Fact Sheet #8: Functions of Riparian Areas for Pollution Prevention

[This fact sheet was prepared by *Russell Cohen, Rivers Advocate*, **Division of Ecological Restoration, Massachusetts Department of Fish and Game**. This document is intended for educational purposes only and does not necessarily represent the viewpoint of agencies and commissions having regulatory authority over riparian lands. Last updated: June 12, 2014.]

Why are the use and condition of riparian lands particularly important from a pollution prevention perspective?

Water pollution problems persist despite improvements in wastewater treatment

Passage of the state and federal Clean Water Acts four decades ago have brought about a substantial reduction in water pollution from major point sources such as industrial and municipal wastewater discharges. Periodic sampling of pollutant levels in Massachusetts' rivers and streams indicates that further improvements in water quality have stagnated over the past several decades, however, with some watercourses actually deteriorating in quality. Over 60% of the state's rivers and streams routinely sampled for water quality continue to fail state and federally mandated Class B ("fishable and swimmable") standards during all or part of the year.

A major reason for the continuing lack of significant improvements in water quality is the increasingly larger share of pollution attributable to nonpoint sources such as runoff from roadways, parking lots and other development on lands adjacent to rivers and streams (otherwise known as riparian areas). Such development on riparian areas, coupled with the removal of streamside vegetation, has also reduced rivers and streams' natural ability to cleanse themselves. Reducing nonpoint source pollution from riparian lands that are already developed (through, e.g., retrofitting storm drains with pollution-filtering devices) can be cumbersome and expensive. Maintaining riparian areas in and/or restoring them to a naturally vegetated condition will, on the other hand, partially or completely prevent nonpoint source pollution generated by adjacent development from getting into rivers and groundwater, as well as helping to mitigate pollution levels in the river itself regardless of their source.

What are the major types of nonpoint source pollutants and the land uses responsible for them? What adverse impacts can these pollutants cause on other functions and values of rivers and riparian areas?

Nutrients (phosphates and nitrates, e.g.) are needed by all living organisms to carry out basic life processes, but in excess they can throw riverine systems out of balance. Excess nutrients in the form of manure or commercial fertilizer applied to farmland, yards and golf courses, and septic system leachate getting into adjacent rivers and streams, may trigger excessive algal and plant blooms which deplete the dissolved oxygen in the water. Too little oxygen harms young fish populations and eventually also causes plants to die. Algal blooms at the surface can interfere with photosynthesis of submerged plants by blocking sunlight, causing them to die. Their decomposition results in further depletion of dissolved oxygen, which sets off a vicious downward cycle. Excess plants and algae, dead or alive, clog up waterways, and cause odors hurting both recreational values of the river and adjacent property values. Excessive phosphates in waters used for public water supply may lead to taste and/or odor problems due to its stimulation of excessive algae growth, while nitrates, which are difficult to remove from source water, may, in excessive concentrations, make the water unhealthful for animals and/or humans to drink, as well as cause degradation of estuarine and other inshore marine ecosystems.

Pesticides and herbicides can get into rivers via surface runoff from roads, agriculture, lawns, and golf courses. Many of these substances are carcinogens and can kill aquatic organisms directly and/or accumulate in the food chain as well as harm water supplies. After application, many pesticides and herbicides are bound to soil particles, thus, if soil erodes from a nearby field and enters a stream, the pollutant will also enter. Pesticides and herbicides getting into riparian areas used for public or private water supplies can be expensive and/or difficult to remove from drinking water, and those that are not effectively removed may pose carcinogenic or other health risks or cause the abandonment of the supply.

Pathogens (viruses and harmful bacteria, e.g.) can get into rivers from a variety of sources, including animal feces washing off urban streets, malfunctioning and/or overburdened sanitary and storm sewers, poor agricultural practices, and septic systems sited too close to rivers and streams. Excessive concentrations of pathogens in rivers and streams can result in brief or extended closures of swimming areas, shellfish beds and sources of public or private water supply. Such closures can have serious adverse economic as well as public health impacts, as shellfishermen are thrown out of work, property values decline, communities lose tourism and tax revenue, etc..

Heavy metals are a common constituent of urban runoff, washing off roads and even galvanized and copper roofs. If these pollutants reach rivers and streams, they can have hidden and long-lasting impacts. Toxic metals such as mercury can kill aquatic organisms directly or accumulate insidiously in the food chain, ultimately killing higher predators that feed on aquatic organisms and making fish unsafe for human consumption. In addition, dissolved metals can harm water supply equipment and degrade the suitability of the water for drinking and other uses.

Although not ordinarily thought of as a pollutant, **excessive sediment** getting into rivers and streams can cause a wide variety of adverse impacts. Sediments can get into rivers by numerous means, including soil washed and/or wind-blown off of bare earth exposed during farming, forestry or mining operations and construction sites. Excessive sediments can also be a byproduct of excessive streambank erosion caused by removal of streamside forests and/or an increase in impervious surfaces upstream. Excessive sediment into rivers reduces flood storage, as eroded sediments settle out of the current and fill channels and deeper spots on the river so they can no longer convey or hold as much water. This reduction of storage capacity results in increasing peak discharges and increased likelihood of flood damage.

Sediments also increase stream turbidity (cloudiness), which leads to increases in stream temperature, which contributes to excessive algal growth and increased pathogenic activity. Many nutrients and other pollutants are bound to sediments, so sediments can serve as a means for the transfer of nutrients and chemicals such as fertilizers and pesticides from adjacent lands into the river. Excessive sediments can harm water supplies by damaging water treatment pumps and other equipment, increasing treatment costs to remove the sediment, and reducing reservoir storage capacity. It can also decrease river bottom infiltration, reducing the yield of nearby wells. In addition, chlorine is generally less effective as a water treatment disinfectant if the water has a high turbidity level.

Sediment can be particularly harmful to fisheries. In excessive quantities, sediment kills small bottom-dwelling stream animals and destroys fish habitat. The cloudiness of soil particles suspended in water irritates the gills of fish and makes them more prone to disease. The soil that settles on the stream bottom smothers insect larvae and other bottom-dwelling organisms that fish depend on for food. It also smothers fish eggs and embryos in their gravel nests. The reproductive habits of trout illustrates this well. A trout selects clean gravel to make a nest (also known as a "redd") and lay its eggs. Cool clean water normally passes through the redd and supplies oxygen to the eggs. Silt settling on the gravel redd blocks the oxygen-rich water, causing the eggs to suffocate and die.

Thermal pollution also has a significant adverse impact on rivers and streams. The two major land use activities on riparian lands responsible for thermal pollution are the removal of shading streamside forests from and/or placing impervious surfaces in riparian areas, both of which lead to increased stream temperature. Water holds less oxygen as it becomes warmer. As a result, less oxygen is available for respiration by aquatic organisms. Furthermore, in the case of some fish species such as trout, higher temperatures increase their metabolic rate and need for oxygen at the very time that less oxygen is available. Other negative effects of increased water temperature include odors and more profuse growth of some pathogens and other bacteria. Small increases in water temperature can also cause nutrients that are sediment-bound at lower temperatures to break free, resulting in a substantial increase in the quantity of nutrients released into the water. When combined with sunlight from a treeless shoreline, these "free" nutrients can create large algal blooms which further diminish water quality.

Last but not least, the **construction, maintenance and use of roads and other paved surfaces** are responsible for a whole host of pollutants, including all of the above categories as well as motor oil, gasoline and other automobile fluids and residue from tire treads and brake linings. Sand applied to roads and parking lots during the wintertime to promote safe driving can become a major source of sediment pollution if it is eventually carried by wind and water into rivers and streams. Road sand not only degrades rivers for fisheries (e.g., smothering gravel spawning beds) and flood control (sand reduces flood storage capacity), but the sand itself carries pollutants from automobiles and other pollutants hitting the pavement into adjacent streams. Even snow on and along roadways can be a significant source of pollution once it melts or is dumped alongside or into rivers and streams. Snowbanks accumulate roadway pollutants such as petroleum products/additives and metals, the direct application of salt and anti-skid grits, even deteriorated pieces of the roadway itself. High levels of chloride, lead, iron, phosphorous, biochemical oxygen demand and total suspended solids have been reported in snow dump runoff. The Mass. Department of Environmental Protection (DEP) issued a Snow Disposal Guidance for snow and ice management in March of 2001 to address this problem; see http://www.mass.gov/eea/agencies/massdep/water/regulations/snow-disposal-guidance.html.

How do naturally vegetated riparian areas act to prevent pollution of adjacent rivers, streams and groundwater?

The most obvious pollution prevention function of riparian areas kept in a naturally vegetated condition is that such land is not in and of itself a pollution generator. In other words, the more that riparian lands along a particular watercourse are maintained in a naturally vegetated state as opposed to being converted to other pollution-generating land uses, the less pollution will get into that waterway from the riparian lands themselves. As an increasingly larger share of pollution in our rivers and streams is attributable to nonpoint source pollution originating from development of riparian areas along rivers and streams, merely keeping our remaining undeveloped riparian areas in a naturally vegetated condition is a highly effective means of pollution prevention.

But riparian lands maintained in a naturally vegetated state do much more than simply take the place of other pollution-generating land uses. Streamside forests and other naturally-vegetated riparian areas act as a **living filter** to intercept and absorb excess nutrients, sediment and other pollutants carried along in runoff from adjacent development as well as by the river itself. Several different and complementary processes within the vegetated riparian area collaborate to accomplish this. First, living, decaying and dead vegetation within the riparian area provide a multitude of barriers that slow down and intercept runoff and wind-blown sand and silt from adjacent lands before they reach rivers and streams.

This slowdown enables a number of pollution-attenuating functions to occur. Much if not most of the runoff infiltrates into the porous, uncompacted soil within the riparian area, where sediments (many of which have pollutants bound to them) are trapped and where excess nutrients, heavy metals and many other pollutants are either taken up onto plant surfaces (adsorption), incorporated and sequestered into plant tissues (absorption), or are broken down into less harmful substances by soil bacteria and other microorganisms. Pesticides and other toxics borne into the riparian area by runoff are converted to non-toxic compounds by a number of biochemical processes, including microbial decomposition, oxidation, reduction, hydrolysis, solar radiation and other biodegrading forces at work in the soil and litter of the streamside forest.

A similar pollution-reducing phenomenon occurs in the river itself. Large woody debris (e.g. tree trunks and roots) extending or falling into the water hold back sediments and also provide ample surface area to support a large population of microbes that consume excess nutrients and other pollutants that have already gotten into the water. In the meantime, the streamside forest shades the water, which in turn lowers its temperature, thus enabling it to have a higher dissolved oxygen content necessary for the microbes to effectively metabolize pollutants and the other items in their diet. Keeping stream temperatures cool with shading streamside forests also keeps phosphorous and other sediment-bound pollutants from breaking free and becoming more harmful as dissolved substances.

When rivers are allowed to flood into adjacent vegetated floodplains, these floodplains act as sediment traps and nutrient sinks. When muddy water from streams and rivers rushes into the stillness of floodplain wetlands and forests, the silt in the water adheres to the stalks of water plants and settles to the bottom. As the flood waters recede, the waters returning to the river via the surface or ground are largely cleansed of their excess sediment and nutrients. Riparian wetlands improve water quality by a variety of anaerobic and aerobic processes, that precipitate or volatize certain chemicals from the water column. The accumulation of organic peat characteristic of many riverine wetlands can ultimately lead to a permanent sink for many chemicals coming from adjacent development and/or the river itself. In addition, the high rate of biological productivity of many wetlands can lead to high rates of mineral uptake by, and accumulation in, plant material with subsequent burial in sediments.

Since for certain organisms and chemicals (fecal coliform bacteria, phosphates and nitrates, for example), it is not merely their presence but their overall concentration in the water that controls how harmful they are as pollutants, naturally vegetated riparian areas also perform an important pollution prevention function by helping to dilute concentrations of these pollutants below harmful levels. Precipitation falling on the vegetated buffer combines with surface and/or groundwater flow to dilute concentrations of pollutants generated from adjacent land uses as they flow through the buffer. The cleaner surface and/or groundwater discharge into adjacent rivers and streams from naturally vegetated riparian areas also helps to dilute the concentrations of pollutants already present in those waterways. Degradation results when these natural pollution attenuation processes are overwhelmed by excessive pollutant loading, however.

What are some best management practices (BMPs) for naturally vegetated riparian areas to maintain or enhance their pollution prevention function?

The effectiveness of riparian areas in preventing and reducing pollution is influenced by several factors, including the width and nature of streamside vegetation, the manner in which runoff is discharged into and passes through the vegetated area, and the slope and composition of the soil within the riparian area. A key characteristic of effective vegetated riparian areas is a relatively long detention time between when the polluted runoff enters the riparian area and when it flows or seeps into the adjacent stream. As is the case with wastewater treatment plants and other pollution control mechanisms, generally speaking, the greater the detention time, the greater degree of pollutant reduction.

Retain/restore natural riparian vegetation

There are a number of ways to help ensure riparian areas' pollution prevention function. First and foremost is to retain as much of the area as possible in a naturally vegetated, undisturbed condition, especially the portion of the riparian area that is closer to the adjacent river or stream. In most situations, "naturally vegetated" in Massachusetts means native forest cover, as that is how most of our riparian areas were before settlement. Streamside forest vegetation, whether living, decaying or dead, on the ground or fallen or extending into the water, should be left in place wherever possible to maximize its detention capability and allow plenty of time for the breakdown of pollutants by plants and microorganisms. Excessive "tidying up" of riparian areas by leaf raking, brush clearing, removing fallen logs or other removal of plant material from the forest floor and/or streambank can significantly reduce detention time and the opportunity for the riparian area's living filter to beneficially interact with and attenuate water-borne pollutants.

Diffuse runoff into riparian areas and discharge as far as possible from the river

In addition to retaining undisturbed forest cover, riparian areas are most effective at pollution prevention when infiltration opportunities are maximized by discharging polluted runoff from adjacent areas at the outside edge of the area (the edge furthest away from the stream) and in a diffuse manner. Runoff has a strong tendency to concentrate and form a channel. The steeper the slope, the greater the tendency of runoff to form a channel. Vegetated streamside buffers are effective only when runoff is evenly distributed across them and given ample opportunity to infiltrate forest soils and interact with plants and microorganisms. Once a channel is formed, the buffer's living filter is effectively "shortcutted" and will not perform as desired. Buffer shortcutting also occurs when runoff is routed directly to receiving waters through storm sewers, culverts, and other confined drainage ways, often bypassing the buffer entirely. Therefore, it is important to ensure that drainage into buffers is not channelized but is instead spread evenly as sheet flow through use of a level lip spreader or similar mechanism. Compacting soils within riparian areas should be avoided for the same reason (it reduces infiltration).

Retain/reestablish a vegetated streamside buffer at least 100' wide

Buffer width is also important. Generally speaking, the greater the width of a vegetated streamside buffer, the more effective it will be in preventing pollutants generated by adjacent development from getting into adjacent rivers and streams. Studies have consistently shown that naturally vegetated buffers must be at least 100 feet wide to achieve substantial reductions in most constituents of polluted runoff. A few pollutants (viruses, e.g.) can travel further distances and need greater buffer widths to be effectively filtered out. Dilution of contaminant-rich runoff by rain falling on the buffer is directly related to buffer width (i.e., the wider, the better). Maximum stream shading for maintaining beneficial lower stream temperatures is achieved when the riparian forest buffer is at least 80 feet wide on both sides of the stream.

Avoid development on steep slopes and/or permeable soils

Last but not least, slope and soil composition affects the ability of riparian areas to prevent pollution from entering adjacent water bodies. It is just as, if not more, important from a water quality standpoint to keep sources of pollution such as septic systems as far away from rivers bordered by uplands with drier permeable soils as it is for rivers bordered by wetlands. This is because riparian uplands are, generally speaking, not as efficient in filtering pollutants as are riparian wetlands. First, uplands typically are more steeply sloped than wetlands. This affects the detention time of water on or below the surface. Generally speaking, the steeper the slope, the shorter the detention time. The shorter the detention time, the less opportunity plants, microbes and other organisms within the riverine upland soils have to act on and absorb waterborne pollutants. The fact that wetland soils are usually flat and already saturated means that water passing on or through them moves at a relatively slower rate. The increased detention time gives wetland organisms a greater opportunity to filter out and absorb waterborne pollutants and excess nutrients before the water reaches the adjacent river. Second, riverine wetlands typically have a higher rate of biological activity (due to a greater diversity and concentration of flora and fauna, most notably of the macroinvertebrate and microscopic kind) than do riverine uplands. This also results in a generally higher level of pollutant and nutrient removal in wetlands than in uplands.

Consider retrofitting existing riparian development with structural pollutant controls where restoration of vegetated streamside buffer is not possible

In areas where riparian lands have already been developed and vegetated streamside buffers no longer exist and cannot be restored, it is important, where opportunities arise, to implement more structural pollution control technologies to reduce nonpoint source pollutant loadings to adjacent streams. The Mass. Department of Environmental Protection (DEP) has developed a Stormwater Management Handbook and other materials intended to help determine which Best Management Practices (BMPs) are the most effective and/or appropriate to deploy in specific situations. The Handbook and related materials are accessible at this link: http://www.mass.gov/eea/agencies/massdep/water/regulations/massachusetts-stormwater-handbook.html.

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