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The Role of Trees & Forests in Healthy Watersheds

Managing Stormwater, Reducing Flooding, and Improving Water Quality

Pennsylvania contains almost 83,000 miles of rivers and streams, ranging from small trickles to large rivers. These waterways are important because they provide water for people, farms, and industries; provide habitat for many kinds of wildlife and fish; and also provide us with great places to fish, swim, and boat.

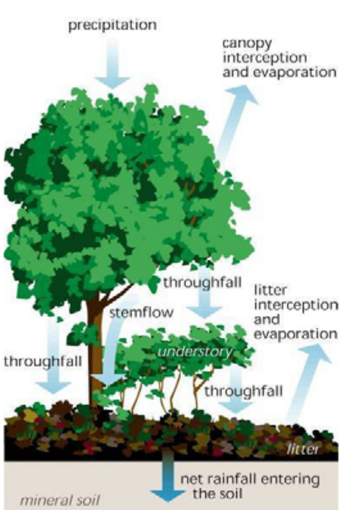
As our landscape changes, it begins to have an impact on stream health. What we do on or to the land affects both the quantity (volume) and quality (pollutant levels) of the water in our streams and lakes. The land area through which any water moves, or drains, to reach a stream is called a watershed.

As we begin to remove forest canopy and replace it with roads, parking lots, driveways, homes, patios, pools (impervious surfaces) and even grass, we immediately have impact on watersheds and receiving streams (or lakes). With the increased amount of impervious surfaces, water runs off the land, traveling on the surface towards the streams. As this 'storm water runoff' travels to the streams it collects pollutants and increases speed. The changes to the landscape, not only increase the volume of water that goes to the stream, it also shortens the amount of time it takes the water to get to the stream. These increased or peak flows cause water to move quickly to the streams. This leads to flooding, stream bank erosion, widening of streams, sediment deposited in streams, a loss of fish habitat, and decline in water quality. In Pennsylvania there are over 12,200 miles of polluted streams and over 3,000 miles of streams that are impaired by storm water runoff.

So how do we protect water quality and our streams as watersheds change?

Trees and forests play an incredible role in reducing storm water in several ways and removing or filtering pollutants that would otherwise wind up in our waterways.

Canopy Interception and Infiltration



Forests filter and regulate the flow of water, in large part due to their leafy canopy that intercepts rainfall, slowing its fall to the ground and the forest floor, which acts like an enormous sponge, typically absorbing up to 18 inches of precipitation (depending on soil composition) before gradually releasing it to natural channels and recharging ground water. In a North Carolina Watershed study (Kays, 1980) the mean soil infiltration rate went from 12.4 in/hr to 4.4 in/hr when a site was converted from forest (duff layer on soils) to suburban turf. Other studies (Bharati et al. 2002) have found similar results when comparing hourly infiltration rates and soil bulk density of forested areas with crops and grazed pasture.

Average interception of rainfall by a forest canopy ranges from 10-40% depending on species, time of year, and precipitation rates per storm event. In urban and suburban settings a single deciduous tree can intercept from 500 to 760 gallons per year; and a mature evergreen can intercept more than 4,000 gallons per year. Even young, small trees help. In a recent Forest Service study a single small tree (callery pear) that was only 9 years old, was able to intercept 58 gallons of storm water from a ½ inch rain event (67% of the rain that fell within the canopy).

A study in the 1980's of Dayton, Ohio's existing tree canopy found that storm water runoff was reduced by 7% and could be increased to 12% through planting more trees. In a more recent UFORE Hydro study conducted by the USDA Forest Service of the Toby Creek Watershed (a suburban area of Wilkes-Barre), 54% tree canopy cover was able to reduce storm water runoff by 11%. One Forest Service Researcher has stated that planting large canopy trees over impervious surfaces, such as a parking lot or street has much greater impact on reducing storm water (up to 8 times greater) because it works to reduce peak flows in urban settings.

Trees Consume Stormwater

Trees and forests absorb and use tremendous amounts of water for growth, thereby consuming storm water. A single mature oak tree can consume (transpire) over 40,000 gallons of water in a year. In Pennsylvania forests, an average of 24 inches of the annual 40 inches of rainfall is taken up by trees through evapotranspiration (movement of water from the ground through the tree and leaves, evaporating back into the environment). That evapotranspiration also serves to cool and modify surrounding summer temperatures. If the forest is removed or harvested, evaporation drops to 14 inches and stream flow increases to receive 26 inches of the annual 40 inches of precipitation. So, just the removal of forests can have an impact on streams in the watershed.

Pollutant Removal and Phytoremediation

Plants, especially woody plants, are very good at removing nutrients (nitrates and phosphates) and contaminates (such as metals, pesticides, solvents, oils and hydrocarbons) from soil and water. These pollutants are either used for growth (nutrients) or are stored in wood. In one study, a single sugar maple growing roadside removed 60mg of cadmium, 140mg of chromium, 820mg of nickel, and 5200mg of lead in a single growing season (Coder, 1996). Studies in Maryland showed reductions of up to 88% of nitrate and 76% of phosphorus after agricultural runoff passed through a forest buffer.

In comparison, studies of residential lawns have shown overuse of chemical fertilizers (over 100 million tons applied to lawns annually) and synthetic pesticides (80 million pounds applied to lawns annually – 10 times the rate per acre used by farmers – Yale graduate study). Excess nutrients from lawns and agricultural fields is one of the largest sources of non-point pollutants that is impacting water quality in our streams, rivers, lakes and the Chesapeake Bay.

Parking lots, one of the fastest growing land uses, have become a major cause of water quality and stream degradation. Non-Point Source pollutants such as petroleum hydrocarbons, nitrates, and heavy metals (cadmium, copper, lead, and zinc) from brakes and rusting automobiles all wash into our water ways. Even a small rain storm (less than .5 inches) will cause 'first flush' – washing these pollutants into streams.

The runoff from one acre of paved parking generates the same amount of annual runoff as: 36 acres of forest; 20 acres of grassland; a 14 acre subdivision (2 acre lots); or a 10 acre subdivision (0.5 acre lots). One inch of rainfall on an acre of parking produces 27,000 gallons of stormwater. Large increases in stormwater volume reaching streams has caused major streambank erosion problems, down stream flooding, increased nutrient/sediment loads, and degraded aquatic habitat. The planting of trees in parking lots, especially in bio-retention areas where stormwater flows, can have a positive impact on water quality and work to reduce flooding and stream impairment.

Streamside or Riparian Forest Buffers

Planting and maintaining woody vegetation along streams provide a wealth of benefits and research at the Stroud Water Center and elsewhere have shown that stream health is dependent on the presence of woody vegetation along its banks. Riparian forest buffers filter sediment from streams during storm events; remove nitrogen and phosphorous leaching from adjacent land uses such as agriculture; provide stability to the bank (wood root systems); shade and modify stream temperatures, critical for habitat and pollution reduction; provide aquatic and wildlife habitat for many species; reduce stream velocity; and reduce down stream flooding. Buffer widths vary from 50 feet, providing some bank stability to 250 feet, providing flood mitigation and wildlife habitat. Planting new buffers has become a state priority over the last 10 years, but regulations to protect existing buffers from removal do not exist. Some municipalities have adopted ordinances to protect riparian forest buffers, and model ordinances do exist (Montgomery County Planning).

Increased impervious surfaces and un-managed storm water continue to erode stream banks and fill streams with sediment. Streambank stabilization projects are costing taxpayers almost $1million per mile and state and federal agencies can't afford or keep up with the increased number of streams needing restoration.

Trees and Forests: a New BMP for Stormwater Management in Pennsylvania

Up until recently, stormwater management strategies have been focused on detaining large volumes of water in basins that had little to no effect on removing the pollutants in the stormwater. In December 2006, DEP unveiled the new Stormwater Management- Best Management Practices (BMP) Manual that works to protect water quality and to put stormwater back into the ground where it fell. One of the ten principles for new stormwater management is "preserve and utilize natural systems (soil, vegetation, etc)".

Several of the Non-Structural BMPs include protecting/conserving existing forests and riparian areas, cluster or concentrate new construction to minimize site disturbance, use conservation subdivision design and low impact development techniques, minimize soil compaction and grading entire areas, re-vegetate and re-forest disturbed area using native species, and reduce impervious cover such as streets and parking lots.

Then there are Structural BMPs that are promoting infiltration of stormwater such as the development of rain gardens or bioretention areas where trees and vegetation play an active role consuming rain water and removing pollutants. Trees and vegetation are also being incorporated into newly designed or retrofitted stormwater basins to promote pollution and sediment removal. Other strategies include Green Roofs, rain barrels or cisterns, vegetated infiltration swales, constructed wetlands, and riparian buffer and floodplain restoration.

In older existing communities, increasing tree canopy cover along streets, in yards and in parking lots can have a positive impact on our watersheds. Planting large canopy trees (where growing space permits) provide the most benefit – 8 times that of small maturing trees, according to new USDA Forest Service research (Greg McPherson, Western Center for Urban Forest Research). A study in Oakland, California will be monitoring 1,800 newly planted trees for 40 years to determine if they will account for a 9 million gallon reduction in contaminated stormwater entering the San Francisco Bay.

The role of trees and forests in managing stormwater and protecting water quality is just beginning to be understood by some engineers, planners and community leaders.   One of the most powerful statements that help support this came from the Chesapeake Bay Executive Council in 2006 and reads:

'Forests are the most beneficial land use for protecting water quality, due to their ability to capture, filter, and retain water, as well as air pollution from the air. Forests are also essential to the provision of clean drinking water to over 10 million residents of the watershed and provide valuable ecological services and economic benefits including carbon sequestration, flood control, wildlife habitat, and forest products'.

Watershed and Stormwater Resources

Center for Watershed Protection - www.cwp.org
(learn more about the impact of impervious surfaces and storm water on our streams and watersheds and access many downloadable publications).
Urban Watershed Forestry Manuals - http://www.cwp.org/forestry/index.htm
Storm water Managers Resource Center - http://www.stormwatercenter.net/
(view slideshow, fact sheets and much more)
USDA Forest Service Riparian Buffers - http://www.na.fs.fed.us/spfo/pubs/n_resource/buffer/cover.htm
Stroud Water Research Center - http://www.stroudcenter.org/
(visit the Leaf Pack Network for Teachers)
University Of Maryland Riparian Buffer - http://www.riparianbuffers.umd.edu/
Alliance for the Chesapeake Bay program - http://www.acb-online.org/pubs.cfm
Natural Stream Channel Design - http://www.nrcs.usda.gov/technical/stream_restoration/
Urban Stream Restoration - http://www.urbanstreamrestoration.com/index2.html
(a video tour of Ecological Restoration Techniques with Ann Riley)
DEP's Watershed TV – http://www.greentreks.org/watershedstv/index.asp
(miniclips on storm water and other issues)
Hubbard Brook Experimental Watershed - http://www.hubbardbrook.org/education/Introduction/Intro1.htm
Forest Service – Urban Forestry Research Center –http://www.fs.fed.us/psw/programs/cufr/research/water.shtml
Green Infrastructure Website - http://www.greeninfrastructure.net/
Maryland's Storm water Website - http://www.mde.state.md.us/Programs/WaterPrograms/SedimentandStormwater/home/index.asp
Nonpoint Education of Municipal Officials (NEMO) - http://nemo.uconn.edu/
Alliance for the Chesapeake Bay - http://www.acb-online.org/
Storm water Journal - http://www.stormh2o.com/sw.html
Low Impact Development Techniques - http://www.lowimpactdevelopment.org/

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Forested Watersheds

Forests make excellent watersheds chiefly because their soils usually have a high infiltration capacity— they are capable of quickly absorbing large amounts of water. Therefore, rainstorms or melting snow in woodlands produce relatively little surface runoff with the associated problems of *erosion* (detachment and movement of soil) and *sedimentation* (the deposition of soil). *Turbidity* is the term applied to water that has reduced clarity due to suspended sediments. Turbid water looks cloudy. Generally, the water flowing through streams in stable forests has very low turbidity.

Trees contribute to the high infiltration capacity of forest soils. When tree roots remove water from soil pores, space is created for additional water to be stored. Forest soils also have a great deal of pore space. The abundance of organic matter from decaying plant parts creates a well-structured soil in which the individual soil particles tend to form *aggregates* (small clumps of soil stuck together). This clumping of soil particles produces large, interconnected pores between the aggregates. Water poured on the surface of such soils quickly disappears into the pores. Microorganisms, insects, small animals, and growing tree roots also contribute to soil aggregation (and consequently more pore space) by moving and mixing soil. These actions put soil particles in contact with each other, increasing the likelihood that soil particles will clump together, resulting in large pores through which water can easily drain. The *litter laye*r, which consists of leaves and bits of wood in various stages of decay on the forest floor, helps maintain healthy populations of soil organ-isms. By shielding the soil from the elements, the litter layer provides soil organisms with a less-hostile, more-stable environment.

Even in the winter, when forest soils may be frozen, they can maintain a high infiltration capacity. *Concrete fros*t, a solid impermeable layer of soil and ice, rarely forms in forest soils. The litter layer insulates soil from extreme cold. Also, because the loose forest soils have high amounts of organic matter and large pores, the frost penetrating such soils is of a more porous, granular, or honeycomb nature, permitting water to percolate through.

How Forest Vegetation Supports Healthy Streams

Vegetation	***Benefits***
Tree and shrub canopy overhanging the channel	• Stable water temperature improves conditions for desirable game fish • Source of large and fine plant debris • Source of terrestrial insects that fish eat
Leaves, branches, and other vegetative debris in stream channel (in proper amounts)	• Help create pools, riffles, and cover • Provide food source and stable base for many stream channel aquatic organisms
Roots in the streambank	• Increase bank stability • Create overhanging bank cover
Stems and low-growing vegetation in the floodplain	• Retard movement of water, sediment, and floating debris in floodwater

Source: Adapted from Craven, S.; Jackson, G.; Swenson, W.; and Webendorfer, B. 1987. *The Benefits of Well-managed Stream Corridors* G-3404. Department of Agricultural Journalism, University of Wisconsin–Madison

The forest vegetation also protects the soil's infiltration capacity. Raindrops falling on exposed soil may have enough energy to break up soil aggregates. Individual soil particles are then easily eroded and washed into soil pores, clogging them and preventing rainwater absorption. When such conditions occur, water tends to flow over the soil surface, increasing the chance of erosion. But in a forest, rain is intercepted by the forest canopy, by the leaves of shrubs or small trees in the understory, and by the organic litter layer covering the forest floor, reducing the force with which rain falls on the soil. Soil pores remain unclogged, allowing infiltration.

Effects of Timber Harvesting

Cutting timber affects both water quantity and quality. Clearcutting (harvesting all trees) allows more water to flow to streams, because there are no leaves to intercept rain and snow (some of which would later evaporate) and roots no longer take water from the soil. Areas being considered for clearcutting should have a substantial ground layer of organic material to help minimize these effects. Much of the water taken into trees by their roots passes through the leaves into the atmosphere in a process called *transpiratio*n. Trees and other plants return water to the atmosphere through *evapotranspiratio*n—a combination of evaporation and transpiration. Evapotranspiration is an important process—during the growing season in a Pennsylvania hardwood forest, as much as sixty percent of the rainfall is returned to the atmosphere through evapotranspiration.

In the humid Northeast, the greatest increase in streamflow occurs during the first growing season after the clearcut. But in following years, as the area begins to revegetate, the increased flow lessens. Five to ten years after the cut, streamflow may return to precut levels. This effect on quantity is most important to managers of water-supply watersheds.

Of greater concern to woodland owners is the effect of timber harvesting on water quality. Because of the possibility of accelerating erosion, logging can contribute to sedimentation—the most damaging and widespread water pollutant from forested watersheds. Sediment harms water resources by destroying fish habitat, reducing the storage capacity of reservoirs, and increasing treatment costs for municipal water supplies.

The greatest problems do not occur as a result of the actual cutting of trees, but from moving them out of the forest, which re-quires the use of heavy equipment on a system of trails and roads. If the transportation system is not carefully designed and maintained, erosion on the watershed can be greatly in-creased, because roads account for the vast majority of sediment associated with timber harvesting.

In Pennsylvania, any activity, including timber harvesting, that disturbs more than 25 acres of earth requires a permit from the Department of Environmental Protection (DEP). Most timber harvests disturb less than 10 percent of the harvested area, so a permit is seldom required for logging fewer than 250 acres. Even if you are cutting less acreage, you must develop an erosion and sedimentation control plan and have it on site throughout the operation.

Protecting the Watershed

SKID TRAILS

Skidding is the process of dragging logs (usually with a rubber-tired tractor called a skidder) from the stumps to a central location, called a *log landin*g, where they are loaded onto trucks and transported to the mill. The process can be very damaging to the soil surface. The weight of the skidder compacts the soil, reducing its infiltration capacity. Dragged logs scour the soil surface, plowing away the protective litter layer and the upper inches of soil. These gouges become channels through which water can flow at erosive velocities, carrying sediment to the streams. The following practices help minimize the damage from skidding. Keep well away from streams and never use streambeds, even dry ones, as skid trails. If streams (even seasonally dry ones) must be crossed, cross them at a right angle with temporary bridges or culverts.

LOG LANDINGS

If not properly located, log landings have the potential to get very muddy or allow large amounts of soil to wash away. Log landings create large areas of unprotected, exposed soil. Because of the skidders and trucks working there, the soil can also become extremely compacted. Therefore, it is crucial that water be kept from flowing through, or collecting in, the landing area.

ROADS

Most erosion and sedimentation problems are caused by the haul roads constructed for logging trucks to carry harvested trees from the forest. Problems can occur both during road construction and after the transportation system is in place. Road construction greatly disturbs forest soil. The protective litter layer is removed, the mineral soil below is compacted, and steep, potentially unstable cut-and-fill slopes are often created. Roadbeds increase surface runoff (by reducing infiltration) and also concentrate the runoff, creating favorable conditions for accelerated erosion.

Natural drainage patterns may be altered—water that once flowed below the surface may be intercepted by road cuts. This formerly subsurface water now seeps from road banks. Road-stream crossing are an especially sensitive area. The presence of flowing water in a stream channel means any disturbance of the streambanks or bottom immediately sends sediment into the stream. To lessen these problems, a haul road system must be properly planned and designed. The shorter the better. Roads should be designed with grades of 2 to 10 percent. Some grade is needed to prevent water from collecting, but grades of more than 10 percent are hard on equipment and promote erosion.

Beyond Logging

In addition to timber harvesting, water quality can be harmed by the following activities:

RECREATION

A forest that is used for recreation often requires roads and sewage facilities. Both of these are potentially harmful to water resources. Install and maintain access roads at least as well as you would logging roads. Ideally, even more care is needed because the road will be used continually and will not be retired after a timber sale. Make sure sewage facilities are located away from water. Such facilities must be properly designed, installed, and maintained. In addition, restrict recreational vehicles to existing roads and trails that avoid sensitive areas such as wetlands and shallow streams.

PESTICIDE APPLICATION

When applying pesticides, follow the label directions and take precautions to prevent spray from landing directly on water. Avoid areas with streams by designating "no-spray" buffer zones and select materials, equipment, and weather conditions that will minimize spray drift.

MINERAL EXTRACTION

Coal mining (strip mines and deep mines) and oil and gas development can degrade water quality dramatically. Mining often contaminates water by producing sediment and acidic drainage that has a high iron and sulfur content. Acid mine drainage causes the formation of "yellowboy" (ferric hydroxide), a yellowish slime that coats stream bottoms. In addition to sediment from access roads, pipeline rights-of-way, and well sites, the use of oil and gas wells makes it difficult to dispose of the brine pumped up with the deposits. In either case, protecting surface water and groundwater is difficult.

CHOOSING STEWARDSHIP

Water resources are intimately connected to land use. The quality of our water resources is affected by the manner in which we use land. Some land-use practices protect water; others degrade it. Forests protect people and wildlife. They are natural guardians, consistently providing us with high-quality water for drinking, fishing, swimming, boating, or simply enjoying the intrinsic natural beauty of a clear stream, lake, or pond. Forests have a great influence on water. Be aware of this connection when using the various resources of your forests and you will profit by enjoying the many benefits of clean water**.**

Revised by Allyson Muth, research support associate.

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