New Mexico Wetlands

Technical Guide #1

Wetland Functions

New Mexico Environment Department
Surface Water Quality Bureau
Wetlands Program

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(Cover Photo: Rio Embudo (2011) by John Busemeyer)

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Introduction

This guide is the first in a series intended to broaden the understanding of wetland types, wetland functions and values, and the need for wetland restoration and protection. Because New Mexico is a dry state, wetland resources have been largely overlooked. There is insufficient current data available to provide important long-term trend information about specific changes and the overall status of New Mexico wetlands. The potential ecological impacts for climate change may also intensify stresses on our natural systems including water resources and wetlands (Glick et al. 2011). Assessment data is needed to determine the quality and condition of wetlands and causes for observed changes. This document will provide basic information about New Mexico's wetlands so that wetland practitioners and landowners start on the same page. This document will serve as a valuable resource for natural resource planners, restoration professionals, and landowners in New Mexico. The document includes reference information about the types of wetlands that occur in New Mexico, wetland functions and the value of wetlands, why wetland condition and buffers are important. Future guides will provide information like where to get permits for wetland work, and an overview of wetland restoration techniques.

Long-term comprehensive wetland restoration and protection will require new and improved approaches and regional collaboration to reduce diversion of water away from natural wetlands, reduce over-pumping of aquifers that support ground water-fed wetlands, and mitigate impacts on wetlands caused by infrastructure and urban development projects. This guide addresses some regional landscape health aspects such as the proliferation of non-native phreatophytes, and impacts that conspire to dry wetlands, such as gully erosion in the area around wetlands. Furthermore, this guide builds on a growing base of documents published in recent years, which promote locally-appropriate ecological restoration techniques for wetlands in the semi-arid southwestern landscape. The References and Resources section in the back of this document lists additional sources of information that complement this guide.

Overview

Wetlands are the most valuable and diverse ecosystems in the western United States (Knopf et al. 1988, Fleischner 1994, Belsky et al. 1999, Wuerthner and Matteson 2002). According to current knowledge, wetlands make up only about 0.6% of land area in New Mexico, however, up to 85% of all species depend upon these ecosystems at some point during their life span (Knopf et al. 1988, Fleischner 1994, Deason 1998, Belsky et al. 1999, Wuerthner and Matteson 2002). Besides habitat for wildlife, wetland ecosystems provide numerous benefits for the human population as well. Wetlands help lessen the impacts of floods and droughts, thus stabilizing water supplies, improve water quality by filtering out pollutants and sediment, recharge aquifers and wells, provide opportunities for recreation, hunting, and fishing, provide opportunities for education, and even offer places of spiritual and cultural significance (Mitsch et al. 2007).

Unfortunately, many wetland ecosystems are in poor condition and are declining due in large part to human impacts (Fleischner 1994, Belsky et al. 1999). New Mexico has lost about one-third of its wetlands, mostly due to agricultural conversion, diversion of water to irrigation, overgrazing, urbanization and groundwater depletion. Other causes of loss or degradation have been mining, erosion from forest clear cutting, road construction, streamflow regulation and impoundment, and invasion by non-native plants (Deason 1998). It is crucial that remaining wetlands be protected and degraded wetlands be restored if we want to benefit from the ecological functions and important values they provide. The common goal of wetland restoration projects is to return these ecosystems to a resilient, self-sustaining and ecologically valuable condition (Palmer et al. 2005).

What is a Wetland?

The State of New Mexico defines "**Wetlands"** as those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions (NMAC 20.6.4). In more general terms, a wetland is an aquatic ecosystem at the interface, or transitional zone, between upland, dry ecosystems and deeper aquatic ecosystems, such as rivers or lakes. However, wetlands are also found in isolated locations far from a larger body of surface water. The upland limit of a wetland is where soil and vegetation is not influenced by shallow water or a water table near the surface, displays predominantly dryland plant cover that cannot tolerate saturated soil conditions. The lower boundary between wetlands and deeper water habitat associated with riverine and lacustrine systems lies at 2 meters (6.6 feet) below low water, or the maximum depth at which emergent plants normally grow.

The main distinguishing characteristics of wetlands include three key components:

- Hydrology - wetlands are found in the presence of water, either at the surface or within the root zone of the soil for at least part of the year.

- Unique soils - wetland soils are subject to anaerobic (without oxygen) conditions sometime during the growing season due to the presence of water. These soils are classified as “hydric soils.”

- Vegetation - wetlands support plants that are adapted to the wet conditions of the soil (hydrophytes) and generally do not support plants that are intolerant to flooding.

All wetlands share these hydrologic, soil and vegetative characteristics (Brinson, 1993), however beyond these general similarities, wetlands exhibit wide variation in terms of their size, complexity, biology, chemistry and physical characteristics (Mitsch and Gosselink 1993). Wetlands include swamps, bogs, marshes, fens, riparian floodplains and forests, seeps, springs, cienegas, playas and other wet ecosystems. Wetlands are found at the edges of lakes and rivers and in low depressions where rain and snowmelt collect. Because of the climatic variability of New Mexico which sometimes includes long periods of drought that dry up even the most persistent water sources, wetlands are not expected to be saturated each year.

Riparian Areas. Riparian areas are intrinsically connected to and interdependent on the water sources and hydrologic regimes that also support wetlands. Riparian areas normally refer to entire floodplains able to support vegetation dependent on runoff and overbank flow, scour, sedimentation, infiltration and shallow groundwater. They include areas considered as somewhat drier portions of a wetland ecosystem and are characterized by habitats associated with flowing or stationary bodies of water. They are dependent on existence of perennial, intermittent or ephemeral surface water and/or hyporheic zones (local shallow water tables). Riparian areas occupy the same areas of the landscape as wetlands, may contribute to the same functions within the landscape, and are interdependent, and, therefore, are considered together as part of a wetlands ecosystem.

Buffers. Buffers are non-disturbance or minimally disturbed areas surrounding a wetland/ riparian area where natural vegetation is maintained to protect wetlands and riparian areas from the impacts of stormwater floods, a variety of pollutants, and solid waste from adjacent terrain (Kusler et al. 2003). Buffers provide the functions and services associated with contiguous natural habitat adjacent to wetlands and riparian areas. Land cover elements which are considered acceptable buffer include natural uplands (forests, grasslands, shrublands), swales, nature or wildland parks, unmaintained old fields, and rangeland in good condition. These buffer elements are expected not to disrupt ecosystem connectivity, provide habitat connectivity, and provide protective services such as preventing erosion, reducing pollutant contamination and preventing encroachment of undesirable landscape elements and activities that affect wetland resources. Wetland assessments include assessment of the condition and extent of buffer areas.

Types of Wetlands

Regional, geologic, topographical, hydrologic and climatic variability produce the natural diversity observed as wetland types. The differences in the geomorphology (landscape setting), hydrodynamics (energy level and direction of flow) and sources of water (surface flow, direct precipitation or groundwater) provide the basis for classifying wetlands.

The following information is used by the NMED Surface Water Quality Bureau to classify wetland types in New Mexico. This classification of wetlands is modified from *A Hydrogeomorphic Classification for Wetlands* by Mark M. Brinson for the US Army Corps of Engineers (1993).

Depressional Wetlands

Depressional wetlands occur in topographic depressions that allow accumulation of surface water. On a topographic map these wetlands would occur within a closed elevation contour. Dominant sources of water are precipitation, groundwater discharge, and overland flow from adjacent uplands. The direction of water movement is normally from the surrounding uplands toward the center of the depression. Depressional wetlands may have any combination of inlets and outlets or lack them completely. Depressional wetlands may lose water through intermittent or perennial drainage from an outlet, by evapotranspiration, and, if they are not receiving groundwater discharge, may slowly contribute to groundwater. Dominant hydrodynamics are vertical fluctuations, primarily seasonal. Peat deposits may develop in depressional wetlands in wet climatic conditions. Playas of the eastern Llano Estacado are a common example of depressional wetlands where the dominant water source is precipitation. Zuni Lake is an example of a predominantly ground-water supported wetland.

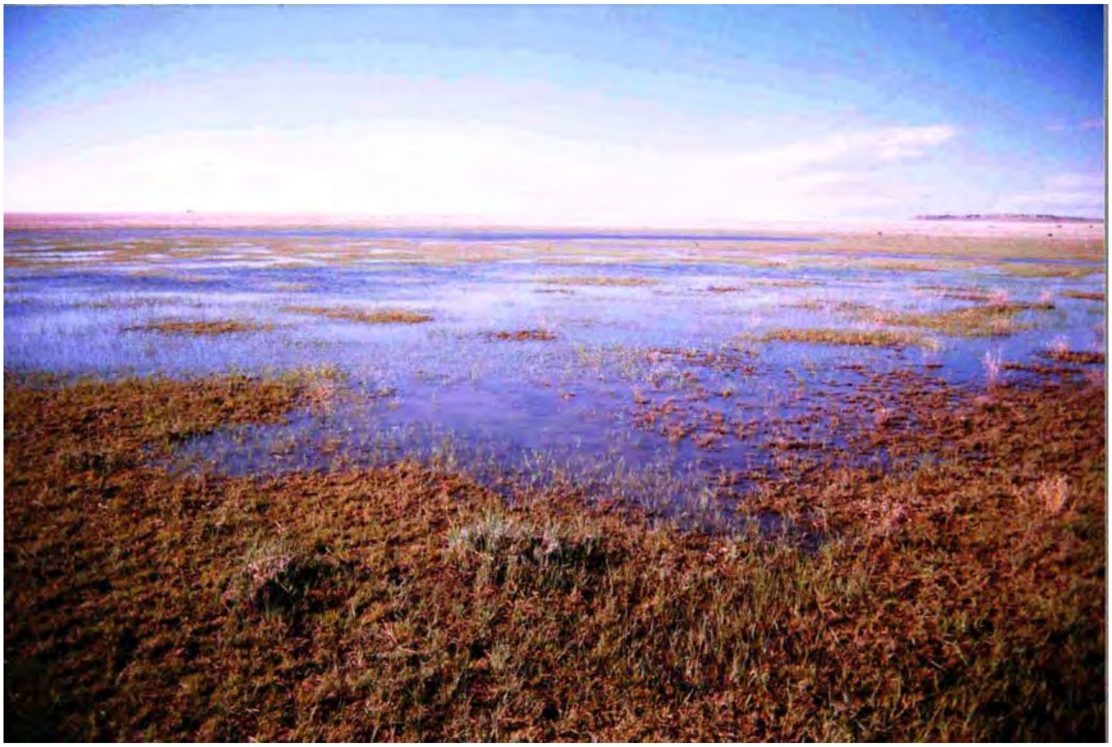

Figure 1. Playa near Wagon Mound, New Mexico (2009)

Figure 2. Playas of the southern high plains in eastern New Mexico support thousands of migrating birds during the winter. Pettigrew Ranch Playa (2013).

Figure 3. Precipitation-dependent playa during the dry season on Johnson Mesa (2011).

Figure 4. Groundwater-dependent depressional wetland at Zuni Lake, Catron County, New Mexico (Preservation Nation photo credit).

Figure 5. This wetland has been ground-water dependent for thousands of years. Recent ground water pumping has lowered the water table and now this wetland depends on precipitation events. Grulla National Wildlife Refuge, Roosevelt County, New Mexico (2013).

Riverine Wetlands

Riverine wetlands occur in floodplains and riparian corridors in association with stream channels. Dominant water sources are overbank flow or side channel flow from the channel, or subsurface hydraulic connections between the stream channel and adjacent wetlands. Additional water sources include overland flow from adjacent uplands and precipitation. When overbank flow occurs, surface flows down the floodplain may dominate hydrodynamics. At their headwaters, riverine wetlands often intergrade with slope or depressional wetlands as the channel (bed) and bank disappear, or they may intergrade with poorly drained flats or uplands.

Perennial flow is not required. Riverine wetlands lose surface water via the return of floodwater to the channel after flooding and through saturation surface flow to the channel during rainfall events. They lose subsurface water by discharge to the channel, movement to deeper groundwater (for losing streams), and evapotranspiration. Peat may accumulate in off-channel depressions (oxbows) that have become isolated from riverine processes and subjected to saturation from ground-water sources. Bosque floodplains are a common example of riverine wetlands. Riverine wetlands are the most common and also the most threatened wetlands in New Mexico (Muldavin et al. 2011).

Figure 6. Riverine wetlands on the broad floodplain adjacent to the Gila River, southwestern New Mexico (2012).

Figure 7. Forested riverine wetlands on the Rio Frijoles at Bandelier National Monument (2002).

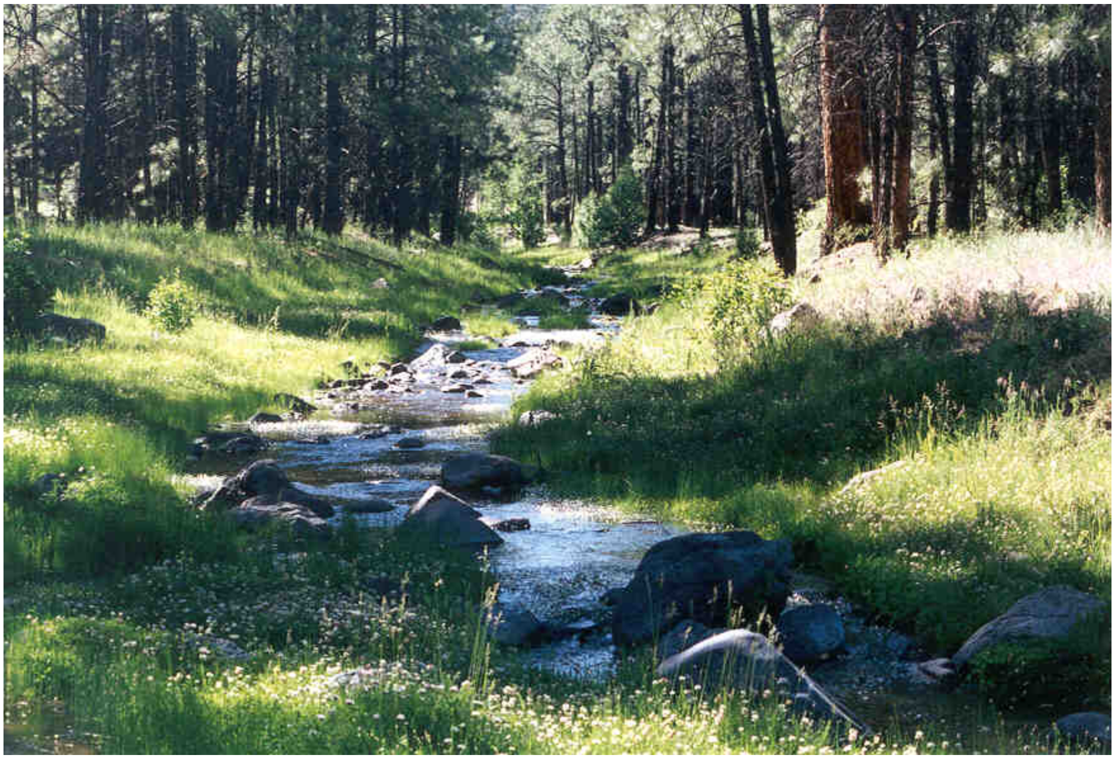

Figure 8. Riverine wetlands along the San Francisco River in Catron County, New Mexico.

Figure 9. Unconfined riverine wetlands along the lower Jemez River, Santa Fe National Forest.

Figure 10. Riverine wetlands along a confined portion of the Rio Grande within the Wild and Scenic River Segment in the Rio Grande del Norte National Monument in northern New Mexico.

Figure 11. Beaver dammed riverine wetlands along the Rio Pueblo de Taos (2007).

Figure 12. Confined riverine wetlands along the Rio San Antonio, Taos County.

Figure 13. Wet meadow riverine wetlands in the Valles Caldera along the Rio San Antonio.

Lacustrine Fringe Wetlands

Lacustrine fringe wetlands are adjacent to lakes where the water elevation of the lake maintains the water table in the wetland. In some cases, they consist of a floating mat of vegetation attached to land. Additional sources of water are precipitation and groundwater discharge, the latter dominating where lacustrine fringe wetlands intergrade with uplands or slope wetlands. Surface water flow is bidirectional, usually controlled by water level fluctuations in the adjoining lake. Lacustrine fringe wetlands are indistinguishable from depressional wetlands where the size of the lake becomes so small relative to fringe wetlands that the lake is incapable of stabilizing water tables. Lacustrine wetlands lose water by flow returning to the lake after flooding, by saturation surface flow, and by evapotranspiration. In New Mexico most lakes are actually man-made reservoirs subject to water level control that may cause inundation or draining of associated fringe wetlands. In some cases, water level control in reservoirs makes it nearly impossible for natural fringe wetlands dominated by perennial wetland plant species to develop extensively. When fringe wetlands are exposed by low water, common annual plants may dominate. Organic matter normally accumulates in areas where the banks around the lakes are flatter or are sufficiently protected from shoreline wave erosion. Marshy areas bordering Abiquiu Lake are an example of lacustrine fringe wetlands.

Figure 14. Lacustrine fringe wetlands developed adjacent to Ramah Lake.

Figure 15. Lacustrine fringe wetlands adjacent to Abiquiu Lake.

Figure 16. Lacustrine fringe exposed at low water in El Vado Lake (2009).

Slope Wetlands

Slope wetlands normally are found where there is a discharge of groundwater to the land surface. They typically occur on sloping land; elevation gradients may range from steep hillsides to slight slopes. Slope wetlands are usually incapable of depressional water storage because the ground lacks the necessary closed contours or are convex in shape. Principal water sources are usually groundwater flow, however interflow from surrounding uplands as well as precipitation may contribute. Hydrodynamics are dominated by downslope unidirectional water flow. Slope wetlands can occur in nearly flat landscapes where groundwater discharge is a dominant source to the wetland surface. Slope wetlands lose water primarily by saturation subsurface and surface flows and by evapotranspiration. Slope wetlands may develop channels, but the channels serve only to convey water away from the slope wetland. Seepage areas that occur along hillsides and can support the growth of wet-tolerant ferns, shrubs, and some of the same herbaceous plants found in other wetlands are included in New Mexico slope wetlands broad classification. Seeps and springs and on a larger scale, fens, cienegas and outflow from the tow of an alluvial fan are common examples of slope wetlands. In fen wetlands, ground water inflows maintain a fairly constant water level year-round, with water at or near the surface most of the time (Rocchio 2005). Constant high water levels lead to accumulation of organic material (peat) and perennially saturated soils. Fens also have distinct soil and water chemistry, with high levels of one or more minerals such as calcium, magnesium, or iron.

Figure 17. Broad valley slope wetland west of Tres Piedras, New Mexico (2013).

Figure 18. Slope wetlands in fall color along the Rio Grande near the Taos County border.

Figure 19. Cebolla Springs slope wetland in Cebolla Wilderness near Grants, NM (2012).

Figure 20. Slope wetlands at Leonora Curtin Wetland Preserve near Santa Fe, New Mexico.

Figure 21. Spring-fed wetlands on Bonanza Creek near La Cienega, New Mexico (2011).

Figure 22. Hydrothermal spring-fed wetlands at Alamo Bog on upper Sulphur Creek, Valles Caldera (2012).

Figure 23. Slope wetland near Amalia, New Mexico (2004)

Figure 24. Fen wetland in the Valles Caldera, New Mexico, mis-named Alamo Bog.

Mineral Soil Flats

Mineral soil flats are most common on interfluves (a region of higher land between two rivers), extensive relic lake bottoms, or large floodplain terraces where the main source of water is precipitation. They receive virtually no groundwater discharge which distinguishes them from some depressional and slope wetlands. Dominant hydrodynamics are vertical fluctuations. They lose water by evapotranspiration, saturation overland flow, and seepage to underlying groundwater. They are distinguished from flat upland areas by their poor vertical drainage and low lateral drainage, usually due to low hydraulic gradients. Mineral soil flats that accumulate peat can eventually become the class organic soil flats.

Figure 25. The Lordsburg Playa in southern New Mexico is an extensive mineral flat wetland that depends on precipitation.

Organic Soil Flats

Organic soil flats differ from mineral soil flats, in part, because their elevation and topography are controlled by vertical accretion of organic matter. They occur commonly on flat interfluves, but may also be located where depressions have become filled with peat to form a relatively large flat surface. Water source is dominated by precipitation, while water loss is by saturation overland flow and seepage to underlying ground-water. Peat bogs can form in northern mountainous cooler climates where decomposition of dead vegetation is slowed and, therefore, accumulates over hundreds and thousands of years and can be several feet to tens of feet deep, or where plant matter accumulates under extreme anoxic conditions that prevent or slow its decomposition such that it accumulates in a similar fashion to peat bogs. So far we have not identified organic soil flats in New Mexico. Further mapping and investigation of high mountain wetlands in New Mexico may reveal the existence of organic soil flats.

Regional Wetland Subclasses

As evident in the discussion above, the broad classes of wetlands include a variety of wetland types that can be distinguished further at the subclass level. In order to develop a classification that is simple enough for use by watershed groups and other stakeholders, yet sensitive enough to detect change in function, the level of variability within a wetland class is assigned to a subclass using the HGM classification at a regional scale. Regions are defined as geographic areas that are relatively homogenous with respect to climate, geology, and other large-scale factors that influence wetland function. For example, differences in precipitation (Munger and Eisenreich 1983; Groisman and Easterling 1994) and temperature may cause wetlands in the southern part the State to function differently from wetlands in the north. There is considerable flexibility in defining wetland subclasses within a region. The hierarchical nature of the HGM classification makes it possible to work at different scales of resolution depending on the region, HGM class, or projects under consideration. The number of regional wetland subclasses defined will depend on a variety of factors such as the diversity of wetlands in the region, assessment objectives, the ability to actually measure functional differences with the time and resources available, and the predilection towards lumping or splitting. In many regions, wetland classifications have already been developed that account for interegional and intraregional differences in wetland ecosystems (Wharton 1978; Golet and Larson 1974; Stewart and Kantrud 1971). These classifications serve as a convenient starting point for identifying regional wetland subclasses.

Regional subclasses, like the HGM classes, are distinguished on the basis of geomorphic setting, water source, and hydrodynamics. However, additional ecosystem or landscape characteristics may also be useful in certain regions. For example, regional subclasses of depressional wetlands could be based on dominant water source (i.e., groundwater versus surface water) or based on salinity gradients. In the slope class, subclasses could be based on the degree of slope, landscape position, elevation, or the source of water or other factors. In the riverine class, subclasses could be based on water source, position in the watershed, stream order, watershed size, channel gradient, or floodplain width. Implicit in the hydrology of a particular wetland is its landscape position, or “geomorphic setting,” which will accommodate the flows and storages of water. From a broad and long-term geomorphic perspective, water flows and wetland position are inextricably linked.

Functions of Wetlands

Wetland functions are defined as a process or series of processes that take place within a wetland (Novitski et al 1997). Wetlands are important for the functions that they provide and the essential role that they play in the environment at the land and water interface. Managing wetlands at the watershed scale requires an understanding of the functions that wetlands provide to the watershed (Center for Watershed Protection 2006).

Wetland functions can be broadly divided into three categories, physical, chemical and biological functions. Not all wetlands provide the same types of functions or to the same degree, due to differences in type, size, location and other factors. Below is a description of the most important wetland functions. The description of wetland functions below has been modified from a variety of sources including Brinson et al. 1995, Hauer et al. 2002, and Tiner 2003.

Physical Functions

Dynamic Surface Water Storage: This function is the ability of riverine wetlands and riparian zones to catch and detain moving waters from overbank flows, side channel flows and/or overland inputs during a flood event. Water is routed and/or stored under the influence of surface and subsurface flows during these events. Also referred to as Flood Water Detention, the ability of riverine wetlands to detain water and slow the velocity of a flood event alters the intensity and impact of peak flows downstream. The capacity of a wetland to control the movement of surface water through the wetland and dynamically store water is related to its roughness, slope, and width. The length of time that the wetland is able to detain flowing water as it moves through the wetland improves the performance of this function, which directly supports other wetland functions.

As the wetland performs this function, sediment and other particulates can settle out of the water improving water quality. The saturation of wetland soils can lead to nutrient cycling and the removal of contaminants. The lowered velocity of the flowing water allows for the export of particulate organic matter for use in the aquatic food chain as well as transport of plant propagules. Slowed and detained flow across the floodplain and in floodplain side channels provides a refuge for aquatic organisms from the strong current in order to feed and recruit (Brinson, et al. 1995). Many aquatic invertebrates, amphibians, and fish are completely dependent on the habitats associated with this function for portions of their life cycle (Hauer et al. 2002).

Performance of the function is essential to the performance of virtually all other characteristic floodplain functions and separates the role of the floodplain in the larger landscape from upland environments (Hauer et al. 2002). Hydromodifications, such as dams and diversions, alterations to the geomorphology of the floodplain by dikes and/or levees, and incision of the streams so that they cannot access their floodplains during storm events, greatly impact the floodplain and associated wetlands ability to fully support this function and therefore the related wetland functions.

Long-Term Surface Water Storage: The ability of a wetland to temporarily store (retain) surface water over long periods. The water that is under long-term storage is standing (not moving) and present for seven days or longer. Often associated with Dynamic Surface Water Storage, Long-Term Surface Water Storage is the retention of surface water in oxbows, depressions, and other backwater areas after the flowing waters have dissipated. The surface water can come from overbank or side channel flow, overland flow, precipitation and/or subsurface flow.

The retained water can percolate into surficial ground water moderating the local water table as well as regulate base flow timing and volume. The retention of surface water extends the period of soil saturation and anaerobic chemical transformations that occur under these conditions. Excess sediments and nutrients settle out into the wetland leading to other wetland functions. The standing water provides important habitat for both aquatic and terrestrial species (Brinson et al. 1995).

Figure 26. Backwater wetland on the Gila River floodplain is located in a side channel supported predominantly by the local water table (2012).

Subsurface Storage of Water: The ability of a wetland to store water below its surface. A wetland is able to perform this function through drawdown of the water table or when soil saturation decreases due to evapotranspiration or vertical or lateral drainage. Soils with small pores allow for percolation and long term storage of water when they are not already fully saturated. As these soils lose water through drainage or evapotranspiration, the pores are filled with air. Wetland plants (hydrophytes) can tolerate long periods of soil saturation and are highly adapted to the fluctuation between aerobic and anaerobic soil conditions. This short and long-term storage of water in the soils maintains the biotic communities and the biogeochemical processes in the soils that lead to other wetland functions. It also recharges surficial ground-water and base-flow timing and volume (Brinson et al. 1995).

Surface Water Storage in a Depressional Wetland: The ability of a depressional wetland to store water above the groundwater table for a period of time that is sufficient for developing other wetland characterisitics. Depressional wetlands are generally dependent upon precipitation and snowmelt within the catchment area but can be influenced by interception with the groundwater table. The stored water is generally lost to evapotranspiration and ground water recharge. The stored surface water effects the biogeochemical cycling within a wetland, the vegetative community, and habitat for invertebrate and vertebrate species. Anthropogenic modifications can cause serious impacts to the ability of a depressional wetland to store surface water. Stressors such as changes to the buffer or wetland edge, soil compaction, roads, tilling and cultivation, or evapotransporation changes due to grazing can have severe impacts (Hauer et al. 2002).

Figure 27. Water from precipitation on its surrounding catchment is captured and stored in this playa (2004).

Energy Dissipation: A wetland's ability to slow down the velocity of water as its energy is allocated to other forms due to roughness of the wetland, vegetation structure, and other factors. This function is linked to Dynamic Surface Water Storage but is more related to how the energy is translated or dissipated as the water moves into, through, and back out of the wetland. The vegetation structure, topography, and roughness of the wetland dissipate the energy of the flowing water as it moves through the wetland. This lowers the pressure on channel beds and banks reducing the erosion of shorelines and floodplains by removing large sediment and debris loads from the flows. This also increases the ability of suspended particles to settle out of the flowing water and into the biogeochemical functions that take place in the wetland environment. (Brinson et al. 1995)

Chemical Functions

Nutrient Cycling: The ability of a wetland to encourage the cycling of nutrients from inorganic to organic and back to inorganic forms. Nutrient cycling is a fundamental function in all ecosystems, but is accomplished at much higher rates in wetlands. In wetlands nitrogen and phosphorus cycles are of most interest. Wetlands are one of the only places where N2 (N gas) is produced. All wetlands recycle nutrients, but wetlands with a fluctuating water table function at a much higher rate in recycling nutrients. Wetlands with seasonally flooded and wetter water regimes contain soils with higher amounts of organic matter near the surface that promote microbial activity when wet (Tiner 2003). Also some types of nutrient cycling are much higher in freshwater wetlands such as methane production.

The characteristic plant community (producers) provide the food and habitat structure (energy and materials) needed to maintain the animal community (consumers). Eventually, the plant and animal communities deposit detritus that is the source of energy and materials necessary for a healthy community of decomposers. The decomposers break down these organic materials into simpler forms that can be used by the plant community. This sustained supply of nutrients in the soil provides the ability of a wetland to maintain the plant community and continue to recycle the nutrients. This plant community (surface roughness) slows surface water flows allowing mineral and organic particles (nutrients) to settle out of the water column into the wetland. The capturing of these nutrients and continued recycling within the wetland help improve the water quality by reducing the amount of dissolved nutrients in the adjacent water bodies (Brinson et al.1995).

Removal of Imported Elements and Compounds: Wetlands are well documented as interceptors of nonpoint source pollution and this function is often referred to as the capability of a wetland to act as a “sink” for pollutants. More specifically, this is a wetland’s ability to remove elements (i.e., macronutrients and heavy metals) and imported materials (i.e., herbicides, pesticides, oils, salts, etc.) either long-term or permanently from incoming water sources. Each individual element, nutrient, chemical compound or heavy metal has its own biogeochemical pathway once in the wetland, but the main mechanisms of removal include sorption, sedimentation, denitrification, burial, decomposition to inactive forms, and uptake and incorporation into long-lasting woody and long-lived perennial herbaceous biomass. Some losses to groundwater seepage, animal export, or as a gas to the atmosphere do occur, but a large percentage may be more or less permanently buried in deeper sediments where they are broken down into innocuous and biogeochemically inactive forms. The elements and compounds that are captured in the wetland reduce downstream loading (Brinson et al. 1995) (Hauer et al. 2002).

Retention of Particulates: This function is capability of a wetland to decrease the velocity of water through increased roughness and area of discharge. As a result, the discharge has a decreased velocity and deposition of particulates suspended within the water column occurs in the wetland. The retention of particulates function is similar to nutrient cycling and removal of imported elements and compounds but relies on physical processes (e.g., sedimentation, flocculation and filtration.) Sediments can then undergo such processes as weathering and the release of elements in forms that are more readily available for mineral cycling. This deposition of sediment can also help trap litterfall and other detritus for decomposition into smaller organic particles for transport back into the adjacent water body or into the nutrient cycle of the wetland. Sediment deposition also increases surface macrotopographic complexity of the wetland (Brinson et al. 1995).

Organic Carbon Export: The export of dissolved and particulate organic carbon by a wetland due to the increased residence time for water in a wetland to be in contact with organic matter in leaf litter and soil. Wetlands export organic carbon at higher rates than terrestrial ecosystems due to the biogeochemical processing in the wetland environment. Mechanisms for export include leaching, flushing, displacement and erosion. Microbial food webs rely on organic carbon as an energy source which is the base for the aquatic food web.

Wetlands with organic rich sediments and long contact times of shallow water allow organic matter to accumulate in surface water. Precipitation events can transport this matter to adjacent water bodies, but floodplains with overbank flow have a much greater water turnover and perform this function at a much higher level (Brinson et al. 1995).

Biological Functions

Maintain Characteristic Plant Communities: A wetland's ability to maintain a diverse native living plant community characteristic of a wetland in reference condition, and the maintenance of properties such as seed dispersal, propagules, density, and growth rates that permit response to natural variation in climate and disturbance (e.g., fire, herbivory). A characteristic plant community accounts for most of the biomass in a wetland and is maintained by heterogeneity of environmental conditions, especially geomorphology, water regime, natural disturbances, and water/soil chemistry.

Wetlands are partly characterized by the vegetative community that they support. This vegetative community is strongly influenced by the depth of water, chemistry of water, nutrient cycling, soil development, disturbance regime, and climatic changes. Invasion by nonnative plants or uncharacteristic native species is an indication that this function has been diminished. Invasion by nonnative plants is known to alter ecosystem processes, causing both structural and functional change in the vegetative community, including fire frequency and intensity.

The maintenance of a characteristic plant community significantly affects a number of other wetland processes. Emergent vegetation provides most of the wetlands primary production and nutrient cycling, and contributes most of the annual detrital material for soil development. As the primary producer, the vegetation also provides most of the trophic support for secondary production, whether through direct grazing or recycling through the detrital-based food web. Plant communities also provide the habitat structure for nesting, resting, and cover for many animal species, maintaining the local and regional diversity of animals.

A vegetative community is dynamic, responding to natural variation and anthropogenic influence, and strongly influenced by periodic disturbances, such as flood and fire, that reset successional patterns. The ability of Riverine wetlands and floodplains to maintain a characteristic plant community is important for species diversity and the many attributes, functions, and processes floodplain vegetation performs. Primary productivity, nutrient cycling, and the ability to provide a variety of habitats are directly related to the plant community. In a riverine system, the quality of the physical habitat and biological diversity of adjacent rivers are also affected by the modification of the quantity and quality of water and the export of carbon from the plant community. Thus, vegetation is an interactive component of the river-floodplain-wetland ecosystem structure and function, operating both as a response variable to driving mechanisms (e.g., hydrologic regime, geomorphology) as well as being a driving mechanism for other functions (e.g., nesting habitat, primary productivity). Vegetation should not be considered as static, but rather as changing in composition and characteristics over a hierarchy of temporal scales; annual cycles, multi-year life history cycles, and as floodplain surfaces are affected by cut and fill alluviation (Brinson et al. 1995)(Hauer et al. August 2002)(Hauer et al. May 2002).

Maintain Characteristic Detrital Biomass: The capacity of a wetland to produce, accumulate, and disperse dead plant biomass of all sizes either on site or from upslope and upgradient. This function refers primarily to categories of fine and coarse woody debris. Functioning ecosystems rely on woody debris to reduce erosion and help build soils. The decomposing detritus can be the primary support for the detrital-based food chains which support the major nutrient –related processes (cycling, export, import) within wetlands. Larger woody debris can provide important resting, feeding, hiding and nesting sites for animals of higher trophic levels, and can create debris dams playing an important role in the dynamics of floodplain-stream ecosystems. This provides surface roughness that decreases velocity of floodwaters, allowing for particulate retention/detention, which contributes to downstream water quality through reduction in peak flows and sedimentation. This also provides wildlife habitat and stores nutrients and water, providing a major source of energy and habitat for decomposers and other heterotrophs (Brinson et al. 1995).

Maintain Spatial Structure of Habitat: The ability of a wetland to maintain a complex structure of vegetative spatial configurations suitable for animal habitat. Plant communities provide complex, three-dimensional structure for both vertebrates and invertebrates. Food, shelter (cover), nesting, breeding, and foraging are all dependent upon the complexity and composition of the vegetation. Vegetation structure refers to dimensional complexity (cavities, canopy gaps, vertical portioning of strata, etc.) not species composition.

Structure is an important component for resident and nonresident animals, including those with wide ranges and migratory animals. Wetland and riparian areas with greater structural complexity, including habitat patchiness, are more diverse and species rich. This heterogeneity of the landscape also allows for gene flow between separated populations and progeny to exploit new areas (Brinson et al. 1995).

Maintain Interspersion and Connectivity: This function is a landscape feature that maintains the habitat interconnectivity and proximity necessary for characteristic plant and animal diversity and abundance. This includes the potential for a wetland to provide scattered conduits to a river for aquatic organisms through overbank flow, hyporheic flow, and permanent or ephemeral channels and the wetland's capacity to provide habitat corridors for terrestrial or aerial organisms.

This function relies on the patterning of landscape elements including the density of wetlands in the landscape, the proximity of a wetland to its nearest neighbor, and land use around the wetland. Vegetation strata in wetlands, from herbaceous layers to tree canopy, provide wildlife corridors between different wetland types, between uplands and wetlands, and between uplands. The decline of many species has been linked directly to habitat loss and fragmentation making this wetland function highly important in species conservation (Brinson et al.1995) (Hauer et al. May 2002).

Maintain Distribution and Abundance of Invertebrates: A wetland's capability to maintain density and distribution of aquatic, semi-aquatic, and terrestrial invertebrates by providing wet and dry conditions. Invertebrate species are incredibly diverse and abundant in wetlands due to their ability to exploit almost every microhabitat in a wetland. Their ability to consume plant materials and detritus including both submerged and surface vegetation and litter, breaks down coarse particulate organic matter and greatly assists in the nutrient cycling functions of the wetland. In drier conditions, the presence of many invertebrates contributes organic material and aeration that are important to soil development. They also provide important food sources to higher level consumers (eg., amphibians, retiles, birds, and mammals)(Brinson et al. 1995) (Hauer et al. August 2002).

Invertebrates are also sensitive to diminished water quality and are therefore good indicators of the condition of a wetland site. Invertebrates are subject to considerable variation over the annual climatic cycle, so this function is generally based on the evaluation of habitat, vegetation structure, hydrographic regime, and the complexity of the floodplain mosaic rather than the direct measurement used in many stream and lake protocols (Hauer et al. August 2002).

Maintain Distribution and Abundance of Vertebrates: A wetland's capability to maintain the habitats/resources necessary for the diversity and abundance of fish, amphibians, reptiles, birds, and mammals. Many vertebrates utilize wetlands for food, cover, rest, and reproduction. Many of these animals are extremely mobile with a high variability in spatial and/or temporal utilization of wetlands. Migratory birds and waterfowl utilization is extremely temporal, while frogs, toads, and salamanders are less mobile and will generally stay within 1 km of the wetland throughout their lifetime. Small mammals, such as voles and shrews, have relatively small ranges, while larger mammals, such as elk, deer, and bear, may range over incredibly vast areas in a single day.

Vertebrate uses of wetland resources and habitats vary as widely as the diversity of species and requires a diverse structure and density of vegetation and water regimes. Some, like beavers, can greatly influence hydrologic regimes, nutrient dynamics, and vegetation structure. Wetlands are generally considered to support a richer fauna than adjacent upland communities, and many that utilize upland habitats require wetlands for some portion of their life cycle. In turn, vertebrates assist in maintenance of the wetland through dispersal of seeds, pollination of flowers, and alteration of hydroperiods and light regime by herbivory and rearrangement of the vegetative structure.

Alteration of hydrographic regimes or geomorphic configuration and land use in the adjacent uplands (transportation corridors, construction of homes, cultivation, grazing by cattle, haying) can have an extremely adverse impact on vertebrate habitat. Alteration of vegetation affects trophic structure and the nutrient and energy cycling that are required to support vertebrates (Brinson et al.1995) (Hauer et al. August 2002).

Importance of Wetland Functions

As described above, wetlands provide a number of ecological functions either at the faster or greater rate or are those that are not provided by either terrestrial or other aquatic environments. These functions are recognized as particularly crucial in New Mexico where only a small percentage of the land area is occupied by wetlands. Wetlands are called the "kidneys of the landscape" (Mitch et al. 2007) because of their functions as downstream receivers of water and waste from both natural and human sources. They stabilize water supplies lessening the extreme effects of floods, drought and fire. Wetlands are critical to the food chain and biodiversity with a significant percentage of terrestrial animals using wetlands for a portion of their lifecycle. At the global level, wetlands contribute to the stability of global levels of available nitrogen, atmospheric sulfur, carbon dioxide and methane (Mitch et al. 2007). Wetlands are important sinks for carbon and increase landscape resilience and adaptation to climate change.

Finally, functioning wetlands directly provide benefits to humans in the form of food, air and water quality, energy resources (peat), shade and aesthetic values.

Conclusions

Wetlands should be managed to achieve and protect their natural state so that they can continue to provide important ecological functions. The different wetland types and subclasses require different management objectives and strategies based on the key characteristics that distinguish the wetland. Some management principles that apply to wetlands have been offered by Baldassarre and Bolen (2006) (from Mitch et al 2007). Wetlands should be protected to include a wide variety of wetland hydroperiods and wetland sizes. Some researchers argue that distribution and abundance may be just as important as wetland size. Protection measures should include small wetlands which can be key to wetland connectivity or provide important habitat requirements for reproduction and survival of certain animal populations. Large wetlands and wetland complexes should be protected in their entirety for species with complex life-history requirements and for the complex interactions and processes of wetland functions. Natural buffer and upland habitats that are contiguous with wetlands should be protected and maintained to maximize the benefits of wetland functions.

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