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Forests and Urban Stormwater

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Introduction

Trees and forests are important to water management in all settings in Arkansas. Most people recognize the valuable role forests play in stormwater management in rural settings, but often the role trees play in assuring healthy water supplies and in stormwater management for urban areas goes unrecognized. This fact sheet will focus on the functions and uses of trees in stormwater management in urban areas.

Arkansas' landscape is changing. As we enter the 21st century, urban areas are spreading rapidly. As urbanization of the landscape increases, stormwater management problems increase. Existing stormwater facilities in some places are being swamped by the volume of stormwater generated by new development. Many past management practices have proven inadequate to handle current stormwater volume and also have proven detrimental to the environment. Clearly, we need to change our thinking and view our existing landscape and forests as part of our stormwater infrastructure. Stormwater management is evolving in that direction as traditional management costs increase and we learn to reduce costs by retaining stormwater for utilization on-site rather than transporting it off-site to the nearest body of water.

What is stormwater?

Stormwater is the flow of water that results from precipitation and which occurs immediately following rainfall or as a result of snowmelt. When a rainfall event occurs, several things can happen to the precipitation. Some of the precipitation infiltrates or soaks into the soil surface, some is taken up by plants and some is evaporated into the atmosphere. Stormwater is the remaining portion of the precipitation that drains from the land surface and from soils.

In urban and suburban areas, much of the land surface is covered by constructed and impervious surfaces, such as buildings and pavement, which do not allow rain to soak into the soil surface as it does in naturally vegetated areas, so more of the rainfall becomes stormwater runoff. Most developed areas rely on storm drains to carry large amounts of runoff from roofs and paved areas to nearby waterways.

Why is stormwater a problem?

Storm sewer systems concentrate runoff into smooth, straight conduits. This runoff gathers speed and erosional power as it travels underground. When this runoff leaves the storm drains and empties into a stream, its excessive volume and power blast out stream banks, damaging streamside vegetation and wiping out aquatic habitats (Figure 1).

Figure 1. Excessive stormwater results in erosional damage to stream channels.

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The stormwater carries sediment from construction sites and other denuded surfaces. Water from streets, roof tops and parking lots is often warmer than that from other surfaces, which can be harmful to the health and reproduction of aquatic life.

Not only does stormwater volume and peak flow increase, but storm flow from urban areas carries more pollutants into streams than stormwater from forests. Many homeowners use pesticides and fertilizers on their lawns. Some of these homeowners ignore recommendations and use more, or far more, than necessary. These materials, along with grass clippings, pet wastes and petroleum wastes from streets and driveways, directly enter streams or enter through municipal stormwater systems. Since stormwater is not treated, anything that enters a storm sewer system is discharged directly into the waters we use for swimming, fishing, and as drinking water. Where it enters drinking water sources, the cost of municipal water treatment is increased. If water treatment is inadequate, this can affect human health.

Household hazardous wastes like pesticides, paints, solvents, used motor oil and other auto fluids can poison aquatic life. Debris such as plastic bags, six-pack rings, bottles, cups and cigarette butts which enter water bodies can choke, suffocate or disable aquatic life like ducks, fish, turtles and birds (Figure 2). Bacteria and other pathogens in stormwater can wash into swimming areas and create health hazards. Land aimals and people can become sick or die from eating diseased fish or drinking polluted water.

Figure 2. Aquatic wildlife can be injured or killed by debris washed into streams with stormwater.

The sediments in stormwater can cloud the streams and lakes and make it difficult or impossible for aquatic plants to grow. Sediment also fills in the spaces around rocks and woody debris in streams. These spaces are critical habitats for aquatic organisms which are the foundation of the aquatic food web. Excess nutrients can cause algal blooms. When algae die, they sink to the bottom and decompose in a process that removes oxygen from the water. Fish and other aquatic organisms can't survive in water with low dissolved oxygen levels.

How do trees fit into the stormwater picture?

Wild forests (as opposed to urban forests) are ideal settings for stormwater management; however, they are incompatible with some human activities. For example, one would not want to play football in a forest. Also, light automobile traffic, or even heavy foot traffic, can compact soil, which can kill tree roots. Urban forests, because of their lower stand density, are less effective at stormwater management than wild forests, but they still provide many benefits in stormwater management.

Let's look at the value of trees in stormwater management, starting with the point where rain first contacts the tree – the canopy. The canopy of a tree is the layer of leaves and twigs that forms the top of the tree. Because urban trees are frequently solitary, the crown may form a shell that covers the upper half or more of the trunk. Raindrops fall at a speed of 5 to 20 mph, depending upon size of the raindrop. An individual raindrop won't pack much wallop, but what about a rain storm? A one-inch rain can deliver about 45 foot-pounds of energy per square foot of soil. That's enough energy to break soil into fine particles which are easily transported. Some of those particles are transported down slope while others clog pores in the soil, reducing infiltration and increasing runoff.

Raindrops falling through a forest canopy impact leaves and twigs and dissipate energy into the tree rather than the soil. Much of this water will be retained on the leaves and twigs for a time. Some of the water retained on the tree drips off the leaves or runs down the limbs and trunk to the soil over a period of time. That time lag delays and reduces the volume of peak storm flow, which reduces the impact of stormwater on stream channels.

Some of the water which is retained on the leaves and twigs never reaches the ground. It evaporates directly from the leaves and twigs and does not contribute to stormwater. Research in forests similar to those found in Arkansas indicates that 12% to 18% of rainfall that falls over mature forests never reaches the ground. A 15% reduction in stormwater doesn't sound like much, but think about it this way. If we assume a storm dropping one inch of rain, a modest storm, this reduces stormwater by more than 4,000 gallons per acre of watershed. Obviously, urban forests are less dense than wild forests, so stormwater reduction will be less.

Both deciduous and evergreen forests annually drop leaves which accumulate on the forest floor as leaf litter. Leaf litter absorbs the energy of the falling rain that gets through the canopy without striking a leaf or twig. Leaf litter also slows surface flow of stormwater and traps much of the sediment and other pollutants carried by stormwater. Most homeowners remove leaf litter in urban areas, leaving the soil vulnerable to erosion and compaction (Figure 3). Dense grass can substitute for some of these benefits; however, grass cannot provide all of the benefits provided by urban forests.

Figure 3. Manicured lawns mitigate some stormwater but are not as effective as urban forests.

Trees also use a substantial volume of water. This water is absorbed from the soil by the roots and released through the leaves to the atmosphere in a process called transpiration. A mature tree can transpire around 50 gallons of water per day, every day through the summer. This is more water than will evaporate from nonforested soils. This process provides two benefits. First, some of the water from storm events is transpired by trees before it reaches streams. That's 50 gallons per tree per day that doesn't enter streams as stormwater. Even well after a storm event, trees continue to extract water from soil. By reducing soil water content below the saturation level, trees make room in the soil for even more water from the next storm event.

Tree roots provide another benefit, as well. Roots are not permanent. Trees continually lose and replace some of the roots. As these dead roots decay, they provide larger channels for water infiltration into the soil. Some evidence indicates that water moving along the root surfaces may infiltrate even dense soil layers. As a result of these processes, less water is available for overland flow and some water infiltrates deeply enough to enter groundwater. Tree roots also absorb some of the pollutants, such as fertilizers, present in stormwater.

Forests provide many benefits in stormwater management. They intercept rain before it becomes stormwater and return part of the rain to the atmosphere. Forests also return water to the atmosphere through transpiration. Forests deposit mulch, which protects the soil from rain impact, and their roots create infiltration channels and absorb some pollutants.

How can we use trees to manage and mitigate stormwater?

When we discuss using trees in urban stormwater management, we really need to discuss two separate situations. First, we need to consider some of the issues we will deal with when wild lands are newly converted to urban or industrial uses. Second, we need to consider some of the issues associated with areas long ago converted to urban or industrial uses. These differences are important because areas which have not been in urban use have a much more dense forest than those which have been in urban use for many years.

Land Conversion

Often when wild land is converted to urban uses, the site is first cleared of all vegetation to facilitate regrading the site to improve construction efficiency (Figure 4). Ornamental trees may be added to the site afterwards. The reduction in forest cover that comes with development will increase the stormwater runoff from the site and change the character of the runoff.

Figure 4. Save as many trees as possible on land under development. Protect trees during construction.

Clearing the vegetation from the site has several negative effects. First, the volume of stormwater increases dramatically. Only about 10% of rain from moderate storms enters streams as stormwater from an intact forest. The remaining 90% is returned to the atmosphere through evapotranspiration or percolates into the soil and is held there until it is taken up by plant roots. In contrast, 40% to 55% of rain falling on lawns runs off as stormwater. The percentage is even higher for impervious surfaces such as streets or roofs. This increase in storm flow erodes stream channels. When this stormwater is diverted away from natural systems and into storm drains, a significantly greater load is placed on municipal stormwater systems.

Stormwater volume isn't the only thing that changes. Stormwater runs off lawns more quickly than off forests, so the stormwater from a rain event is delivered to the stream over a shorter period of time. Since a greater volume of water is being discharged during a shorter time period, peak storm flow is greater, which causes higher water levels, more erosion in stream channels and potentially more flooding.

Several general guidelines will be helpful for planning stormwater management before development begins. First, leave buffers of undisturbed forest along streams. Thirty-five feet on each side of the stream channel should be considered the minimum. Wider buffers should be considered on sloped sites. It may be tempting to incorporate these buffers into parks, but this should not be done because most parks are raked clean to facilitate usage. Leaf litter is important to the function of buffer strips. Removing the leaf litter and the foot traffic associated with park uses results in soil compaction and greater runoff. Light foot traffic will not harm buffer strips, but heavy foot traffic should not be encouraged. Don't set up picnic tables in the buffer strips. Paved walking trails through the buffer strips will not greatly impede buffer function; however, care should be taken to preserve water flow through the buffer strip. Do not place walking trails within 25 feet of the stream channel.

Trees in buffer strips should not be removed unless absolutely necessary. Removing a few hazardous trees will not impair the function of the buffer strip, but do not remove more trees than necessary. Trees absorb water from the soils of the buffer strip before that water reaches the stream channel. Fewer trees result in more water delivered to the stream. Trees also provide the leaf litter which protects the soil from overland flow and erosion.

All of the trees on the site are important to stormwater management; however, development cannot take place without removing some of the trees. Developers must balance the need to remove trees for safe and efficient development with leaving trees for stormwater management. Remove only trees which must be removed to safely accomplish development. To the extent possible, the healthiest trees should be left on the site. In general, healthy trees will be part of the upper forest canopy on the site. Seek the advice of a consulting forester to determine which trees should remain after development. Construction activities around trees can severely damage root systems. See UACES fact sheet FSA5011, *Ten Easy Ways to Kill a Tree (And How to Avoid Them)*, for more information about protecting trees during construction. The fact sheet is available from the Cooperative Extension Service web site or your county extension agent. Also, consider planting trees after development is complete. Don't forget to look for tax breaks and conservation easements to help offset some of the cost of leaving trees for stormwater management.

Peak storm flows can be delayed and reduced by holding stormwater in detention or infiltration basins. Detention basins can take the form of constructed wetlands which hold water permanently and serve as sinks for stormwater. Detention basins usually have wetland vegetation, including trees, around the edges and may have an outlet to a creek or other drain for excess stormwater. Infiltration basins serve a similar function; however, they do not hold water permanently. They are dry most of the time and are designed to hold water only immediately after a storm event. Infiltration basins have no surface outlet. As the name implies, water soaks into the soil from infiltration basins. Infiltration basins contain vegetation which may include shrubs and trees which can tolerate flooding for short periods.

Existing Urban Areas

While it is relatively easy to plan stormwater management before development is conducted, changing stormwater management practices in existing urban areas is much more difficult. Streams have already been moved to surface or underground concrete conduits, buffer zones have been covered with lawns or impervious surfaces, and almost all available land has been put to residential or commercial use. Little land is available to manage stormwater on-site in these situations. Municipalities can maintain the health of existing trees and plant new trees where opportunities are available. Isolated trees still catch rainfall before it enters the stormwater stream and help remove soil water before it enters streams.

Sometimes opportunities may be found in existing urban landscapes. Most urban areas contain at least some land suitable for urban forests. These areas include lawns, parks, athletic complexes, schools, road medians and cemeteries. While some parks and athletic complexes will not be suitable for trees because of the type of use, often parts of these public lands can support an urban forest. Public lands are the easiest to incorporate into a stormwater management system because they are publicly owned and already under control of the local government. Protect existing trees on these properties and plant trees where they are appropriate. Cemeteries and lawns, even though privately owned, could be incorporated into stormwater management systems through offering incentives to maintain or establish tree cover. Tree protection ordinances can be used to maintain forest canopies on private properties where incentives produce inadequate results, but these ordinances often are unpopular. Many private citizens and businesses are eager to participate in green redevelopment. Those who own land adjacent to streams may be willing to donate easements along streams so that buffer strips can be installed where none currently exist. Citizens are often willing to help plant trees, as well.

When urban sites are redeveloped, opportunities arise to install stormwater management systems. Soils under parking lots, roads and sidewalks can be used to temporarily store stormwater. Engineered soils are available that provide greater water storage capacity than compacted soils typically found under parking lots without a loss in soil strength. Stormwater should be directed to the storage under the parking lot instead of being directed into stormwater drains. These systems should be used in conjunction with trees to dispose of stormwater on-site. The trees are important to making this system work because the trees reduce the stormwater volume entering the system and remove stormwater from the engineered soils through transpiration. The tree roots penetrate compacted subsurface soils and provide channels for infiltration to further remove water from the engineered soils. Trees must be carefully matched to local rainfall patterns to provide a good balance between tolerance to flooding and tolerance to drought.

Urban soils are often compacted enough to reduce stormwater infiltration. Compaction results in poor plant growth and increased stormwater runoff. In the long term, trees can remediate compacted soils and improve water infiltration. Tree roots growing through the soil create open channels for air and water infiltration. Besides increasing infiltration, the increase in soil porosity will improve plant growth and further increase the value of the site for stormwater management.

Conclusion

Stormwater management is a significant cost for many cities and can have a significant impact on our environment; however, the costs and impacts can be reduced. Appropriate planning at the time of development or redevelopment greatly reduces the cost of stormwater management in terms of dollars and environmental impact. Even when redevelopment is not an option in the near future, proper management of the urban forest can reduce stormwater costs and impacts.

Available Resources

The concept of Low Impact Development (LID) and other sustainable stormwater management techniques is gaining popularity. Increased awareness of "green development and construction" in urban areas is causing urban planners to develop new approaches to stormwater management.

The Low Impact Development Center, Inc. promotes a planning and design approach with the goal of maintaining and enhancing the predevelopment hydrologic regime of urban and developing watersheds. The link to their site is: http://www.lowimpact development.org/index.html

The Watershed Forestry Resource Guide provides information on the role of trees in stormwater management. The link to their site is: http://www.forestsforwatersheds.org/

The Stormwater Management consortium has a web site which describes uses of trees in "structural soils" for stormwater management. The link to their site is: http://www.cnr.vt.edu/urbanforestry/stormwater/index.html

The Urban Forestry South Expo web site contains information on a wide range of urban forestry topics including stormwater issues. The link to their web site is: http://www.urbanforestry south.org/

The Urban Design Tools web site has a number of design tools and ideas for low impact urban development. Some of these designs make use of trees for stormwater management. The link to their web site is: http://www.lid-stormwater.net /index.html

The Environmental Protection Agency web site provides abundant information on stormwater management. Links to their sites are: http://www.epa.gov/guide/stormwater/
http://www.epa.gov/npdes/pubs/nps_urban-facts_final.pdf
http://www.epa.gov/nps/lid/

The American Forests web site has documents describing the benefits and uses of trees in urban stormwater management. The link to their site is: http://www.americanforests.org /graytogreen/stormwater/

The Villanova Urban Stormwater Partnership web site provides information on stormwater management. The link to their web site is: http://www3.villanova.edu/vusp/

The Stormwater Center provides an array or resources for stormwater management planning. The link to their site is: http://www.stormwatercenter.net/

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