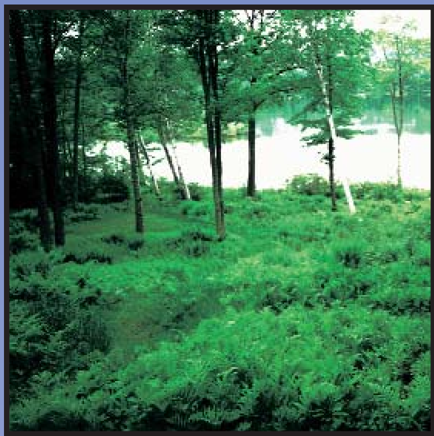


The Massachusetts Buffer Manual

Using Vegetated Buffers to Protect our Lakes and Rivers

Prepared by
the Berkshire Regional Planning Commission

For
The Massachusetts Department of Environmental Protection

2003

Appendix

A

How Vegetated Buffers Improve Water Quality and Benefit Wildlife

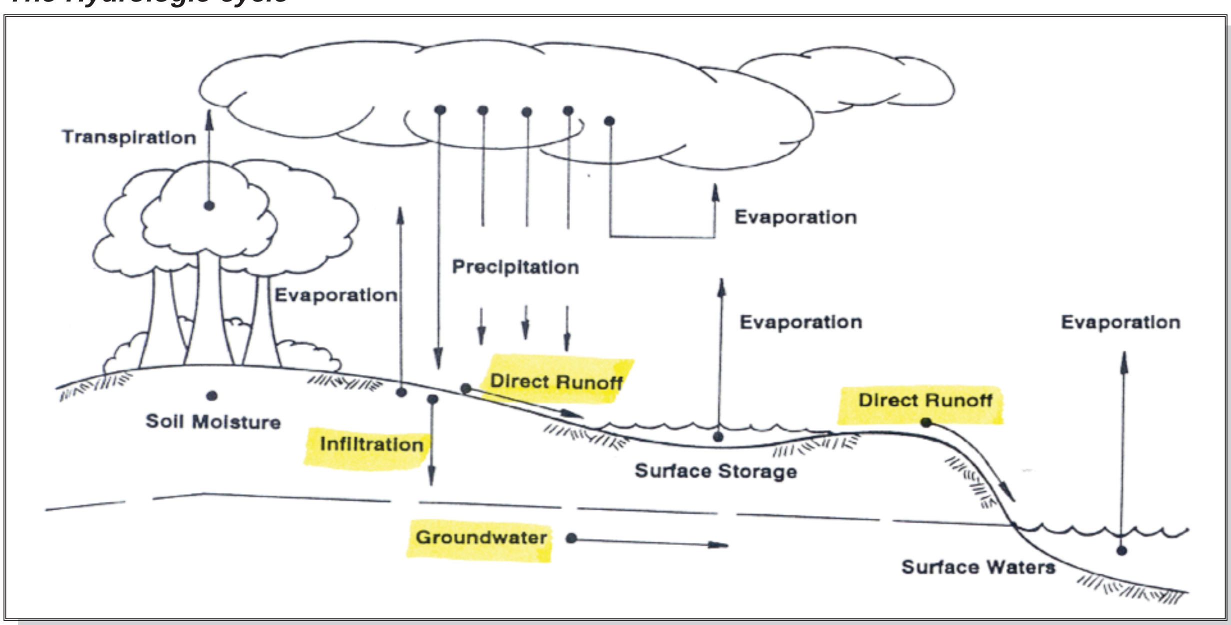
How Vegetated Buffers Improve Water Quality and Benefit Wildlife

Welcome to a more detailed discussion of how pollution impacts water quality and wildlife, and how the use of vegetated buffers can mitigate those impacts. In this section we will discuss different types of pollution, such as sediment deposition, nutrient enrichment and thermal increases. We will describe how these types of pollution lead to algae blooms, explosive weed growth and lower dissolved-oxygen levels. We will also describe how the life cycles of wildlife are affected.

Surface runoff, which usually occurs as stormwater runoff, contributes over 80% of the sediment and nutrients to Massachusetts water bodies. Vegetated buffers can capture much of these before they wash or seep into our rivers, lakes and ponds. Several detailed studies have been conducted in the Chesapeake Bay watershed. One study found that forests can capture, absorb, and store amounts of rainfall 40 times greater than disturbed soils (tilled soils or construction sites) and 15 times more than grass, turf or pasture (Palone & Todd, 1998). Studies have also been conducted in the states of Maine, Minnesota and Wisconsin, and elsewhere across the country by the U.S. Forest Service and by the U.S. Department of Agriculture. We will refer to some of these as we move forward.

To understand how surface and subsurface water moves, it is important to understand the hydrologic cycle. The figure below represents the earth's surface and atmosphere and depicts how precipitation is cycled through the earth's system. Direct surface runoff, infiltration, subsurface flow and groundwater flow are the pathways that we will be discussing in this section. Water that enters a surface water body through precipitation, runoff or subsurface flow recharges the water supply. Stormwater runoff is the flow of rainwater, snow and ice melt across the land's surface. During the first few minutes of a rainstorm the first flush, which is the

The Hydrologic cycle



Adapted from Terrene Institute, 1996.

first half inch to 1 inch of rain, washes the landscape and carries a high concentration of pollutants. These pollutants include debris, sediment, nutrients, bacteria, petrochemicals, metals and salts. If we are to minimize the amount of pollution washing into our water bodies in runoff, it is critical that we somehow treat that first flush of a rainstorm.

Subsurface or groundwater flow is the movement of water as it percolates through the soil and moves underground toward the water body. Water that reaches the water body through subsurface flow is valuable in many ways. First, it is generally of higher quality than surface runoff, especially in developed areas. This is because the physical, biological and chemical processes in the soil help to render pollutants into less harmful forms prior to recharging the receiving water body. Second, subsurface water seeps into streams and lakes at a slower and steadier pace, which helps to maintain healthy water levels in times of dry weather or droughts. Third, subsurface water temperatures remain cool and constant. The soil through which it travels helps to cool down runoff that has been heated on roads, parking lots, driveways and lawns.

Vegetation Creates a Physical Barrier to Stormwater Movement

Vegetation within the buffer physically intercepts the movement of water on several levels. First, it absorbs the impact of rainfall, breaking the force that falling raindrops have before hitting the ground, dispersing the water over a wider area. Like a watering can with a sprinkler head, the softer and wider flow caused by foliage is less prone to dislodging soil particles and creating ruts. This is especially true in buffers that consist of different layers of foliage, as in forested buffers or those with thick shrubs and grasses.

The impact of falling rain can dislodge soil particles, making the soil vulnerable to erosion.
Source: FISRWG, 1998.

Second, the forest floor acts like a rough sponge, slowing down, filtering and absorbing most of the rainfall and runoff of the first flush. Vegetation and leaf litter impede the flow of stormwater runoff and encourage infiltration. Stormwater runoff tends to concentrate and create channels. Water flowing through channels generally travels faster and has a greater capacity to carry sediment, which then has a greater capacity to scour and erode the soil and pick up more sediment. It is in this way that channels perpetuate themselves and continue to grow. The standing stems, trunks and leaves of vegetation, as well as fallen logs, branches and leaf litter, physically block the path of stormwater runoff. Lessening the velocity of stormwater runoff causes it to drop its sediment load.

Buffers Capture Sediment and Nutrients Above the Ground

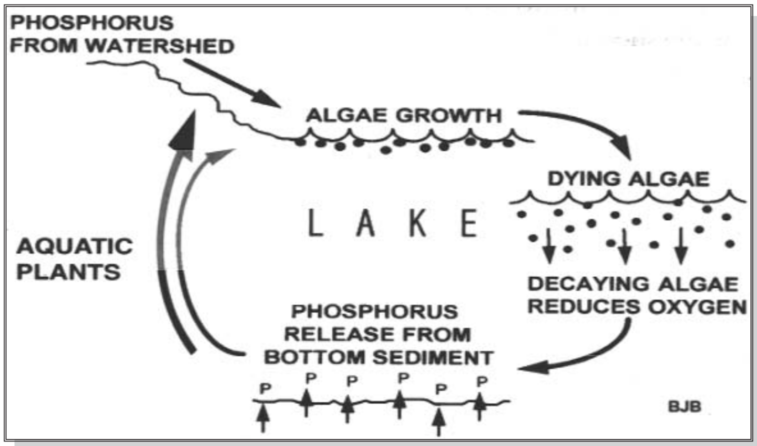
High concentrations of nutrients can be found in stormwater runoff adhered to sediment particles and dissolved in the water. Vegetated buffers have been shown to effectively remove 50-100% of sediment from stormwater (CRJC, 2000). They capture sediment on which pollutants such as phosphorus, petrochemicals, pathogens and some heavy metals are known to adhere. This is the reason that the Massachusetts Stormwater Management Policy requires developers to remove at least 80% of total suspended solids from post-developed stormwater runoff.

Sand and gravel washed from a dirt road after a severe rainstorm is captured by a forested buffer. The nearby lake is in the background.
Source: BRPC archive, 2000.

Phosphorus is the nutrient of main concern for most freshwater ecosystems in Massachusetts (nitrogen is the nutrient of concern for most brackish or saltwater ecosystems). All lakes, pristine and developed, can accept a certain amount of phosphorus without experiencing a significant change in water quality. However, excessive amounts of phosphorus from our activities can over-fertilize algae and noxious aquatic weeds, creating algae blooms and weed-choked shorelines. Once in a water body, phosphorus will continue to be recycled through the system. Refer to the figure on page A-4 for a simplified illustration of the phosphorus cycle.

It is estimated that 80%-90% of phosphorus reaches water bodies adhered to soil particles, and retaining sediment within the buffer effectively lowers the phosphorus load of stormwater runoff. Removal rates are dependent on site conditions (precipitation rates, slope, soil, vegetation types) and the width of the buffer.

An Overview of The Phosphorus Cycle



Source: MA DEP, 2001b.

Researchers in Wisconsin conducted a study to identify the main sources of phosphorus in urban stormwater runoff. Phosphorus data was collected from lawns, streets, roofs, driveways and parking lots to determine the loads from each. They found that lawns and streets were the largest sources of total and dissolved phosphorus (Waschbusch et al, 1999). The source of phosphorus in lawn runoff is from fertilizers and cut grass, while the source of phosphorus from streets is lawn runoff, lawn clippings and leaves. The phosphorus was adhered to sediment and plant debris.

Most soils in Massachusetts contain sufficient phosphorus to support vegetation, so there is no need to apply it through commercial fertilizers. The overapplication of phosphorus is the reason that some states are beginning to encourage or require the use of low- or no-phosphorus fertilizers in sensitive watersheds. Minnesota has enacted a new law that restricts the use of phosphorus-containing fertilizers on established lawns, unless a soil test proves that phosphorus is truly needed.

The state of Maine is sponsoring a program to strictly reduce the use of phosphorus-containing fertilizers. Many in the commercial sector had already been using phosphorus-free fertilizers, and they are now readily available at dozens of hardware and lawn care retail stores, including the large retailers like Agway, Home Depot and True Value. The program has been a success, as phosphorus-free fertilizer sales jumped from early amounts of approximately 3,000 pounds per year to over 56,000 pounds per year by 2001 (ME DEP, 2003). Many retailers offer phosphorus-free fertilizers in Massachusetts as well - you just have to ask for them.

Buffers Capture Nutrients Underground

Ground level vegetation and leaf litter act as a blanket, holding in soil moisture that facilitates microbial action, chemical breakdown and retention of pollutants. As stormwater percolates through the soil, plant root systems and microorganisms have a chance to take in nutrients and use them in their life processes. Soil is composed of inorganic mineral particles of differing sizes (sand, silt, clay), organic matter in various stages of decomposition, numerous species of living organisms (worms, insects, microbes), water, various gases, and a variety of water-soluble ions.

Leaf litter helps to physically impede the movement of runoff. It also provides an ideal blanket to protect soil microorganisms, which can transform pollutants into less harmful forms.
Source: Welsch, 1991.

The roots of grass and other ground-level plants are concentrated at or near the surface and they can absorb the nutrients settling out from sediment deposition. The roots of shrubs and trees grow both laterally and vertically, adding to the complexity and depth of the total root zone. These roots can absorb dissolved nutrients that percolate deep into the soil and travel in subsurface flow. The main sources of dissolved nutrients in developed areas are fertilizers from lawns and gardens, leachate from improperly functioning septic systems and detergents from car washing and domestic use.

Root systems continually push through the soil and create pockets for life-giving air and water; they provide a surface and food source for insects and microbes; and they provide a microhabitat in which gases, water and ion exchanges can occur. It is the minute organisms within soil that immobilize, break down, absorb, and render less harmful many of the pollutants within stormwater, including toxins.

Stormwater percolates downward through the soil, joining subsurface flow. This water will flow through the moist environment of the rooting zone of the vegetated buffer, which maintains a low oxidation/reduction potential. This condition allows for a freer exchange of ions and is conducive to chemical reactions within the soil that retain nitrogen, phosphorus and other pollutants. Studies conducted on nitrogen retention in Maryland and North Carolina have shown that vegetated buffers are removing 89% and 85% of the nitrogen inputs for those sites, respectively (Palone, et al, 1998). Although the exact processes by which this is occurring is unknown, suspected mechanisms include denitrification (by chemical and biological means), assimilation and retention (by vegetation), and transformation to more basic compounds. Field studies of nitrate balance within a buffer show that it is effectively removes nitrogen at all times of the year, even in temperate climates, and from subsurface waters at depths of several meters (Correll, 1996).

Researchers with the U.S. Department of Agriculture studying the nitrogen removal rates of river buffers have found that vegetation within the buffer can take in and store large amounts of the nutrient from subsurface flows. However, the amount of the nutrient that they are able to take in is directly related to the amount of moisture within the soil (Gold, 2002). As areas become more developed and the impervious cover increases, surface flow is channeled through storm drain systems, bypassing vegetated buffers and entering the nearest waterbody untreated. Maintaining buffers, directing stormwater through them as sheet flow, and increasing infiltration will ensure that the soil at the root zone will have the constant moisture content necessary for plants to take in much of the nutrients created by human activity.

Generally speaking, waterfront areas are better at retaining pollutants than are upland areas. This is due to the fact that uplands are often more sloped than waterfront areas, thus the retention time is shorter. The shorter the retention time, the less opportunity there is for infiltration and uptake of pollutants. In addition, moist soils have a higher rate of pollution retention than dry soils, due to microbial action and ion exchange. It is therefore critical that vegetation be maximized along the waterfront.

General summary of buffer composition and water-quality benefits when applied in an agricul-

BUFFER SIZE AND VEGETATIVE MIX	BENEFITS*	COMMENTS
• Woody veg. along bank • Dense stiff grasses 35'-50'	• Traps 75% sediment from runoff • Traps 25% of nitrates & phosphorus from surface runoff	• Allows most nutrients to pass into water body
• Woody veg. along bank • Shrubs 37'-75' • Dense stiff grasses 25'	• Traps 75% of sediment from runoff • Shrubs trap more nitrates & phosphorus than grass alone	• Additional root complexity and depth improves soil porosity and promotes more infiltration
• Woody veg. along bank • Trees & shrubs 50'-75' • Dense stiff grasses 25'	• Traps 95% sediment • Traps 75-80% nitrogen • Traps 80% phosphorus	• Maximum canopy breaks force of storms • Root complexity and depth provides maximum porosity and infiltration • Root complexity and depth provide maximum nutrient "sink" through plant uptake and storage

Adapted from CRJC, 2000, "Buffers for Agriculture," Fact Sheet #5.
Source: http://www.crjc.org/buffers/Buffers%20for%20Agriculture.pdf
** Note: General removal rates are from agricultural lands, where surface runoff and subsurface flow often contain high nutrient concentrations.*

Buffers Capture Sediment and Nutrients From Agricultural Activities

Maintaining vegetation as a living buffer between intensive land uses, such as agricultural and logging operations, has been well documented by both the U.S. Department of Agriculture and the U.S. Forest Service. Buffers are not only effective; they are simple to oversee and extremely cost-effective.

If vegetated buffers can capture pollutants from such a land-intensive use as tilled fields, they can certainly help capture pollutants from residential development. The table on the previous page describes the benefits of planting vegetated buffers between natural water bodies and agricultural operations. All buffers include forest vegetation immediately along the shoreline, which benefits the water body by anchoring the bank, shading the water, dropping coarse woody debris for the food web and taking up and storing a maximum amount of nutrients. A mix of trees and shrubs within this buffer will provide vertical layering of foliage to attract a wider variety of birds. A buffer of grasses landward of the trees and shrubs will trap sediment, disperse stormwater into sheet flow and take in some surface nutrients. The ability of a grass strip to disperse runoff into sheet flow is the buffer's great asset, facilitating infiltration and all its benefits.

Buffers Protect Aquatic Ecosystems

Runoff flowing over roads, paved drainage ditches, parking lots and driveways is heated as much as 2-10 degrees Fahrenheit as it travels (FISRWG, 1998). This can also happen to water that runs across open grass lawns. In some instances, runoff can transform a naturally cold-water stream to a warm-water stream, seriously stressing or killing sensitive microorganisms, insects and fish species.

Temperature changes within a water body alter chemical composition within the system, which ultimately alters the biological composition. Warmer temperatures can cause nutrients that are sediment-bound at lower temperatures to break free, resulting in a substantial increase in the concentration of nutrients available for algae and aquatic plants. For example, slight increases in water temperature can produce substantial increases in the amount of phosphorus released into the water column (Palone & Todd, 1998).

The increase in temperature allows the algae population to grow exponentially and consume large amounts of oxygen. Warmer waters also aid plant growth, and when the plants die back, an inordinate amount of oxygen is consumed by organisms that feed on the dead material. In lakes and shallow rivers that are infested with noxious invasive plant species such as curly leaf pondweed or Eurasian water-milfoil, the oxygen levels drop precipitously at certain times of the year as the plants flourish and die back in great numbers. In addition to all this, warm waters are not able to chemically hold as much oxygen as cooler waters. The metabolic rate of fishes like trout is raised when temperatures are raised, which is unfortunately right at the very time that less oxygen is available for them. It is during such times that fish kills occur.

Temperature governs many biochemical and physiological processes in freshwater fishes, amphibians, reptiles and insects because their body temperature is essentially that of the surrounding water.

An overview of habitat conditions needed for sustainable fish populations

Fish Species	Max. Weekly Avg. Temp. for Growth (Juveniles)*	Max. Temp. for Survival of Short Exposure (Juveniles)*	Max. Weekly Avg. Temp, for Spawning*[a]	Max. Temp. for Successful Incubation and Hatching*[b]	General DO Requirements**	General Turbidity Tolerance**
Atlantic Salmon	68°F	73°F	41°F	52°F	NA	Low
Brook Trout	66°F	75°F	48°F	55°F	>5.0 ppm	Low
Common Carp	NA	NA	70°F	91°F	>0.5 ppm	High
Channel Catfish	90°F	95°F	81°F	84°F	>4.0 ppm	High
Largemouth Bass	90°F	93°F	70°F	81°F	>5.0 ppm	Low-moderate
Rainbow Trout	66°F	75°F	48°F	55°F	>5.0 ppm	Low
Smallmouth Bass	84°F	NA	63°F	73°F	>5.0 ppm	Low-moderate

** Adapted from FISRWG, 1998.*
a. Optimum or mean of the range of spawning temperature for the species
b. Upper temperature for spawning
*** Adapted from Palone + Todd, 1998*

Temperature therefore plays a central role in the life cycles of several aquatic organisms, regulating behavior, growth, and mating and spawning habits. The hatching rate of some fish and other aquatic organisms is also dependent on temperature. For more information on how temperature affects the life cycles of fish, refer to the table above.

Because temperature and oxygen play such subtle but critical roles in the life cycles of aquatic organisms, they are a major determinant in their distribution within a watershed. Fish such as trout and bass are at the top of the freshwater food web, and their distribution and abundance are often seen as water-quality indicators for aquatic ecosystems. Freshwater fish species have different levels of tolerance when it comes to temperature, dissolved oxygen and turbidity. Trout and salmon are the most sensitive, able to tolerate only a slight change in temperature. Bass are slightly more tolerant, while catfish and carp can tolerate the highest change in temperature. In general, brook and rainbow trout are among the most sensitive of the freshwater species in Massachusetts, needing cool, clear and well-aerated waters to live and breed successfully.

Shallow waters, often located along the shoreline of a lake or pond, are more vulnerable to the warm summer sun than are deeper waters. On land, shoreline vegetation can help to shade the water. Below the surface, soil cools runoff to a more natural temperature. Shallow waters of lakes and ponds are breeding grounds for aquatic insects and the many animals that feed on them, including fish, frogs, and turtles. Therefore, maintaining cooler temperatures along the shoreline is critical to sustaining a healthy aquatic ecosystem.

Aquatic ecosystems also rely on shoreline vegetation to provide the basic organic matter that drives their food webs. Vegetation along banks and overhanging streams drops leaf litter, branches and insects into the water. This natural organic matter provides food and cover to aquatic microbes and macroinvertebrates (insects, worms, tiny crustaceans) that are the base of the aquatic food web. This organic matter is coarse and relatively difficult to break down and decomposition and uptake of nutrients by creatures at the bottom of the food web occurs slowly and in balance with the ecosystem.

The logs, branches and snags that fall into a water body provide more than energy for the food web. They provide fish and other aquatic creatures with shade and cover from predators. They also break the flow of streams and rivers, creating eddies and pools. Fish and other aquatic creatures must constantly be on the move and run water through their gills to take in oxygen. By breaking and diverting the current, trunks and branches provide creatures a place to swim less vigorously and rest.

Buffers Provide Wildlife Habitat

Waterfront areas are used by wildlife more than any other type of habitat. They are important areas of transition between the terrestrial and aquatic worlds, and are critical for those animals that need both worlds to complete their life cycles. Most turtles, frogs and salamanders are such creatures, as are some waterfowl. Wildlife habitat consists of areas for cover, food and breeding.

Many species of insects breed and live much of their lives underwater, providing a rich energy source near the bottom of the aquatic food web. In the water, fish, salamanders, frogs and turtles rely on these creatures. Above the water, these and other insects provide a valuable protein source for songbirds and waterfowl during the breeding and nesting seasons. Young birds of many species eat insects during their early stage of growth, turning to a mix of insects and vegetation as they mature.

Mayfly nymphs (left) grow underwater, but the adults (right) leave the water to breed. They are an important food source for trout and other fish, as well as swallows and other birds.
Source: Welsch, 1991.

Many rare and endangered species rely on the aquatic-terrestrial transition zone to complete their life histories. Maintaining or restoring vegetated buffers in the areas where rare species are known or strongly suspected of living helps to sustain viable populations across the state. The Natural Heritage and Endangered Species Program (NHESP), which is administered by the Massachusetts Division of Fisheries and Wildlife, collects and maintains information on over 400 rare and endangered species around the Commonwealth. The goal of the NHESP is to protect biological diversity in the state through biological research and the inventorying of species, data management, environmental impact review, restoration and management of rare species and their habitats, land acquisition, and education.

NHESP has created the Massachusetts Natural Heritage Atlas, which attempts to map rare species habitats across the state. Copies of the atlas are available at local Conservation Commission municipal offices. Maintaining or restoring natural vegetated buffers in the areas highlighted in the atlas would greatly benefit and support healthy populations of the rare species that live within these areas.

Wood, spotted and Blanding's turtles are three rare species that require both aquatic and terrestrial habitats to survive and breed successfully. These turtles need aquatic habitats for mating, resting, foraging and hibernating, but also spend much of the time traveling through upland habitats to find food and nesting sites (Chase et al, 1997). Populations of these three species have declined dramatically over the past few decades, due to collections for the pet trade, pollution and disturbance of habitat. Turtles living in fragmented habitats also become victims of increased vehicle traffic and predation. Predation often increases in developing areas, due to domestic pets and common wildlife such as raccoons, skunks, coyotes and crows.

Aquatic habitat for wood turtles typically is streams, small ponds or swamps that offer them a permanently wet or damp place to overwinter. Nests are located in upland sites not far from the mother's home stream or pond. Hatchlings and young turtles tend to stay close to their home stream, but adults often travel a mile or more from home.

Spotted turtles and Blanding's turtles prefer densely vegetated, slow-moving streams or ponds, where they spend much of their lives. Nests of both are located in uplands. Spotted turtles can only eat when submerged, so they tend to stay near their home, but they are known to frequent nearby vernal pools and wetlands as far as one-third of a mile away for food. There are only a handful of known breeding populations of Blanding's turtles, so little is known about their life cycle or population trends.

Shoreline areas with a complex vegetative mix provide birds with areas to rest and feed, as well places to nest. Osprey, kingfishers, flycatchers and other birds use tree branches and snags as feeding perches. Wood ducks prefer shoreline trees for nesting. Rivers often serve as routes for migrating songbirds, waterfowl and raptors.

Wildlife also use vegetated buffers as travel corridors because of the cover they provide. Sprawling development continues to consume and fragment wildlife habitat and isolate animal populations. Vegetated buffers provide cover for animals as they travel through developed areas to reach new habitat. Black bears, raccoons, beavers and otters are known to prefer traveling along shoreline buffers. Maintaining or improving vegetated buffers along water bodies is now encouraged or required for most types of development, and buffers will play an increasing role in maintaining healthy wildlife populations and allowing these animals to move freely.

Buffers Help to Dissipate Floodwaters

The impervious surfaces created with development alter the hydrology of a watershed. Surface runoff creates higher and faster peak floodwaters. Buffers absorb and help break the force of high-velocity floodwaters that overflow their banks. The higher the velocity of the flow, the higher the ability to cause property damage. Therefore, maintaining woody stems and trunks can aid in protecting landscapes and structures. By comparison, grass covered areas, when submerged underwater, do not impede flow at all (Palone & Todd, 1998).

Buffers Help to Stabilize Banks

Vegetated buffers help to stabilize the banks of streams, rivers, lakes and ponds. Roots hold bank soil together, while trunks and stems protect banks by absorbing the erosive energy of water flow, waves, ice and boat wakes. Although not often thought of, the constant cutting action of boat wakes should not be underestimated, especially for properties located on the shores of recreational lakes or rivers where motorized traffic is heavy. Boat wakes eat away at the shoreline, causing a reduction in lot size and a lowering of property value.

Buffer Width

Ideally, buffers should be designed with one or more purposes in mind, such as capturing pollution, shading streams, providing wildlife habitat or offering privacy to waterfront property owners. In general, the wider the buffer and the more complex the vegetation within it, the more effective it is in meeting those purposes. However, the capacity of a vegetated buffer to meet its intended purposes depends on several site-specific factors. To capture pollution, those factors include land use, soil type, slope, buffer width and vegetative mix within the buffer. To provide wildlife habitat, those factors include the buffer width, vegetative mix within the buffer and wildlife value of the water body along which the buffer is located. To provide privacy, those factors include location, vegetative mix and density.

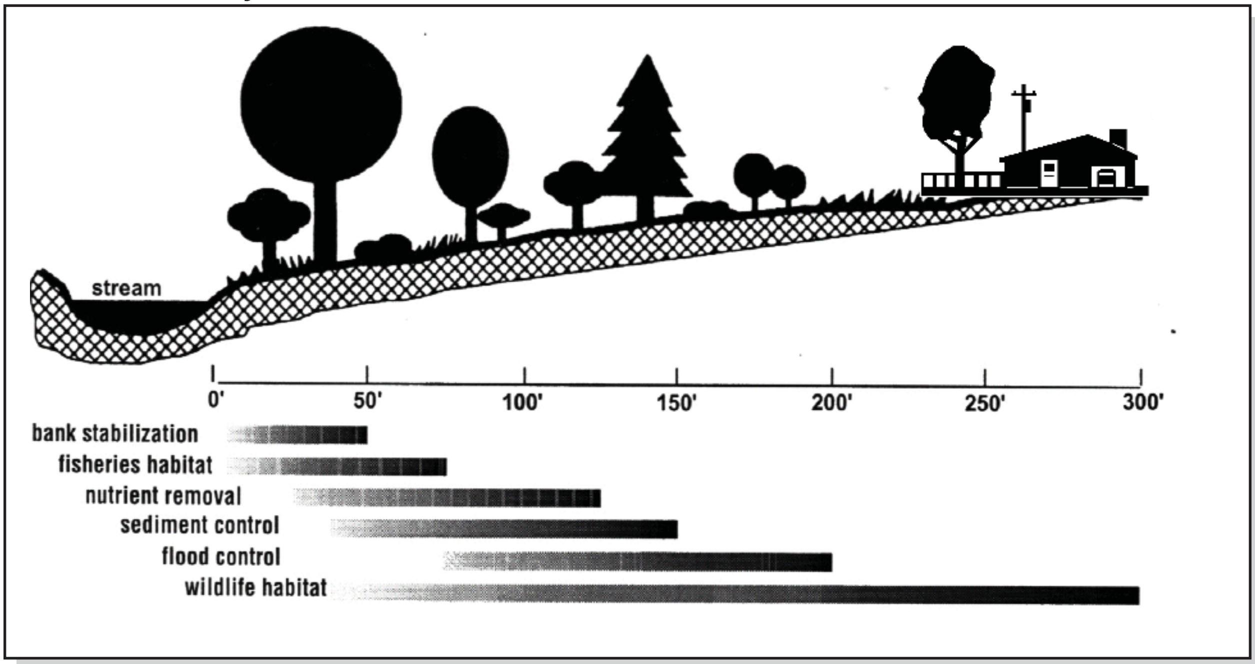
No one buffer width can satisfy all needs. For example, a narrow buffer of trees, 15-20 feet in width, can adequately shade a small stream, and it may be wide enough to act as a travel corridor for small animals. But such a simple and narrow buffer is probably not wide enough or complex enough to adequately capture pollutants from intensive land uses or to provide habitat for most animal species. This is because a narrow line of trees may be only one mature tree in width. Adding a mix of shrubs and herbaceous vegetation will greatly increase its ability to capture pollution and provide habitat.

That said, there does seem to be some consensus that a 100-foot width for buffers is an acceptable standard to adopt. However, land uses that generate high pollutant loads adhered to sediment, such as from intense development, tilled agricultural fields or concentrated livestock operations, will require a fairly wide buffer (at least 100-150 feet) of mixed forest, shrubs and grass. Low-density residential development, such as modest cottages on lots no smaller than one acre and with limited impervious area, may only require 35-50 feet of buffer (Palone & Todd, 1998). Buffer width should be increased for areas where stormwater runoff is unnaturally high due to human activity (land uses are intense, impervious surface cover is high, soils are heavily compacted), or where slopes are steep (greater than 15%) and soils are highly erosive.

There have been dozens of studies conducted on the effectiveness of buffers in capturing pollution and providing wildlife habitat, and their results are varied. Most scientific studies focus on a very select site and collect detailed data. Some of the findings are transferable to other sites and situations and others are not. A summary of some of these studies, their findings and their complete references can be found at the end of this appendix. As can be seen in the table, the recommended widths for sediment removal alone range from 25 to 375 feet.

One of the most important scientific criteria for determining buffer size and vegetative mix is to identify the impacts that the buffer is expected to mitigate. Proper buffer size to mitigate different types of nonpoint source pollution or to provide wildlife habitat varies widely. For example, a relatively narrow buffer of forest will help to stabilize banks and shorelines and provide some shading of the water, but it will not have the area needed to retain stormwater for pollution removal or the width to allow a canopy diverse enough to create a self-sustaining ecosystem. A general summary of minimum buffer widths needed to perform specific functions is found below. Please note that these estimates are very general and are meant to provide a comparative overview of functions and buffer width recommendations. These estimates should not be accepted as absolute truths.

General Summary of Recommended Buffer Widths



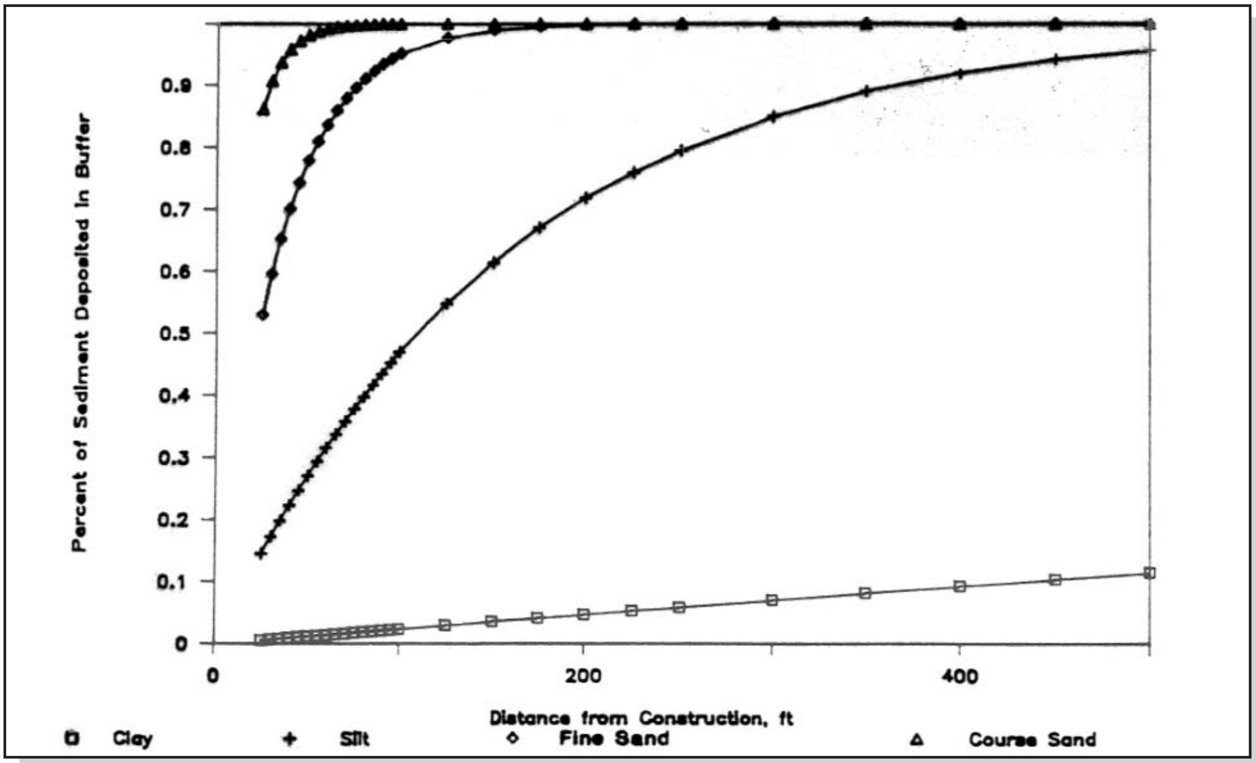
Adapted from CRJC, 2000.
Source: http://www.crjc.org/buffers

The true effectiveness of a buffer in removing pollutants varies, depending on site-specific conditions, such as land use, pollutant content, soil, slope, and vegetated cover. The interaction of all these things influences how water flows through the buffer (surface and subsurface) and how long it is detained within the buffer before reaching the water body. The dynamic interrelationship between these conditions is complex and not easily determined without long and thorough research. The effectiveness of a buffer in supporting wildlife habitat depends on the needs of the target species or community.

Width and Sediment Removal

In general, sediment capture (and inherently its adhered nutrient and pesticide load) will increase with the width of the buffer, as runoff is impeded by vegetation and leaf litter. However, the exact amount of deposition depends in part on runoff volume, particle size and roughness of the ground's surface. The East Florida Regional Planning Commission developed a predictive methodology to determine buffer width based upon sediment composition. Although soils and topography of Florida and Massachusetts may not be identical, the commission's work does illustrate the correlation between particle size and buffer width. For instance, coarse sand, which is relatively large and heavy, is the first to settle out, and vegetated buffers are often able to capture almost all of it within 100 feet. The coarser grades of sediment are those often generated during the construction phase of development. In sharp contrast, clays, which remain suspended in water longer due to their minute size, require almost 500 feet for a mere 10% capture rate.

Sediment Trapping and Buffer Width (USDA, 1975)



Source: Chase et al., 1997.

The vast majority of phosphorus within stormwater runoff is carried on sediment particles; most pesticides in common use also adhere to sediment. It is for this reason that sediment removal is the main focus of the Massachusetts Stormwater Management Policy, which requires that development projects incorporate measures to retain or remove 80% of total suspended solids from post-construction stormwater runoff. The illustration above clearly illustrates that the first 100 feet of buffer is the most critical for retaining sands and silts, and that the second 100 feet remains important for retaining silts and clays but not so much sands.

As discussed earlier, stormwater has a tendency to concentrate and flow in channels, most seriously as the slope of the site increases. While studies have shown that 100-foot buffers are adequate for retaining sediment, this efficiency decreases as slope increases. This is because channeled stormwater flows rapidly through the buffer, bypassing the physical, biological and chemical processes that retain pollutants within the buffer area. Buffers of 100-feet are often 3 to 5 mature trees wide. One-hundred-foot buffers that have a mixture of trees at different stages of development can be as many as 8 to 10 trees in width (Palone & Todd, 1998). As stated earlier, a complex mixture of trees, saplings, shrubs and forbs has the highest capacity for retaining nonpoint pollution and supporting wildlife.

Designing a buffer with a grassed filter strip upland of the buffer, between it and developed areas, will help to deliver runoff to the buffer as sheet flow. Therefore, modest-sized lawns around residential or commercial development are not necessarily inappropriate when a vegetated buffer along the waterfront is maintained. It is important, however, that the lawns themselves not become sources of pollution, so the use of fertilizers and pesticides should be minimized.

Width and Wildlife

Plant communities can be viewed in terms of their internal complexity. Complexity includes the number of layers of vegetation and the species composing each layer, competitive interactions among species, and the presence of detrital components, such as litter, downed wood, and snags. Complexity also includes a variety in plant height. Simple vegetative structure, such as an herbaceous layer without woody overstory or canopy, creates fewer niches for wildlife. Similarly, canopy with little ground cover or with few lower branches or foliage provide fewer niches. Low-level branches provide cover and a place for songbirds to escape from predators. The fewer niches there are, the fewer wildlife species there are. Thus, the more complex the vegetation, in species and height, the more opportunities there are for viewing a variety of wildlife.

Buffer widths for providing habitat for wildlife vary greatly, depending on the species. In general, the wider the buffer and the more complex the vegetation, the more valuable it is to wildlife. Buffers of 100 feet have been shown to provide adequate travel corridors for migratory songbirds when the buffers are connected to existing patches of woodland (Palone & Todd, 1998). However, buffer widths of 100-300 feet are needed to provide reliable habitat for migratory songbirds or to provide travel corridors for large mammals, such as deer, moose and bear. The table on page A-16 summarizes what a 100-foot forested buffer is likely to provide for several commonly found Massachusetts animals.

There are many animal species that normally remain within 100 feet of the water's edge, such as painted turtles, dusky salamanders, green frogs and bullfrogs. However, the buffer should be wide enough to provide cover and food for those animals, especially juveniles, who need to disperse to new territories. Upland-dwelling amphibians that spend the vast majority of their lives in the forest (wood frogs, spring peepers and several salamander species) travel several hundred feet or more from their breeding pool. The Jefferson salamander, for example, will travel as far 1 mile to forage. Many large mammals (black bear, bobcat and moose) and many raptors (hawks, owls, and falcons) require very large areas for home ranges. The average 100-foot buffer cannot accommodate such extensive areas, but may provide travel corridors for animals traveling between larger expanses of unbroken habitat (Chase et al, 1997).

Overview of wildlife habitat functions within a 100-foot Buffer

Wildlife	What a 100' buffer provides	What a 100' buffer does not provide
Stream invertebrates (bottom of the food web) and fish	shading; bank stability; organic debris; prevention of siltation and excess nutrients	adequate floodwater abatement
Eastern spotted newt	probably maintain water quality of wetlands and surface waters; habitat for breeding	habitat for dispersing terrestrial juveniles (efts); travel for adults
Four-toed salamander	habitat for breeding and most activity	cover for dispersal routes to neighboring wetlands
Northern dusky salamander	habitat for breeding and most activity	dispersal habitat
Northern two-lined salamander	habitat for breeding and most activity	foraging area – adults may wander 330 ' on rainy nights; dispersal of juveniles (only 25% return to natal waters)
Green frog	habitat for breeding and most activity	dispersal habitat
Wood frog	breeding habitat (if buffer protects vernal pool)	habitat for most of terrestrial lifestyle, which is often several hundred feet from water
Spotted turtle	large organic debris; invertebrate and small vertebrate prey; streambank stability; protective cover near water; winter hibernating habitat	habitat for most terrestrial activity – will travel up to ½ miles (2,680') from water to find temporary food sources
Wood turtle	large organic debris; invertebrate and small vertebrate prey; streambank stability; protective cover near water; spring basking and winter hibernating habitat	habitat for most activities; hatchlings usually stay within 130' of water; spend most of time within 1,000' of water, but will travel up to 1 miles to search for food; nests up to 330' away from water
Mink	most foraging habitat and den sites	hunt up to 600' from the water; den sites can be up to 330' away from water
Black bear	foraging, especially in lowland wet areas which provide early spring greens; cover; travel corridors	den sites; habitat for most activities – males need up to 19 square miles (depending on habitat & food sources)
Bald eagle	foraging; perching; roosting sites	protection from human disturbance; nest sites - most eagle nests are within 1,300' from water

Source: Chase, et al., 1997.

Fixed or Variable Widths

There are two principal ways by which most buffer widths are defined: 1) the width may be set as a fixed distance from the water or 2) the width may be variable depending on specific site features or needs. Standard "fixed width" buffers are typical in the context of protective regulatory programs, because they are simple to understand and relatively simple to implement and administer. Minimum width protective areas, such as the 100-foot buffer zones and the 200-foot Riverfront Area cited in the Massachusetts Wetland Protection Act, have been developed using scientific evidence on vegetated buffer functions and public acceptance of their legitimacy. Fixed buffer widths in common use across the country range from 25 to 300 feet or more (Palone & Todd, 1998). Where political compromise has resulted in the establishment of narrow minimum buffer widths, the public may be given a false perception that a stream or lake is protected when, in fact, serious threats from pollution and loss of habitat still exist. Unless fixed-width approaches are conservative and establish buffer widths that would be effective under the worst-case scenario (e.g. steep slopes, erosion-prone soils, land uses generating high concentrations of pollutants), they will offer inadequate protection for some water bodies. On the other hand, if they are too conservative, it may result in unnecessarily wide buffers for many situations and may be rejected by the public (Haberstock, et al., 2000).

"Variable width" approaches attempt to integrate scientifically acknowledged buffer functions with local and site-specific conditions. Variable width buffers are better able to protect desired buffer functions in a customized and flexible manner when incorporating local site conditions. The width of the buffer depends not only on the minimum width needed for a specific function, but also on the sensitivity and characteristics of the water body on which it located. However, the vast majority of development within a water body's watershed occurs on private land and, because variable buffer design is based on the scientific evaluation of each situation, it is unrealistic to determine variable minimum widths for each situation. Probably more realistic is the adoption of a minimum buffer width, such as 100 feet, with the understanding that additional width may be required under unusual or extreme conditions relating slope, soils, and intensity of land use.

In sum, vegetated buffers are a relatively cost-effective way to protect water quality and provide wildlife habitat. In addition, they can provide waterfront property owners with an array of benefits, including added privacy, determent of geese and increased property values. Entertain the idea of planting a buffer on your property or on a public property to protect your river, stream, lake or pond.

Summary of Studies conducted on Buffer Width and Effectiveness

Author(s) and citation	***Functions Protected***	***Range of Buffer Widths Recommended (in feet)***	***Average Range (feet)***
Rogers, Golden, Halpern, 1988. *Wetland Buffer Delineation Method*, NJ Dept. of Environmental Protection, Pub. No. CN 401, Trenton, NJ.	Water Quality – nontidal. Wetlands - intermediate	25 – 50	37
Budd, W.W., Cohan, P.L., Saunders, P.R., 1987. "Stream Corridor Management in the Pacific Northwest: I. Determination of Stream Corridor Widths," *Environmental Management*, Vol. 11, No. 5:587– 597.	Water quality, temp. control, wildlife habitat, stream corridor	25 – 50	37
Swift, L.W. 1986. "Filter Strip Widths for Forest Roads in the Southern Appalachians," *Southern J. of Applied Forestry,* 10: 27-34.	Water quality (sediment), filter strips for logging w/ brush barrier	32' – 64	48
Palmstrom, N. 1991. *Vegetated Buffer Strip Designation Method Guidance Manual.* I.E.P., Inc. Consulting Environmental Scientists.	Water quality (subsurface)	50	50
Brown, Brazier, 1972. (in Palfrey, R., Bradley, E., 1981. *Natural Buffer Areas: An Annotated Bibliography*. Coastal Resources Div., Tidewater Admin., MD Dept. of natural Resources.).	Stream temp.	55 - 80	67
Castelle, A.J., et al., 1992. *Wetland Buffers: Use and Effectiveness*. Adofson Assoc. Inic., Shoreland and Coastal Zone Management Program, Wash. Dept. of Ecology, Olympia, Pub. No. 92-10.	Water quality, temp. control, review of other literature	49 - 98	74
Trimble, G.R. Jr., Sartz, R.S., 1957. " How Far from a Stream Should a Logging Road be Located?", *J. of*	Water quality (sediment), filter strip for logging, general situations, slope dependent	25 - 165	95

Summary of Studies conducted on Buffer Width and Effectiveness

Author(s) and citation	***Functions Protected***	***Range of Buffer Widths Recommended (in feet)***	***Average Range (feet)***
Swift, L.W., 1986. "Filter Strip Widths for Forest Roads in the Southern Appalachians," *Southern J. of Applied Forestry,* 10: 27-34.	Water quality (sediment), filter strips for logging, w/out brush barrier	43 - 154	99
Pinay, G., Roques, L.., Fabre, A.. 1993. "Spatial and Temporal Patterns of Denitrification in a Riparian Forest," *J. of Applied Ecology* 30: 581-591.	Water quality (nitrate removal), winter conditions	100	100
Stauffer, D.F., Best, L.B., 1980. "Habitat Selection by Birds of Riparian Communities: Evaluating Effects of Habitat Alteration," *J. Wildlife Management*, 44: 1-15.	Breeding birds	11 - 200	106
Rogers, Golden, Halpern , 1988. *Wetland Buffer Delineation Method*, NJ Dept. of Environmental Protection, Pub. No. CN 401, Trenton, NJ.	Water quality	75 - 150	113
Welsch, 1991. *Riparian Forest Buffers, USDA, Forest Service*, NA-PR-07-91, Radnor PA.	Water quality, riparian forest buffer	95 - 150	123
Erman, 1977 (in Palfrey, R., Bradley, E., 1981. *Natural Buffer Areas: An Annotated Bibliography*. Coastal Resources Div., Tidewater Admin., MD Dept. of Natural Resources.)	Water quality (sediment)	150	150
Phillips, J.D. 1989. "Nonpoint Source Pollution Control effectiveness of Riparian Forests along a Coastal Plan River," *J. of Hydrology*, 110:221-127.	Water quality control along a coastal plain river (uses model)	49 - 260	155
Palmstrom, N. 1991. *Vegetated Buffer Strip Designation Method Guidance Manual.* I.E.P., Inc. Consulting Environmental Scientists.	Water quality (sediment)	25 - 300	163

Summary of Studies conducted on Buffer Width and Effectiveness

Author(s) and citation	***Functions Protected***	***Range of Buffer Widths Recommended (in feet)***	***Average Range (feet)***
Roman, C.T., Good, R.E., 1985. *Buffer Delineation Method for New Jersey Pineland Wetlands*, Rutgers, State Univ. of New Jersey. New Brunswick, NJ.	General	50 - 300	175
Nieswand, G.H, et al., 1990. "Buffer Strips to Protect Water Supply Reservoirs: A Model and Recommendations," *Water Res. Bull.,* 26: 959-966.	Water quality	45 - 300	183
Brown, M.T., Schaefer, J.M., and Brandt, K.H. 1990. *Buffer Zones for Water, Wetlands, and Wildlife*. CFW Pub. #89-0, Florida Agricultural Experiment Stations Journal Series No. T-00061. East Central Florida Regional Planning Council.	Water quality (sediment)	75 - 375	225
Clark, 1977 (in Palfrey, R., Bradley, E., 1981. *Natural Buffer Areas: An Annotated Bibliography*. Coastal Resources Div., Tidewater Admin., MD Dept. of Natural Resources.)	Nutrient removal	150 - 300	225
Castelle, A.J., Johnson, A.W., Conolly, C., 1994. "Wetland and Stream Buffer Size Requirements – a Review," *J. of Environmental Quality*, 23: 878-882.	Review of buffer literature	varies	varies

Source: Chase, et al, 1997.