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Wetland Functions, Management, Evaluation, and Enhancement

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Well-functioning wetlands are vital components of healthy watersheds. They absorb flood waters, remove excess sediment and nutrients, and help maintain base flow. Where these and other functions are degraded, wetland enhancement can contribute mightily to recovery of salmon and other valued aquatic life.

Wetlands are found in many locations where the soil is saturated and other conditions are right to support their development (Figure 1). Typical locations include:

- Along rivers and streams
- In depressions on floodplains and at higher elevations
- On hill slopes where water seeps out of the ground
- Along the shores of lakes and estuaries
- On flats such as vernal pools in southern Oregon or peat bogs near the coast

Wetlands perform many valuable functions that contribute to watershed health. For example, they help to purify runoff water, reduce flood damage by temporarily storing water, supplement base flows through release of this stored water, and provide life support through habitat for aquatic species, fish, wildlife, and pollinators.

In this chapter you'll learn:

- How wetlands are defined and identified
- The principal functions and services that wetlands perform
- Actions that can improve specific wetland functions
- How different kinds of wetlands are classified
- How to obtain and use National Wetlands Inventory maps, local wetland inventories, soil surveys, and other wetland information
- The basics of several methods for classifying and assessing wetland functions

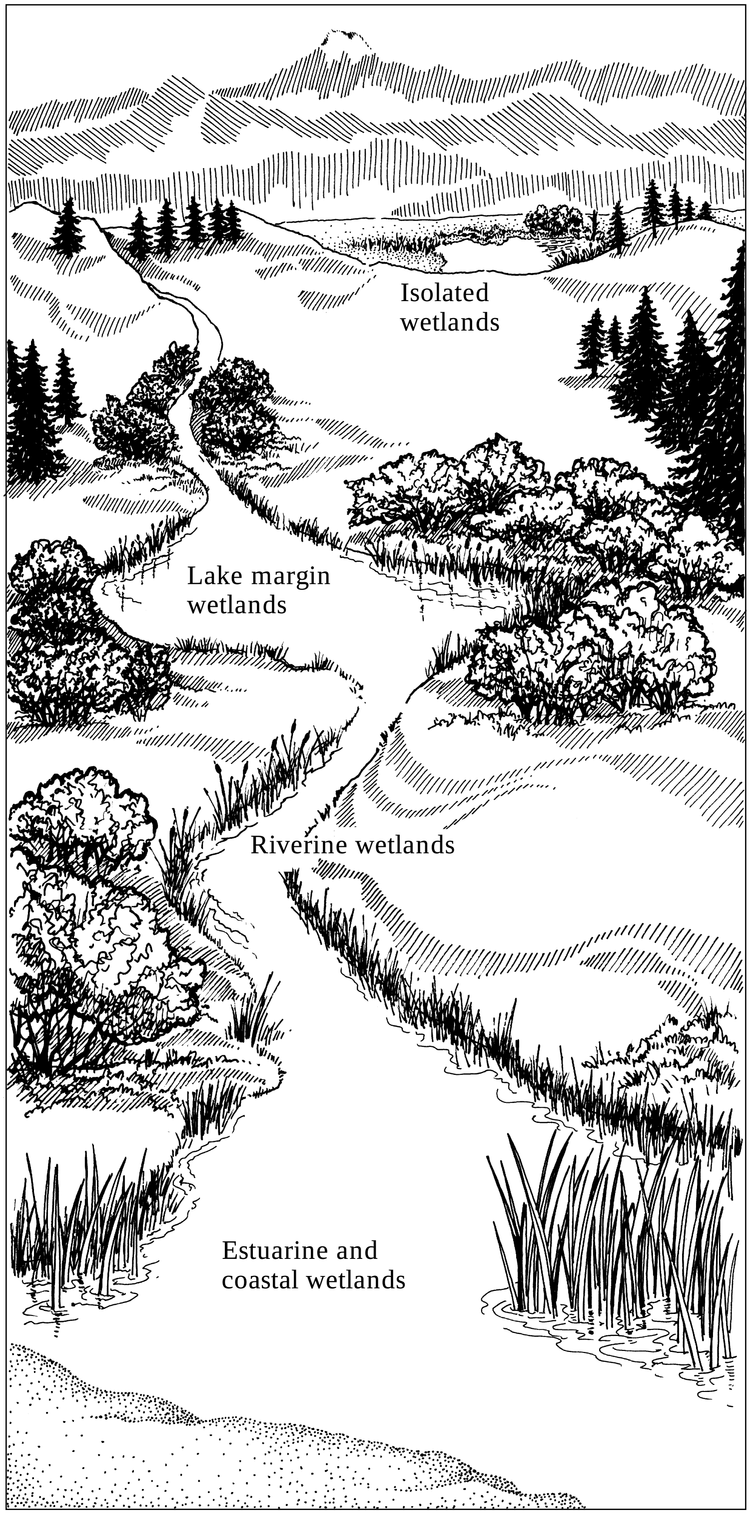


Figure 1.—Types of wetlands.

If you look around, you may see many wetlands in your area that have suffered from neglect or changes in the landscape—roads that interrupt drainage patterns, dirt fill over wetlands to provide building sites, and stream diversions that cut off the water supply to wetlands. These changes greatly diminish the watershed support functions of these wetlands. With increased care and attention, however, some degraded wetlands can be rehabilitated, thereby increasing their capacity to support fish, wildlife, and human needs.

Approximately 40 percent of Oregon's original wetlands have been altered or converted to other uses since European-Americans arrived. Many of the remaining wetlands have been degraded and no longer function as they should. Some of these former and degraded wetlands could be restored or enhanced to help restore salmon runs, improve water quality, and contribute to flood control. Identifying wetland restoration and enhancement potential thus is an important part of watershed action planning.

WHAT IS A WETLAND?

Marshes, bogs, swamps, fens, sloughs, and wet meadows are some of the more common names for particular kinds of wetlands. These terms conjure up an image of ecosystems that aren't quite aquatic and aren't quite terrestrial. In other words, they are "transitional."

Many wetlands fit this image of being part of a continuum between upland and open water ecosystems. Other wetlands, however, are isolated from open-water habitats and are maintained purely by groundwater and precipitation.

So is there an accepted scientific definition of wetland that covers all types? The answer is yes. To understand these definitions, you need to know three key terms–hydric soil, wetland hydrology, and hydrophyte.

Hydric soil is soil that is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions in the upper layer. *Anaerobic* means there is no oxygen in the soil. This condition occurs when water fills all of the pore spaces in the soil, leaving no room for oxygen. Indicators of anaerobic conditions that can be observed in the field include low chromas according to the Munsell Color Chart (<2), distinct mottles, and Soft Iron Masses (SIMs).

Wetland hydrology recognizes that the conditions that support wetlands and form hydric soils range from permanently inundated to seasonally saturated. At minimum, saturation is required within 12 inches of the surface during approximately 2 weeks of the growing season to meet the hydrology criteria as a jurisdictional wetland as defined by the U.S. Army Corps of Engineers.

A *hydrophyte* is any plant growing in water or in soil that is at least periodically deficient in oxygen as a result of excess water. Hydrophytic also can mean plants typically found in wetland habitats. The U.S. Fish and Wildlife Service (USFWS) has developed a list of plants found in and near wetlands.

A well-accepted *comprehensive definition* of wetlands was developed in 1995 by the National Research Council:

A wetland is an ecosystem characterized by sustained or recurrent shallow inundation or saturation at or near the surface of the substrate and the presence of physical, chemical, and biological features reflective of such inundation or saturation. Common diagnostic features of wetlands are hydric soils and hydrophytic vegetation. These features will be present except where specific physiochemical, biotic, or human factors have removed them or prevented their development.

In other words, a wetland typically has hydric soils and hydrophytic plants, unless it has been disturbed by humans.

Another definition that is very important if you plan to do wetland restoration projects is the *regulatory definition*. This definition is used by the U.S. Army Corps of Engineers (the Corps) and the Oregon Division of State Lands (DSL) in their regulatory programs:

Wetlands are those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted to life in saturated soil conditions.

See Section II, Chapters 1, 2, and 5; and Section III, Chapters 1, 3 and 4 for information related to this chapter.

Section II
1 Planning
2 Hydrology
5 Assessment

Section III
1 Riparian Functions
3 Livestock
4 Stream Ecology

Three features of wetlands are common to these and most definitions:

- The presence of enough water to cause saturation of the upper 12 inches of soil for at least 2 weeks during the growing season
- Soils that are typical of saturated or ponded areas
- Plants that can tolerate such conditions

Detailed criteria for identifying upland-wetland boundaries for regulatory purposes are described in the Corps' 1987 *Wetland Delineation Manual*. These criteria also are used by most other state and federal agencies. Most of the time, however, a formal delineation of wetland boundaries isn't required for nonregulatory wetland restoration or enhancement projects.

AN OVERVIEW OF WETLAND FUNCTIONS

Wetlands often are ecological "hot spots," playing a role disproportionate to their size in supporting endangered species and maintaining biodiversity. Wetlands play other roles too; they usually help remove excess nutrients and other contaminants from water, store flood waters, release water during low flow periods, and provide food and shelter for salmon, trout, other animals, and pollinators.

All of these roles are known as *wetland functions*. You might think of them as the services that wetlands provide to watersheds. Although there are many ways to group and describe wetland functions, we will divide them into four categories:

- *Biogeochemical* (water-quality) functions
- *Hydrologic* (water movement) functions
- *Habitat and food web* functions
- *Cultural and social* functions

There are at least 16 functions within these 4 categories. They are discussed in this chapter. We'll describe why each function is important to watershed health, how wetlands contribute to the function, and ideas for wetland restoration or enhancement.

Note that these functions may not be unique to wetlands. Streams, lakes, riparian areas, and upland habitats also contribute to many of these functions. Although we separate watersheds into parts for analysis, the parts themselves and the functions they perform are interconnected. Thus, our analyses also must be interconnected.

Many wetland functions have an especially significant impact on water quality and fish habitat in streams. Thus, Chapter III-4, "Stream Ecology," is closely related to the topics covered in this chapter. The hydrologic processes discussed in Chapter II-2, "Watershed Hydrology," also are affected by wetland functions. Chapter III-1, "Riparian Area Functions and Management," also discusses many related topics.

IMPROVING WETLAND FUNCTIONS

There are three basic kinds of wetland improvement projects–creation, enhancement, and restoration. *Wetland creation* involves the construction of a wetland at a site where no wetland has existed in the past 100–200 years (Figure 2). It may take a lot of landscape manipulation and/or maintenance to develop and maintain such a wetland.

Wetland enhancement involves the alteration, maintenance, or management of existing wetlands for long-term improvement of particular functions or services. In many cases, by choosing to enhance certain functions, you may diminish a wetland's ability to perform other functions or services.

Wetland restoration is the return of a former or degraded wetland to a close approximation of a previous higher functioning state. *Former wetlands* are areas that once were wetlands, but now are nonwetland. *Degraded wetlands* are those that have been damaged but still perform some wetland functions (Figure 3).

In restoration, both the structure and the functions of the ecosystem are recreated, and ecological damage is repaired. The goal is to recreate a natural, functioning system that is integrated into the surrounding ecological landscape (Figure 4).

Wetland enhancement generally aims to improve a specific wetland function. Based on your assessment of wetlands in your watershed and the functions you want to improve, the following discussion suggests some actions you might take to identify potential wetland enhancement projects.

Figure 2.–Wetland creation projects, even in urban settings such as this one adjacent to a Portland-area shopping center, help reestablish some of the functions of stream and wetland corridors important to fish and wildlife. (Photo: Jim Good)

Wetland functions and possible enhancement opportunities

Water-quality functions

Function 1—Water temperature maintenance

Why important: High water temperatures can limit a stream's habitat value for fish and wildlife. High temperature can decrease fish survival, encourage growth of disease-causing organisms and undesirable algae, and reduce dissolved oxygen concentration.

Weather, volume of stream flow, streamside vegetation, flows to and from groundwater, and water released from industrial plants can influence stream temperature. Solar heating is the major cause of increased water temperature.

How wetlands contribute: Wetlands can help maintain desirable stream temperatures. In summer, wetlands discharge cool groundwater into streams. In winter, wetlands receiving substantial groundwater discharge may maintain ice-free conditions, which are required by wintering waterfowl. Riparian vegetation also can play an important role in shading streams from solar heating. See Chapter III-4, "Stream Ecology," and Chapter III-1, "Riparian Area Functions and Management," for more information.

To improve this function, watershed groups might:

- Target restoration efforts to watersheds with known water temperature problems.
- Identify native riparian corridors that shade streams and wetlands from solar heating.
- Identify existing and potential wetlands that receive groundwater discharge and release it to a stream either through surface or subsurface flows.
- Identify existing and potential wetlands that might recharge the aquifers that discharge groundwater to a stream.
- Identify headwater wetlands that maintain base flows during summer low flows.

Figure 3.—These farmed fields are an example of a degraded but still functioning wetland with good restoration potential. (Photo: Jim Good)

Function 2—Reducing bacterial concentration

Figure 4.—Periodic monitoring of restoration projects is necessary to judge progress toward goals and to implement needed corrective measures. (Photo: Jim Good)

Why important: Many *pathogenic* (disease-causing) intestinal bacteria pose a substantial health risk to humans. Fecal coliform bacteria *(Escherichia coli)* are used as a general indicator of the presence of this group of bacteria. When these indicator organisms are present, it represents a strong possibility of the presence of pathogenic bacteria that threaten public health. Reduction of these bacteria in aquatic systems makes it safe for humans to use water and eat shellfish from the water.

Intestinal bacteria come from human and animal waste. For example, bacteria may enter streams from septic tank failure, poor pasture and livestock management, city sewage, pet wastes, urban runoff, and sewage from stormwater overflows.

How wetlands contribute: Wetlands can retain and destroy intestinal bacteria. Wetland size, location, water source, and volume of inflow are key factors in determining how well a wetland performs this function. For example, wetlands constructed for wastewater treatment can assist with this function. A healthy riparian area also can play an important role by filtering runoff. See Chapter III-4, "Stream Ecology," and Chapter III-1, "Riparian Area Functions and Management," for more information.

To improve this function, watershed groups might:

- Target restoration efforts to watersheds with known or anticipated fecal coliform problems.
- Identify wetlands with the greatest potential to retain and process fecal coliform bacteria.
- Identify riparian areas that buffer streams from fecal coliform inputs.

Function 3—Sediment capture

Why important: Excess suspended sediments can cause many problems in streams. For example, they:

- Reduce stream channel capacity
- Transport bacteria and pollutants
- Fill gravel spaces, thus smothering eggs and juvenile fish
- Reduce algal growth

- Reduce fish feeding and growth
- Reduce dissolved oxygen concentrations
- Bury benthic (bottom-dwelling) organisms

Many human activities can increase suspended sediments, including timber harvest and related road development, construction-related earth moving, poor pasture management, and building of dikes. Loss of in-stream large woody debris, which often is caused by human activity, also reduces a stream's ability to store sediment.

How wetlands contribute: Wetlands can reduce the amount of suspended sediments in streams. Some wetlands capture and keep sediments from reaching a stream, while others capture sediments that already have entered a stream system. The flow of sediment-bearing runoff slows down when it enters a wetland, allowing suspended sediment to drop out of the water before entering a stream. See Chapter III-4, "Stream Ecology," and Chapter II-2, "Watershed Hydrology," for more information.

To improve this function, watershed groups might:

- Target restoration efforts to watersheds with known sediment retention problems.
- Identify wetlands that capture sediments before they enter streams.
- Identify wetlands that remove suspended sediments from stream systems.
- Create wetlands to remove suspended sediments from surface sheet or stream flows.

Wetland creation for sediment removal is a challenge in areas where land-use practices create large pulses of sediments.

Function 4—Nutrient removal and transformation

Why important: Nitrogen and phosphorus are essential nutrients for all aquatic systems. Each ecosystem has its own level of nutrient inputs and outputs. When inputs and outputs change, problems can occur. For example, excess phosphorus can cause lake eutrophication or algal blooms. Too much nitrogen in the form of nitrate also can cause problems, including fish habitat degradation, excess plant and algae growth, and reduced dissolved oxygen concentrations.

Human activities can substantially increase nutrient inputs to stream systems, thus changing the ecosystem. In-stream increases in nitrogen and phosphorus can come from agricultural and residential fertilizers, detergents, cleaning products, sewage, septic tank effluent, food residues, soil erosion, and decomposing vegetation.

How wetlands contribute: Wetlands can retain nutrients and change them into less harmful forms. For example, they can convert inorganic nutrients to their organic forms, which don't move as easily in water so are less likely to end up in streams. They also can change nitrate nitrogen into gaseous nitrogen through a process known as *denitrification*. Nitrogen gas then can escape harmlessly into the air. By keeping excess nutrients out of streams, wetlands help maintain fish habitat, dissolved oxygen levels, and nitrogen balance, while reducing algae blooms. See Chapter III-4, "Stream Ecology," for more information.

To improve this function, watershed groups might:

- Target restoration efforts to watersheds with known nutrient problems.
- Identify existing and potential wetlands capable of keeping nutrients from reaching streams.
- Identify existing and potential wetlands capable of removing nutrients from stream systems.
- Identify existing and potential native riparian buffers that could keep nutrients from entering wetlands or streams.

Function 5—Improving groundwater quality

Why important: In many areas, domestic water supplies are taken from groundwater *aquifers*. Aquifers are resupplied with groundwater as water percolates downward in *groundwater recharge areas*. The greatest potential for groundwater recharge occurs within *alluvial outwash deposits* (areas where flooding has deposited sediment).

Human activities within groundwater recharge areas can diminish groundwater quality and quantity. Drinking water contaminated with nitrate at levels above 10 mg/l can cause infant sickness or, in extreme cases, death. Threats to groundwater quality come from commercial and industrial development, concentrated dairy farming, and the use of agricultural chemicals within recharge areas.

How wetlands contribute: Wetlands in groundwater recharge areas can capture and retain nitrate-nitrogen from overland flows before it percolates downward into groundwater aquifers. Wetlands can store and release nitrate seasonally or retain it for a long time. How effective a wetland is in playing this role depends on how long the water and nitrate are retained, the level of dissolved oxygen, and how much of the nitrogen is converted to gas.

To improve this function, watershed groups might:

- Identify wetlands that recharge groundwater aquifers of importance to humans.

- Identify groundwater recharge wetlands whose ability to efficiently capture, retain, or remove nutrients has been reduced.

Hydrologic or water-flow functions

Function 6—High flow storage and reducing peak flows

Why important: Flooding can result in property damage, soil erosion, increased bedload movement, loss of fish redds (nests) and stream habitat, increased sediment, invasion by non-native plants, and stream channel erosion. See Chapter III-4, "Stream Ecology," and Chapter II-2, "Watershed Hydrology," for more information.

Runoff volume is related to human development. For example, hard surfaces such as pavement don't let water enter the soil. Soils that have been compacted by heavy equipment don't let water percolate very well. In these soils, plants also have a hard time taking up water and transferring it to the air through transpiration. Furthermore, water flowing just beneath the soil surface becomes surface runoff when road cuts send it into road ditches.

Thus, development, soil disturbance, timberland conversion, timber harvest, and slope alterations within the watershed all can increase the intensity of high flow or flood events.

How wetlands contribute: Wetlands can store waters that otherwise would intensify downstream high flows. In concert with other floodplain management activities, wetland restoration may reduce property damage, crop loss, and soil erosion by minimizing the effects of current and future development.

To improve this function, watershed groups might:

- Target wetland restoration efforts to watersheds with known flooding problems.
- Identify wetlands that capture surface flows before they reach the river system.
- Identify wetlands that capture and reduce peak surface flows within the floodplain.
- Identify wetlands that capture and reduce runoff from residential, agricultural, and disturbed lands.

Function 7—Base flow maintenance

Why important: Base flow is groundwater discharge and detained storm water that contributes to streamflow during periods of little or no direct precipitation. To function properly, a stream needs a minimum base flow. When flows drop below this rate, the stream is more susceptible to temperature increases and pollution from industrial, municipal, and agricultural wastes. Low flows also can obstruct fish passage to available habitat or can change habitat conditions.

Human activities have substantially altered both the timing and extent of surface and groundwater inputs to many streams by decreasing groundwater recharge and increasing overland flows. The result in many cases is reduced base flows.

Examples of factors that reduce base flows include:

- Draining of bottomland and depressions with seasonally high water tables
- Shallow excavations (e.g., road cuts) on well-drained soils, which intercept subsurface flows and convert them to overland flows
- Groundwater withdrawals for irrigation or domestic use
- Increased runoff resulting from forest conversion to agricultural or residential use
- The increase of hard surface areas

How wetlands contribute: Wetlands can help regulate the release of groundwater into streams and can recharge the aquifers that discharge groundwater to streams.

To improve this function, watershed groups might:

- Target wetland restoration efforts to watersheds with known or anticipated base flow problems.
- Identify wetlands that receive groundwater discharge and release it to a stream through either surface or subsurface flows.
- Identify wetlands that recharge the aquifers that discharge groundwater to a stream.
- Identify headwater wetlands that maintain base flows during summer low flows.

Function 8—Groundwater recharge

Why important: Groundwater is an important water source for domestic use.

The opportunity for surface water to recharge an underlying aquifer system depends largely on several physical conditions that don’t change very much, including soil permeability, type of rock the surface soil was derived from, depth to water table, and topography. However, human activities often change these physical conditions so that less surface water recharges aquifers. Examples of factors that increase surface water runoff and reduce recharge potential include:

- Wetland drainage
- Forest clearing
- Soil compaction from agricultural activities, residential development, and other landscape-altering activities

- Road cuts that intercept groundwater and bring it to the surface
- Hard-surface barriers such as roads, parking lots, and roofs
- Incorrect riparian conversions that damage fragile streamside wetland areas

How wetlands contribute: Within groundwater recharge areas, wetlands capture and hold water that otherwise might become surface runoff, thus allowing it to move downward into groundwater aquifers.

To improve this function, watershed groups might:

- Identify potential wetland sites that could recharge groundwater.

Function 9—Shoreline stabilization

Why important: Erosion caused by waves, currents, tides, or ice can cause substantial shoreline property damage, loss of fish and wildlife habitat, and increased turbidity (cloudiness of water).

How wetlands contribute: Wetlands serve as a buffer between open water and upland areas. *Shoreline stabilization* is the binding of soil at the shoreline or water's edge by wetland plants, thus making the soil less susceptible to erosion. Wetland plants, therefore, protect beaches, stream edges, property, and ecosystems from erosion.

To improve this function, watershed groups might:

- Identify wetland restoration sites that stabilize shorelines of importance to public or private property or fish and wildlife habitat.

Habitat and food web support functions

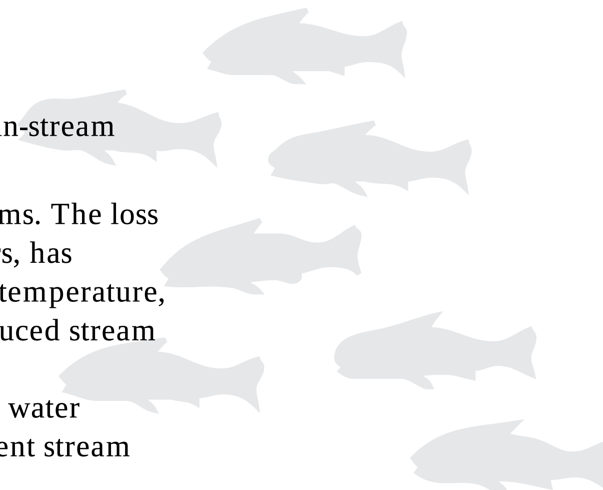
Function 10—Anadromous and resident fish diversity and abundance

Why important: Development and land-use change have had a significant negative impact on fish habitat. While each river system is unique in the type and amount of habitat it has lost, fish habitat degradation has occurred throughout the Pacific Northwest.

Timber harvest, agricultural activities, residential development, and other activities have altered wetlands, riparian areas, and floodplains. As a result, there is less food, spawning gravel, and refuge for anadromous (migratory) and resident fish. Some of the biggest problems in Oregon include:

- Loss of channel structure
- Sedimentation in the upper watershed
- Loss of riparian trees, plants, and large organic debris

- High stream temperatures and low water quality
- Blocked access to wetland habitats
- Excessive sediment in the estuary
- Increased flooding frequency and intensity
- Loss of estuarine wetlands
- Tide gate and culvert passage problems
- Low summer flows
- Loss of winter cover
- Excessive bedload
- Degradation of near-shore habitat
- Scouring of spawning habitat
- Incorrect riparian conversion schemes that damage in-stream habitat



Damage to wetlands has contributed to these problems. The loss of wetland and riparian habitat, along with other factors, has increased flows and frequency, sediment inputs, water temperature, and barriers to fish passage. The same factors have reduced stream base flows and stream habitat diversity.

How wetlands contribute: Wetlands help maintain cool water temperatures, retain sediments, store high flows, augment stream base flows, and provide food and cover for fish.

Along with these broad watershed-level contributions to fish habitat, some wetlands may play other specific roles. For example, coho smolts survive winters of extremely high flows by using small tributary wetlands as winter habitat. In these cases, the best way to improve coho smolt production may be to restore side-channel and slough wetlands. See Chapter III-4, “Stream Ecology,” for more information.

To improve this function, watershed groups might:

- Identify sites recognized by professional fish habitat biologists as having the greatest potential to provide the fish habitat that is needed most within your watershed.
- Identify additional wetland restoration sites that have some potential to provide the fish habitat that is needed most within your watershed.
- Restore degraded estuarine wetlands.
- Restore riparian habitat along stream reaches that support resident and/or anadromous fish (Figure 5).

Function 11—Migratory water bird diversity and abundance

Why important: Many migratory water birds have recreational and economic importance to humans. Extensive agricultural, industrial, and residential development within estuaries and river floodplains has destroyed or disturbed water bird wintering and migration habitat. As a result, birds are forced to seek alternative habitats. As birds are crowded into smaller areas, they must compete for limited food and space, and they're more exposed to predators, adverse weather, and disease.

In some cases, however, human activities create new habitats. Many waterfowl species, in particular, have adapted to new habitat opportunities. For example, farming practices in Oregon's Willamette Valley now provide abundant, readily available winter food that didn't exist before the area was cleared for agriculture. Some waterfowl that traditionally wintered in the central valley of California now winter in this area. On the other hand, many migratory shorebirds and wading birds haven't been able to adapt when confronted with a loss or change in their habitat.

How wetlands contribute: Wetlands provide important migration and wintering habitat for migratory water birds (Figure 6). Restoring degraded wetlands where there is a shortage of habitat can help stabilize and, in some cases, increase populations. The conversion of forested wetlands to emergent/open water wetlands also can create new wintering, migration, and production habitat for some migratory water bird species, although it may degrade habitat for others.

To improve this function, watershed groups might:

- Identify degraded wetlands that currently provide important habitat for water birds.
- Identify wetlands that are known to support migratory water birds.
- Identify wetlands that currently provide limited habitat for water birds but have the greatest potential to provide important habitat if restored.

Figure 5.—Dike and tide gate removal in a 1978 Salmon River estuary restoration project opens up tidal channels that provide important rearing habitat. (Photo: Diane Mitchell)

Function 12—Aquatic diversity and abundance

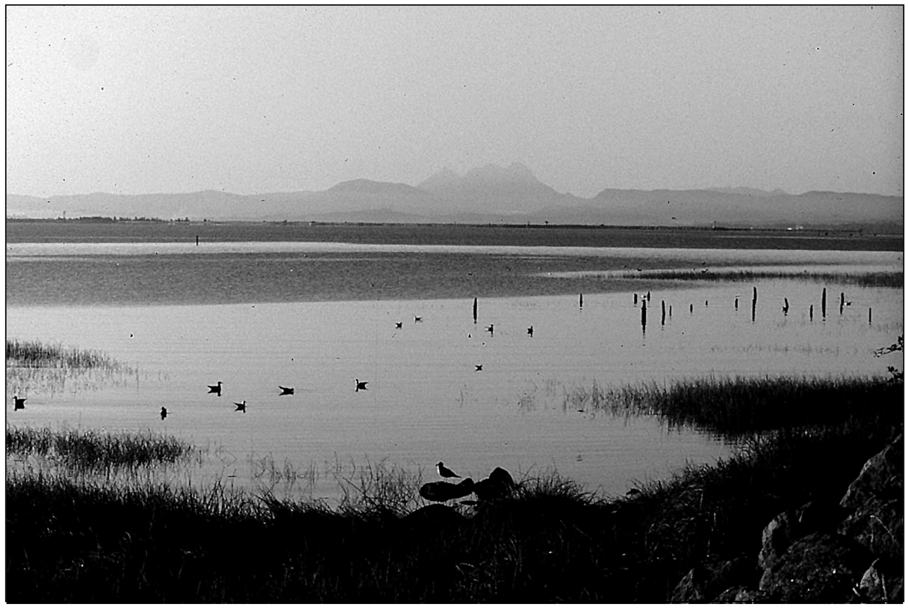


Figure 6.—Fringing marshes and shallow waters of the Columbia River estuary attract a wide variety of wildlife. (Photo: Jim Good)

Why important: Both direct and indirect impacts such as changing patterns of water movement, land-use change, and habitat fragmentation adversely affect native plant and animal communities. As wetlands are disturbed, the *number* of species may increase or decrease, but *complexity* usually decreases as non-native species tend to invade and dominate.

How wetlands contribute: Healthy wetlands support a wide variety of native plant and animal communities. Thus, by reestablishing near-natural conditions, wetland restoration can restore native species richness and abundance. This process takes time though. Once the natural water cycle is reestablished, it can take years to recreate the conditions most suited for native plants and animals. See Chapter III-4, "Stream Ecology," for more information.

To improve this function, watershed groups might:

- Identify wetlands with ditches, tile, canals, levees, or similar artificial features that change the retention time of water.
- Identify wetlands that have been altered by tilling, filling, excavation, addition of inlets, or blockage of outlets.
- Identify wetlands that support or once supported rare or unique plant communities.

Function 13—Rare, threatened, and endangered species diversity and abundance

Why important: Natural systems are made up of many related parts that are in a constantly changing state of balance (*equilibrium*). The loss of species diversity and abundance alters this equilibrium and the food chain it supports, thereby affecting many other species.

As species are lost, humans lose opportunities to find solutions to medical, agricultural, and industrial problems. Species loss is important in another way; it's a good indicator of how well or poorly we take care of our environment.

The exact causes of species declines are complex and not fully understood. We do know that species declines and extinction result from both human impacts and climate change. Some of the problems caused by humans are habitat destruction, poisoning from pesticides, competition from non-native species, and indiscriminate killing and overharvest.

How wetlands contribute: Wetlands provide habitat for many rare, threatened, or endangered plants and animals. The restoration of wetlands close to populations of these species can provide opportunities for them to relocate or expand their range.

To improve this function, watershed groups might:

- Identify wetland restoration sites having the greatest opportunity to provide habitat for rare, threatened, and endangered species.

Function 14—Food web support

Why important: Within a watershed or basin, there is a food web consisting of producers, consumers, and decomposers. Organic matter that reaches a stream system is eaten by fish and aquatic invertebrates, which in turn are eaten by predators.

How wetlands contribute: Wetlands are highly productive biological systems. *Food web support* is the production of organic material and its movement out of a wetland to areas downstream where it provides food for many fish and wildlife species. Thus, loss of wetland areas can adversely affect fish and wildlife that depend on these food sources. See Chapter III-4, “Stream Ecology,” for more information.

To improve this function, watershed groups might:

- Identify wetland restoration sites with the greatest potential to support food webs by supplying organic material to streams.

Cultural and social functions

Function 15—Recreation

Why important: As our population grows and prospers, interest in outdoor activities increases. At the same time, nature-centered recreational opportunities continue to be pushed farther from city centers as development spreads into previously “undeveloped” land. As a result, outdoor recreation opportunities become less accessible. Increasing development and population also cause more pollution in areas used for recreation.

How wetlands contribute: Fishing, hunting, shellfish gathering, swimming, kayaking, boating, sightseeing, birdwatching, and nature photography are just some of the recreational opportunities that wetlands provide. The restoration of wetlands and provision for public access provide new opportunities for recreation (Figure 7).

To improve this function, watershed groups might:

- Identify wetland restoration sites having the greatest potential to provide recreation opportunities.

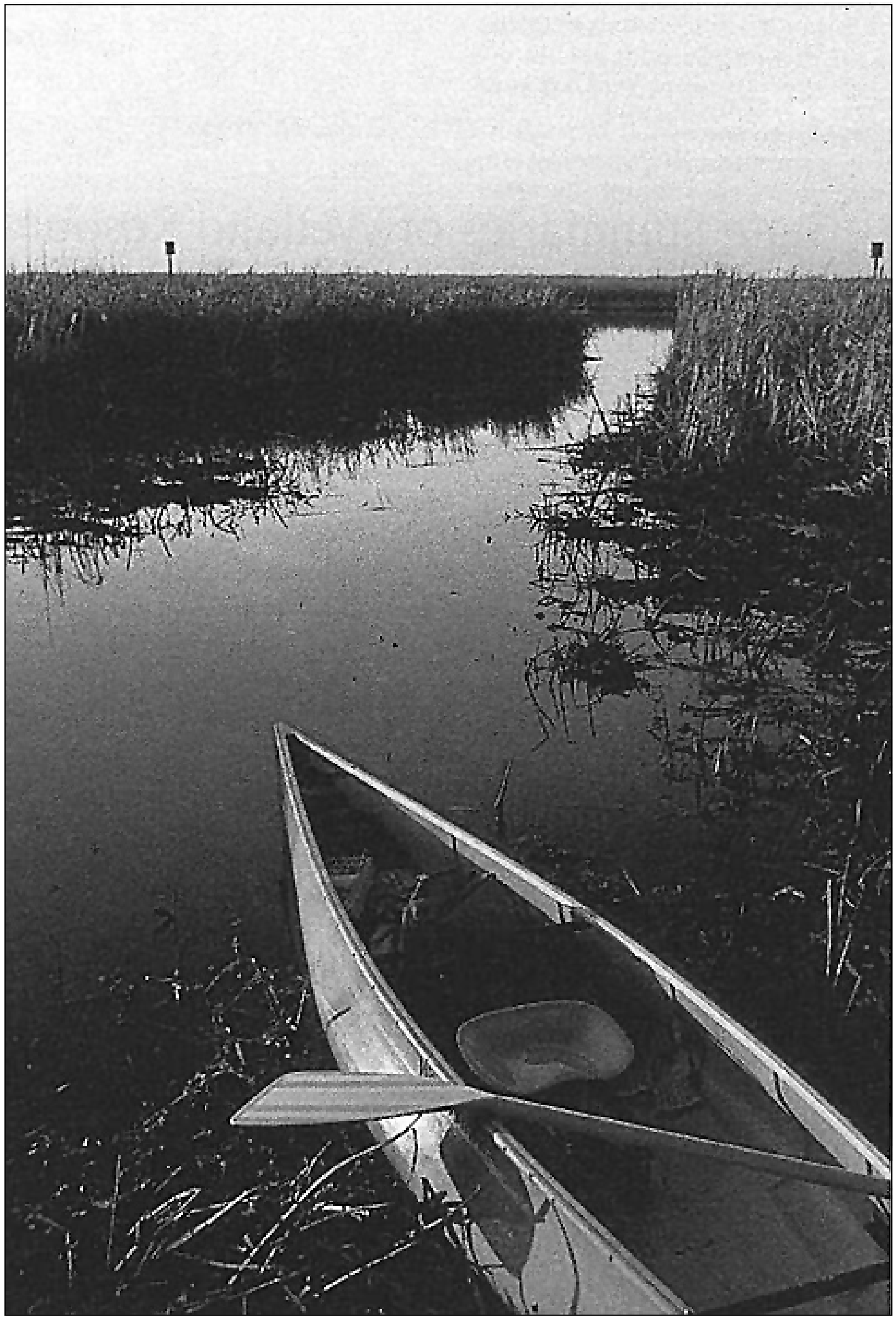


Figure 7.–In addition to their ecological functions, wetlands also are valued as recreational resources. (Source: USGS)

Function 16–Outdoor education

Why important: The use of outdoor classroom settings has increased substantially as educators recognize the benefits of allowing students to explore and test what they learn in the classroom. Opportunities to use an outdoor classroom setting depend on its distance from school, ease of access, and the diversity and condition of habitats found there. Activities that degrade natural areas mean less areas are available for educational use.

How wetlands contribute: Wetlands are excellent outdoor education classrooms because of the diversity of plants and animals that live there and because of their combination of aquatic, transitional, and terrestrial environments.

To improve this function, watershed groups might:

- Identify wetland restoration sites that can provide outdoor education opportunities.

CLASSIFYING WETLANDS FOR INVENTORY AND MANAGEMENT

The National Wetlands Inventory and the Cowardin classification system

The most widely available and comprehensive wetlands information in the United States is the U.S. Fish and Wildlife Service's National Wetlands Inventory (NWI).[1] The NWI does more than locate and classify wetlands. It also maps the entire aquatic ecosystem network.

NWI maps contain information on location in the watershed, water regime, vegetation class or subclass, morphology, and sheet versus channel flow. Thus, the NWI is a useful starting point for evaluating restoration opportunities for all aquatic ecosystems, not just for wetlands. It also is useful for planning at a watershed or subwatershed level.

The NWI wasn't developed for use in regulatory programs, although it has proved useful as a basic indicator of wetlands and their boundaries. It also is used to classify wetlands at larger scales.

The NWI is based on the *Cowardin classification system*, which was published as the *Classification for Wetland and Deepwater Habitats of the United States*. This system is the most widely used wetland classification system in the United States. It has four objectives:

- To describe ecological units whose natural attributes are fairly homogenous
- To arrange these units in a system that will help people make decisions about resource management
- To provide information for inventory and mapping
- To create standard concepts and terminology for use in classifying aquatic ecosystems

An electronic version of the *Classification for Wetland and Deepwater Habitats of the United States* is available on the World Wide Web at http://www.nwi.fws.gov/

The Cowardin system includes five major *systems:* Palustrine (marshes), Lacustrine (lakes), Estuarine (estuaries), Riverine (rivers), and Marine (ocean). These systems are divided into *subsystems,* which reflect water flow regimes. Finally, the subsystems are divided into many different *classes* (Figure 8). If site data are available, users also can include information on plants, water chemistry, soil types, wetland origin, and other site-specific factors. NWI maps use codes to convey all of this information (Figure 9).

The Cowardin system classifies wetlands by structural vegetative characteristics such as forest or meadow. It's easy to identify these characteristics through aerial photos.

[1]*In Oregon, the NWI has been adopted as the State Wetland Inventory (SWI) and is distributed by the Division of State Lands (DSL). Local Wetland Inventories (LWIs), based on the Cowardin classification system and mapped according to rules published by DSL, also have been developed for many cities and parts of counties where more detailed information is needed to meet advance planning goals or deal with regulatory problems in advance.*

System	Subsystem	Class
M---Marine	1 Subtidal	RB Rock Bottom UB Unconsolidated Bottom AB Aquatic Bed RF Reef OW Open Water/Unknown Bottom
	2 Intertidal	AB Aquatic Bed RF Reef RS Rocky Shore US Unconsolidated Shore
E---Estuarine	1 Subtidal	RB Rock bottom UB Unconsolidated Bottom AB Aquatic Bed RF Reef OW Open Water/Unknown Bottom
	2 Intertidal	AB Aquatic Bed RF Reef SB Streambed RS Rocky Shore US Unconsolidated Shore EM Emergent Wetland SS Scrub/Shrub Wetland FO Forested Wetland
R---Riverine	1 Tidal	RB Rock bottom UB Unconsolidated Bottom AB Aquatic Bed SB Streambed RS Rocky Shore US Unconsolidated Shore EM Emergent Wetland OW Open Water/Unknown Bottom
	2 Lower Perennial	RB Rock bottom UB Unconsolidated Bottom AB Aquatic Bed RS Rocky Shore US Unconsolidated Shore EM Emergent Wetland OW Open Water/Unknown Bottom
	3 Upper Perennial	RB Rock bottom UB Unconsolidated Bottom AB Aquatic Bed RS Rocky Shore US Unconsolidated Shore OW Open Water/Unknown Bottom
	4 Intermittent	SB Streambed

Figure 8.–Cowardin wetland classification system showing systems, subsystems, and classes.

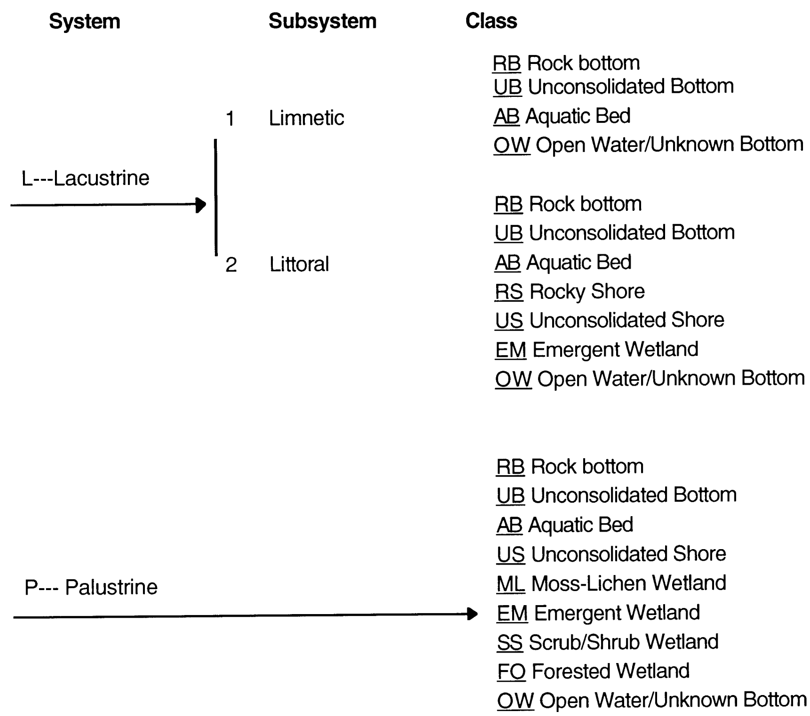


Figure 8.–Cowardin wetland classification system showing systems, subsystems, and classes (continued).

The classification of a mapped wetland is coded by a series of letters and numbers. The classification legend at the bottom of each map includes the alphanumeric code. The first letter of the code represents the system, the subsequent number represents the subsystem, and the next two letters indicate the class. If a wetland contains two different classes, they are separated by a horizontal line (see third example, below). Modifiers, when used, may be a letter or number.

CLASSIFICATION EXAMPLES

E2EM
System: Estuarine (E)
Subsystem: Intertidal (2)
Class: Emergent (EM)

Typical vegetation:
Lyngby's sedge (*Carex lyngbyei*)
seaside arrowgrass (*Triglochin maritimum*)
pickleweed (*Salicornia virginica*)
saltgrass (*Distichlis spicata*)

PSSC
System: Palustrine (P)
Subsystem: none
Class: Scrub-Shrub (SS)
Modifier: Water regime—Seasonally flooded (C)
Note: Palustrine system does not have subsystems.

Typical vegetation:
willow (*Salix spp.*)
salmonberry (*Rubus spectabilis*)
Douglas Spiraea (*Spiraea douglasii*)
red-osler dogwood (*Cornus stolonifera*)

P EM Hx
AB
System: Palustrine (P)
Subsystem: none
Class: Mixed—Emergent (EM)/Aquatic Bed (AB)
Modifiers: Water regime—Permanently flooded (H)
Special modifier—Excavated (x)

Typical emergent vegetation:
cattail (*Typha spp.*)
skunk cabbage (*Lysichitum americanum*)
reed canarygrass (*Phalaris arundinacea*)
slough sedge (*Carex obnupta*)

Typical Aquatic Bed vegetation:
common duckweed (*Lemna minor*)
white water lily (*Nymphaea odorata*)

Figure 9.–Cowardin classification codes for wetlands.

A major weakness of the Cowardin system and the NWI is that the descriptors of mapped units often don't relate consistently to ecosystem functions. Because of the system's reliance on plant types as identifying criteria, wetlands that function very differently often are grouped into the same Cowardin class simply because they have the same vegetation.

Nevertheless, because the NWI is the only universally available data, people try to identify wetland functions from NWI maps and descriptors. Often, scientists create hybrid systems that use both NWI data and other information.

Hydrogeomorphic classification

The *hydrogeomorphic* (HGM) wetland classification does address differences in wetland functions. This system is under development and will use three criteria–where a wetland is positioned in the landscape (*geomorphology*), its water source (precipitation, surface water, or groundwater), and its *hydrodynamics* (how water moves through it).

The HGM approach is being developed by the Army Corps of Engineers for use with the Section 404 regulatory program. It meets the need for a better rapid assessment tool to evaluate how wetlands are functioning and to develop requirements for actions to compensate for previous damage.

Nationally, all of the major resource agencies have agreed to develop and use HGM, but the process of "regionalizing" HGM will take some time. Oregon is just beginning to develop HGM in a way that will help people understand wetland functions at regional, watershed, and site-specific scales. Meanwhile, the national HGM prototype is being applied in Oregon because of its usefulness in describing and characterizing wetland functions.

There are seven wetland classes in the HGM system (Table 1). Identifying a wetland's class is the first step in the HGM approach to wetland functional assessment. Classes are based on three principal characteristics of wetlands, although water chemistry and soil properties also are important. These three characteristics are:

- *Geomorphic setting,* or the wetland's topographic position in the landscape
- *Water source* and *transport vector*. *Water sources* include precipitation, lateral flows from upstream or upslope, and groundwater. The *transport vector* is how water is transported. Precipitation is transported from the atmosphere; lateral flows are transported by surface or near-surface flows; and groundwater is transported by subsurface flow.

Table 1.–Hydrogeomorphic classes of wetlands showing associated dominant water sources, hydrodynamics, and examples of subclasses.

Hydrogeomorphic class	Dominant water source	Dominant hydrodynamics	Examples of subclasses
Riverine	Overbank flow from channel	Unidirectional, horizontal	Riparian forested
Depressional	Return flow from groundwater and interflow	Vertical	Vernal pools
Slope	Return flow from groundwater	Unidirectional, horizontal	Avalanche chutes
Mineral soil flats	Precipitation	Vertical	Large playas
Organic soil flats	Precipitation	Vertical	Peat bogs
Estuarine fringe	Overbank flow from estuary	Bidirectional, horizontal	Tidal salt marshes
Lacustrine fringe	Overbank flow from lake	Bidirectional, horizontal	Lakeside emergent marshes

- *Hydrodynamics*, or how water moves. There are three kinds of flow–vertical, unidirectional and horizontal, and bidirectional and horizontal. *Vertical* movements result from evapotranspiration and precipitation; *unidirectional* flows are downslope movement; and *bidirectional* flows are tides or wind-driven fluctuations in bays.

The strength of HGM is that variations in these hydrogeomorphic properties are directly related to the ecological functions of wetlands. Wetlands also will be evaluated in comparison to regional reference sites that are established by agencies during the process of developing the HGM for a particular state or region. However, the HGM classification system isn't intended to replace other wetland classification systems such as the NWI's Cowardin system. Both systems are useful in wetlands management.

ASSESSING WETLAND FUNCTIONS

Wetlands provide many benefits because of their functions. It therefore is important to evaluate each wetland from a functional point of view. What functions does it or could it perform, and how well is it performing them? This kind of evaluation is called a *wetland functional assessment*.

One of the frequent criticisms of wetland management and regulation is that all wetlands are treated equally, when in fact they often are very different in structure, function, and quality. Although these criticisms often are overstated, it's true that wetland managers haven't settled on a standard way to characterize and compare the functions of one wetland to another. There are many reasons for this lack of consistency:

- The ecological processes that support wetland functions often are quite complex.
- These processes aren't well understood, and there isn't enough information about them.
- Wetlands vary a lot, even within a particular type.
- Wetland functions have many parts, all of which must be considered as part of the whole.
- Assessments often have very different purposes.

Despite these very real limitations, it still is important to use the best available scientific information about wetlands to assess their functions. To accomplish this, several standardized rapid assessment methods have been developed.

Several of these methods are used in Oregon or elsewhere in the Pacific Northwest. Others are in the process of being customized for this region. No single approach is universally accepted. The most common approaches include:

- "Best professional judgment"
- The Wetland Evaluation Technique (WET)
- The Oregon Freshwater Assessment Methodology (OFWAM)
- The hydrogeomorphic approach (HGM)
- The Puget Sound Watershed Approach (PSWA)

Most of these methods require some training either in wetlands science and/or in the use of the particular method. They all rely on *indicators* of wetland function that can be observed in the field or gleaned from aerial photos, wetland or soil maps, and other resource materials.

Each of these methods is described briefly below, and sources of more information on each are listed in the Resources section of this chapter. In addition, National Wetlands Inventory (NWI) maps, local wetland inventories (LWIs), soil surveys, and other sources can help you characterize existing wetlands and identify restoration and enhancement opportunities in your watershed. See the Resources section of this chapter for more information.

Best professional judgment

Best professional judgment (BPJ) probably is the most commonly used and flexible method for evaluating wetland functions. In this approach, well-trained, experienced wetland professionals evaluate the principal functions and conditions of a wetland based on extensive field experience and information from NWI maps, soil maps and surveys, and aerial photos.

However, because BPJ is not a standardized approach, it isn't very precise, and no two individuals are likely to get the same results. Thus, it's often criticized in terms of scientific, legal, and public credibility. These shortcomings are the driving force behind the development of more precise, standardized approaches.

Wetland Evaluation Technique

The Wetland Evaluation Technique (WET) is a broad-brush, field-based approach to wetland evaluation. It's based on information about correlative predictors of 11 wetland functions and values. *Correlative predictors* are variables whose presence is highly correlated with certain watershed functions.

Data on correlative predictors can be gathered quickly in the field. Based on these correlative predictors, the WET process generates high, moderate, or low probability ratings that a particular wetland performs a given function.

A site-specific method, WET has been used mostly by regulatory agencies to assess wetlands proposed for alteration and to design and monitor restored or created wetlands. It also has been used to identify important wetlands needing protection and to set priorities for acquisition or research. WET isn't easily adaptable to landscape-level evaluation of wetland functions.

Oregon Freshwater Wetland Assessment Methodology

The Oregon Freshwater Wetland Assessment Methodology (OFWAM) assesses six wetland functions (wildlife habitat, fish habitat, water quality, hydrologic control, education, and recreation) and three wetland conditions (sensitivity to impacts, enhancement potential, and aesthetics). This method involves asking a series of questions about each of these functions or conditions. Based on the answers to these questions, assessments have three possible outcomes:

- The function is performed or is intact.
- Some of the function is performed, or it may be impacted or degraded.

- The function is not performed or has been lost.
- For each wetland assessed, results for each of the six wetland functions and three conditions are summarized in a tabular and narrative description.

OFWAM is used extensively as a planning tool because it allows functions and conditions of several wetlands to be assessed and compared. Its most common use has been as a follow-up to local wetland inventories. In this case, each wetland is assessed, and the results are used by a community to help decide which wetlands are significant and deserve special protection.

OFWAM's use for watershed-level restoration planning is limited for two reasons. First, only one of the assessed conditions addresses restoration potential. Second, OFWAM focuses solely on existing rather than on former wetlands. Nevertheless, it could be adapted for restoration purposes by asking the question, "If we restored or created a wetland here, how might each of these functions be performed?"

See the Resources section of this chapter for information on how to obtain the OFWAM.

The hydrogeomorphic approach

The hydrogeomorphic (HGM) wetlands classification system was described above as the first step in an HGM approach to assessing wetland functions. Recall that this classification is based primarily on three principal characteristics of wetlands (although water chemistry and soil properties are other important variables):

- *Geomorphic setting* (the wetland's topographic position in the landscape)
- *Water source* (e.g., precipitation or groundwater) and *transport vector* (for example, surface flows or subsurface flows)
- *Hydrodynamics* (how water moves)

Once the characteristics of the seven national HGM classes are described for a particular class or subclass of wetlands, they are used to develop a profile of the functions that subclass performs.

Oregon is developing a regional application of HGM for use at site-specific, watershed, and ecoregion scales. It will be several years before the Oregon HGM assessment method is complete. In the meantime, however, the national HGM system can be used to better understand and assess the functions of different types of wetlands. HGM also is the basis for the PSWA assessment method described below, so an understanding of HGM is important for watershed groups.

Puget Sound Watershed Approach (PSWA)

Washington State, in implementing the Puget Sound water-quality program, has developed a watershed-based wetland restoration approach known as the Puget Sound Watershed Approach (PSWA). It has been pilot-tested in the Stillaguamish basin and now is being extended to other watersheds. PSWA uses aspects of both HGM and OFWAM to evaluate the 16 functions of wetlands described earlier.

The PSWA guidebook *Restoring Wetlands at a River Basin Scale* includes a multistep process that explains how to analyze the functions a particular wetland might perform once restored. This process involves the following steps:

- Identifying a wetland's HGM class
- Establishing priorities for restoring functions based on the problems in the watershed (e.g., high water temperatures during low flows)
- Determining the potential of different wetland types to perform these functions
- Assessing the restoration potential of sites and ranking each function

One of the end products of this process is a "menu" of restoration sites and a description of how their functions could help solve locally identified watershed problems.

The PSWA method is relatively high tech, incorporating the best available science about wetland functions and using geographic information system (GIS) analysis to carry out some of the steps. At the same time, it is locally driven in terms of problems to be solved and the constraints on project implementation. And, as with watershed groups in Oregon, its restoration projects are based on the "willing landowner" principle.

You can download *Restoring Wetlands at a River Basin Scale: A Guide for Washington's Puget Sound: Operational Draft*, Publication No. 97-99, from the World Wide Web (http://www.ecy.wa.gov/). A hard copy is available from the Washington State Department of Ecology at the address given in the Resources section of this chapter.

WETLAND MANAGEMENT IN OREGON TODAY

The protection, restoration, and enhancement of wetlands in Oregon involves many players. Federal, state, and local government agencies each have certain legal responsibilities and authority, but private nonprofit land trusts and other nongovernmental organizations also play important roles. Responsibilities generally break out along functional lines and governmental levels as summarized in Table 2.

Mapping, assessment, and research

Responsibilities in this area are shared among levels of government and agencies and relate primarily to assigned management responsibilities. The U.S. Fish and Wildlife Service conducts the National Wetlands Inventory (NWI). All of Oregon has been mapped, but some maps, particularly in the Coast Range, are of poor quality. Only about 20 percent of the state's NWI maps are available in digital form.

The Division of State Lands (DSL) uses the NWI as its base State Wetlands Inventory (SWI) and also funds the development of Local Wetlands Inventories (LWIs) that provide more detail. As of 1997, 35 communities had developed LWIs.

Wetland functional assessment also is a priority at each governmental level and is used for a variety of purposes. The *Oregon Freshwater Wetland Assessment Methodology* (Roth et al., 1996), for example, is used in conjunction with LWIs and local land-use planning.

Wetland research in Oregon is conducted mainly by federal agencies–the Environmental Protection Agency (EPA), the U.S. Fish and Wildlife Service (USFWS), the Natural Resources Conservation Service (NRCS), and the U.S. Geological Survey (USGS) in particular. But state agencies, university academics, and private nonprofits such as The Nature Conservancy also conduct important research on wetland functions and characteristics, providing useful management information.

Nonregulatory wetland management

A variety of federal, state, and private programs focus on nonregulatory wetland management in Oregon. The principal activities of both public agencies and private organizations are land acquisition; management, restoration, or enhancement of wetlands; technical assistance to private landowners undertaking restoration or enhancement; and public education (Figure 10).

Table 2.–Principal wetland management functions, governmental agencies, private organizations, and authorities in Oregon.

Function	Federal government	State government	Local government	Private/ nonprofit
Mapping, assessment, and research	• *U.S. Geological Survey:* hydrology, nutrients, habitat • *U.S. Fish and Wildlife Service:* National Wetlands Inventory, habitat research, and functions assessment • *U.S. Army Corps of Engineers:* restoration and assessment research • *U.S. Environmental Protection Agency:* mitigation, risks, and cumulative impacts • *Natural Resources Conservation Service:* agricultural wetlands, functions assessment	• *Division of State Lands*: • State and Local Wetland Inventories, Oregon Freshwater Wetland Assessment Method, wetland research through EPA state grants program • *Governor's Watershed Enhancement Board:* funding for watershed assessments • *Universities and colleges:* scientific research on wetland characteristics, functions, and restoration	*Cities and counties:* Local Wetland Inventories, wetland functions assessment	• *The Nature Conservancy:* research on wetland characterization and mapping, historical ecology, functions assessment, and restoration monitoring
Nonregulatory: Land acquisition, management, restoration, enhancement, education, and technical assistance	• *U.S. Fish and Wildlife Service:* national wildlife refuges, Partners for Wildlife • *U.S. Forest Service:* natural areas management and restoration • *U.S. Bureau of Land Management:* natural areas • *Natural Resources Conservation Service:* Wetland Reserve Program, Conservation Reserve Program • *National Park Service:* national parks and monuments	• *Department of Fish and Wildlife:* wildlife management areas, funding and technical assistance, public education • *Division of State Lands:* public trust lands and waters of the state, South Slough National Estuarine Research Reserve, forest and range lands, public education • *Parks and Recreation Department:* state parks, public education • *Department of Forestry:* state forest lands • *Governor's Watershed Enhancement Board:* funding for restoration and enhancement projects, public education	• *Counties and cities:* parks, green spaces, and natural areas • *Watershed councils:* facilitation of private landowner cooperation, on-the-ground restoration	• *Oregon Wetland Joint Venture:* implementing North American Waterfowl Act-related plans for habitat restoration and enhancement, coordination and facilitation of public-private action • *The Nature Conservancy:* acquisition, restoration, and enhancement projects • *Ducks Unlimited:* acquisition, restoration, and enhancement projects • *Wetlands Conservancy:* acquisition, restoration, and enhancement projects • *Other local land trusts:* acquisition, restoration, and enhancement projects

Table 2.–Principal wetland management functions, governmental agencies, private organizations, and authorities in Oregon (continued).

Function	Federal government	State government	Local government	Private/ nonprofit
Regulation, mitigation, and permit review	• *U.S. Army Corps of Engineers*: Clean Water Act Section 404 • *U.S. Environmental Protection Agency:* Section 404 oversight • *Natural Resources Conservation Service*: "Swampbuster" agricultural wetlands • *U.S. Fish and Wildlife Service:* coordination under Fish and Wildlife Coordination Act (FWCA) • *National Marine Fisheries Service:* coordination under Fish and Wildlife Coordination Act	• *Division of State Lands:* Removal/Fill Law, Mitigation Banking Act • *Department of Fish and Wildlife:* permit review under Removal/Fill Law and federal FWCA • *Department of Environmental Quality:* CWA Section 401 wetland water quality certification • *Department of Land Conservation and Development:* state and federal consistency certification	• *Counties and cities:* local wetland and natural resource protection ordinances, federal and state permit review for consistency with local plan	No role except as occasional public commenter
Land use and watershed planning	• *U.S. Forest Service:* on national forest lands • *U.S. Bureau of Land Management:* on BLM-managed forest and range lands • *National Park Service:* on national parks and monuments	• *Department of Land Conservation and Development:* Goals 5, 16, and 17 • *Division of State Lands:* Goals 5, 17, and Wetland Conservation Plans, state-owned lands • *Department of Forestry:* watershed and land-use planning on state lands • *Governor's Watershed Enhancement Board:* funding for watershed action programs and plans	• *Counties and cities:* Goal 5, Goals 16 and 17 (coastal), and Wetland Conservation Plans • *Watershed councils:* restoration action plans, facilitation of private landowner cooperation	No significant role

The Oregon Department of Fish and Wildlife (ODFW), USFWS, the Bureau of Land Management (BLM), U.S. Forest Service (USFS), NRCS, and local Soil and Water Conservation Districts are the principal government agencies involved. Private nonprofit land trusts and similar groups involved in wetlands management include The Nature Conservancy, Ducks Unlimited, the Wetlands Conservancy, and others. Many of these private groups come under the umbrella of the Oregon Wetlands Joint Venture.

Regulation, mitigation, and permit review

At the federal level, Section 404 of the Clean Water Act (40 CFR 230) is the principal nationwide wetland regulatory program. Section 404 requires that anyone discharging dredge or fill material in the waters of the United States, including wetlands, obtain a permit from the U.S. Army Corps of Engineers (the Corps). The permit is subject to review by a number of agencies, principally the EPA (which also may veto the permit), USFWS, the National Marine Fisheries Service (NMFS), the Oregon Department of Fish and Wildlife (ODFW), and the Oregon Department of Environmental Quality (DEQ) (to certify that water-quality standards are met).

As part of the effort to implement the federal no-net-loss policy for wetlands, Section 404 applicants must follow a sequential mitigation process. First, wetland impacts must be avoided if at all possible, usually by maximizing use of nonwetland areas on or off the property. Next, onsite wetland impacts must be minimized. Finally, unavoidable wetland losses must be compensated by restoring, creating, or enhancing wetlands.

In practice, wetland compensatory mitigation (WCM) occurs on a project-by-project basis. In recent years, *mitigation banking* has become a popular alternative to the project-by-project approach. Mitigation banking involves restoration (or creation) of large

Figure 10.—Technical assistance teams with a range of expertise can be effective for watershed planning and for designing specific projects. (Source: ODFW)

wetland areas in advance of use as WCM. As needed, WCM credits are sold to permit applicants by the bank sponsor in lieu of requiring separate WCM projects.

The “swampbuster” provisions of the Food Security Act of 1985–often referred to as the “Farm Bill”–reversed a long-standing national policy of promoting drainage of wetlands for agricultural cropping. Instead, farmers who convert wetlands to agricultural uses may be penalized by removal of certain agricultural price supports and other subsidies. Wetlands that were converted to cropland prior to 1985 are exempted from the law.

The swampbuster provision of the farm bill is administered by the Natural Resources Conservation Service (NRCS) and was amended in 1990 and again in 1996. The most recent farm bill gives farmers more flexibility in meeting wetland conservation requirements, in particular expanded mitigation provisions that allow for restoration, creation, and enhancement of wetlands.

The Oregon Removal/Fill Law is the principal state regulatory tool for protecting Oregon’s wetlands. Although it predated the Section 404 program, the Removal/Fill Law is very similar. The law requires permits for fill or removal of 50 cubic yards or more from wetlands or waters of the state. In some areas, such as essential salmonid habitat, a permit is required for smaller amounts of fill or removal.

An important component of the law is a three-part sequential mitigation process similar to the federal requirement. Mitigation thus is the principal link between regulatory programs and wetland restoration programs. The program is administered by the Division of State Lands and applies statewide. Federal-state streamlining is achieved through a joint permit application and review process.

Wetlands regulatory policy and programs have been a lightning rod in recent years, as farming interests, developers, and private property rights advocates generally have sought to reverse the expanding jurisdiction of federal regulatory programs, speed up the permit process for development, and as much as possible, externalize the costs associated with cropping, dredging, filling, and other wetland conversions.

These efforts have been blunted to some degree by conservationists and resource managers who are promoting even stronger wetlands protection. Although protection of remaining wetlands remains a federal and state priority, the impasse over regulatory program changes has provided at least part of the rationale for putting more emphasis on nonregulatory programs such as restoration.

Land use and watershed planning

Oregon's statewide land-use planning program includes several provisions that provide for wetland protection and restoration. Statewide Planning Goals, especially Goal 5 (Open Spaces, . . . and Natural Resources), Goal 16 (Estuarine Resources), and Goal 17 (Coastal Shorelands) require the inventory and protection of significant wetlands.

However, there is little consideration of wetland restoration, except in Goals 16 and 17, where the emphasis is on locating sites for regulatory mitigation, not nonregulatory restoration. Recent revisions to Goal 5 have improved provisions for wetland and riparian protection, but again do not address restoration or enhancement as land-use management strategies.

The other principal planning authority dealing with wetland protection and restoration is the 1989 wetland conservation law (ORS 196.668 et seq.), also administered by DSL. This legislation enabled the development of local wetland inventories (mentioned above) and the preparation of local wetland conservation plans (WCPs). Although locating potential wetland restoration sites is a required part of the WCP process, only those necessary to mitigate future development affecting wetlands actually must be identified in inventories and plans.

Watershed planning in Oregon is carried out by federal, state, and private landowners and organizations. In recent years, the watershed approach has been institutionalized in Oregon, largely through the Oregon Watershed Enhancement Board (OWEB), which provides for establishment of local watershed councils and associations. More than 60 local watershed groups have been established in Oregon so far.

Many watershed councils have developed restoration action plans. However, few watershed plans and programs address wetland restoration as part of overall ecosystem restoration.

This brief overview of wetland management in Oregon illustrates the diversity and complexity of programs and activities addressing restoration in Oregon. In many ways, this diversity mirrors the larger society within which wetland and other aquatic ecosystem management occurs. What becomes very obvious as you examine these programs is the need and opportunity for improved public-private and interagency cooperation, better integration of wetland restoration into existing watershed and planning programs, and the enhancement and redirection of human and other resources if such goals are to be accomplished.

Summary/Self review

Wetlands are areas where water is at or near the surface at least part of the year, where soil development reflects this saturation, and where vegetation is dominated by plants adapted to a wet environment. Many wetlands are found at the transition between upland and aquatic environments, but others are isolated from open water.

Wetlands are ecological “hot spots” in watersheds, performing a variety of valuable functions that can be divided into four categories:

- Water quality-related functions
- Hydrologic functions
- Habitat and food web support functions
- Cultural and social functions

Functional interconnectedness with stream, lake, estuarine, and riparian ecosystems also is important. Thus, none of these environments can be considered in isolation from the others.

Wetlands types are classified using a number of systems. The most important are the Cowardin classification system (used for inventory and mapping) and the HGM classification system (being regionalized for Oregon to provide a better basis for functional assessment at a variety of scales).

Wetlands functions can be evaluated using a variety of methods. OFWAM is most commonly used today, and HGM is in the process of development. The PSWA method in Washington State is the only “watershed-level” method applicable to Oregon’s watersheds; it incorporates aspects of both OFWAM and HGM.

EXERCISES

Identifying and describing wetland characteristics using an NWI map

This exercise will familiarize you with the wetland and watershed information that can be gleaned from NWI maps and soil surveys. This information is useful in characterizing current watershed conditions, the predisturbance extent of wetlands, and the relationship of wetlands to aquatic and upland environments. You can do this exercise on your own, but it's helpful to work as a group so you can discuss your observations.

You'll need to order NWI maps (called "quad sheets") for your area. The Division of State Lands (DSL) can help you identify which maps you need. Each map covers about 56 square miles. Because most watersheds are larger than that, you may want to order all of the maps that overlap into your area of concern, or you may want to order just those in your immediate area. Many local Natural Resources Conservation Service (NRCS) field offices own a complete set of NWI maps for their county. You also should obtain your *county soil survey*, *hydric soils list*, and a large-scale aerial photo of the study area (color is best). See the "Resources" section for ordering information.

Using an NWI map and the soil survey and hydric soils list for the same area, answer these kinds of questions. (Locate specific areas or streams, and adapt the questions as needed.)

1. Following a creek or small river tributary to its headwaters source, what wetland types (classifications) do you encounter? List them in order, using the full name. Mark them on the map where the classification changes.
2. Moving to an area of more isolated wetlands, what are the general types of wetlands and how do they differ from the stream system you first examined?
3. Using your soil survey sheet for the two areas where you identified wetlands, draw cross-section lines through each area. Then, using the hydric soils list for the county, list the soil map units and identify which ones are hydric.
4. Using a highlighter, shade the approximate locations of the NWI wetlands you identified on your soil survey sheet. What are the differences in area between the NWI-mapped wetlands and the hydric soils? Which includes more area? Speculate why.

Conducting a wetland function assessment using OFWAM

Conducting a wetland functional assessment will familiarize you with the range of functions these ecosystems perform, how the functions vary among wetland types and within a given class of wetlands, and the "indicators" used to estimate whether or not a function is performed.

You will need a copy of the Oregon Freshwater Wetland Assessment Methodology, available from DSL (see Resources). OFWAM is designed as a step-by-step guide, and you can go through the process on your own or with your watershed group. However, it's best to arrange for some classroom and/or field training by DSL staff or other experienced users, such as wetland consultants. See "Resources."

1. Select at least three wetlands for the exercise. Two should be of a single Cowardin wetland type, for example, palustrine emergent seasonally flooded (PEMC). Collect site and regional information and do the off-site analysis.
2. Then go into the field (get property owner permission first!) and go through the OFWAM field questions, tally the results, characterize, and compare wetland functions for each site. Consider these questions:
   - Do the two wetlands that are of the same type (PEMC in the above example) perform the same functions? Are the assessment results the same? Speculate why or why not.
   - How does the assessment for the third, different type of wetland compare to the first two? Are the functions performed the same? Are the assessment results the same? Speculate why or why not.
   - Which of the wetlands is the most intact functionally? Which is the least intact? What are the causes for these differences?
   - If wetland functions at any (or all) of the sites are degraded to some extent, what would you suggest doing to restore each site to improve wetland functioning?

RESOURCES

Training

Training on the following topics may be offered by the agencies listed, or these agencies can provide contacts or information for other scheduled training programs, some of which are fee-based.

The Cowardin classification system, the NWI, and local wetland inventories

Oregon Division of State Lands, Wetlands Program. Phone: 503-378-3805

U.S. Fish and Wildlife Service, Regional Wetland Coordinator. Phone: 503-231-6154

Agricultural wetlands, soil surveys, hydric soils

Natural Resources Conservation Service, regional office. Phone: 503-414-3200

Natural Resources Conservation Service, local offices

Oregon Division of State Lands, Wetlands Program. Phone: 503-378-3805

Wetland function assessment using OFWAM

Oregon Division of State Lands, Wetlands Program. Phone: 503-378-3805

Wetland identification and delineation

Oregon Division of State Lands, Wetlands Program. Phone: 503-378-3805

U.S. Army Corps of Engineers, Portland District, Wetlands Specialist. Phone: 503-808-4373

Information

National Wetlands Inventory maps

You can order NWI maps for your area or watershed from two sources. Specify the USGS quadrangle sheets you wish to order. (You can obtain a statewide map index and order form from DSL.)

State Distribution Center
Oregon Division of State Lands
Wetlands Program
775 Summer Street NE
Salem, OR 97310-1337
Phone: 503-378-3805, ext. 246

Earth Science Information Center
Western Mapping Center–ESIC
U.S. Geological Survey
Mail Stop MS 532
345 Middlefield Road
Menlo Park, CA 94025
Phone: 650-853-8300

Inventories of farmed wetlands, hydric soils, and soil surveys

The Natural Resources Conservation Service (NRCS) is compiling an inventory of farmed wetlands. It also maintains and distributes the Oregon list of hydric (wetland) soils.

Natural Resources Conservation Service
101 SW Main, Suite 1300
Portland, OR 97204
Phone: 503-414-3200

Local NRCS offices also can supply your county soil survey, which includes upland and hydric soils. Contact your local NRCS office or county Extension agent for more information.

Other materials

The U.S. Fish and Wildlife Service has a variety of information on the National Wetlands Inventory and other wetlands information. Contact the USFWS regional office (below) or explore the NWI Web site at: http://www.nwi.fws.gov/

Regional Wetland Coordinator
U.S. Fish and Wildlife Service
911 NE 11th
Portland Eastside Federal Complex
Portland, OR 97232-4181
Phone: 503-231-6192

The State Distribution Center (DSL) has a number of wetland fact sheets and other information that may be ordered from the address or phone listed on the previous page. Materials include:

About Local Wetlands Inventories, Just the Facts #2 (1993).

About the National Wetlands Inventory, Just the Facts #1 (1991).

How to Identify Wetlands, Just the Facts #4 (1992).

How Wetlands And Waterways Are Regulated, Just the Facts #3 (1992).

Oregon Freshwater Wetland Assessment Methodology, 2nd edition, by E. Roth, R. Olsen, P. Snow, and R. Sumner (Oregon Division of State Lands, Salem, 1996). 184 pages.

The Oregon Wetlands Conservation Guide: Voluntary Wetlands Stewardship Options for Oregon's Private Landowners (1995). 34 pages plus appendices.

Wetlands Functions and Assessment, Just the Facts #5 (1994).

Wetlands Inventory User's Guide, Pub. 90-1.

Wetlands Update (a periodic wetlands newsletter available by subscription; ask for available back issues as well).

The U.S. Army Corps of Engineers also has information on wetlands functions assessment, wetland restoration, and other topics. For a list of available publications, contact:

U.S. Army Engineer Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180
Phone: 601-634-2355

The Washington State Department of Ecology has many publications that may be applicable to wetlands in Oregon. Call 360-407-7470 to obtain a free order form, or write:

Washington State Department of Ecology
Publications Distribution Center
PO Box 47600
Olympia, WA 98504-7600

Restoring Wetlands at a River Basin Scale: A Guide for Washington's Puget Sound: Operational Draft, Publication No. 97-99 is available on the Web at http://www.ecy.wa.gov/. A hard copy is available from the address above.

MOVING FORWARD–THE NEXT STEPS

On your own, use the lines below to fill in steps, actions, thoughts, contacts, etc. you'll take to move yourself and your watershed group ahead in understanding wetland functions, management, evaluation, and enhancement.

1. ____

2. ____

3. ____

8

Water-quality Monitoring

Beth Lambert

Water quality is a term used to describe the chemical, physical, and biological characteristics of water, generally in terms of suitability for a particular use. *Water-quality monitoring* is the process of sampling and analyzing water conditions and characteristics (EPA, 1997). These characteristics, such as dissolved oxygen, pH, and temperature, are known as *parameters*. Under guidance from the U.S. Environmental Protection Agency, states develop water-quality standards that designate levels of each parameter that are acceptable for beneficial uses such as drinking water, irrigation, swimming, and aquatic life.

For many years, agencies and citizens across the United States have been monitoring water quality as a way to track pollution and determine the condition of aquatic ecosystems. We monitor water quality to:

- Identify particular pollutants of concern
- Identify whether the quality of the water is sufficient for a particular use
- Target sources of pollution
- Detect trends
- Determine the effectiveness of watershed restoration and enhancement projects

IN THIS CHAPTER YOU'LL LEARN:

- Why citizens are involved in water-quality monitoring
- Common water-quality monitoring parameters and why each is important
- Considerations for developing a monitoring plan
- The components of a successful monitoring program

Recently, citizens and agencies have begun to monitor additional aspects of aquatic systems to gain a more complete picture of watershed health. These aspects include stream life, such as macroinvertebrates, the physical structure of the stream, and habitat conditions. By monitoring water quality, stream life, and habitat, we can better understand the health of stream ecosystems.

Monitoring goals and objectives are discussed further in Chapter II-5, “Assessment and Monitoring Considerations.”

See Section II, Chapter 5 for information related to this chapter.

Section II

5 Assessment

CITIZEN-BASED MONITORING

Citizens play a large role in water-quality monitoring in our country. Citizen monitors work in partnership with a variety of groups, from grassroots nonprofits to watershed councils, soil and water conservation districts, and agencies. Citizens become involved in monitoring programs for many reasons. These reasons include:

- To promote stewardship
- To take ownership and responsibility for local water resources
- To identify problems in a water body
- To contribute to their community
- To learn about the environment

Citizen groups also partner with state agencies in the process of establishing Total Maximum Daily Loads (TMDLs) of pollutants, while others work with landowners to monitor the effects of best management practices.

Citizen monitors come together to share data, program management techniques, and experiences through such forums as the quarterly newsletter *The Volunteer Monitor* and the National Volunteer Monitoring Conference. Organizations such as Global Learning and Observations to Benefit the Environment (GLOBE) and Global Rivers Environmental Education Network (GREEN) promote the involvement of youth in water-quality monitoring.

This chapter is aimed at individuals or groups interested in learning more about citizen-based monitoring. It introduces parameters commonly monitored by volunteers and agencies. It also describes several monitoring strategies and presents 10 components of a successful monitoring project. This chapter complements chapter II-5, which discusses monitoring designs, goals, objectives, and results. Detailed information on parameters, monitoring strategies, and citizen-based monitoring can be found in the references at the end of this chapter.

WATER-QUALITY PARAMETERS

This section describes many common parameters monitored by citizens and agencies. These parameters are monitored for one or more of the following reasons:

- They are important for human health.
- They are important for aquatic health.
- They are part of state water-quality standards or federal water-quality criteria.

Information on recommended monitoring protocols is available from the *Water Quality Monitoring Guidebook,* published by the Oregon Plan for Salmon and Watersheds (1999). Information on Oregon's water-quality standards is available from the Oregon Department of Environmental Quality. Federal water-quality criteria, which serve as guidance for the states, are available from the U.S. Environmental Protection Agency.

Chemical parameters

pH is a measure of the level of activity of hydrogen ions in a solution, resulting in its acidic or basic quality (Figure 1). pH is measured on a range from 0 (acidic) to 14 (basic), with 7 being neutral. Each stream organism is adapted to a specific pH range.

The pH in most rivers unaffected by humans ranges from 6.5 to 8. In eastern Oregon, alkaline soils cause many rivers to have unusually high pH levels. Humans can impact pH through mining

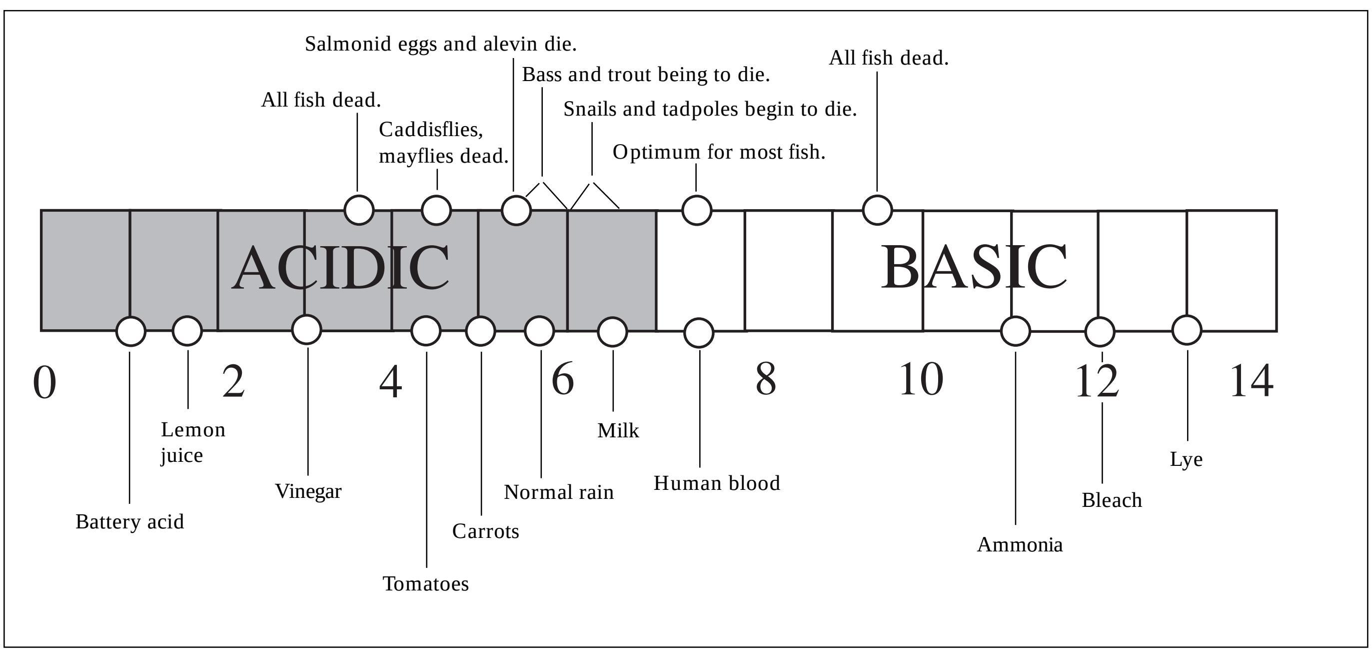


Figure 1.–pH scale. (Source: The Stream Scene, *by P. Bowers et al., Oregon Department of Fish and Wildlife, 1992)*

activities (some of which can make the water more acidic) and by increasing nutrients, which leads to increased algae growth and higher pH.

Total dissolved solids is a measure, in milligrams per liter (mg/L), of the amount of dissolved materials in the stream. Ions such as potassium, sodium, chloride, carbonate, sulfate, calcium, and magnesium all contribute to a dissolved solids measurement. Measuring total dissolved solids is a way to estimate the suitability of water for irrigation and drinking. This is an important parameter for drinking water.

Groundwater has higher levels of dissolved solids than does surface water because of its greater contact with rock and more time to dissolve rock and mineral materials. When stream flow is low, most of the source water is from groundwater, and dissolved solids concentrations are high. When stream flows are high from rain or snowmelt, dissolved solids measurements typically are low.

Conductivity is the ability of a substance to conduct an electrical current, measured in microsiemens per centimeter (µS/cm). Ions such as sodium, potassium, and chloride give water its ability to conduct electricity. Thus, conductivity is an indicator of the amount of dissolved salts in a stream. Conductivity often is used to estimate the amounts of dissolved solids rather than measuring each dissolved constituent separately.

Nutrients are chemical elements that are essential to plant and animal life and growth. Nitrogen and phosphorus are two nutrients that are important to aquatic life. At high levels, however, they are considered contaminants. High levels of nutrients can cause increased growth of algae beyond what is normal. Decaying algae mats can cause foul odors and tastes. And as algae decay, they remove dissolved oxygen from the water.

Nutrients are measured in milligrams per liter (mg/L). Commonly measured forms of nutrients are nitrate, ammonia, orthophosphate, and total phosphorus.

Both nitrogen and phosphorus are affected by chemical and biological processes that change their form and transfer them to or from water, soil, decaying organisms, and the atmosphere. In nature, both nitrogen and phosphorus come from the soil and decaying plants and animals. Fertilizers and domestic animal waste are common human-added sources of nutrients.

The EPA has developed criteria for ammonia-nitrogen, nitrite-nitrogen, and nitrate-nitrogen. The ammonia criteria are designed to protect fish, while the nitrite and nitrate criteria are set for drinking water. The federal government does not have formal criteria for phosphorus, but it does have recommended levels. Because background levels of nutrients can vary from watershed to watershed, the EPA is working to develop nutrient criteria based on regional characteristics.

Dissolved oxygen is needed by fish and other stream organisms. In unaltered streams, dissolved oxygen levels usually are 100 percent of the carrying capacity of the water. As plant and animal material decays, it consumes dissolved oxygen. Turbulence, interaction with the air, and photosynthesis replenish oxygen in the water. Cold water can hold more dissolved oxygen than warmer water.

Dissolved oxygen measurements can be expressed as a concentration, milligrams per liter (mg/L) or as percent saturation (the amount of oxygen the water holds compared to what it could absorb at that temperature).

Manufactured chemicals such as solvents, PCBs, pesticides, and metals are expensive to monitor. The samples must be collected following strict protocols, and the water must be analyzed by a professional lab. State forest practices regulations and the Oregon Department of Environmental Quality have established procedures for sampling these chemicals.

Water temperature is a crucial aspect of aquatic habitat.

Physical parameters

Stream flow (discharge) is the volume of water moving through a stream at any given time. Stream flow often is expressed in cubic feet per second (cfs). The discharge of a stream can vary on a daily, weekly, monthly, and seasonal basis in response to precipitation, snowmelt, dry periods, and water withdrawals by people. Stream flow affects water chemistry; thus, water-quality measurements always should be interpreted in relation to stream flow.

Water temperature is a crucial aspect of aquatic habitat. Aquatic organisms are adapted to certain temperature ranges. As the upper and lower limits of the range are approached, the organism becomes more susceptible to disease. Also, fish that spend extra energy searching for cool areas might be at a disadvantage when competing for food. Stream temperature is regulated by solar energy, the surface area of the stream, the volume of water moving through the stream, and several other factors.

Suspended solids are particles of sand, silt, clay, and organic material moving with the water. Suspended solids usually are measured as a concentration, milligrams per liter (mg/L).

High levels of suspended solids can cause problems for aquatic organisms, both as the solids travel through the water and after they are deposited on the streambed. Suspended solids can reduce visibility, making it hard for fish to find prey. Solids also can clog the gills of fish and suffocate macroinvertebrates. Once the material is deposited, it can fill the spaces between gravel pieces in the streambed. This reduces the permeability of the bed material, meaning that water cannot filter through, bringing dissolved oxygen and nutrients to stream insects, fish eggs, and fry.

Turbidity measures the ability of light to pass through water, or its clarity. Turbidity is measured in Jackson Turbidity Units (JTUs) or Nephelometric Turbidity Units (NTUs). High levels of turbidity make it difficult for fish to find prey and indicate high levels of suspended solids. Turbidity often is measured by citizens as a way to estimate amounts of suspended solids. Turbidity is an optical property, however, and does not directly reflect the amount or types of solids; thus it must be used carefully.

Biological parameters

Bacteria such as *Escherichia coli (E. coli)* and fecal coliform are measured as indicators of more harmful bacteria. High numbers of these types might indicate the presence of other bacteria that cause illness.

Most analytical methods involve growing bacteria in a water sample and counting the colonies. The results are given as the number of colony-forming units per 100 milliliters (ml) of water.

Bacteria populations fluctuate in response to stream flow, disturbance of the streambed, time of year, and time of day. Bacteria can survive for long periods on land and in stream sediments.

MONITORING STRATEGIES

A monitoring strategy describes what, how, and where you will monitor in order to answer a particular water-quality question. In order to gain useful data from a water-quality monitoring project, it is essential to articulate the question you are trying to answer. From this question you develop the goals and objectives for the project. In turn, these goals and objectives will guide you in designing a monitoring strategy.

Chapter II-5, "Assessment and Monitoring Considerations," addresses the importance of asking a monitoring question and outlines several types of monitoring. This section applies the monitoring concepts from Chapter II-5 to water-quality monitoring and examines baseline, trend, and effectiveness monitoring.

Asking monitoring questions

In order to get an answer from your monitoring project, you must have a question. The question will guide you in setting goals and objectives for monitoring. It also will guide you in deciding which

Table 1.–Examples of increasingly specific goals for watershed monitoring projects (DEQ Volunteer Monitoring Coordinator, 2001).

Purpose	Goals	Sample objectives
Support DEQ total maximum daily load (TMDL) development.	Collect data of appropriate quality for use in DEQ temperature computer models.	Measure continuous temperature and flow (end of summer) at the mouth of major tributaries to the mainstem river. Compile temperature data and quality assurance information in DEQ data forms. Submit data electronically in DEQ forms at end of season.
Fill data gaps identified in watershed assessment.	Measure water quality and habitat in low-gradient streams flowing through agricultural lands.	Measure pH, dissolved oxygen, and temperature frequently enough to detect diurnal fluctuations in summer. Collect macroinvertebrates in early fall and compare results from professional identification with those from DEQ reference sites.
Educate community about links between water quality and land use.	Collect sufficient data to demonstrate differences in water quality in streams bordered by healthy and degraded riparian zones.	Assemble existing water quality information from two contrasting areas and summarize in a poster for library display. Measure shade, channel width, and substrate once a year and water quality quarterly at two contrasting sites. Interpret data by comparing with existing standards and illustrating differences in seasonal fluctuations.
Monitor effectiveness of restoration projects.	Collect sufficient water quality data to detect trends or for at least 5 years.	Measure shade, flow, and channel characteristics at restoration sites once a year. Collect continuous temperature data upstream and downstream of restoration sites during summer. Use appropriate step trend analysis to compare temperature data collected before and after a restoration project.

parameters, where, and when to sample. Examples of monitoring questions include:

- Have suspended sediment levels changed over time at a site?
- How do nutrient levels vary among streams that flow through areas with different land uses?
- Has water temperature changed as a result of planting willows along a small stream?

Each question will produce a different monitoring strategy. See Table 1 for examples of increasingly specific goals and objectives.

One of the challenges of designing a water-quality monitoring strategy and interpreting the resulting data is that stream conditions can change hourly, daily, seasonally, annually, and over the long term, even without human impacts. Dissolved oxygen concentrations, for example, can change throughout the day as water temperature changes and algae respire. Stream flow can vary from day to day, month to month, and between years; these changes affect the levels of many parameters. To yield useful information, a monitoring strategy must address this variability.

Trend, baseline, and effectiveness monitoring

Trend, baseline, and effectiveness are three types of monitoring that address common monitoring questions. This section briefly introduces each type and applies it to monitoring stream temperature. These and other monitoring types are discussed further in many of the resources listed at the end of this chapter.

Trend monitoring: Has stream temperature increased over time at a particular site? Trend monitoring involves repeated measurements at a site over a period of time. These measurements are examined to see whether a pattern emerges such as an increase, decrease, or cycle.

In order to determine whether stream temperature has increased at a site, it is important to measure other factors that affect stream temperature. Stream flow, for example, is extremely important. The smaller the volume of water, the more easily it heats. Therefore, stream flow should be considered when developing a monitoring strategy. It is important to separate the effects of changes in stream flow from the effects of changes in land use.

It also is important to monitor at the same time in the summer each year. Monitoring should be done during the time that impacts are expected.

Baseline monitoring: What is the stream temperature at a site and how does that compare to Oregon's water-quality standard? Baseline monitoring establishes a reference point. This reference point then can be compared with future conditions or against a standard.

For stream temperature, monitor from late spring throughout the summer and into early fall at a particular point. If a particular part of the year is of concern due to fish use of the stream, monitoring should focus on that time. The resulting data can be compared with Oregon's water-quality standard for temperature.

Effectiveness monitoring: Did planting willows along the stream improve water temperature? Effectiveness monitoring is used to determine whether a management activity has produced the desired water-quality results or benefits. Three common approaches to effectiveness monitoring are to monitor before and after the project, upstream and downstream of the project, or paired reaches.

Monitoring before and after riparian planting provides data that can be difficult to interpret. In this approach, monitoring takes place at a single point at the downstream end of the area to be planted (Figure 2). Stream temperature is monitored before the trees are planted and again as the shade develops.

This approach is challenging because changes in precipitation and discharge can affect water temperature. The year before the willows are planted, for example, might be a low water year, while two summers later the flows might be extremely high. Take these fluctuations into account when interpreting data. It might be hard to say with certainty whether changes in stream temperature were caused by the increased shade or by natural factors.

Another common approach is to monitor upstream and downstream of a project (Figure 3, page 10). This strategy provides more information than the before–after approach because both sites experience the same changes in stream discharge, climate, and other factors. The natural variations in stream conditions are accounted for.

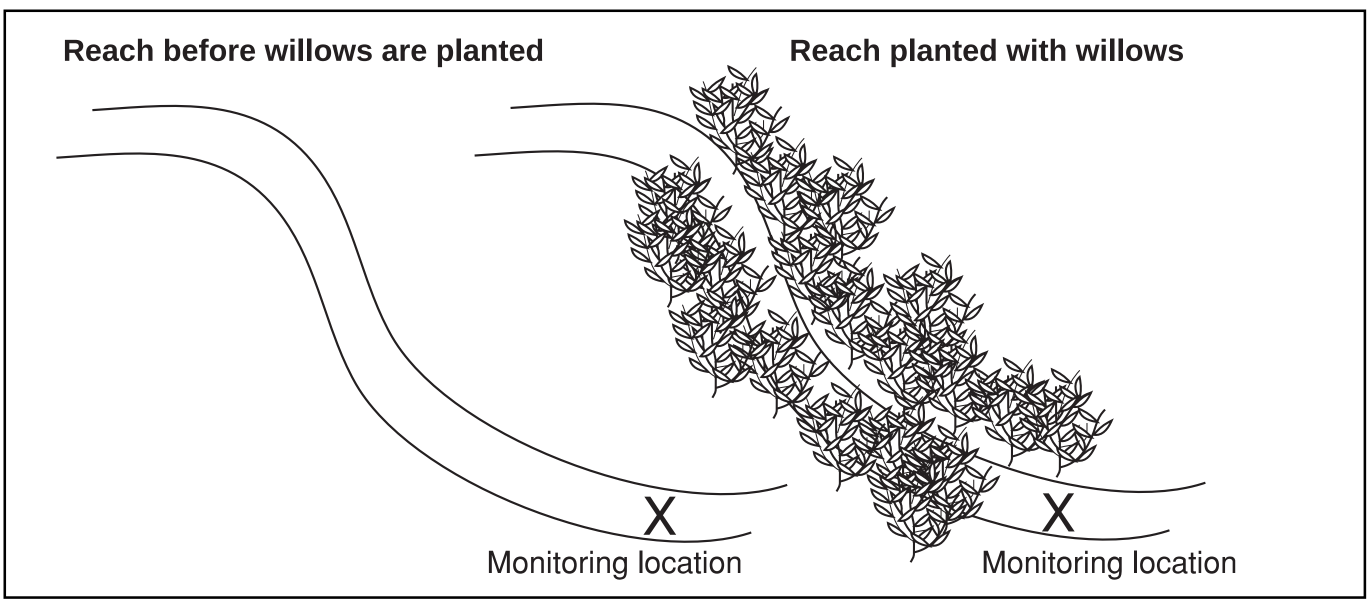


Figure 2.–Before-and-after monitoring. (Diagram is schematic and not to scale.)

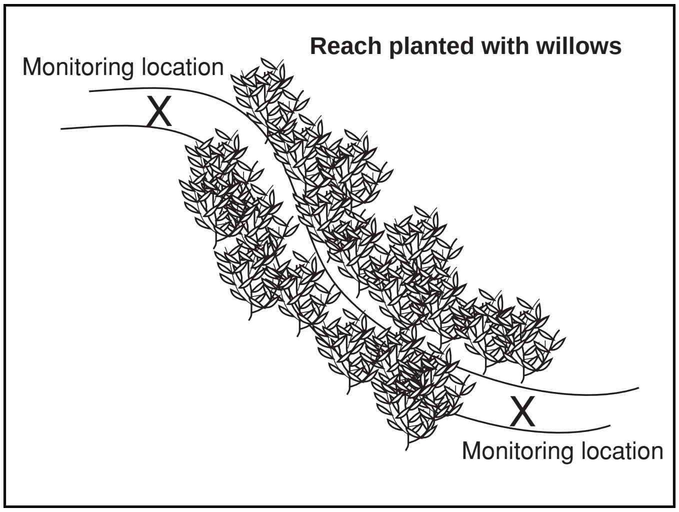


Figure 3.–Upstream and downstream monitoring of a reach planted with willows. (Diagram is schematic and not to scale.)

A drawback to this strategy, however, is that it's not known how the water temperature in the reach with trees compares to a reach without trees at the same time. There is no "control" reach for this experiment.

The most useful monitoring strategy is the paired reach strategy (Figure 4). In this strategy, water temperature is monitored at the upstream and downstream ends of two adjacent stream reaches. Then willows are planted along one of the reaches. Both reaches are monitored to see whether the planted reach responds differently over time than the unplanted reach. This strategy accounts for sources of variability before, during, and after the project. It also provides a control reach against which the planted reach can be compared.

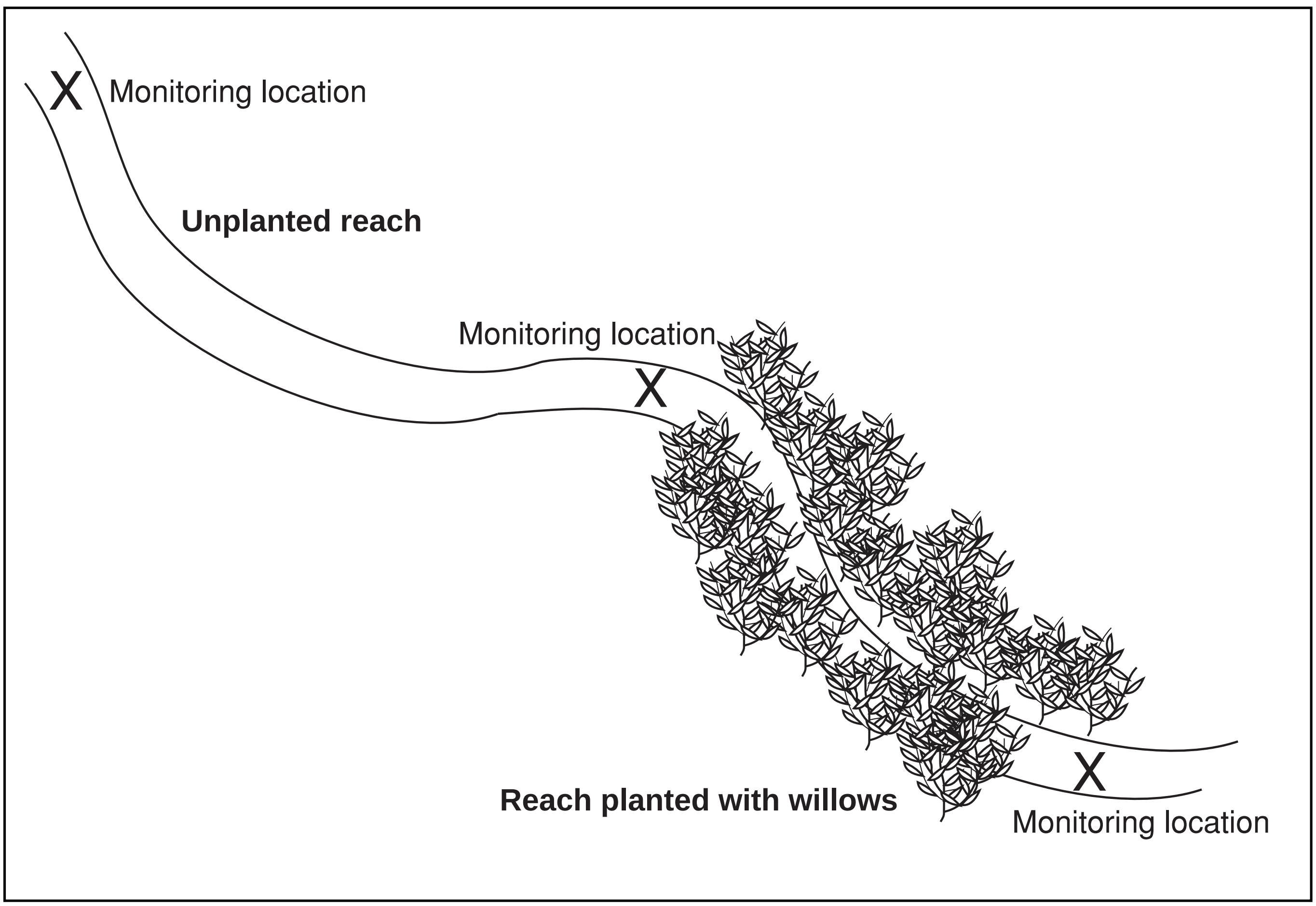


Figure 4.–Monitoring of paired reaches, one of which has been planted with willows. (Diagram is schematic and not to scale.)

TEN COMPONENTS OF A SUCCESSFUL WATER-QUALITY MONITORING PROGRAM

This section introduces considerations for anyone wishing to start a water-quality monitoring program. These considerations and others are discussed in more detail in publications such as *Volunteer Stream Monitoring: A Methods Manual* (EPA, 1997), *The Volunteer Monitor's Guide to Quality Assurance Project Plans* (EPA, 1996), and the *Water Quality Monitoring Guidebook* (OPSW, 1999).

1. A diverse Technical Advisory Committee

A Technical Advisory Committee (TAC) is a group of people who can provide technical review of all stages of the monitoring project. A TAC might:

- Give advice on monitoring questions and the sampling strategy
- Find resources such as monitoring equipment and money
- Promote community buy-in of the project
- Review the results and conclusions for credibility
- Assist with data interpretation and presentation
- Vouch for the project's credibility to agencies

A broad selection of technical expertise and diverse perspectives will make the project both scientifically sound and acceptable to the community. The TAC might be composed of university scientists, natural resource agency staff, watershed stakeholders, landowners, and interested citizens.

Include state and federal monitoring experts as much as possible. You might want to invite participation from the United States Geological Survey, the Oregon Department of Fish and Wildlife, the Oregon Department of Environmental Quality, agencies that manage land in the watershed, major industries in the basin, and industries or cities that have permits to discharge into the river.

Different TACs have varying amounts of involvement in monitoring projects. Some meet annually to review the project and results. Other TACs never meet formally, but their individual members review draft plans and reports and are available for consultation as time allows.

2. Clear monitoring questions

A clear monitoring question is essential for producing useful monitoring results. The *Water Quality Monitoring Guidebook*, published by the Oregon Plan for Salmon and Watersheds, suggests that defining the problem, goals, and objectives at the beginning of a monitoring project will help structure the monitoring so that the data collected provide reliable answers to the questions (OPSW, 1999). Table 1 (page 7), produced by the Oregon Department of Environmental Quality Volunteer Monitoring Coordinator, provides a matrix that can help you set goals and objectives for your project. The TAC also can help with this process. Monitoring questions and objectives are discussed further in Chapter II-5.

A sampling design or strategy is the "what, where, when, and how" of water-quality monitoring.

3. A quality assurance project plan

A quality assurance project plan outlines monitoring procedures in detail so that the samples, data, and reports are of high enough quality to meet project objectives. It describes the field, lab, and data management protocols; procedures for training and overseeing volunteers; and data interpretation and presentation methods.

Ideally, the plan is developed in collaboration with the TAC and is approved by funding agencies or those that will use the data, such as DEQ. In Oregon, the DEQ's Volunteer Monitoring Coordinator provides input into these plans and approves them. EPA's *The Volunteer Monitor's Guide to Quality Assurance Project Plans* provides step-by-step instructions on how to develop a quality assurance project plan.

4. A well-designed sampling strategy

A sampling design or strategy is the "what, where, when, and how" of water-quality monitoring. Choose parameters, sampling schedules, sampling locations, and methods that will answer your monitoring questions. Sampling designs are discussed in Chapter II-5, "Assessment and Monitoring Considerations."

5. Appropriate testing methods

The method you choose to measure each parameter plays a large role in the overall quality of your data. In choosing methods, take the following factors into consideration.

Precision and accuracy describe the repeatability of the measurement and how close it is to the true value of the parameter. Most parameters can be measured at varying levels of precision and accuracy. A colorimetric pH kit, for example, might measure pH to a precision and accuracy of +/- 1 pH unit. A pH meter and probe, on the other hand, might measure pH with a precision and accuracy of 0.1 pH unit.

Cost generally increases as precision and accuracy increase. It is not always necessary to use highly accurate methods, so you might want to prioritize where to put your money.

The level of expertise necessary to produce reliable data depends on the method. Depending on the time available for training and supervision of volunteers, you might want to choose a simple method with few steps and chemical reagents versus a more complex method.

6. Quality assurance (QA) and quality control (QC)

Quality assurance and quality control, often referred to as QA/QC, ensure the quality of the data. According to the Oregon Plan for Salmon and Watersheds' *Water Quality Monitoring Guidebook*, quality assurance is the overall project management, including organization, planning, data collection, documentation, and quality control. Quality control, on the other hand, is a series of technical activities conducted routinely to minimize errors (OPSW, 1999). Errors can occur in the field, lab, or office, so QC should be included in all aspects of the project.

Examples of QC activities include repeating field measurements, splitting samples with a professional lab, reviewing data sheets for errors, and checking an electronic database against data sheets. The *Volunteer Monitor's Guide to Quality Assurance Project Plans* provides more detailed guidance on QA/QC activities (EPA, 1996).

7. Training

Monitoring staff or volunteers must receive training and commit to collect data according to the monitoring plan and selected methods. Staff or volunteers must coordinate sample collection, equipment calibration and maintenance, and chemical management (if any). Training should be conducted periodically, even if participants have been monitoring for a long time. Include a description of the training procedures and schedule in the monitoring plan.

8. Safety

Always follow safety precautions in the field and laboratory; no water sample is worth injury or death. Encourage individuals collecting field data to work with a partner at all times. Cancel monitoring during hazardous weather. If monitors will be wading streams, provide training on estimating hazardous stream flows. In both the lab and the field, wear gloves and goggles when using chemicals. Dispose of chemicals properly.

9. Data management

Collect and store data so that they are easily accessible in case your project experiences staff turnover or receives requests for data from outside organizations. Use a field data sheet when collecting water samples and testing them in the field. Data sheets will help you be consistent in your field procedures. They also provide space to record observations that might help you interpret the data.

Store data on a computer and back them up on disks. Whether you use a database program or spreadsheet program, the format should be easy for someone outside the project to understand. The Oregon Department of Environmental Quality might have a preferred data storage format for sharing data.

10. Data interpretation and presentation

Data interpretation and presentation are the final steps, and often the ultimate goal, of monitoring. When designing a monitoring plan, it is critical to include enough time and funding for data interpretation and presentation to the community, TAC, agencies, and other stakeholders. These steps allow the data to be used by water resource management agencies, landowners, and local decision makers.

When interpreting data, keep in mind the questions you asked when developing your monitoring plan. Use charts and graphs to attempt to answer the questions. Ask the TAC to review drafts of your reports and findings before you present them to the public.

When presenting your results and findings, keep your audience in mind. Different groups might want different products. An agency, for example, might be interested in tables, or might prefer to receive the data electronically. Citizens, on the other hand, might be more interested in seeing the information in newspaper articles, a poster at the local library, or an easy-to-read publication. For a lay audience, it is important to:

- Use charts, graphs, maps, and pictures
- Reduce tables of numbers to summary statistics
- Write clearly and eliminate technical terms

The Massachusetts Water Watch Partnership has produced a manual *Ready, Set, Present!* that focuses on presenting water-quality data to a range of audiences using many different methods. The manual covers oral presentations, written presentations, effective graphics, media relations, and exhibits (Massachusetts Water Watch Partnership, 2000).

Summary/Self review

Water quality describes the chemical, physical, and biological aspects of water, generally in terms of suitability for a particular use. Water-quality monitoring is the process of sampling and analyzing water conditions and characteristics (EPA, 1997). These characteristics, such as dissolved oxygen, pH, and temperature, are known as parameters.

Citizens and agencies monitor water quality to:

- Identify particular pollutants of concern
- Identify whether the quality of the water is sufficient for a particular use
- Target problem areas
- Detect trends
- Determine the effectiveness of restoration or enhancement projects

Commonly monitored parameters are:

- pH
- Total dissolved solids
- Conductivity
- Nitrogen
- Phosphorus
- Dissolved oxygen
- Stream flow
- Temperature
- Suspended solids
- Turbidity
- Bacteria

Asking a monitoring question and developing a monitoring strategy are two important parts of water-quality monitoring. Three common types of monitoring are trend monitoring, baseline monitoring, and effectiveness monitoring. To monitor the effectiveness of a best management practice, paired reaches provide the most useful information.

Ten important considerations to keep in mind when developing a monitoring program are:

1. A diverse Technical Advisory Committee
2. A quality-assurance project plan
3. Clear monitoring questions
4. A well-designed sampling strategy
5. Appropriate testing methods
6. Quality assurance and quality control
7. Training
8. Field and laboratory safety
9. Data management strategy
10. Data interpretation and presentation

EXERCISES

You can do these exercises on your own.

Water-quality monitoring field work

Volunteer to help an agency scientist collect water samples in the field. You might choose to participate in routine monitoring or a specific project. Observe the methods used. What is the precision and accuracy of each method? Why was it chosen? Observe the quality assurance and quality control protocols followed. How does each action contribute to a technically sound program?

Water-quality monitoring data interpretation

Contact a local watershed council involved in water-quality monitoring. Volunteer to help with the data interpretation part of the monitoring program. Obtain a copy of the monitoring plan. What monitoring questions does the group want to answer? Do the data answer those questions? Are some questions left unanswered? How would you answer them?

RESOURCES

Training

For more information, contact your local watershed council, OSU Extension Service office, Soil and Water Conservation District, or the Oregon Department of Environmental Quality Volunteer Monitoring Coordinator (DEQ Laboratory, 1712 SW 11th Ave., Portland, OR 97201, 503-229-5983).

Information

Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska, EPA 910/9-91-001, by L. MacDonald and R. Wissmar (U.S. Environmental Protection Agency, 1991).

Monitoring Protocols to Evaluate Water Quality Effects of Grazing Management on Western Rangeland Streams, by S. Bauer and T. Burton (Idaho Water Resources Research Institute, University of Idaho, Moscow, 1997).

Oregon Watershed Assessment Manual (Oregon Watershed Enhancement Board, Salem, 1998).

Ready, Set, Present! (Massachusetts Waterwatch Partnership, Amherst, 2000).

Volunteer Estuary Monitoring: A Methods Manual, EPA 842-B-93-004 (U.S. Environmental Protection Agency, 1993)

The Volunteer Monitor's Guide to Quality Assurance Project Plans, EPA 841-B-96-003 (U.S. Environmental Protection Agency, 1996)

Volunteer Stream Monitoring: A Methods Manual, EPA 841-B-97-003 (U.S. Environmental Protection Agency, 1997).

Water Quality Monitoring Guidebook (The Oregon Plan for Salmon and Watersheds, Salem, 1999).

MOVING FORWARD–THE NEXT STEPS

On your own, use the lines below to fill in steps, actions, thoughts, contacts, etc. you'll take to move yourself and your watershed group ahead in your ability to monitor water quality.

1.

2.

3.