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The Science of Wetlands Buffers

INTRODUCTION TO WETLAND BUFFERS

Wetland protection depends not only on managing wetlands themselves, but on managing the surrounding water sources and landscape, above all in buffer areas. An abundance of scientific research published since the 1970s documents the value of establishing, maintaining, and enhancing vegetated buffers along wetlands. Wetland buffers provide important benefits including water quality improvement, streambank stabilization, flood control, wildlife habitat, and groundwater recharge (USDA, 2003; Castelle et al., 1992; EOR, 2001; Wenger, 2000; Correll, 1996). Wetland buffers also provide significant social and economic benefits by improving aesthetics and increasing property values (Lovell and Sullivan, 2005; Qui et al., 2006).

Wetland buffers are located along the edges of streams, and ponds, as well as on hill slopes and in depressions. Water bodies and adjacent lands are generally divided into three zones:

- the aquatic zone includes the area below the high water mark
- the riparian zone is between the high water mark and the upland area
- the upland areas are adjacent to the riparian zones with distinctly different vegetation and soils

Because they are not wetlands, buffers generally have unsaturated soils that did not develop under saturated conditions and vegetation communities with few if any plant species that require saturated soils. A wetland buffer is the vegetated transition zone between an upland area and the aquatic ecosystem, and depending on the definition, the buffer may include portions of both riparian and upland zones. This unique position in the landscape enables buffers to mitigate certain impacts of upland land use on adjacent wetlands. In the absence of wetland buffers, these impacts are typically magnified and become more damaging.

Width, length, and vegetation composition of buffer areas are key features that enhance many functions essential to establishing and maintaining healthy wetlands. Wetland buffers vary in size based on factors such as adjacent land use, land ownership, topography, wetland area, and ecological functions. Generally speaking, buffers that are wider, longer, and more densely vegetated with herbaceous, shrub, and tree layers provide more benefits than buffers that are narrower, shorter, and sparsely vegetated with only herbaceous species.

In riparian areas adjacent to active stream channels, buffers provide important hydrological and ecological “rights-of-way”. Stream buffers maintain lateral connectivity between the streams and adjacent floodplains and uplands, as well as longitudinal connectivity up and down stream.

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FUNCTIONS AND BENEFITS OF BUFFERS

This subsection summarizes major wetland buffer functions including water quality protection, streambank stabilization, floodflow alteration and storage, groundwater recharge, and habitat protection. Vegetated wetland buffers also provide an array of sociological and economic benefits to communities which are only briefly noted here.

Water Quality Protection – *Wetland buffers improve water quality by trapping and/or transforming pollutants such as sediments, nutrients, pathogens, and pesticides in surface water and groundwater* (Pearsell and Mulamoottil, 1996; numerous articles cited in Correll, 1996 including Mitsch et al., 1979; Peterjohn and Correll, 1984; Lowrance et al., 1988; Klarer and Millie, 1989; Chesair et al., 1991; Parsons et al., 1995). Surface runoff is slowed by buffer vegetation, causing larger sediment particles and pollutants adsorbed to sediment particles to settle out (Lee et al., 2003; Correll, 1996). This filtering function is greatly enhanced as the density of ground layer vegetation and the width of a buffer increase. Further removal and/or transformation of smaller sediments, nutrients, pathogens, and pesticides can occur through groundwater filtration, uptake by vegetation, biogeochemical processes, and microbial processes in the shallow soil profile (Lee et al., 2003; Correll, 1996; USEPA 2005b). For certain pollutants, such as bacterial pathogens, drier, unsaturated buffer soils will be more effective at reducing concentrations than saturated wetland soils (Pearsell and Mulamoottil et al., 1996). Elevated nitrate levels can be reduced where groundwater contacts roots of vegetation and denitrifying microbes in soils in buffer areas, thereby reducing growth of excess aquatic vegetation such as algae blooms (Lee et al., 2003). Heavy metals may be precipitated in the soil and removed from groundwater or may be transformed such that they become immobile or less toxic or otherwise less biologically active.

Without mature, densely vegetated buffers, common runoff pollutants such as pesticides and fertilizers easily find their way into and degrade receiving waters (Miltner et al., 2004; CWP, 1995; Meyer et al., 2005). It is important to note, however, that the filtering function that wetland buffers can provide depends largely on the proportion of surface runoff traversing the buffer via sheet flow. If runoff in an area is mostly channelized or routed into storm sewers, the filtering function would be greatly reduced.

Streambank Stabilization – *Vegetated riparian buffers stabilize streambanks and therefore help to protect infrastructure, improve safety, and reduce sediment loading.* The strong, thick roots of trees and/or shrubs growing along the edge of a stream channel greatly increase the stability of the stream banks and can effectively dampen energy in stream water, slow water velocities, and promote infiltration. Plant roots increase the effective size and cohesiveness of soil particles, thereby protecting soil in stream banks from the erosive forces of water, reducing the amounts of streambank erosion.

Channel and shoreline erosion occur as a result of fast-moving and turbulent flows contacting

unstable stream banks. Accelerated erosion is typically associated with increased and uncontrolled stormwater runoff (Dunne and Leopold, 1978; Wohl, 2001). Hardened and compacted land surfaces contribute to increased volumes and higher velocities of runoff by reducing the degree of stormwater infiltration and increasing the rate of runoff. Where streambank erosion occurs, landowners can lose property, infrastructure may become undermined, and wildlife habitat can be destroyed. Furthermore, as the energy of the water in a stream diminishes following a storm, eroded materials are deposited in the stream channel. These depositional areas can cause channel widening, reduce flood storage capacity, block fish movement, and smother aquatic habitats (Jacobson et al., 2001; also Waters, 1995 in Jacobson et al., 2001 and Burton and Pitt, 2002 in Sprague et al., 2006).

Floodflow Alteration and Flood Storage – *Wetland buffers provide space for flood water to spread laterally once it leaves a channel; thereby slowing flood water velocity and unsaturated soils help provide additional temporary storage for flood water.* Flooding is a natural event that is essential to maintaining sediment transport and deposition, biodiversity (e.g., by seed dispersal and creation of spatially heterogeneous habitat), and contaminant removal (Naiman at al., 2005; Briggs, 1996). Wetland buffers that are undeveloped and vegetated with trees and shrubs in floodplains help to slow, store, and gradually release flood waters. Dense vegetation in a wetland buffer increases surface roughness of a floodplain and slows the velocity of overland flow while promoting shallow groundwater recharge, depressional surface storage, and subsequent uptake of water by vegetation. The reduced velocity and volume of flood water results in reduced flood peaks (Leopold, 1994) and improved base flows due to subsequent slow release of water stored in floodplain soils. Wetland buffers play a key role in reducing property damage associated with flooding while at the same time maintaining natural processes necessary for the health of stream and river systems. Limiting development in wetland buffers means that flooding does not threaten structures in the portion of the floodplain covered by the wetland buffer.

Development activities associated with construction increase the proportion of impervious surfaces in a watershed and reduce infiltration of precipitation. Greater impervious surface increases the volume of surface runoff and the speed with which it reaches a stream (both via direct overland flows and indirect flows routed into storm sewers). This leads to an increase in the occurrence and severity of floods and increased property damage (Wohl, 2001; Briggs, 1996; Wenger and Fowler, 2000; Sprague et al., 2006 and numerous citations therein including McMahon et al. 2003, Poff et al. 1997, and USEPA 1997a).

Groundwater Recharge – *During long, dry periods, the water in streams and wetlands may come solely from groundwater which is recharged in upland buffers.* Vegetated wetland buffer areas help to slow surface runoff and promote infiltration thereby helping to maintain groundwater levels. Elevated groundwater then discharges into streams to provide baseflow (EOR, 2001). Elevated soil moisture also provides a source of water for riparian vegetation (Naiman et al., 2005; Poff and Allan, 1997, Pearsell and Mulamoottil, 1996). In addition, water quality benefits arise from the interaction of surface water and groundwater. Groundwater discharge into streams also helps moderate temperature fluctuations (Sprague et al., 2006).

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In the absence of wetland buffers, the groundwater table can decline because of the reduced infiltration of precipitation. Reduction in groundwater discharge to a stream and attendant reduction in baseflow can negatively impact aquatic life during low flow periods by reducing available habitat and causing stream temperatures to increase. Groundwater decline can also negatively impact riparian vegetation when the plant roots are unable to reach saturated soils (Briggs, 1996). If riparian trees and shrubs die as a result of water table decline, a stream channel can become unstable with an increase in streambank erosion and downcutting. Loss of riparian shrubs and trees could lead to reduced leaf fall into a stream. Leaves from riparian plants are a primary energy source for aquatic food chains (Naiman et al., 2005).

Habitat Protection & Food Chain Support – *Riparian areas make up only 1% of the landscape but support 80% of all vertebrate wildlife and more bird species than any other habitat area* (NRCS, 1996; Miller et al. 1995). Buffers provide critical habitat for a wide range of aquatic and terrestrial species living in and around wetlands (Semlitsch and Bodie, 2003; Naiman et al., 2005). Wetland buffer vegetation provides three critical functions for aquatic systems:

1. First, leaves and twigs from trees and shrubs, and to a lesser extent, herbaceous species, provide energy for aquatic food webs. Leaves in the stream are colonized by algae and microscopic invertebrates. The algae are eaten and the leaves are shredded by aquatic organisms (e.g., caddis fly larvae). These invertebrates are, in turn, eaten by fish. Studies have shown loss of riparian vegetation causes reduced growth of aquatic insects that rely on leaves from trees and shrubs for food (Johnson et al., 2003).

2. Second, riparian trees and shrubs shade streams and help moderate water temperatures. This is especially important for cold-water (as opposed to warmwater) aquatic life such a trout. Streams and ponds with overhanging vegetation will have lower water temperatures than those that lack overhanging vegetation (Westchester County, 2007). Stream water temperatures are also influenced by direct surface runoff from nearby impervious surfaces. These thermal impacts can be mitigated by directing the surface runoff as sheet flow to vegetated buffers, allowing it to infiltrate and slowly return to the receiving water as shallow groundwater flows.

3. Third, tree trunks and large limbs that fall across a stream channel create small dams that help prevent channel downcutting (Wohl, 2001; Naiman, et al., 2005).

The location of wetland buffers makes them ideal links between aquatic and upland ecosystems. As a result of the presence of water, buffers provide habitat for a broad range of birds, small mammals, reptiles, insects, and amphibians that require both upland and wetland areas to complete their life cycles (numerous articles cited in Semlitsch and Bodie, 2003). Deciduous

shrublands and forests found in wetland buffers are vital for many bird species. For example, numerous migratory bird species use wetland buffers in the spring and fall as they travel through our area.

Wetland buffers provide habitat corridors which facilitate wildlife movement between habitat patches (Hilty, 2006). In developing areas, these important corridors often become fragmented, significantly limiting the movement of key species and facilitating the colonization of opportunistic invasive and predator species (Schaefer, et al., 2006; Lineham et al., 2006). Establishing wetland buffers can reduce this fragmentation and help maintain important floral and faunal populations on a local scale (Lovell and Sullivan, 2006; Miltner et al., 2004; Johnson et al., 2003; Peak and Thompson, 2006).

Other Benefits – Recreation, Aesthetic, Education, and Economic - *Wetland buffers offer recreational, aesthetic, economic, and educational opportunities for neighborhoods and schools, promoting healthy lifestyles and enhanced community stewardship and relationships (Lovell and Sullivan, 2006).*
It should be noted, however, that recreation can also degrade wetlands if it occurs at high levels and in an unmanaged setting. In addition to the ecosystem services and benefits previously noted, communities and property owners that establish and implement wetland buffers typically benefit from increased property values due to the aesthetic appeal of open space. (Qiu et al., 2006). Development near streams, lakes, or wetlands is often able to sustain premium sale prices. Where aquatic resources lack buffers, communities and property owners often are faced with mitigation and repair costs to protect infrastructure and property being impacted by erosion, sediment deposition and floods.

Wetland buffers can provide cost-effective and reliable human health and safety services such as flood control, erosion control, water quality protection and enhancement, and recreational opportunities that would otherwise cost our community significant amounts of money to provide through highly engineered structures and systems.

FUNCTIONS OF WETLAND BUFFERS IN RELATION TO LOCATION, DIMENSIONS, AND VEGETATION

The effectiveness of wetland buffers varies by function and depends on a number of factors including vegetation, width, length, and landscape setting, but generally speaking, the wider the buffer, the more effective it will be. Vegetation composition can have a significant effect on the health, function, maintenance and effectiveness of a buffer. Vegetation composition can vary widely across a wetland buffer Examples of buffer benefits provided by grasses, shrubs, and trees are provided in Table 1. Note that increased benefits are generally associated with deciduous trees and shrubs in a wetland buffer.

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Table 1 Effectiveness of Different Vegetation Types for Specific Buffer Benefits

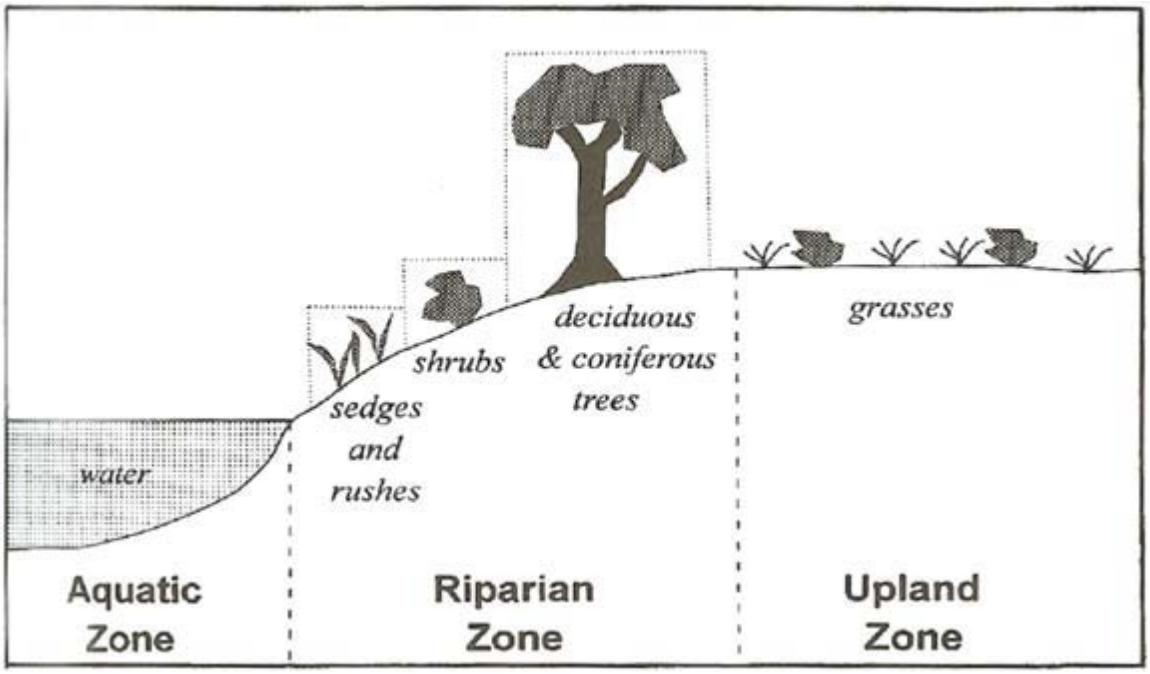

Table 2 Benefit of Vegetation Types for Specific Buffer Benefits

Benefit	Grass	Shrubs	Trees
Stabilize streambanks	Low	High	High
Filter sediment & the nutrients, pesticides & pathogens bound to it	High	Moderate	High
Filter nutrients, pesticides, & microbes from surface water	Moderate	Low	Moderate
Protect groundwater and drinking water supplies	Low	Moderate	High
Improve overall aquatic habitat	Low	Moderate	High
Improve wildlife habitat for field animals	High	Moderate	Low
Improve wildlife habitat for forest animals	Low	Moderate	High
Moderation of water temperatures	Low	Moderate	High
Provide visual interest	Moderate	Moderate	High
Protect Against Flooding	Low	Moderate	High
>>> Adapted from: New Hampshire River Joint Commissions, 2000 Riparian Buffers for the CT River Watershed			

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There is not one optimal width for a wetland buffer. Instead, widths depend on the desired wetland functions and local conditions such as topography. A substantial body

Function	Special Features	Recommended Minimum Width (feet)
Sediment reduction	Steep slopes (5-15%) and/or functionally valuable wetland	100
	Shallow slopes (<5%) or low quality wetland	50
	Slopes over 15%	Consider buffer width additions with each 1% increase of slope (e.g., 10 feet for each 1% of slope greater than 15%)
Phosphorus reduction	Steep slope	100
	Shallow slope	50
Nitrogen (nitrate) reduction	Focus on shallow groundwater flow	100
Biological contaminant and pesticide reduction	N/A	50
Wildlife habitat and corridor protection	Unthreatened species	100
	Rare, threatened, and endangered species	200-300
	Maintenance of species diversity	50 in rural area 100 in urban area
Flood control	N/A	Variable, depending on elevation of flood waters and potential damages

Source: Center for Watershed Protection and United States Environmental Protection Agency. 2005. *Wetlands and Watersheds: Adapting Watershed Tools to Protect Wetlands.*

of research exists that correlates wetland buffer widths with function (NRCS, 2003; USACE, 2000; CWP &USEPA, 2005; USEPA, 2005b); there is a wide range of recommended widths for different functions as shown in the following table and graph. Regardless of the climate or contaminant, the pathway of sheet flow as opposed to channelized flow across a wetland buffer is the key variable influencing the effectiveness of capturing sediment and increasing infiltration.

Table 3 Recommended Minimum Buffer Widths

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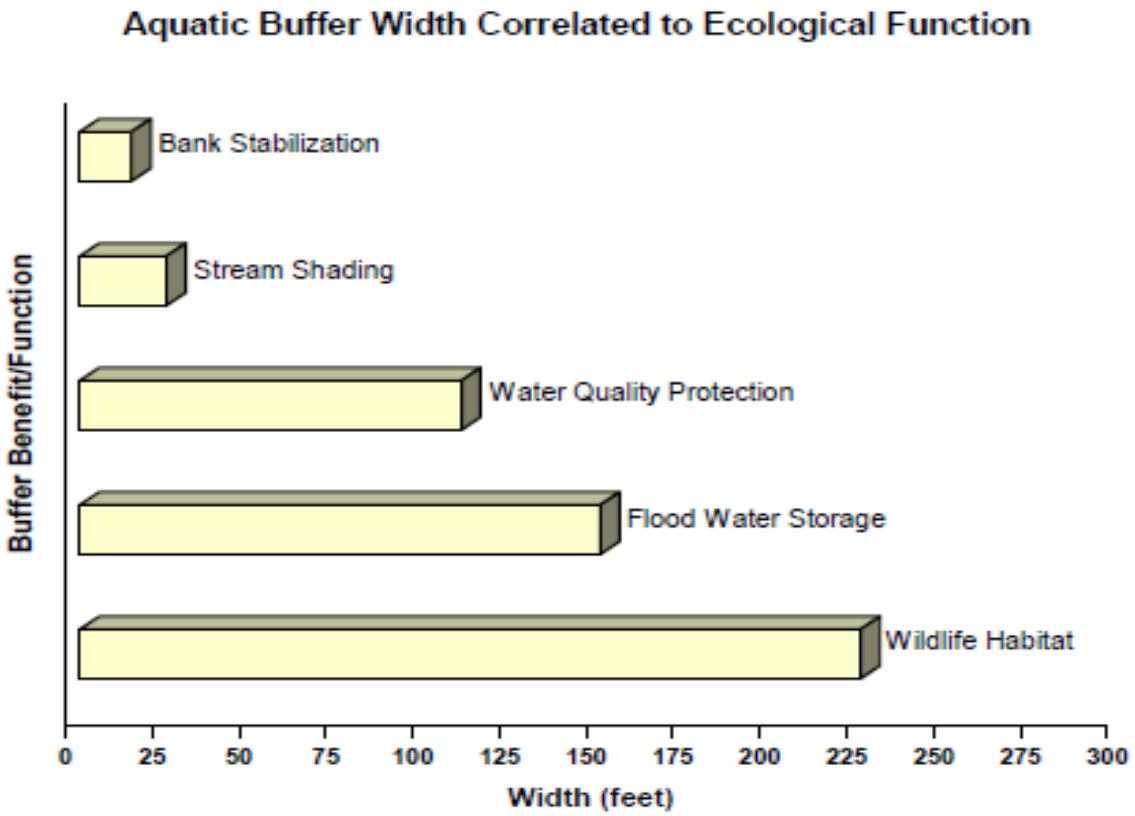

Adapted from USDA Natural Resources Conservation Service. *Where the Land and Water Meet: A Guide for Protection and Restoration of Riparian Areas First Edition.* USDA NRCS, September 2003.

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Terrestrial habitat widths have an even wider range than aquatic habitat. One literature survey reported that most of the current municipal buffer programs are not wide enough to protect the life cycle activities of many reptile and amphibians (Semlitsch and Bodie, 2003). In their study, Semlitsch and Bodie (2003) summarized data on the use of terrestrial habitat by numerous amphibians and reptiles. They found for example, that certain species can migrate within a core habitat area of 200-600 meters, and the range of core habitats for amphibians was 159-290 meters. While protection of buffer distances of this size is difficult to achieve, they highlight the need for large buffers where possible to protect wildlife habitat.

> ***"Our data clearly indicate that the 15-30 meters used to protect wetland species in many states, are inadequate for amphibian and reptiles. Further, we emphasize that our estimates are derived from the core terrestrial habitats used by amphibians and reptiles and therefore are not buffers per se but necessary habitat." (Semlitsch and Bodie, 2003)***

Riparian buffer widths also have been found to be a factor influencing effectiveness of water quality improvements such as nitrogen removal. USEPA conducted an extensive review of the current science and regulations pertaining to buffer width, vegetation cover, and nitrogen removal (USEPA, 2005b). Buffer vegetative cover was not found to play a major role in nitrogen removal efficiencies. Although variations occur due to soil type, loading, and organic carbon, in general, the wider the buffer the more effective nitrogen removal. "Wider buffers (>50m) more consistently removed significant portions of nitrogen entering a riparian zone" (USEPA, 2005b).

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CONCLUSIONS

Scientific literature provides extensive evidence that buffers are an important tool for achieving wetland protection. Characteristics of a good buffer depend on the individual wetland and the function being evaluated. For flood control benefits, a buffer should try to maximize available space in the floodplain so as to increase short term water storage, and vegetated banks should be present to stabilize streambanks. For water quality benefits, buffers need vegetation to slow runoff and for groundwater to pass through and undergo pollutant removal. For terrestrial habitat, it is desirable to have buffers with native vegetation in a variety of strata, providing connectivity to other patches, and with minimal disturbances. For overall stream ecology purposes, buffers are most effective when they provide leaf litter to supply the food chain, canopy for shade, large woody debris for in-stream cover, and a place for groundwater recharge which in turn supports baseflow in the stream.

There is not one optimal width for a wetland buffer. Instead, widths depend on the desired functions and local conditions such as topography. A substantial body of research exists that correlates wetland buffer widths with function; there is a wide range of recommended widths for different functions ranging from 50 feet to reduce sediment loading in streams to 300 feet for protection of certain types of wildlife habitat.

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