

Forest Management in the Interface: Water Management¹

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A concern often voiced by interface residents is the continued supply of clean water to both people and natural ecosystems. Managing water in the wildland-urban interface requires an understanding of the water cycle and how urbanization alters its pathways and rates of flow. This fact sheet briefly describes the role of forests in the water cycle and the hydrological effects of land development. At the interface many of these changes can be prevented or mitigated, especially through proactive planning that involves resource professionals, land-use planners, and residents. It introduces four strategies for lessening the negative hydrological effects of urbanization: protecting forests, reducing impervious surface cover, controlling sources of pollutants, and managing stormwater runoff.

Effects of Urbanization on the Water Cycle

Forests play a critical role in the global water cycle, acting as an enormous net that intercepts precipitation and releases most of it back to the atmosphere. In contiguous forests, approximately two-thirds of incoming precipitation is returned to the atmosphere through evaporation from soil and plant surfaces and transpiration by plants. The remaining water infiltrates the soil, where it is filtered and stored, eventually recharging groundwater and contributing to base flow in streams. Forests can absorb much of the rainfall

from most storms, and therefore they contribute little if any storm-water runoff to surface waters.

Forest clearing for development generates increased storm-water runoff and reduces the amount of precipitation that soaks into the ground. This is the case even when other types of vegetative cover such as lawns are substituted, because they have less ability than forests to trap and transpire water. However, by far the greatest hydrological changes result when forests are replaced with impervious surfaces such as roads, driveways, parking lots, and rooftops. In these cases, rainfall does not infiltrate at all and quickly runs off, reaching streams or lakes in minutes in contrast to the hours, days, and even months that infiltrated rain may take. The total volume and peak discharge rate of runoff increase (Schueler 1995), leading to more frequent and more extensive flooding downstream.

Storm water carries nutrients, pesticides, heavy metals, sediment, and other pollutants that it washes from lawns, roads, and other surfaces. In urbanizing areas, the result of the altered hydrology and the greater pollutant loads is physical and biological degradation of the receiving ecosystems, including streams (Paul and Meyer 2001) and wetlands (Ehrenfeld 2000). The degree of degradation is correlated with the amount of impervious cover in the watershed (Schueler 2003). Even cover values of 10 percent or less have been associated with changes in stream fauna in some areas.

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Because precipitation tends to run off rather than infiltrate the soil, urbanizing areas lose their ability to recharge underlying groundwater. This results in less water both for base flow of streams and for rural residents, whose drinking water needs are often met by local groundwater resources.

Strategies for Preventing or Minimizing Threats to Water Resources

The threats to water resources posed by land development are difficult and costly to offset in densely urbanized areas, but they can be lessened or even avoided at the wildland-urban interface (Korhnaak and Vince 2005). The most promising approaches aim to maintain the predevelopment water cycle and are framed within a watershed management plan.

A watershed is an area of land that drains water, sediment, and dissolved materials to a common water body. It is the most appropriate geographic unit on which to focus water protection efforts, although its limits rarely correspond with political and property boundaries. A watershed management plan is a long-term strategy for protecting water resources and human health. The producers of a plan—stakeholders, including planners, resource professionals, and residents—consider all the factors that affect water quantity and quality in a watershed; set appropriate management goals by integrating ecological, social, and economic considerations; and decide on the actions and tools to best achieve these goals.

The following are four general strategies for managing water at the interface that are increasingly being considered in watershed management plans. A common feature is their intent to treat the underlying causes of hydrological changes rather than the consequences.

Forest Protection

Forest protection is the cornerstone of an effective watershed management plan. Making certain that forests' natural hydrological systems are retained is often less costly and more effective than replacing these systems with technological solutions. Sufficient forest cover can offset the effects of impervious cover in watersheds with low-density development. For example, in Puget Sound watersheds where impervious cover is 4 percent, forest cover of 65 percent can prevent excessive storm-water flow (Booth, Hartley, and Jackson 2002).

The Center for Watershed Protection produced a manual in collaboration with the USDA Forest Service that details how to assess watershed forest cover and how to prioritize forest parcels for protection (Cappiella, Schueler, and Wright 2005). Large tracts of undeveloped forest have high priority, but where the forest is located is also a factor. Because of their landscape position, riparian forests are especially important for protecting the water quality of adjacent streams and lakes. They intercept and remove pollutants and sediment that enter from the uplands, buffering receiving waters from watershed land use changes. Forests associated with small headwater streams are often most vulnerable to urban degradation, but they are especially important in regulating the water quality of the entire watershed and need protection.



Figure 1. Retention ponds help remove pollutants from storm water. Credits: Larry Korhnaak

Communities may employ a variety of means to ensure the protection of sufficient forest cover in their watershed (Cappiella, Schueler, and Wright 2005). Land acquisition generally affords the most protection, but it is too expensive to play more than a small part. Other less costly tools for protecting lands, such as conservation easements and transfer of development rights, allow lands to remain in private ownership and compensate the owners for keeping the lands undeveloped. Also, a number of regulatory tools can be applied to reduce forest clearing associated with development. These include forest conservation regulations, special types of zoning, and stream buffer ordinances.

Reduction of Impervious Cover

Because impervious cover and altered hydrology are so closely linked, an important strategy for managing water in the interface is to minimize the extent of paved surfaces. A key element is reducing the size of the transportation network, the main component of impervious cover in an urbanized watershed (Schueler 1995). This can be accomplished at various spatial scales, from the regional level to local parking lots (Table 1).

At the regional level, concentrating growth within existing urban centers limits sprawl and, therefore, the extension and proliferation of roads. New residents live closer to workplaces and shops and require fewer additional roadways to meet transportation needs. A variety of growth management tools are available for promoting infill development and controlling sprawl (Myszewski and Kundell 2005).

A recent approach to site design called clustering or conservation design promotes more compact development of residential subdivisions. Homes are clustered on smaller lots, requiring fewer and shorter roads and leaving more undeveloped areas than conventional designs. The consequence in many cases is a substantial decrease in impervious cover and projected stormwater runoff (Zielinski 2002). Even in more standard developments, the extent of paved surfaces can be reduced by many means (Schueler 1995).

Parking lots are the greatest source of impervious cover in commercial developments. They can be downsized by making various design changes and by reducing the number of parking spaces to meet normal rather than peak parking demand (Zielinski 2000).

Control of Pollutant Sources

Water quality in urbanizing watersheds declines not only because water moves off the land more rapidly, but also because it carries more nutrients and pollutants added by human activities. Each new resident increases the demand for water by about 700 liters per day (Solley, Pierce, and Perlman 1998) but only drinks a liter. Most public water is used for waste flushing and washing, introducing nutrients to surface and groundwaters. In many interface landscapes, more fertilizers and pesticides are applied to residential lawns and golf courses than to agricultural fields. Lawns frequently cover the largest surface area in urban watersheds and can be the greatest source of phosphorus in runoff (Waschbusch, Selbig, and Bannerman 1999). Therefore, the two primary ways of controlling pollution sources in the interface are limiting fertilizer application and improving the treatment of wastewater.

Many communities have initiated programs to encourage landowners to adopt gardening practices and landscape designs that use fewer pollutants and produce less runoff. The town of Falmouth, Massachusetts, has sent a brochure to every homeowner explaining the connection between lawn fertilization and water quality impairment and describing better lawn care practices to reduce nutrient leaching. These methods include recycling lawn clippings

back onto the yard and testing the soil prior to fertilization, then fertilizing only when and in the amount needed. Other programs, such as BayScapes around the Chesapeake Bay and Florida Yards and Neighborhoods, use extensive outreach and demonstration gardens to promote attractive alternatives to lawns that require less input of water and chemicals. In some areas, control of nutrient inputs is mandated: a Minnesota law prohibits phosphate in lawn fertilizer in the Twin Cities metropolitan area and limits its content to 3 percent in other areas of the state.

In rural areas and much of the wildland-urban interface, most homes are beyond the reach of public sewer lines and instead use on-site systems for disposal of wastewater. Conventional septic systems consist of a belowground holding tank that receives the raw wastewater and a drainage field where pollutants in the partially treated wastewater are removed by adsorption and microbial degradation. The effluent then disperses into surrounding soils and flows down slope, ultimately entering groundwater and receiving water bodies. The retention efficiency of on-site systems, and therefore the amount of nutrients and pollutants escaping treatment, varies greatly. One survey found that nitrogen retention ranged from 10 to 90 percent and averaged 46 percent (Valiela et al. 1997). Factors contributing to poor performance of septic systems include improper sizing, inadequate maintenance, and unsuitable soil conditions.

Rural communities face a challenge in ensuring that the cumulative impact of numerous septic systems does not compromise their water resources. This is particularly important when a single aquifer serves the dual role of receiving wastewater and providing drinking water. Management tools include zoning to limit the density of on-site systems and setback rules to prevent installation of septic systems too close to wells and surface waters. Special wastewater disposal restrictions can be applied to areas with shallow soils, steep topography, and unprotected aquifers. New on-site systems need to be inspected for proper installation and functioning, and older, failing ones need to be identified and eliminated.

It is important to recognize that wastewater disposal is often the de facto controller of land use in the wildland-urban interface. Building permits frequently depend on septic tank permits; when rules for on-site systems are relaxed, the amount of land that can be developed increases. In some cases, a community may have little choice but to replace septic systems with a more efficient, centralized wastewater plant. While in the short term this change can decrease the pollution threat to water resources, it is likely to result in more rapid development and greater population density.

Management of Storm Water

Storm-water management has long been required in urbanizing landscapes because land development inevitably results in increased surface runoff. In the past the aim was to solve on-site drainage problems by moving storm water off-site as quickly as possible via connected impervious surfaces. Often this merely transferred the flooding and pollution problems downstream, and so a variety of Best Management Practices (BMPs) have been designed and implemented to manage better the stormwater generated by developed areas. The newest techniques, collectively termed low impact development (LID) practices, promote water infiltration and treatment at the source of surface runoff, thereby preventing excessive and polluted runoff.

The goals and designs of detention ponds, the most common type of constructed BMP, have greatly evolved during the past two decades (Wang 2002). These ponds capture, detain, and slowly release storm-water runoff from developed areas, preventing peak discharges from exceeding pre-development levels. More recently, the goal has extended from flood control to water quality improvement, and many jurisdictions require that detention ponds are sized and configured to hold water longer and so enhance pollutant settling. Other types of BMPs, such as retention ponds, infiltration basins, and constructed wetlands, are even better at removing pollutants from storm water.

Although many conventional BMPs are effective at cleaning runoff and reducing peak discharge rates, they do not address the fundamental problems of excess surface water generation and insufficient groundwater recharge in urbanized watersheds. The LID approach tackles these problems at the source—where water hits paved and other impervious surfaces. The objective is to treat the water where it falls and to direct it back into the ground, restoring the natural hydrological pathways of infiltration and evapotranspiration. The Department of Environmental Resources in Prince George's County, Maryland, (PGCDER) has pioneered the LID approach to storm-water management and produced a design manual for national use (PGCDER 1999). Up-to-date information can be found at the Low Impact Development Center Web site <http://www.lowimpactdevelopment.org/>.

LID techniques can be applied to residential and commercial lots of various sizes and to parking lots. A number of tactics are used in combination to achieve the goal of restoring pre-development hydrological processes: conservation of critical natural features and permeable soils; reduction and disconnection of impervious surfaces;

slowing of runoff; and distribution throughout the development site of microscale management practices to reduce and clean storm water. Some of the on-site management practices, such as vegetated rooftops, store and evaporate precipitation where it falls, reducing the volume and rate of storm-water discharge. Others route stormwater from hard roofs, parking lots, and driveways to depressions on the site that are specifically engineered to hold back and treat water. LID designs exclude conventional curb and gutter systems, which store and move storm water underground, and instead convey water through open grass channels and wetland swales.

Although use of LID techniques is growing, most new developments still depend on conventional stormwater management. Steep slopes, impermeable soils, and a shallow water table may prevent use of LID techniques on some sites. Other obstacles to widespread adoption of LID practices include homeowner misperceptions, lack of familiarity with LID techniques on the part of developers and engineers, and local development regulations that forbid some LID practices such as open roads without curbs and gutters. Better education, changed ordinances, and incentives such as stormwater credits may help to overcome some of these barriers. In regions that experience large storm events, a combination of conventional BMPs—such as detention ponds, and LID practices—is likely to provide the best solution for handling the storm water generated by development.

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Table 1. Ways to minimize impervious surfaces

Scale	Goal	Techniques
Regional	Reduce extent of transportation network	Incentives and regulations to promote infill in existing urban centers and control sprawl
Subdivision	Reduce extent of paved surfaces used for parking and transportation	Fewer, shorter, narrower streets Shortened, shared driveways Fewer sidewalks Elimination of cul-de-sacs Substitution of permeable pavements or gravel on driveways
Parking lot	Limit area of pavement	Fewer parking spaces Narrower driving aisles Smaller stalls for compact cars Grass or porous pavement on overflow lots