wetland Inventory maps
- Local Wetland Inventories
- FEMA floodplain maps



FEMA Floodplain Maps:

The Federal Emergency Management Administration (FEMA) produces and maintains flood maps for insurance purposes. These maps can be used to identify those areas that are prone to flooding and thus, are candidates for having hydric soils that support wetlands.

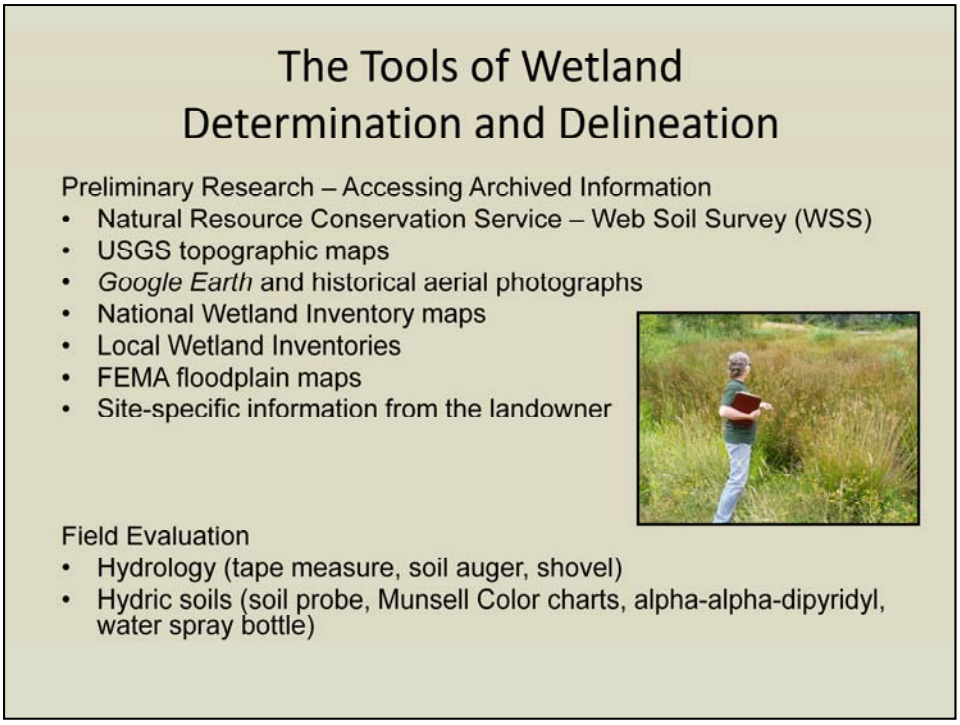
On this map:

Zone A (double blue cross hatch) – corresponds to 100-year floodplain determined by approximate methods (rather than detailed hydraulic analyses)

ZONE AE (single blue cross-hatch) corresponds to 100-year floodplain as determined by detailed hydraulic analyses

NOTE: The 100-year floodplain is that area that is expected to be inundated during flooding that occurs on average once every 100 years.

Image credit: FEMA, www.hazards.fema.gov/femaportal/wps/portal



Site-specific information from the landowner:

Landowners, particularly those who have a long-term association with the site, can be a valuable source of site-specific information that is not available elsewhere. Anecdotal accounts of historical changes in land use, excavations, fill/dumping, changes in hydrology, crop history, flooding episodes, etc. may all be obtained through interviews with the landowner or sometimes, adjacent landowners. This information can often be used to explain observations seen in the field.

Field Evaluation
Field evaluation generally involves an assessment of the three criteria that determine wetlands in an effort to determine the boundary between wetland and upland.

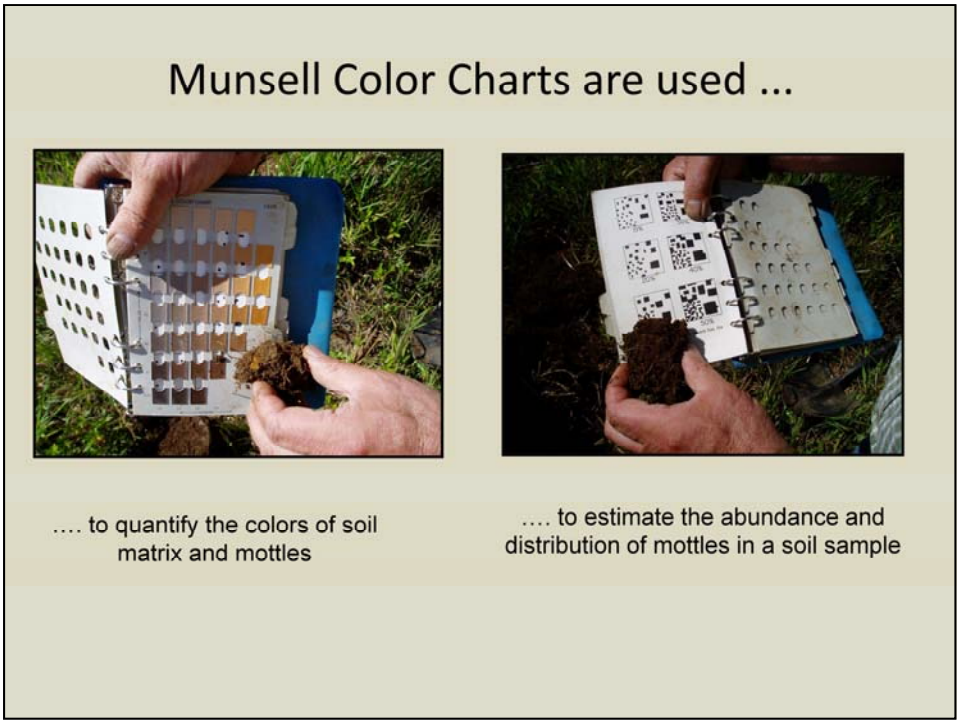
Hydrology – few specialized tools required because technicians are generally looking for indicators of hydrology as previously discussed. A long pointed shovel or a soil auger may be used to dig soil pits to determine the level of soil saturation and the depth of the water table.

Hydric soils – soil probes and/or shovels are used to examine soil layers; color charts are used to quantify color changes that occur in soils; alpha-alpha-dipyridyl may be used as an indicator of hydric soils. A water spray bottle is often used to moisten soils to determine physical properties and color. A sharp knife is also used to cut vertically through a soil sample so that the soil profile can be more easily seen.

Wetland vegetation – Field guides are used to identify plants on the study site and the National Plant List is used to determine the wetland status of plants.

General – Data sheets, flagging (to mark boundaries). GPS units are commonly used now to indicate the position of the boundary between wetland and upland. Maps and other archived information obtained in the preliminary research may also be brought into the field for reference.

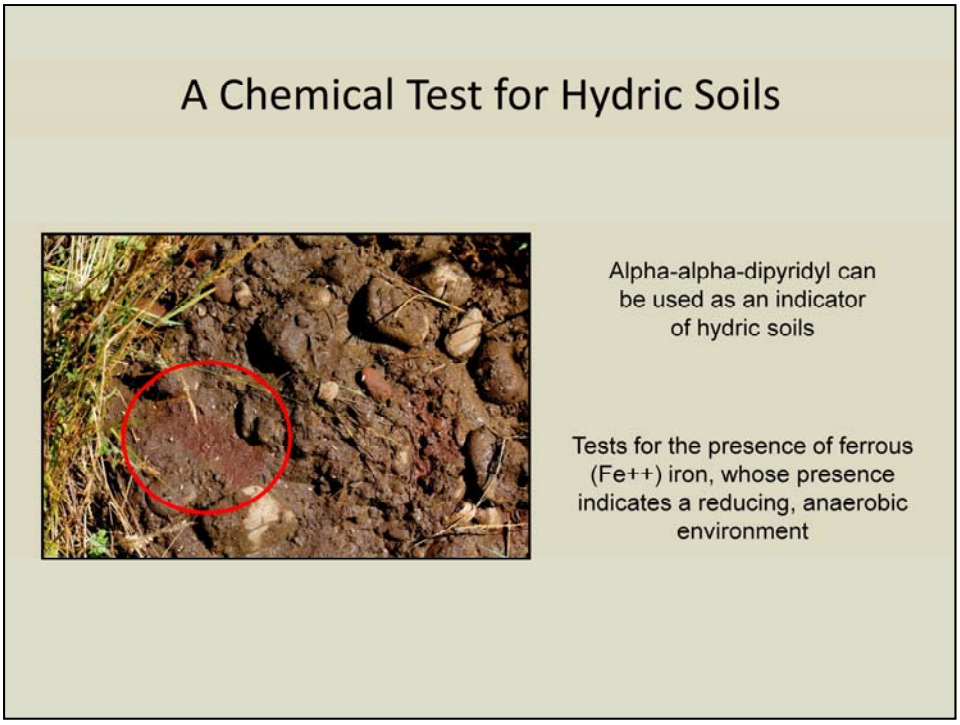
Photo credit: Becca Cudmore



The color of soils is commonly used to identify hydric soils. The background color of the soil (the matrix) as well as the color of mottles within the matrix are important considerations. Standard colors on Munsell Color Charts are used for comparison with samples taken in the field. Note the presence of orange iron oxide mottles in the photograph and the color comparison on the color chart.

The abundance and distribution of mottles is visually estimated by comparison with diagrams, which illustrate the appearance of various percentages of mottles.

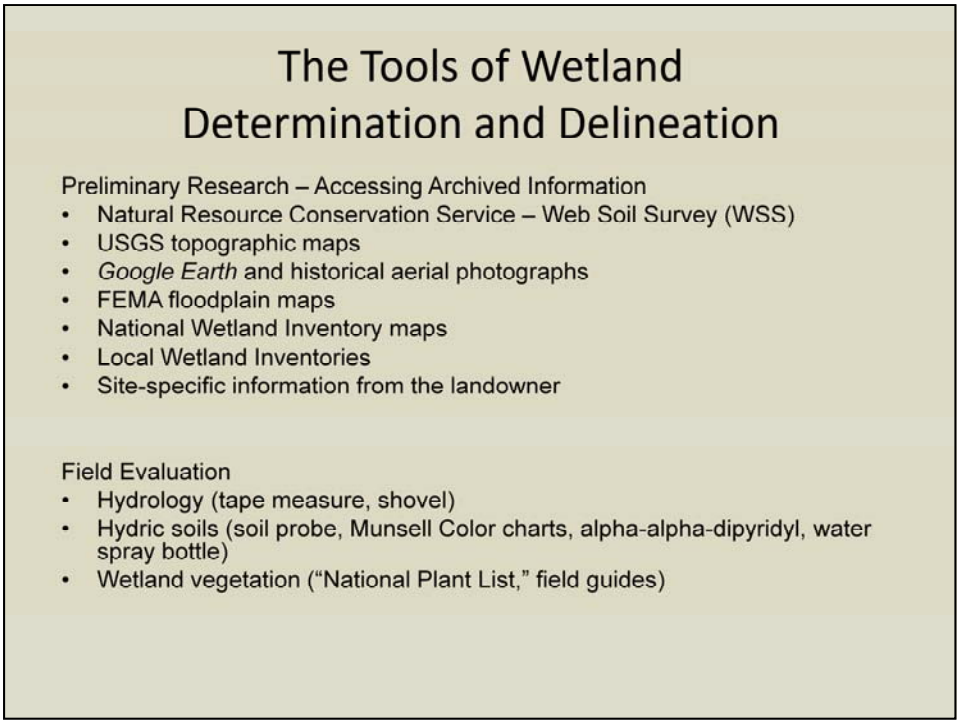
Photo credits: Becca Cudmore



Alpha-alpha-dipyridyl is a dye that can be used as an indicator of hydric soils. It is actually a test for the presence of ferrous (Fe++) iron whose presence indicates a reducing, anaerobic soil environment. Under aerobic conditions iron exists in its ferric (Fe +++) state. When sprayed on freshly exposed soil, alpha-alpha-dipyridyl will produce a pink or red color within a few seconds if Fe++ is present at adequate concentrations. This reaction indicates that the soil is reduced and anaerobic at the time of the test.

In this photo, alpha-alpha-dipyridyl has been sprayed on freshly exposed soil. The red color (brick red in photo) indicates a positive test (= hydric soil).

Photo credit: Becca Cudmore



Field Evaluation (continued)

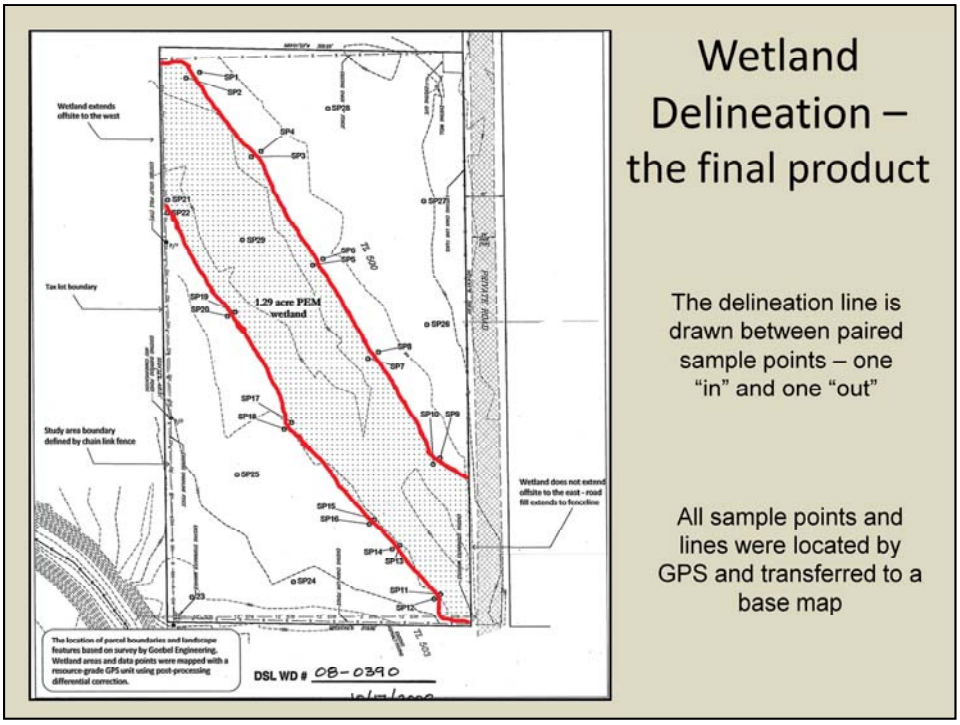
Wetland vegetation – Field guides are used to identify plants on the study site and the National Plant List is used to determine the wetland status of plants.

General – Data sheets are used to record all measurements and field observations and flagging is used to mark the wetland boundaries. GPS units are commonly used now to indicate the position of the boundary between wetland and upland. Alternatively, standard surveying methods can be used to establish the boundary. Maps and other archived information obtained in the preliminary research may also be brought into the field for reference.

This photo shows the results in the field of a completed wetland delineation in Eugene, Oregon. The pink stake flags represent the wetland-upland border; “wetland” is to the right of the flags and “upland” to the left. Note also two of the sample points (blue stake flags), which are used to establish the delineation line. The upland (left) flag represents the “out of wetland” sample point; the wetland (right) flag represents the “in wetland” sample point. Standing water can be seen in the right portion of the photo.

Photo Credit: Allen Martin

Photo Credit: Allen Martin



This map is the final product of the delineation shown in the previous photo. Several paired sample points (one "in wetland" and one "out of wetland") can be seen in the image indicated by "SP#." Measurements and observations of the various wetland indicators (hydric soils, wetland vegetation and hydrology) are recorded at each pair of sample points. The delineation line (red on slide) is drawn between each of the sample points. For this delineation, all sample points and lines were located using a GPS unit in the field and later transferred to a base map. The number of sample points required is determined by how complex the topography is along the upland-wetland border. This delineation resulted in a 1.29-acre palustrine emergent (PEM) wetland indicated by the stippled area on the map.

Figure Credit: Allen Martin

Wetland Determination and Delineation - Summary

- The determination of the presence of wetlands and their boundaries is commonly required to comply with laws protecting wetlands
- A wetland delineation establishes a line between “wetland” and “upland”
- The criteria for the identification of wetlands and accepted delineation methods have been established by the U.S. Army Corps of Engineers
- Wetlands are identified by field and remote investigations that examine hydric soils, hydrology and wetland plants
- Hydric soil indicators are used in the field to detect chemical changes in the soil created by the absence of oxygen
- The hydrological regime is determined by examination of archived records and hydrological indicators in the field
- Plants are categorized according to their adaptation to saturated soils and are used as wetland indicators
- Several sources of archived information are used in wetland determination and delineation to supplement field data

Photo Credits

- Allen Martin
- Becca Cudmore
- David Lonsdale, Chemeketa Community College
- FEMA, www.hazards.fema.gov/femaportal/wps/portal
- Google Earth
- IAN Image Library (ian.umces.edu/imagelibrary), Ben Fertig, Emily Nauman, Jane Thomas
- Natural Resource Conservation Service. Peat soils in Richland County, Wisconsin. Ho Chunk Nation of the Winnebago Tribe of Wisconsin
- Oregon Department of State Lands
- USDA Natural Resources Conservation Service: Mark DeBrock
- USDA-NRCS PLANTS Database: Jennifer Anderson, Lee Casebere, Robert H. Mohlenbrock
- U.S. Geological Survey
- U.S. Fish and Wildlife Service, Robert Shallenberger
- U.S. Fish and Wildlife Service, National Wetlands Inventory
- Wynn Cudmore

Extra Photo

Photo credit: Becca Cudmore

Wetland Determination and Delineation Laboratory

INTRODUCTION

Early wetland policy was driven by the perception of wetlands as wastelands that should be drained and filled to better accommodate human uses such as agriculture and urban development. This view of wetlands led to the elimination of over half of the total wetlands in the lower 48 states by the end of the 20th century. As our understanding of the ecological role of wetlands grew, a change in the perception of wetlands occurred and, along with this change, legislation that protected wetlands and made it more difficult to destroy them.

Implementation of this legislation required answers to questions that had not previously been considered. What is a wetland and what criteria should be used to distinguish wetlands from non-wetlands? How much wetland is on a given property? Where is the boundary between "wetland" and "non-wetland?" This is the realm of wetland identification (determination) and delineation.

Several types of people in our society now have compelling reasons to identify and delineate wetlands. Environmental groups may use these methods to identify ecologically significant wetlands to be protected as a park or preserve or to help resist or modify the development of wetlands. Financial institutions may require an assessment of wetlands on a property before a loan is granted. Landowners, developers and planners may need to have wetlands delineated prior to developing a site plan so as to avoid impacting wetlands or to determine the cost for mitigating unavoidable impacts. Governments at local, state and federal levels may require assessments of wetlands as infrastructure such as new roads, bridges, or utilities are being planned that may impact wetlands.

The identification of potential jurisdictional wetlands is based on an examination of the three criteria that are used to define wetlands – hydrology, soils and vegetation. Each of these criteria is evaluated using a combination of the analysis of available data and reference material and field evaluation (measurement) of wetland indicators.

OBJECTIVES

Upon successful completion of this activity students should be able to:

1. Describe the need for wetland identification and delineation in wetland management.
2. Conduct research on a potential wetland site using various resources.
3. Conduct a preliminary field study that examines soils, hydrology and vegetation as criteria for wetland determination.
4. Identify an approximate wetland boundary using both archived information and data collected on the site.

PROCEDURE

I. Preliminary Research – Accessing Archived Information

Prior to a field visit, a wealth of information concerning a potential wetland site can be determined from archived sources. Several of these will be made available to you or you will be directed to web sources that will provide specific types of information. Use these resources to learn what you can concerning the field site. Record any pertinent information on the attached "Wetland Determination and Delineation - Archived Information" data sheet.

Natural Resource Conservation Service – Web Soil Survey (WSS)
http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm

> NOTE: Alternatively, hardcopies of county soils surveys available from your local NRCS office may be used here.

Examination of a soil survey to determine whether or not the soils at the study site have been identified as "hydric" is a common first step in identifying and delineating wetlands. Soil types at the site are identified and then compared to a wetlands soils list (some soils are listed as hydric soils). Soil surveys, once only available in hard copy, are now available for most areas in the U.S. on-line. The Web Soil Survey (WSS) provides soil data and information produced by the National Cooperative Soil Survey. It is operated by the USDA Natural Resources Conservation Service (NRCS) and provides access to the largest natural resource information system in the world. NRCS has soil maps and data available on-line for more than 95 percent of the nation's counties and anticipates having 100 percent in the near future. The site is updated and maintained on-line as the single authoritative source of soil survey information.

Using this resource is a four step process:

1. Navigate to the study site and define an "area of interest"
2. Generate a soils map using the "Soil Mapper" (soils are overlaid on an aerial photo)
3. Use the "Soils Data Explorer" to retrieve soils data
4. Generate a personalized soils report using the "Shopping Cart"

Detailed instructions on the use of the Web Soil Survey are provided on the NRCS web site. The following is a brief overview:

1. The study site is first located on a base map and an "area of interest" (AOI) is defined by the user as an overlay on this map. Several options are provided that allow you to navigate to the study site, such as the site's street address, state and county, latitude/longitude coordinates, legal description (section, township, range), etc. An area of interest is defined by selecting the AOI tool and dragging in a box that establishes borders around the desired area.
2. Once an area of interest is defined, the "Soil Map" tab can be selected to superimpose a soils map over the AOI. Different soil types are designated by map unit symbols. The map unit name and the area of each soil type within the AOI are given in a table to the left of the soils map.

3. Various soils data can be accessed by clicking on the "Soil Data Explorer" tab. The presence of hydric soils is determined by opening the "Suitabilities and Limitations for Use" tab and then the "Land Classification" link and then the "Hydric Rating by Map Unit" link. Click on "View Rating" to generate the color-coded hydric soils map. The "Legend" tab on the left margin of the map defines each of the colors used in the map.
4. The Web Soil Survey automatically generates a site report as a .pdf file. A template that includes a title, an explanatory narrative, a soils map, etc. is provided. The user can add any other element to the report by selecting the "Shopping Cart" tab while viewing that element. For example, if you would like to add a hydric soils map to the report, simply select the "Shopping Cart" tab after you have generated that map. When all desired elements have been added, select "Check out." A site-specific report will be generated that can be printed or saved. Unlike almost any site where "Shopping Cart/Check Out" functions are used, you will not be asked to enter your credit card number. The service is free.

USGS Topographic maps

USGS topographic maps can be accessed using *NASA World Wind* or will be available for you in hard copy.

Open the topographic map for your site and examine to determine:

- Location
- Topography – flat, terrace, position on slope, depression, hummock, etc.
- General land use of site and surrounding area (urban, forested, agriculture, etc.)
- Position of study site relative to natural stream network (proximity to other water sources such as streams, ponds, drainage ditches, other wetland areas) – drainage patterns
- Excavated or not (look for mining symbol on map)

***Google Earth* and historical aerial photographs or other remote sensing imagery**

Examine to determine:

- Location
- Topography – flat, position on slope, etc.
- Land use of site and surrounding area (past and present)
- Position of study site relative to natural stream network
- Evidence of disturbance (excavation, landslides, etc.)
- Evidence of inundation (flooding, saturation of soils, etc.)

Historical *Google Earth* imagery is now available for many locations across the United States. This imagery can sometimes be used to determine any land use change that has occurred on the site. To access historical imagery, Select **View** from the main menu and then **Historical Imagery**. A slider bar will appear superimposed over the image indicating the availability of historical imagery. Click on the slider bar to select images. Dates available will vary from site to site, but most go back to at least the mid-1990s.

National Wetlands Inventory
www.fws.gov/wetlands

The U.S. Fish and Wildlife Service has produced a national wetlands inventory that is based primarily on an analysis of aerial photographs. Wetlands are identified, mapped and then superimposed on topographic maps. The inventory does not identify all wetlands in an area, but probably the most significant ones. Thus, if your site is found within a wetland identified in this survey, it has a high probability of being a wetland.

The "Wetlands Mapper" allows viewing of identified wetlands either on-line or hard copy maps can be ordered for every state (see "Hard Copy Orders"). Each wetland is mapped as a polygon (a multi-sided closed figure) with an imbedded code that indicates the specific wetland type and other information related to this site. In the on-line version, codes may not be seen initially, but will appear as you zoom in on the site. A measure tool ("Tools") allows linear and area measurements (polygons) on the site. In general, linear wetlands are not mapped since their extent is difficult to determine from aerial photographs. Therefore, most riparian wetlands do not show up on the "Wetlands Mapper."

General wetland types ("Freshwater emergent," "Marine and estuarine," etc.). are color-coded on NWI maps. Similar wetland types are assigned the same color. All freshwater emergent wetlands, for example, are displayed in a light green. In the on-line version, click on the wetland polygon to decode the site designation. To obtain more detail on the classification of the wetland, go to the web site below and enter the case-sensitive code found on the NWI map for the study site:

http://137.227.242.85/Data/interpreters/wetlands.aspx

Alternatively, use the "Help" function (beside "Available Layers" on the NWI map) and navigate to the decoder. See *Wetlands Mapper – Documentation and Instructions Manual* (May 2010) for further explanation of codes used in NWI maps.

Local Wetland Inventories

For some areas, more detailed inventories of wetlands may be available. Local wetland inventories are systematic surveys of wetlands that are conducted using aerial photos, soils maps and field observations. They are usually done within cities and maintained by local government agencies (e.g., county land use, city planning). Their availability is highly uneven across the country, but if a local wetland inventory is available for the study area, smaller wetlands that would not show up on NWI maps can be identified. LWIs are more detailed than NWI soils maps, but less detailed than a delineation.

FEMA Floodplain maps
www.msc.fema.gov/

The Federal Emergency Management Administration (FEMA) produces and maintains flood maps for insurance purposes. These maps can be used to identify those areas that are prone to flooding and thus, are candidates for having hydric soils that support wetlands. FEMA's Map Service Center has scalable digital maps that can be searched by address, state or zip code. Click on the "Map Viewer-Web" link to access the floodplain maps. See the "FEMA Dictionary" link for an explanation of the codes used on the floodplain maps.

Site-specific information from the landowner

Landowners, particularly those who have a long-term association with the site, can be a valuable source of site-specific information that is not available elsewhere. Anecdotal accounts of historical changes in land use, excavations, fill/dumping, changes in hydrology, crop history, flooding episodes, previous ownership, etc. may all be obtained through interviews with the landowner or sometimes, adjacent landowners. This information can often be used to explain observations seen in the field or to help guide your areas of investigation.

II. Field Evaluation

After all archived information on the site has been examined and recorded, a field evaluation is required. The first step in a basic wetland determination and delineation is to "walk the site" looking for low elevation areas and any streams, ditches, seasonal creeks or adjacent wetlands. Particular attention should be paid to those areas where hydric soils have been identified using soils maps. Recall that hydric soils inclusions may be included within soil map units that are not identified as "hydric." The presence and abundance of wetland plants should also be noted.

The field evaluation can now turn to more detailed examination of the three criteria that are used to distinguish wetlands from uplands – hydrology, soils and vegetation. To be considered a "jurisdictional wetland," a site must meet minimum criteria for at least two out of three of these criteria.

Your instructor will assign your group an area or sample points for evaluation. Record all of your observations as indicated on the attached "Wetland Determination and Delineation - Field Evaluation Data Sheet." A separate data sheet should be completed for each sample point.

Hydrology

The quantitative measurement of hydrological parameters at a potential wetland site requires long-term measurement of hydrological parameters such as surface water inflow and outflow, water levels, and ground water flow. These data are generally available only when the area in question is close to a body of water whose water levels are routinely measured at a tidal or stream gauging station. Since this is the exception rather than the rule in most areas, it is not often used by wetland practitioners. There are, however, a number of indicators that indirectly

demonstrate the presence of hydrological conditions that support wetlands. The following list provides some examples:

- The presence of standing water
- The presence of a seasonal or permanent high water table (<12") (e.g., water seepage into a pit dug for soil analysis)
- The presence of saturated soils at a depth of 12 inches or less (indicated by "glistening" of soil layers or if you are able to squeeze water out of a handful of soil)
- Water marks on trees, fences or other fixed objects
- Sediment deposits - coatings of silt or clay particles on plants and other structures
- Drift deposits - rafted debris on the ground or suspended on plants, trees, fence posts, logs, etc.
- Algal mats or crust on surface
- Iron deposits (orange or yellow color) on soil or other surfaces
- Surface soil cracking
- Sparsely vegetated concave surface (depression)
- Salt crust
- Aquatic invertebrates (e.g., aquatic snails, clam shrimp)
- Water-stained leaves
- The presence of drainage channels or scouring
- Matting or bending of vegetation in direction of water flow indicating previous flooding
- Proximity of site to other water sources seen in the field – e.g., streams, ditches, depressions

A test that provides more immediate results involves that application of a solution to suspect soils to indicate the presence of reduced (ferrous) iron in the upper 12" of the soil profile. Alpha-alpha-dipyridyl solution turns pink or red in a reducing environment indicating a hydric soil. Additional tests that indicate the oxidation-reduction (redox) status of soils are also available and are described in the 1987 Army Corps of Engineers wetlands delineation manual.

Examine your site for the presence of any hydrological indicators and enter your observations on the data sheet.

Soils

Hydric soils are defined as soils that are water saturated for extended periods of time during the growing season. Soils that are "waterlogged" will often demonstrate characteristics that distinguish them from non-hydric soils. In non-hydric soils, oxygen is trapped in the many spaces between soil particles. This oxygen is used by plants to carry out respiration – the metabolism of sugars to obtain energy. In hydric soils however, this soil oxygen is rapidly depleted due to chemical and biological oxygen demands and anaerobic conditions result. This lack of oxygen has a number of effects on the biological and chemical processes in soil.

Depending on the season when field observations are being done, soils may not be saturated upon field inspection. However, manifestations of saturated or waterlogged soils can usually be detected by either using a soil probe to obtain samples or digging soil pits to obtain samples.

With a shovel, dig a soil pit approximately 18-inches deep that is close to what you think is the wetland-upland boundary, but clearly in the wetland. Use the shovel to extract a thin longitudinal slice from the side of your soil pit to examine the soil layers. Gentle moistening of dry soils with a spray bottle facilitates the observation of layers. Moist soils need not be sprayed.

Examine your soil profile for the following features and record their presence on the attached data sheet.

1. Dark organic soil
2. Gleyed matrix – gleyed soils are formed when a soil is saturated for a prolonged period and is highly reduced. Gleyed soils have a characteristic steel-gray color. If the soil matrix matches the color chips found on the "gley page" of Munsell Color charts, it is considered "gleyed."
3. Oxidized rhizosphere and iron oxide root channels
4. Hydrogen sulfide odor
5. Mottles - Redox concentrations and redox depletions
6. Ferrous iron test - a solution of alpha-alpha-dipyridyl may be applied to soils to detect a reducing soil environment, which is indicated if the solution turns pink or red.
7. A restrictive layer that would prevent or slow water from seeping into deeper soil layers. This may be a layer of clay or bedrock that lies below the surface.

Vegetation

A site satisfies the vegetation criterion for a "jurisdictional wetland" when more than 50% of the dominant species of plants on the site are in the FAC, FACW and OBL categories. For delineations, visual estimation is often used to estimate plant dominance, but more sophisticated vegetation sampling methods can also be used. Of these, plot and line-intercept methods are the most common. Plant species found on the site are first identified and then compared to the National List (cited below).

Use your sample point as a center for the following circular plots:

- 1-meter radius – for herbaceous (soft-tissued) plants
- 2-meter radius – for shrubs and saplings (woody plants <1" diameter)
- 3-meter radius – for trees (woody plants >1" diameter)

Using your field guide, identify the most common herbaceous plants, shrubs and trees within your plots.

Estimate the percent cover of the dominant plants within each stratum and enter your data on the data sheet. Dominant plants are those that account for at least 20% cover within your plot. For each stratum, the total percent cover should add up to 100%. Bare ground, if present, should not be included in the percent cover estimate. Rather, record bare ground separately at the bottom of the data sheet.

For example, in a 1-m radius plot, you find the following:

Species A – 35%
Species B – 25%
Species C – 25%
Species D – 10%
All others – 5%
Total – 100%

Species A, B and C would be considered "dominant plants" in this example since all account for at least 20% cover.

If your plot has a large number of species, no one of which exceeds 20% cover, just list the species in descending order of dominance and add up the percent cover for each until you reach at least 50%. These plants will be considered your "dominant species."

For example, in a 1-m radius plot, you find the following:

Species A – 15%
Species B – 15%
Species C – 15%
Species D – 10%
Species E – 5%
All others – 40%
Total – 100%

Species A, B, C and D would be considered "dominant plants" in this example, since over 50% cover is reached by adding up those species (15+15+15+10 = 55%).

Once vegetation sampling is complete, determine the wetland status of each species by consulting your field guide or the National Plant List referenced below. Then, complete the *Dominance Test Worksheet* and the *Prevalence Test Worksheet* as indicated on the data sheet. To meet the vegetation criteria for wetlands, the dominance test should be >50% and the prevalence index should be <3.0.

The "National Plant List"

www.usace.army.mil/CECW/Documents/cecwo/reg/plants/list96.pdf
www.usace.army.mil/CECW/Documents/cecwo/reg/plants/national.pdf

Originally prepared by the U.S. Fish and Wildlife Service and now maintained by the U.S. Army Corps of Engineers, the national plant list includes all vascular plants known to occur in U.S. wetlands. Thus, it is a useful resource in the field determination of wetlands based on an analysis of vegetation. Those plants that have been identified in the field can be compared to this list to see if they are associated with wetlands. Note that there are plant lists for different regions of the U.S. Be sure you are using the list that is specific to your region.

III. Delineating the Wetland (OPTIONAL)

Place a stake flag between your "in-wetland" and "out-of-wetland" sample points. Other groups will do the same. Stake flags may be placed on the boundary between student groups to construct a continuous boundary line between wetland and upland. Although only a portion of the wetland has been delineated by this activity, continuing the process would result in a completed delineation. In practice, once the boundary is flagged the line would be surveyed or located by Global Positioning Systems (GPS) to generate a map that would document the wetland-upland boundary and the area of the wetland.

NOTES TO INSTRUCTORS

Introduction

The *Wetland Determination and Delineation Laboratory* is intended to provide students with a hands-on experience that introduces the concepts and practice of wetland determination and delineation. The activity is not designed to provide the training that is required by individuals to become certified wetland delineators or other types of wetlands technicians, as these curriculum materials and mechanisms for their delivery are available elsewhere.

The activity is designed to be presented over two 3-hour laboratory periods. The first is dedicated to accessing archived information on the study site. Students should also be introduced to the concepts of and the need for wetland determination and delineation using the *PowerPoint* presentation associated with this module. The second laboratory is dedicated to field evaluation of the study site.

A word on adaptation of the activity

Although this activity is designed to be as generic as possible, it will likely require some modification to tailor to your specific region. This is particularly true for the field evaluation portion of the activity. Some indicators for hydric soils, for example, may not apply to soils in your area. Plant identification will certainly differ from one location to another. In some cases, a plant species that has one wetland status in Oregon, will have a different designation in other parts of the country. Refer to local or regional resources cited in this module or state agencies (e.g., Department of State Lands in Oregon) with primary responsibility for wetland management in your state.

NRCS Web Soil Survey (WSS)

While soils maps may indicate whether or not hydric soils are found in the area, field examination is required to gain a finer scale and to verify the results of the soil survey. Soil surveys are generated primarily by examination of aerial photographs and within each area identified with a hydric soil, there may be areas that are not hydric. Likewise, upland areas that are not identified as having hydric soils may have small areas of hydric soils (**inclusions**) imbedded within them. Because of this, it is a good idea to see if your "upland" soil is known to have hydric inclusions.

The presence of inclusions can be determined from the Web Soil Survey and instructors may want to incorporate this determination into the activity. This is accomplished by investigating those soils on the study site that are not hydric to see if they are likely to have hydric inclusions within them. After identifying the names of soils series on site, go to "Official Soils Descriptions" on the WSS home page and then "View by Series Name." Enter the soils series name where indicated and then click "View Description," which will provide a narrative description of the soils series in question. Scroll down to the header "Geographically Associated Soils." That section will provide the names of those soils that are commonly found "associated with" or "imbedded in" this soil type. Check these soils names against the hydric soils list to see

if any of them are hydric soils. Those that are hydric are potential hydric inclusions that may be encountered on your study site.

The *NRCS Hydric Soils National List* can be found at:
www.soils.usda.gov/use/hydric

USGS topographic maps and historical photos

Topographic maps can be purchased locally or ordered through the U.S. Geological Survey web site. They are also available on-line. See *NASA World Wind* (http://worldwind.arc.nasa.gov/download.html) for free download.

Although *Google Earth* (www.google.com/earth/index.html) is probably the most accessible source for remote sensing imagery, there are also other sources:

- *NASA World Wind*
- University map libraries
- Commercial aerial photography companies – detailed, current, but expensive

Field Site Identification

Any field site with wetlands and easy access can be used for this activity. Relatively simple sites with a clear wetland-upland boundary work better than complex sites where a mosaic of wetlands occurs within an upland matrix. I have successfully used a local county park for the activity with my students and one of my Oregon colleagues is fortunate to have an on-campus wetland.

Students work in small groups of 3 or 4. Spread the groups along the suspected wetland-upland boundary to be delineated. Have each group sample two points (more, if time allows) along the suspected wetland-upland boundary – one in the wetland and one outside the wetland within a few feet of each other. I would suggest pre-selecting and marking sample points for students. For sites with rocky or gravelly soils that are difficult to dig, in the interest of time, you may even want to pre-dig soil pits for students. Sampling can then be conducted by using a shovel to take a slice from the side of the pre-dug hole.

If you are conducting the delineation portion of the activity, the wetland-upland boundary will occur between the "in wetland" and "out of wetland" sample points and should be flagged with a colored stake flag. When all groups have completed their sampling, a continuous line should be flagged between student groups, marking the delineation line. The spacing between flags will vary depending on how convoluted the boundary is. You might try having students continue flagging the delineation line as a large group beyond where sampling was conducted using only surface features (especially plant species) as indicators. Debates over the positioning of the flags can be a good learning experience for students.

Once the wetland boundary has been flagged, the line would ordinarily be surveyed or GPS units would be used to generate a map of the site (see *PowerPoint* presentation for example). The map would be used to determine the wetland boundary and the area of wetland involved. Instructors

may want to incorporate this step into the activity or perhaps involve instructors and students in a surveying class.

Data Sheets

Students should complete one of the "Wetland Determination and Delineation - Archived Information" data sheets prior to the field activity. For the field evaluation, each sample point will require a separate data sheet. Data sheets may need to be customized for the conditions present at your study site.

Field Evaluation of Hydric Soils

Complete analysis of hydric soils is complex and beyond the scope of this module. When delineations are done by wetlands practitioners, the determination of soil color throughout the profile is critically important. This determination is made by comparing soils at various strata with standard colors found in *Munsell Color Charts*. Three values are assigned – hue, value and chroma:

Hue – the soil color relative to primary colors red, yellow and blue
Value – the lightness of the hue
Chroma – the strength of the color; departure from a neutral of the same lightness

Instructors who are interested in applying this level of sophistication to the *Wetland Determination and Delineation Laboratory* would benefit from attending a wetland delineators course that includes instruction on the identification of hydric soils. Possible sources for these courses are cited in the introduction to the *Wetland Mitigation* series (see beginning of this module).

As described in this activity, it is probably not necessary for each student group to have a *Munsell Color Chart*. Instructors may find it useful to have a single copy for reference or to use in a demonstration

Field Evaluation of Hydrology

In this activity the presence of wetland hydrology is evaluated indirectly by looking for "hydrological indicators." There are a number of ways to more directly demonstrate the presence of hydrological conditions that support wetlands. Baldwin (2001), for example, describes a simple method for determination and visual demonstration of hydrology at a site. The method relies on the anaerobic nature of wetland soils due to waterlogging or saturation. Stick large non-galvanized nails into wetland and nearby upland soils. After a few weeks, return to the site and observe the amount of oxidation that has occurred on the nails as indicated by the amount of orange coloration. Upland nails should be more orange than wetland nails due to the presence of oxygen and the formation of iron oxides (rust-colored). Nails in wetland soils will remain unchanged or be covered with dark, gray patches indicating the presence of reduced iron compounds. It is prudent to flag the location of the nails for ease of finding them again, and counting in advance to ensure all are collected for the safety of future visitors to the site.

Hydrology can also be measured on-site by sinking an array of "water monitoring tubes" – approximately 24-inch long, 3-inch diameter plastic pipes – into the ground at the study site. Water depth in each of the tubes can be measured at regular intervals as an indication of how close the water table lies to the surface. For example, in Oregon, to be considered a hydric soil, the water table must be within 12" of the ground surface for at least two weeks during the growing season.

Field Evaluation of Vegetation

Proper identification of dominant plants is essential to this activity and can be a challenge for the novice. Each student group should have a local plant identification guide. Citations for examples of identification guides are provided under "Wetland Plants" of the Resources section of this module. As part of your introduction to the activity, you may want to point out the most commonly encountered species. In addition, tagging those pages in the identification guide of the most common plants encountered on the site can streamline the identification process. Labeled specimens can also be made available to students to confirm their identifications.

MATERIALS

For the "Preliminary Research" portion of this activity, students should have access to a computer with Internet access to:

- National Wetland Inventory maps (hardcopy or on-line)
- U.S. Geological Survey topographic maps (hardcopy or on-line)
- Natural Resource Conservation Service soil surveys (hardcopy or on-line)
- *Google Earth* or historical aerial photos of study site

For the "Field Evaluation" portion of the exercise:

- Wetland plant identification guides
- Shovels (or soil corers)
- Soil probes (optional)
- Stake flags
- Meter sticks
- Tape measure 30m
- Clipboards
- Data sheets
- Munsell color chart (optional)
- Alpha-alpha dipyridyl solution
- Hand lens

WETLAND DETERMINATION AND DELINEATION DATA SHEET - ARCHIVED INFORMATION

Project/Site: _____ Owner: _____
City/County: _____ State: _____
Site Location (Latitude/Longitude): _____
Investigator(s): _____ Date: _____

Record any relevant information from the following sources in the space provided. Enter "NA" if information is "not available."

Natural Resource Conservation Service – Web Soil Survey (WSS)

Soil Map Unit Name(s): _____
Are hydric soils present? _____

Comments: _____

_____

Print soils map and indicate location of study site on map.

USGS Topographic maps

Location (Section/Township/Range): _____

Topography: _____

Land use: _____

Proximity to water sources: _____

Evidence of excavation: _____

Comments: _____

_____

Print topographic map and indicate location of study site on map.

***Google Earth* and Historical Aerial Photographs**

Location: _____

Topography: _____

Land use (past): _____ Date: _____

_____ Date: _____

_____ Date: _____

Land use (present): _____

Position relative to natural stream network: _____

Evidence of disturbance: _____

Evidence of inundation?: _____ Date: _____

Comments: _____

_____

Print Google Earth image and indicate location of study site on map

National Wetland Inventory

Site within NWI-mapped wetland? _____ NWI Wetland type(s): _____

Adjacent areas within NWI-mapped wetland? _____

NWI Wetland type(s): _____

Comments: _____

_____

Print NWI map and indicate location of study site on map.

Local Wetland Inventory

Site within LWI-mapped wetland? _____ LWI Wetland type(s): _____

Adjacent areas within LWI-mapped wetland? _____

LWI Wetland type(s): _____

Comments: _____

_____

FEMA Floodplain Map

Site within 100-year floodplain? _____

Comments: _____

_____

Site-specific information from the landowner

_____

_____

_____

_____

_____

WETLAND DETERMINATION AND DELINEATION DATA SHEET – FIELD OBSERVATIONS

Project/Site: _____ City/County: _____ Sampling Date: _____

Owner: _____ State: _____ Sampling Point: _____

Investigator(s): _____ Local relief (concave, convex, none): _____

SUMMARY OF FINDINGS

Hydrophytic Vegetation Present? Yes ____ No ____ Hydric Soil Present? Yes ____ No ____ Wetland Hydrology Present? Yes ____ No ____	**Is the Sampled Area within a Wetland?**	**Yes** ____ **No** ____

Remarks:

VEGETATION

Tree Stratum (Plot radius: 3 meters)	% Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
	____ = Total Cover		
Sapling/Shrub Stratum (Plot radius: 2 meters)			
1.			
2.			
3.			
4.			
5.			
	____ = Total Cover		
Herb Stratum (Plot radius: 1 meter)			
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
	____ = Total Cover		

% Bare Ground in Herb Stratum _____

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: _____ (A)

Total Number of Dominant Species Across All Strata: _____ (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: _____ (A/B)

Prevalence Index worksheet:

Total % Cover of:	Multiply by:
OBL species _____	x 1 = _____
FACW species _____	x 2 = _____
FAC species _____	x 3 = _____
FACU species _____	x 4 = _____
UPL species _____	x 5 = _____
Column Totals: _____ (A)	_____ (B)

Prevalence Index = B/A = _____

Hydrophytic Vegetation Indicators:

___ 1 - Dominance Test is >50%

___ 2 - Prevalence Index is ≤3.0

Hydrophytic Vegetation Present? **Yes** ____ **No** ____

Remarks:

SOIL

Hydric Soil Indicators:

Check all that apply:

Results of Ferrous Iron Test: _____

___ Dark organic soil
___ Gleyed matrix
___ Oxidized rhizosphere
___ Hydrogen sulfide odor
___ Redox concentrations
___ Redox depletions

Comments:

Is a restrictive layer present? _____

Type: _____

Depth (inches): _____

Hydric Soil Present? Yes _____ No _____

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Check all that apply:

___ Surface Water
___ High Water Table
___ Saturation
___ Water Marks
___ Sediment Deposits
___ Drift Deposits
___ Algal Mat or Crust
___ Iron Deposits
___ Surface Soil Cracks
___ Inundation Visible on Aerial Imagery
___ Sparsely Vegetated Concave Surface
___ Water-Stained Leaves
___ Salt Crust
___ Drainage Patterns
___ Aquatic Invertebrates
___ Hydrogen Sulfide Odor
___ Oxidized Rhizospheres along Living Roots
___ Presence of Reduced Iron
___ Dry-Season Water Table
___ Stunted or Stressed Plants
___ Other (Explain in Remarks)

NOTES:

Field Observations:

Surface Water Present? Yes _____ No _____ Depth (inches): _____

Water Table Present? Yes _____ No _____ Depth (inches): _____

Saturation Present? Yes _____ No _____ Depth (inches): _____

Wetland Hydrology Present? Yes _____ No _____

Describe any recorded hydrological data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

SUGGESTED ASSESSMENT

1. Which archived resource(s) were the most useful in the determination of whether or not the study site was a wetland? Explain why.

2. Submit all supporting evidence (completed data sheets, maps, etc.) that establishes whether or not the study site is a wetland.

3. Write a brief (approximately 2-page) narrative that presents the case for why this site should or should not be considered a jurisdictional wetland. Incorporate relevant information from both archived sources and your field evaluation.

Use the following format for the narrative:

INTRODUCTION – Site description, location, ownership, etc.

HYDROLOGY
Archived information:
Field evaluation:

SOILS
Archived information:
Field evaluation:

VEGETATION
Archived information:
Field evaluation:

SUMMARY

Wetlands Determination and Delineation - Resources

Wetland Delineation

Adamus, P.R. 2001. Guidebook for hydrogeomorphic (HGM)-based assessment of Oregon wetland and riparian sites: Statewide classification and profiles. Oregon Division of State Lands, Salem, OR.

Describes a classification system for Oregon wetlands and riparian areas based on hydrogeomorphic characteristics – dominant water sources and their setting in the landscape.

Adamus, P.R. and D. Field. 2001. Guidebook for hydrogeomorphic (HGM)-based assessment of Oregon wetland and riparian sites. I. Willamette Valley ecoregion, riverine impounding and slope/flats subclasses. Volume IA. Assessment methods. Oregon Division of State Lands, Salem, OR.

Methods for assessment of Willamette Valley wetland sand riparian systems. Based on visual observation of indicators during a single site visit.

Adamus, P.R. 2001. Guidebook for hydrogeomorphic (HGM)-based assessment of Oregon wetland and riparian sites. I. Willamette Valley ecoregion, riverine impounding and slope/flats subclasses. Volume IB. Technical Report. Report to Oregon Division of State Lands, Salem, OR.

A description of wetland and riparian assessment based on wetlands found in the Willamette Valley, Oregon.

Brinson, M.M. 1993. A hydrogeomorphic classification of wetlands. Tech. Rept. WRP-DE-4. U.S. Army Corps of Engineers Waterways Exp. Station. Vicksburg, MS.

Original document proposing HGM as a wetlands classification system. (cited in Adamus 2001a)

Federal Emergency Management Administration (FEMA) – Map Service Center
www.msc.fema.gov/

The Federal Emergency Management Administration (FEMA) produces and maintains flood maps for insurance purposes. These maps can be used to identify those areas that are prone to flooding and thus, are candidates for having hydric soils that support wetlands. FEMA's Map Service Center has scalable digital maps that can be searched by address, state or zip code. Click on the "MapViewer-Web" link to access the floodplain maps. See the "FEMA Dictionary" link for an explanation of the codes used on the floodplain maps.

Lyon, J.G. 1993. Wetland identification and delineation. CRC Press, Boca Raton, Florida. 157 pp.

The details of how wetland determinations and delineations are conducted have changed somewhat since this text was published. However, it remains an excellent introduction to the topic. Clear explanations of the types indicators that are used to identify hydrological, soil and vegetation characteristics of wetlands are provided.

National Research Council. 1995. Wetlands: Characteristics and boundaries. Committee on Characterization of Wetlands. National Academy Press, Washington, D.C.
www.nap.edu

ORWAP. 2009. Manual for the Oregon rapid wetland assessment protocol. Oregon Department of State Lands.
www.oregon.gov/DSL/WETLAND/or_wet_prot.shtml

U.S. Army Corps of Engineers. 1987. Corps of Engineers wetlands delineation manual. U.S. Army Waterways Expt. Station, ER-W, Vicksburg, MS.
http://www.wetlands.com/regs/tlpge02e.htm

This is the document that establishes the methodology for wetland delineation in the U.S. In the West, it is used in conjunction with the following updated 2008 supplement. Similar supplements are available for other regions of the U.S. Instructors looking for more detail on wetland indicators (hydrology, soils, vegetation) used to delineate wetlands in their region should seek out the supplement for their region.

U.S. Army Corps of Engineers. 2008. Interim regional supplement to the Corps of Engineers wetland delineation manual: Western mountains, valleys, and coast region, ed. J.S. Wakeley, R.W. Lichvar, and C.V. Noble. ERDC/EL TR-08-13. Vicksburg, MS: U.S. Army Engineer Research and Development Center. 139 pp.
www.usace.army.mil/cecw/pages/reg_supp.aspx

Updates and supplements to the 1987 manual for other U.S. regions are available.

U.S. Army Corps of Engineers. 1989. Federal manual for identifying and delineating jurisdictional wetlands. Federal Interagency Committee for Wetland Delineation. U.S. Army Corps of Engineers, U.S. Environmental Protection agency, U.S. Fish and Wildlife Service, U.S.D.A. soil Conservation Service, Washington, D.C.
www.wetlands.com/pdf/89manv3b.pdf

Tiner, R.W. 2000. An overview of wetland identification and delineation techniques with recommendations for improvement. Wetland Journal 12(1):15-22.
http://www.fws.gov/northeast/wetlands/publications/189_overview_wetland_id.pdf

USDA Natural Resources Conservation Service - Wetlands Science Institute.
www.wli.nrcs.usda.gov

This is a good source for technical publications used by wetlands practitioners for wetland identification, delineation and field identification of hydric soils. The institute publishes technical leaflets on most wetlands topics. The institute also develops training and course materials for wetlands professionals on wetland restoration and enhancement, hydric soils, wetland delineation, wetland plant identification and hydrology. Several (e.g., Field Identification of Hydric Soils) are available as PowerPoint presentations for on-line training.

Wetland Soils

Hurt, G.W. and L.M. Vasilas (eds.). 2006. Field indicators of hydric soils. Version 6.0 United States Department of Agriculture, Natural Resources Conservation Service.

Richardson, J.L. and M.J. Vepraskas. 2001. Wetlands soils. CRC Press, Boca Raton, FL.
www.crcpress.com

USDA Natural Resources Conservation Service (NRCS). Hydric soil lists, criteria, technical notes, and field indicators publication.
http://soils.usda.gov/use/hydric/

USDA Natural Resources Conservation Service. 1996. Field indicators of hydric soils in the United States. USDA, NRCS, Fort Worth, Texas. 27 pp.

USDA Natural Resources Conservation Service. 2010. Field Indicators of hydric soils in the United States – Version 7.0 – 2010.
ftp://ftp-fc.sc.egov.usda.gov/NSSC/Hydric_Soils/FieldIndicators_v7.pdf
www.ftp-fc.sc.egov.usda.gov/NSSC/Hydric_Soils/FieldIndicators_v7.pdf

USDA Natural Resource Conservation Service – Hydric soils list (February 2011)
http://soils.usda.gov/use/hydric/

This is the site for all hydric soils listed state by state.

USDA Natural Resource Conservation Service – Web Soil Survey (WSS)
www.websoilsurvey.nrcs.usda.gov/app/HomePage.htm

Soil surveys are a critical element of wetland identification and delineation. Soil surveys once only available in hard copy are now available for most areas in the U.S. on-line. Web Soil Survey (WSS) provides soil data and information produced by the National Cooperative Soil Survey. It is operated by the USDA Natural Resources Conservation Service (NRCS) and provides access to the largest natural resource information system in the world. NRCS has soil maps and data available on-line for more than 95 percent of the nation's counties and anticipates having 100 percent in the near future. The site is updated and maintained on-line as the single authoritative source of soil survey information.

Wetland Plant Identification Guides

Chadde, S.W. 1998. A Great Lakes wetland flora. Pocket Flora Press. Calumet, Michigan. 569 pp.

Cooke, S. (ed.). 1997. A field guide to common wetland plants of western Washington and northwest Oregon. Seattle Audubon Society and Washington Native Plant Society. Seattle, WA. 416 pp.

Eastman, J. 1995. The book of swamp and bog – trees, shrubs and wildflowers of eastern freshwater wetlands. Stackpole Books. Pennsylvania. 237 pp.

Eggers, S.D. and D. Reed. 1997. Wetland plants and plant communities of Minnesota and Wisconsin. U.S. Army Corps of Engineers. St. Paul, Minnesota. 263 pp.

Guard, J. 1995. Wetland plants of Oregon and Washington. Lone Pine Publishing. Washington and Canada. 238 pp.

Wilson, B., et al. 2008. Field guide to the sedges of the Pacific Northwest. Oregon State University Press. Corvallis, Oregon. 432 pp.

Wetlands Plants

Tiner, R. 1991. The concept of hydrophyte for wetland identification. BioScience 41:236-247.

Tiner, R. 1999. Wetland indicators: A guide to wetland identification, delineation, classification, and mapping. CRC Press, Inc. Boca Raton, FL.

Tiner, R.W. 2006. Lists of potential hydrophytes for the United States: A regional review and their use in wetland identification. Wetlands (26):624-634.
http://library.fws.gov/Wetlands/TINER_WETLANDS26.pdf

Reed, P.B., Jr. 1988. National list of plant species that occur in wetlands: 1988 national summary. U.S. Fish and Wildlife Service Biological Report 88(24). 244 pp.
http://www.fws.gov/pacific/ecoservices/habcon/pdf/National%20List%20of%20Plant%20Species%201988.pdf (1988)
http://www.fws.gov/pacific/ecoservices/habcon/pdf/1998%20National%20list.pdf (this is a 1998 update to the list)

U.S. Army Corps of Engineers "National Plant List"
www.usace.army.mil/CECW/Documents/cecwo/reg/plants/list96.pdf

Originally prepared by the U.S. Fish and Wildlife Service and now maintained by the U.S. Army Corps of Engineers, the national plant list includes all vascular plants known to occur in U.S. wetlands. Thus, it is a useful resource in the field determination of wetlands based on an analysis of vegetation.

USDA Natural Resources Conservation Service - *PLANTS* Database
www.plants.usda.gov

This Natural Resources Conservation Service (NRCS) plant database provides standardized information about vascular plants, lower plants and lichens of the U.S. On-line keys are also provided for some of the more difficult groups. Although regional field guides and plant identification may provide more detailed information, this is a good starting point for identification of wetland plants. The following information is provided for each entry in the database:

- *Names*
- *Characteristics*
- *Distribution*
- *Species abstracts*
- *Wetland status*
- *Threatened and endangered status*
- *Further links and references*

Digital images of plants in the database are also provided and may be used for non-commercial use, although copyrighted images require notification of the copyright holder.

General and Comprehensive Resources

The following resources cover a broad range of wetlands-related topics. Several are comprehensive web sites that contain a variety of information on wetlands that may be relevant to instructors. More detailed descriptions of the content of these web sites are provided in a separate section entitled "Detailed Descriptions of Comprehensive Resources" that follows. These resources have been identified with an asterisk (*) in the list below. More specific resources that cover one or few aspects of wetlands are provided in the module that is most relevant to those topics.

Association of State Wetland Managers (*)
www.aswm.org

The Association of State Wetland Managers is a nonprofit membership organization established to promote and enhance protection and management of wetland resources, to promote application of sound science to wetland management and to provide wetland training and education.

Batzer, D.P. and R.R. Sharitz. 2007. Ecology of freshwater and estuarine wetlands. Univ. of Calif. Press. 581 pp.
www.ucpress.edu

This is a comprehensive undergraduate text in wetland ecology. It is appropriate for a course devoted entirely or primarily to wetlands. Otherwise, it would be a useful reference for instructors who incorporate wetlands topics into a broader course in ecology.

Dahl, T.E. 2006. Status and trends of wetlands in the conterminous United States 1998-2004. U.S. Fish and Wildlife Service, Washington, D.C. 112 pp.
http://www.fws.gov/wetlands/StatusAndTrends/

Environmental Protection Agency (*)
www.epa.gov/wetlands

The EPA wetlands site provides some good introductory information on wetlands. Wetlands definitions, types, status and trends, functions and values and wetlands management (including mitigation) and protection are all covered.

Hammer, D.A., ed. 1989. Constructed wetlands for wastewater treatment. Lewis Publishers, Inc., Chelsea, MI . 831 pp.

Kusler, J.A. and T. Opheim. 1996. Our national wetland heritage: A protection guide, 2nd ed. Environmental Law Institute, Washington, D.C. 149 pp.

This is a comprehensive guide to the protection and restoration of wetlands by local governments, private citizens, conservation organizations and landowners.

Maltby, E. and T. Barker (eds.). 2009. The wetlands handbook. Wiley-Blackwell, Inc. San Francisco, CA. 800 pp.
www.wiley.com

At $300 this text is probably only for the most serious wetlands instructors. It is a comprehensive analysis of ecosystem-based approaches to wetlands management. The emphasis is on maintaining/restoring ecological functions in freshwater wetlands.

Marks, R. 2006. Ecologically isolated wetlands. Natural Resources Conservation Service and Wildlife Habitat Council. Fish and Wildlife Habitat Management Leaflet #38. 8 pp.

This brief document is an excellent introduction to wetlands and is suitable to assign for student reading. Wetland processes and functions, ecological and economic benefits and issues associated with wetland loss and degradation are covered. As the title suggests, management issues emphasize what can be done to reduce the effects of wetland isolation.

Millennium Ecosystem Assessment. 2005. Ecosystems and human wellbeing: Wetlands and water – Synthesis. World Resources Institute, Washington, D.C.
www.millenniumassessment.org/documents/document.358.aspx.pdf

http://www.maweb.org/documents/document.358.aspx.pdf

This is a global assessment of wetlands resources with recommendations for future management.

Mitsch, W.J. and J.G. Gosselink. 1986. Wetlands. Van Nostrand Reinhold Co., Inc. New York, NY. 539 pp.

Mitsch, W.J. and J.G. Gosselink. 2007. Wetlands. 4th ed. John Wiley and Sons, Inc., Hoboken, NJ.

A potential choice for a textbook for a course on wetlands, but designed for junior/senior level students and for those with some background in ecology.

Mitsch, W.J., et al. 2009. Wetland ecosystems. John Wiley and Sons, Inc., Hoboken, NJ. 285 pp.

Earlier editions of the Mitsch and Gosselink Wetlands *classic wetlands text (described above) included seven "ecosystem" chapters that described the structure and function of wetland ecosystems found in North America. In the interest of reducing the size of this text, the authors decided in the most recent edition to pull out these chapters and develop a separate text.* Wetland Ecosystems *is the result of that effort.*

National Research Council (NRC). 1995. Wetlands: Characteristics and boundaries. National Academy Press, Washington, D.C. 306 pp.

National Research Council (NRC). 2001. Compensating for wetlands losses under the Clean Water Act. National Academy Press, Washington, D.C. 158 pp.

Oregon Wetlands Explorer (*)
www.oregonexplorer.info/wetlands/

This joint project of Oregon State University, The Wetlands Conservancy and Oregon Division of State Lands is primarily designed for wetlands professionals, but educators (especially those in Oregon) will find some useful information here.

Payne, N.F. 1992. Techniques for wildlife habitat management of wetlands. McGraw-Hill, Inc., New York, NY. 549 pp.

Ramsar Convention on Wetlands
www.ramsar.org

The Ramsar site is most useful for international wetlands information. The Ramsar Convention is an intergovernmental treaty that commits its member countries to maintain the ecological character of "wetlands of international importance." The site provides digital photos and other media for instructor use including a 4-minute introductory You-tube video that introduces Ramsar and describes the value of wetlands.

Society of Wetland Scientists (*)
www.sws.org

The Society of Wetland Scientists (SWS) is the premier professional organization for wetland scientists and other professionals in the field. SWS publishes, Wetlands*, the leading journal on wetlands science and issues. Their web site has a number of resources that educators will find useful.*

Tiner, R.W. 2005. In search of swampland: A wetland sourcebook and field guide. Rutgers University Press, New Brunswick, NJ
http://rutgerspress.rutgers.edu

This resource is an excellent introduction to wetlands issues written for the "average citizen."

U.S. Army Corps of Engineers (*)
www.usace.army.mil/CECW/Pages/techbio.aspx

The Army Corps of Engineers has primary responsibility for waterways in the U.S. and is the primary agency that regulates wetlands at the federal level. As a focal point for federal wetlands management, this site has links to lots of wetlands resources with an emphasis on wetland delineation and classification, wetland functions and values, mitigation banking, and wetland plants and soils.

U.S. Fish and Wildlife Service - National Wetland Inventory (*)
www.fws.gov/wetlands

This site, maintained by the U.S. Fish and Wildlife Service, provides a wealth of useful information and tools including wetland status reports (national and regional), Google Earth with wetlands maps overlay and digitized wetlands maps.

U.S. Geological Survey – National Wetlands Research Center
www.nwrc.usgs.gov

Wetlands International
www.wetlands.org

The mission of this international conservation organization is "to sustain and restore wetlands, their resources and biodiversity for future generations." The organization uses science-based information to promote the protection and restoration of wetlands. Instructors looking for an international perspective on wetlands issues, especially those related to climate change and wetland bird conservation, will find Wetland International publications to be useful resources. The organization also produces a number of short (5-15 min.) videos available for download on their web site. Topics include the impacts of climate change on mangrove forests, wetland restoration and carbon dioxide storage in peatland forests.

Details on Comprehensive Web Sites (*)

Association of State Wetland Managers
www.aswm.org

The Association of State Wetland Managers is a nonprofit membership organization established to promote and enhance protection and management of wetland resources, to promote application of sound science to wetland management and to provide wetland training and education. Their web site has lots of resources related to all wetlands topics including:

A wetlands glossary:
http://www.aswm.org/watersheds/wetlands-and-watershed-protection-toolkit/887-wetlands-and-watershed-protection-toolkit?start=15

An excellent collection of publications that examine the relationship between wetlands and climate change:
www.aswm.org/science/climate_change/climate_change.htm

A collection of publications that examine the Gulf Oil Spill and its impact on wetlands. Includes coverage of wetland legal issues such as the Rapanos decision, "navigability," landmark legal cases,"takings." Instructors may also want to subscribe to "Wetland Breaking News" a newsletter on up-to-date wetlands issues and new publications.
http://aswm.org/wetland-science/2010-gulf-oil-spill

Environmental Protection Agency
www.epa.gov/wetlands
http://water.epa.gov/type/wetlands/index.cfm

The EPA wetlands site provides some good introductory information on wetlands. Wetlands definitions, types, status and trends, functions and values, wetlands management (including mitigation) and protection are all covered. The "Fact Sheets" are concise, 1-2 page summaries of various wetlands topics. Specific EPA sites of interest to instructors include:

This EPA wetlands module outlines the various values assigned to wetlands and describes how they are measured.
www.epa.gov/watertrain/wetlands/index.htm

This is an EPA site dedicated to wetland mitigation.
www.epa.gov/wetlandsmitigation

This EPA fact sheet is an excellent introduction to wetland mitigation banking.
www.epa.gov/owowwtr1/wetlands/facts/fact16.html

This is a short (approx 15 min.) video designed for a general audience that emphasizes the importance of providing outdoor, nearby nature, experiences for children – emphasis is on wetlands and includes interviews with wetlands scientists and environmentalists. Web site has directions for saving/ downloading video.
www.epa.gov/wetlands/education/wetlandsvideo/

A series of wetlands fact sheets on most aspects including an overview of wetland types, functions and values, threats, restoration, and monitoring and assessment.
www.epa.gov/owow/wetlands

The EPA wetlands helpline
http://water.epa.gov/type/wetlands/wetline.cfm

U.S. Fish and Wildlife Service – National Wetlands Inventory
www.fws.gov/wetlands

The U.S. Fish and Wildlife Service is the principal federal agency that provides information to the public on the extent and status of the nation's wetlands. This site provides a wealth of useful information and tools including wetland status reports (national and regional), Google Earth *with wetlands maps overlay and digitized wetlands maps. Perhaps the most useful tool is the "Wetlands Mapper," which visually displays the results of the national wetlands inventory, based primarily on an analysis of aerial photographs. Wetlands are identified, mapped and then superimposed on topographic maps. The inventory does not identify all wetlands in an area, but probably the most significant ones. The "Wetlands Mapper" allows viewing of identified wetlands either on-line or hard copy maps can be ordered for every state (see "Hard Copy Orders"). Each map is mapped as a polygon with an imbedded code that indicates the specific wetland type and other information related to this site.*

The WetlandsMapper shows the location of wetlands identified on National Wetlands Inventory (NWI) maps and integrates digital map data with other resource information. The following links provide a useful introduction to this feature:

- Wetlands Mapper Documentation and Instructions Manual (www.fws.gov/wetlands/_documents/gData/WetlandsMapperInstructionsManual.pdf)
- Frequently Asked Questions: Wetlands Mapper (www.fws.gov/wetlands/_documents/gData/QuestionsAnswersAboutNewMapper.pdf)
- Frequently Asked Questions web page (www.fws.gov/wetlands/FAQs.html)

NWI wetlands data can also be viewed with Google Earth. Instructions and a link to do so are included at the NWI web site.

This U.S. Fish and Wildlife site also includes Wetlands Status and Trends Reports, *which provide long-term trend information about specific changes and places and the overall status of wetlands in the United States. The historical database provides photographic evidence of land use and wetlands extent dating back to the 1950s. This provides an accurate record to assist in future restoration efforts.*

Status and Trends Reports available on the web site include:

- NOAA/USFWS joint report on Coastal Wetland Trends 1998-2004 (www.fws.gov/wetlands/_documents/gSandT/NationalReports/StatusTrendsWetlandsCoastalWatershedsEasternUS1998to2004.pdf)

- Status and Trends of Wetlands in the Conterminous United States 1998 to 2004 (Dahl, 2006) (www.fws.gov/wetlands/_documents/gSandT/NationalReports/StatusTrendsWetlandsConterminousUS1998to2004.pdf)
- Status and Trends of Wetlands in the Conterminous United States 1986 to 1997 (www.fws.gov/wetlands/_documents/gSandT/NationalReports/StatusTrendsWetlandsConterminousUS1986to1997.pdf)
- Wetlands Status and Trends in the Conterminous United States, Mid-1970's to Mid-1980's (www.fws.gov/wetlands/_documents/gSandT/NationalReports/WetlandsStatusTrendsConterminousUS1970sto1980s.pdf)
- Status and Trends of Wetlands and Deepwater Habitats in the Conterminous United States 1950's to 1970's (www.fws.gov/wetlands/_documents/gSandT/NationalReports/StatusTrendsWetlandsDeepwaterHabitatsConterminousUS1950sto1970s.pdf)

Links to other resources such as the National Wetlands Plant List and an EPA evaluation of the impact of climate change on coastal wetlands are also available.

Oregon Wetlands Explorer
www.oregonexplorer.info/wetlands/

This joint project of Oregon State University, The Wetlands Conservancy and Oregon Division of State Lands was first launched in 2009 as "a useful tool for anyone doing wetland work in Oregon." It is primarily designed for wetlands professionals, but educators (especially those in Oregon) will find some useful information here. The following are included:

1. *Statewide database of wetlands maps, hydric soils, FEMA flood zones, Wetland Reserve Program (WRP) sites, wetland mitigation banks. Local wetland inventories and recommended priority sites for conservation*
2. *A tool for rapid assessment for wetlands*
3. *Oregon-related information on various wetland topics*
4. *Wetland GIS and vegetation plot data*

Society of Wetland Scientists
www.sws.org/

The Society of Wetland Scientists (SWS) is the premier professional organization for wetland scientists and other professionals in the field. SWS publishes, Wetlands*, the leading journal on wetlands science and issues. Their web site has a number of resources that educators will find useful. Several are described below:*

This newly developed web page was designed to document the impact of the Deepwater Horizon oil spill in the Gulf of Mexico on wetlands. It includes insights from wetland scientists, links top pertinent resources and digital photographs.
www.sws.org/oilspill/

This page lists links to specific short courses in wetlands training – delineation, hydric soils, plant identification, restoration, mitigation, and constructed wetlands.
www.sws.org/training/

This is a directory of wetland-related academic programs at U.S. colleges and universities.
www.sws.org/colleges/

These "position papers" on various wetlands topics are designed to "increase public understanding of wetlands issues and to promote sound public policy." They are written by experts in the field and are based on the best available science. Topics include oil effects on wetlands, mosquito control, mitigation banking, performance standards for wetland restoration and creation, and definitions of wetland restoration. The papers are brief, well-referenced and provide excellent background for educators with a particular interest in specific wetland issues. They are also suitable to assign as student reading to provide a basis for discussions on wetland issues.
www.sws.org/wetland_concerns/

The SWS also publishes the "SWS Research Brief," which helps translate wetland research results for a non-technical audience. The research of selected wetlands scientists is highlighted in each brief. These make excellent student reading and serve to familiarize students with the process of science – how scientists formulate questions, collect data, present their findings and draw conclusions from them.
www.sws.org/ResearchBrief/

Some topics include:

- *Restoration of mangroves*
- *Invasive plants in wetlands*
- *Impact of elevated CO_2 levels on wetlands*
- *Impact of hurricane Katrina on wetlands*
- *Relationship between marshes, mosquitoes and malaria*

The SWS education page is designed with the college educator in mind and is intended "to facilitate sharing of techniques, skills, tools and ideas on and about wetlands education." See for educational resources including labs, field activities, courses, links to other web sites, etc. The Society of Wetlands Scientists also maintains a list of colleges and universities that offer courses or programs in wetland science or ecology.
www.sws.org/education/

Here are some examples of materials that college instructors will find most useful:

1. *Links to general information on wetlands*
2. *Syllabi, lab exercises and exams for wetlands courses*

NOTE: Instructors with an interest in teaching wetland concepts using digital imagery and aerial photography will find the "Wetland Education Through Maps and Aerial Photography" (WETMAAP) site to be particularly useful.

3. *Digital images collection for wetlands education*

U.S. Army Corps of Engineers
www.usace.army.mil/CECW/Pages/techbio.aspx

The Army Corps of Engineers has primary responsibility for waterways in the United States and is the primary agency that regulates wetlands at the federal level. As a focal point for federal wetlands management, this site has links to lots of wetlands resources. Those that are most relevant to this series of modules include the following:

Wetlands delineation and classification

- Corps Wetlands Delineation Manual (www.el.erdc.usace.army.mil/elpubs/pdf/wlman87.pdf)
- Regional Supplements to the Corps Delineation Manual (www.usace.army.mil/CECW/Pages/reg_supp.aspx)
- USFWS National Wetlands Inventory (www.fws.gov/wetlands/)
- Classification of Wetlands & Deepwater Habitats of the U.S. (www.npwrc.usgs.gov/resource/wetlands/classwet/index.htm)
- Recognizing Wetlands - An Informational Pamphlet (www.usace.army.mil/CECW/Documents/cecwo/reg/rw_bro.pdf)

Wetlands functions and values

- Current HGM Information and Guidebooks (http://el.erdc.usace.army.mil/wetlands/hgmhp.html)
- Hydrogeomorphic Approach to Assessing Wetland Functions (http://el.erdc.usace.army.mil/wetlands/hgmhp.html)
- National Plan to Implement the Hydrogeomorphic Approach to Assessing Wetland Functions (www.usace.army.mil/CECW/Documents/cecwo/reg/hydro_geo.pdf)
- Wetland Functions & Values - A Report by the National Science Foundation, 1995 (www.usace.army.mil/CECW/Documents/cecwo/reg/wet_f_v.pdf)
- Consequences of Losing or Degrading Wetlands
- U.S. Environmental Protection Agency Wetlands Information Website http://water.epa.gov/type/wetlands

Mitigation banking

- Federal Guidance for the Establishment, Use and Operation of Mitigation Banks (http://water.epa.gov/lawsregs/guidance/wetlands/mitbankn.cfm)
- National Wetland Mitigation Banking Study: Technical and Procedural Support to Mitigation Banking Guidance, 1995 (www.iwr.usace.army.mil/index.php?option=com_content&view=category&layout=blog&id=7&Itemid=3/iwrreports/WMB-TP-2.pdf)
- National Wetland Mitigation Banking Study: Model Banking Instrument, 1996 (www.iwr.usace.army.mil/index.php?option=com_content&view=category&layout=blog&id=7&Itemid=3/iwrreports/WMB-TP-1.pdf)
- National Wetland Mitigation Banking Study: The Early Mitigation Banks: A Follow-up Review, 1998 (www.iwr.usace.army.mil/index.php?option=com_content&view=category&layout=blog&id=7&Itemid=3/iwrreports/98-WMB-WP.pdf)

- National Wetlands Mitigation Action Plan (www.usace.army.mil/CECW/Documents/cecwo/reg/Mit_Action_Plan.pdf)
- IWR - Wetlands and Regulatory (www.iwr.usace.army.mil/index.php?option=com_content&view=category&layout=blog&id=7&Itemid=3/publications.cfm)

Plants and soils

- NRCS Soils Website (www.soils.usda.gov/)
- Field Indicators of Hydric Soils in the U.S. ftp://ftp-fc.sc.egov.usda.gov/NSSC/Hydric_Soils/FieldIndicators_v7.pdf
- National List of Vascular Plant Species that Occur in Wetlands:
    - 1996 (www.usace.army.mil/CECW/Documents/cecwo/reg/plants/list96.pdf)
    - 1988 (www.usace.army.mil/CECW/Documents/cecwo/reg/plants/list88.pdf)
    - National Wetland Plant List (NWPL) https://rsgis.crrel.usace.army.mil/apex/f?p=703:1:2631898853215485
- NRCS Plants Database (www.plants.usda.gov/java/)
- Center for Aquatic and Invasive Plants - University of Florida (www.plants.ifas.ufl.edu/)
- Global Invasive Species Database (www.issg.org/database/welcome/)
- Interactive Key to Wetland Monocots of the U.S. (www.npdc.usda.gov/technical/plantid_wetland_mono.html)

Sources for Digital Images

Barras, J.A. 2007. Satellite images and aerial photographs of the effects of Hurricanes Katrina and Rita on coastal Louisiana. U.S. Geological Survey Data Series 281.
www.pubs.usgs.gov/ds/2007/281

Bureau of Land Management Image Library
www.blm.gov/wo/st/en/bpd.html

Most of the images in this web site are "public domain" and can be used without further authorization from the BLM.

The Integration and Application Network (IAN)
www.ian.umces.edu/imagelibrary/

The Integration and Application Network (IAN) is an initiative of the University of Maryland Center for Environmental Science. IAN emphasizes environmental problems in the Chesapeake Bay and its watershed. Although registration is required, there is no cost to download images.

The Natural Resources Conservation Service Photo Gallery
www.photogallery.nrcs.usda.gov

The Natural Resources Conservation Service Photo Gallery provides a comprehensive collection of natural resources and conservation-related photos from around the U.S. They are available for non-commercial use, free-of-charge with proper acknowledgement (described on web site).

NBII Life – Library of Images From the Environment
www.life.nbii.gov/dml/home.do

The National Biological Information Infrastructure (NBII) Library, Images from the Environment (LIFE), provides high-quality environmental images that are freely available for educational use. The collection includes images of plants, animals, fungi, microorganisms, habitats, wildlife management, environmental topics, and biological study/fieldwork. Images are annotated with background information(context, scientific names, location, habitat classifications, etc.), greatly improving their use as educational materials.

NOAA Photo Library/NERR Collection
http://www.photolib.noaa.gov/nerr/index.html
This collection includes images of estuaries in the National Estuarine Research Reserve System. Collection contains more than 1000 photos with images of landscapes, habitats, and individual specimens with descriptions.

U.S. Department of Agriculture PLANTS Database
www.plants.usda.gov

Plant images may be used for non-commercial use although copyrighted images require notification of the copyright holder.

The Society of Wetland Scientists
www.sws.org/regional/pacificNW/photo.html

The Ramsar Convention on Wetlands
www.ramsar.org/cda/en/ramsar-media-photos/main/ramsar/1-25-126_4000_0__

Has a good collection of photos from sites that have met Ramsar criteria.

U.S. Environmental Protection Agency Image Gallery
www.epa.gov/newsroom/pictures.htm

EPA maintains several collections of photographs and other images available for use by the public. Please note that while photographs and graphic materials produced by the federal government are not subject to copyright restriction, some photographs included in these collections may be copyrighted. Please observe carefully all rights and permissions information.

U.S. Fish and Wildlife National Digital Library
www.fws.gov/digitalmedia/

The U.S. Fish and Wildlife Service's National Digital Library is a searchable collection of public domain images, audio/video clips and publications. Permission is not required for use; however you are asked to give credit to the photographer or creator and the U.S. Fish and Wildlife Service.

U.S. Forest Service
www.fs.fed.us/photovideo/

USDA Forest Service's "Find-a-Photo" site allows access to thousands of copyright- free wildlife, fish, wildflower and environmental education photographs, donated by Forest Service employees, their partners and volunteers.