Article 129

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The Peculiarities of Perviousness

Much has been made of the importance of imperviousness in determining the quality of aquatic systems in urban watersheds. Indeed, impervious cover is a very useful measure to predict current and future stream quality (Schueler, 1995). Still, pervious areas dominate much of the urban landscape, and their management should not be ignored or neglected. Many urban water managers feel that land that hasn't been paved must be providing some benefit to the watershed. While it is true that pervious areas are generally green, this does not always imply that they are environmentally benign. In fact, many pervious areas in the landscape are as intensively managed or cultivated as any cropland, as far as the input of water, fertilizer or pesticides are concerned.

In this article, the hydrology and pollutant dynamics of pervious areas are explored. To do so, it is necessary to examine the types and distribution of pervious cover found in urban landscapes. Next, the complex interactions of pervious and impervious cover are investigated, particularly along the many edges between the two. The next section examines the hydrological consequences of the direction of flow from pervious areas to impervious ones, and vice versa. Finally, this paper looks closely at the pervious areas that receive high inputs of chemicals and water: lawns, golf courses, and public turf areas. The evidence that this high input turf, which comprises perhaps a third of all pervious areas, influences the water quality of urban streams is evaluated.

The Many Natures of Perviousness

Pervious areas are very diverse in size and vegetative cover. Each community consists of a mosaic of forest, wetlands, meadow, lawn, turf, landscaping and the ubiquitous "vacant" lands. While the mix among these types varies based on the history and intensity of past development, pervious cover can be grouped into one of six general types (Figure 1). The estimated distribution of each type of pervious cover in a typical urban landscape is shown in Figure 2. It should be noted that these estimates are a composite drawn from many different sources and regions, and should be considered very provisional. More accurate local estimates of the distribution and management of pervious cover need to be developed.

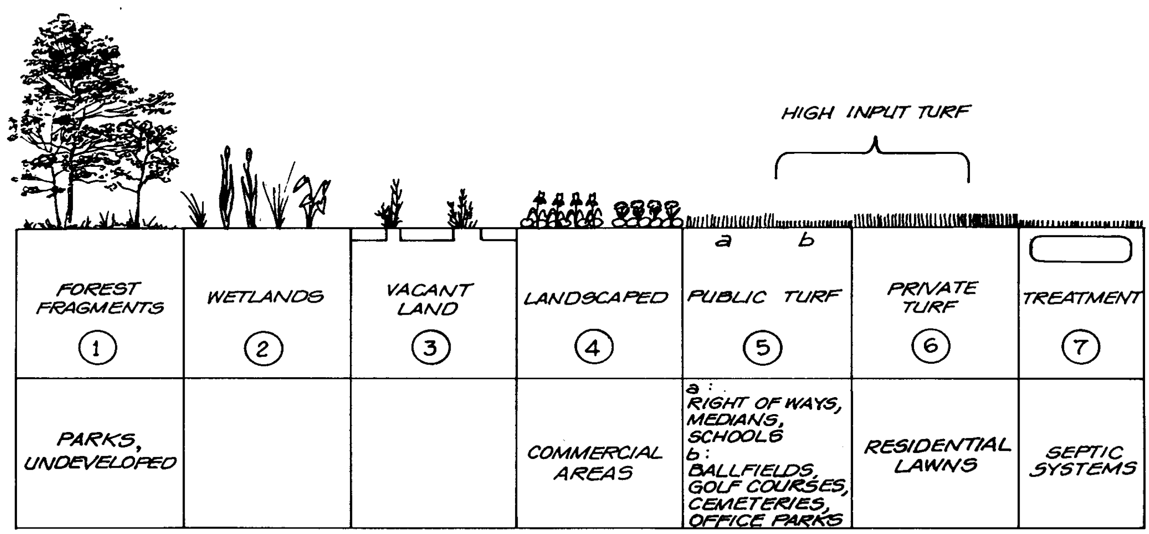

Figure 1: The Six Categories of Pervious Cover in the Urban Landscape

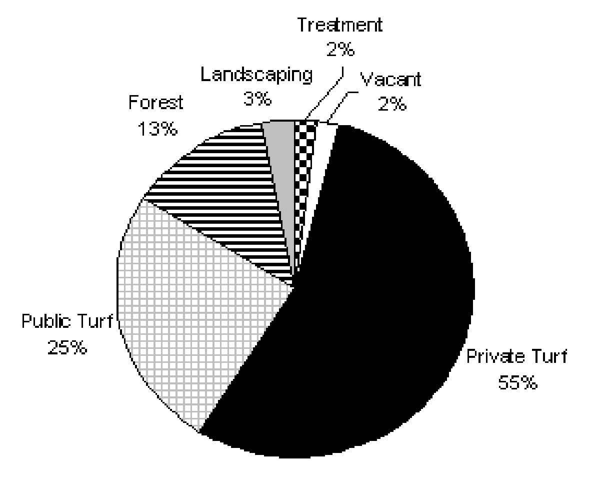

Figure 2: Distribution of Urban Pervious Cover

1. Forests and Wetlands

The extent of forests and wetlands in the urban landscape varies considerably from one region of the country to another, and even one city to another. After several decades of urbanization, however, much of the forest cover is restricted to public parks, stream buffers and the like. An example of the progressive loss of forest cover over time is seen in Sligo Creek, MD where the clearing of forests for new development has reduced forest cover to about 8% of watershed area over five decades, with the overwhelming majority now confined to the park system (MWCOG, 1991). The composition and diversity of the forest often changes remarkably due to urbanization, with a strong shift to non-native tree species and invasive shrubs and vines (Adams, 1994). As many as 30 to 60% of native forest species disappear from the highly urban forest community. Much of the forest cover in urban areas is often limited to isolated stands or individual street trees. While these small forest islands are important, they lack the structure, soils, and understory found in natural forests.

2. Private Turf (Lawns)

Our best estimate of the extent of home lawns is that they comprise about 70% of the total turf area in our urban landscape (Cockerham and Gibeault, 1985). Various authors estimate that lawns occupy a total area of some 25 to 30 million acres across the country (Roberts and Roberts, 1989). The lawn category can be further subdivided into high and low input lawns. High-input lawns are defined as those that are regularly fertilized, irrigated and receive applications of herbicides or insecticides. Homeowners apply chemicals to roughly two thirds of high-input lawns, while the remaining third is treated by lawn care companies. Low-input lawns are defined as those lawns that are regularly mowed, but seldom receive any chemical inputs. Surveys indicate that the percentage of high- and low-input lawns are about equal in urban areas.

3. Public Turf

About 30% of the remaining turf in urban areas is devoted to "public turf," located within parks, golf course, schools, churches, cemeteries, median strips, utility corridors and office parks. The greatest share of public turf appears to be contained within parks, golf courses and school grounds (Cockerham and Gibeault, 1985). Management of public turf runs the gamut from regular mowing to very intensive turfgrass management (e.g, golf courses). Reliable estimates on the management status of public turf are hard to find, but it is thought that at least a third of it falls into the high input category.

4. Intensively Landscaped Areas

Commercial areas can comprise up to 20% of the urban landscape. Although commercial areas are highly impervious, many localities require that five to 10% of the site be intensively landscaped to provide visual relief, shade and create a more attractive environment. Much of this landscaping is in small fragments that are graded to run onto adjacent impervious areas.

5. Vacant Lands

Some portion of urban lands are always in transition from one use to another and remain vacant until that change occurs. In general, these vacant or open lands are temporary in nature and receive little in the way of vegetative management. They are frequently invaded by invasive or pioneer plant species. Depending on how long an area has been vacant, the cover can range from bare earth, weeds, meadow or shrubs. Erosion can be severe if vegetative cover is poor.

6. Treatment Areas

This last category includes lands devoted to treating urban stormwater runoff or septic system effluent. Collectively, these areas can constitute up to 3% of total area, and may be composed of open water (stormwater ponds and wetlands), grass (septic systems, filter strips and grass swales) or stone (infiltration trenches).

Pervious but Not Natural

Nearly all of the pervious cover types have been highly disturbed and lack many of the qualities associated with similar pervious cover types situated in non-urban areas. Perhaps the greatest single change relates to the disturbance of native soils. Development usually involves wholesale grading of the site, removal of topsoil, severe erosion during construction, compaction by heavy equipment, and filling of depressions.

In recognition of this disturbance, most soil surveys change the native soil type to the ubiquitous moniker "urban soils" after a site is developed. Urban soils tend to be highly compacted, poor in structure and low in permeability. As a result, urban areas often produce more runoff than before they were disturbed. For example, Pitt (1992) noted that one third of the disturbed urban soils he tested in Milwaukee had an infiltration rate of zero or near zero, exhibiting the same runoff response as concrete or asphalt.

Many pervious areas are also heavily influenced by stormwater that runs on from adjacent impervious areas, such as rooftops. These pervious areas actually receive an extra water subsidy, over and above the rainfall. Many pervious areas are also quite thirsty, and must be extensively irrigated during the drier summer months. Indeed, water demand for lawn irrigation often sharply increases municipal water use during the summer, and lawn watering restrictions are among the first restrictions to be taken extreme droughts.

The Edge Effect: Fragments of Pervious Cover

When seen from the air, most impervious areas are small islands interspersed in a sea of pervious cover, ranging from a few hundred square feet to a few acres in size. The urban landscape is a complex mosaic of pervious and impervious cover that are linked and interlaced together. Since many impervious areas are linear in form (e.g., roads, sidewalks, and parking lots), extensive edges are created between the two types of cover. This "edge effect" is exemplified in the corner lot example portrayed in Figure 3, where nearly a thousand feet of edge are created in a little less than an acre. The many interactions between pervious and impervious cover have not been extensively investigated, but they are probably very important.

We tend to think of pervious and impervious areas as distinct and separate. Indeed, most hydrological models simulate the hydrological and water quality response of each area independently. Given the close proximity to each other, the assumption that the two areas do not interact is questionable. The greatest interaction probably occurs within a few feet of the "edge" between the cover types (Figure 3). Consider just a few pathways that a pollutant can travel across the edge—from a pervious to an impervious surface :

- Lawnmowers discharge lawn clippings (nutrients) from the yard to the street .
- Pollen (nutrients) blows from trees to the street in the spring.
- Leaves (organic carbon, nutrients) fall from trees and blow into the road or are stored along the curb to await municipal collection in the fall.
- Pesticides drift into the street during lawncare applications.
- Weed growth near the street is directly controlled by herbicides.

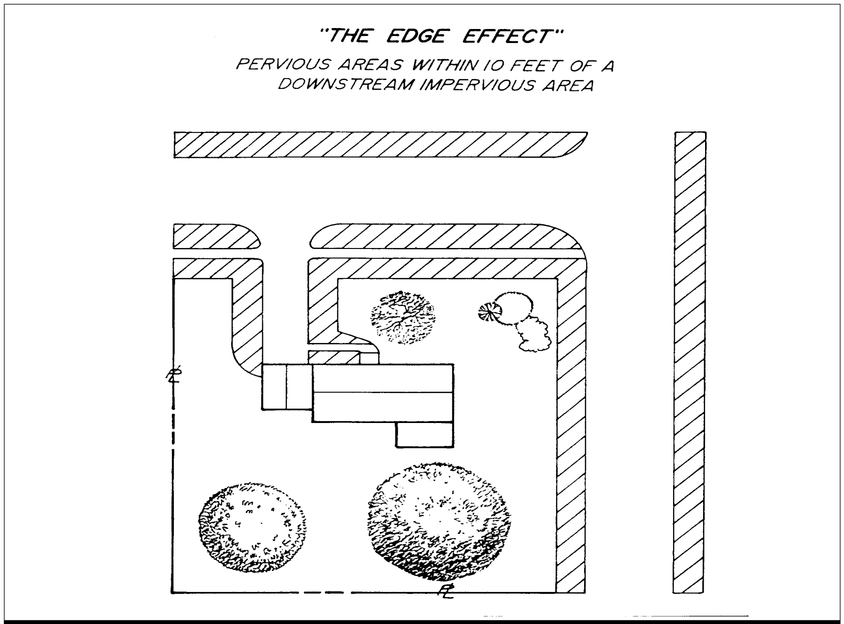

Figure 3: Single Family Home on 1/2 Acre Corner Lot

- Snow is plowed and stored along the edge, collecting pollutants (sediment, chloride, nutrients) throughout the winter and releasing them during the spring snowmelt.
- Pet owners are more likely to walk their pets along the edge, resulting in more pet droppings (bacteria, nutrients) along the edge.
- Significant erosion (sediments) can occur at the edge of the lawn and the street if this edge is not "protected" by curb and gutters.

Lastly, it is probable that a short zone close to the edge produces the bulk of the runoff from pervious areas, given the very short distance of overland flow. Any pesticides or fertilizers applied to this zone should have a greater potential to wash off during intense storm events. Clearly, more research needs to be done to examine how activities along this narrow edge influence the pollutant loadings generated by residential watersheds.

Runon to and Runoff from Pervious Areas

From a hydrological perspective, pervious cover can be classified in terms of its relation to impervious cover, or more precisely, the direction of runoff from the pervious area (Figure 4). If the direction of flow is from pervious cover to impervious cover, then the stormwater will occur as *runoff*. On the other hand, if water flows from impervious cover to pervious cover, then the stormwater will occur as *runon*, and is much more likely to infiltrate into the soil. The practical implication is that if a site is graded to produce runon, it may be possible to significantly reduce the volume of stormwater runoff. Under some conditions, it may be possible to reduce stormwater pollutant loads, as well.

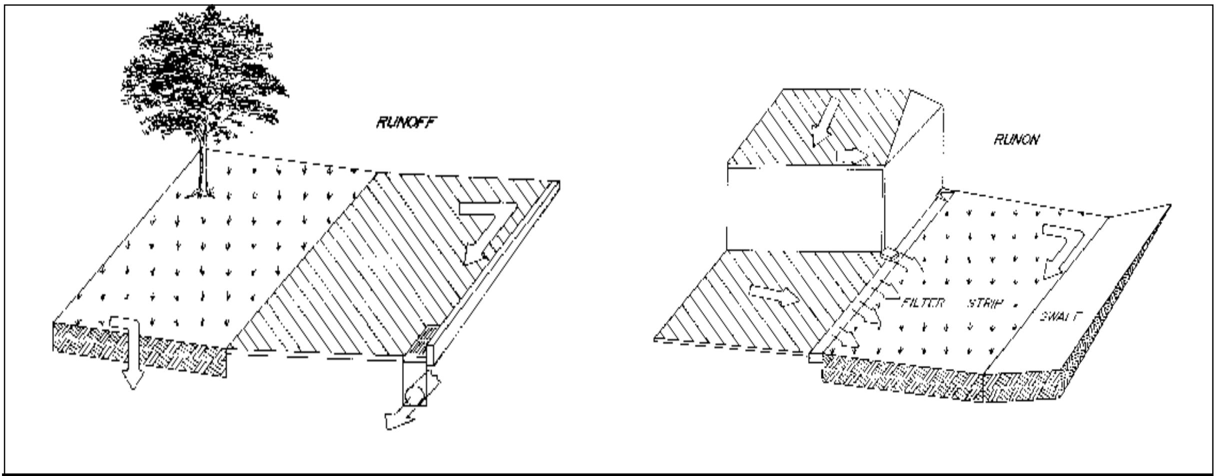

Figure 4: Directional Flow of Runoff and Runon

The Benefits of Runon

Not all impervious areas are connected to a storm drain network, and instead run onto pervious areas. Some examples are the following:

- Rooftop runoff that travels through downspouts and across grassed yards
- Road runoff that is directed into swales rather than curb and gutters
- Small parking lots that drain to forests or fields
- Isolated sidewalks and bike paths

The hydrologic effect of these disconnected impervious areas can be very significant, particularly in low-density residential watersheds. In some cases, disconnecting these impervious areas can create enough runon to reduce the "effective" impervious cover in a watershed by 20 to 50%. Roger Sutherland provides some useful equations for estimating the benefit of "runon" in reducing the effective impervious area in article 32.

Another way to increase runon is to send runoff from an impervious area to a stormwater practice in a pervious area. If the practice allows runoff to infiltrate or filter through vegetation, a portion of the runoff volume is effectively converted into runon. Some examples include filter strips, swales, biofilters, bioretention areas and infiltration trenches. Widespread installation of stormwater practices should have the effect of reducing the effective impervious area in residential watersheds, but this effect has never been measured.

Runoff from Pervious Areas

While every effort should be made to maximize runon to pervious areas, drainage considerations often dictate that most pervious areas will still be graded to drain to impervious areas or storm drains. Consequently, the hydrologic response of each of the six types of pervious cover is of great interest. Most hydrologic research, however, has lumped all the types of pervious cover into a single category, or has assumed that pervious cover has the same properties as well-tended turfgrass. Thus, the majority of urban hydrology models utilize the Natural Resources Conservation Service (NRCS) curve number approach, where the runoff rate is dependent primarily on the soil type and to a lesser extent the vegetative cover at a site.

While these models have proven effective for predicting runoff volumes from pervious areas during large storm events (three to five inches or more), the curve number approach tends to grossly over-predict the runoff volumes produced during the smaller but more common events (Pitt, 1992). The small storm hydrology data presented by Pitt for two test watersheds (Figure 5) illustrate the increased runoff properties of urban lawns, presumably due to soil compaction. The volumetric runoff coefficients (Rv) at these sites tended to progressively increase with rainfall depth, and typically were in the 0.10 to 0.23 range for soils in the "D" hydrologic soil group for moderate storm events. Lawns with more permeable soils (in the "B" soil group) produced less runoff volume (Rv's ranging from 0.01 to 0.04 for small to moderate sized storms). Clearly, lawns may produce greater runoff volume then has been traditionally assumed. Even runoff testing of well-tended turfgrass has revealed that it still produces about half the runoff of bare soil during larger storms.

On the other hand, some pervious surfaces produce little or no runoff. For example, no runoff was recorded from meadow and mulch areas in simulated rainfall experiments conducted by Ross and Dillaha (1993), despite a total rainfall depth of 3.7 inches (Table 1). This finding suggests that creative and natural landscaping can strongly reduce stormwater runoff from yards.

In summary, we are just beginning to understand the hydrologic properties of urban pervious areas, and the evidence suggests that they behave quite differently from pervious areas located in rural or agricultural landscapes.

High-Input Turf

About a third of all pervious cover in the urban landscape can be considered as high-input turf, whether it is private lawn or public turf, according to our earlier provisional estimates. The inputs include water, fertilizer, and pesticides. The potential links between high-input turf and stream quality are reviewed below:

Irrigation

High input turf receives more water than is supplied by rainfall, due to extensive irrigation that sustains turf during dry periods in the summer. A typical lawn irrigation rate of an extra inch per week is frequently recommended in most regions of the country. Over the course of a dry summer, this can amount to perhaps a dozen inches of extra water. While much of the irrigation water is transpired by the grass or evaporates, studies have shown that the infiltration rate can double at excessive watering rates, resulting in additional water infiltrating into the soil. (Morton *et al.*, 1988). If the same lawn also receives runon from adjacent rooftops or roads, it gets a second bonus of water. Given irrigation and runon, it is probable that some high-input lawns may have greater recharge rates than would be expected from rainfall alone. It is further speculated that higher recharge rates from lawns may partially compensate for the lack of recharge from impervious areas, and may be a reason why some urban streams still maintain dry weather flows even when impervious cover is high.

Fertilization

Most surveys indicate that high input lawns are subject to heavy fertilization rates, although the exact rates vary with each individual yard and who actually conducts the fertilization. Reported nitrogen fertilization can average over 100 lbs/ac/yr when homeowners apply fertilizers to over 200 lbs/ac/yr when they are applied by commercial lawn care companies (Morton *et al.*, 1988). Although homeowners on average apply fertilizers at somewhat lower rates, they often apply them at the wrong time of year or too close to rain storms. The percentage of homeowners that actually take a soil test to determine if fertilization is actually needed is also quite low— usually no more than 10 to 20%.

The link between the high-input lawns and higher nutrient concentrations in the stream, however, has not been conclusively demonstrated at the watershed level. This may reflect the different routes each nutrient takes to the stream. Phosphorus, for example, is much more likely to reach a stream in surface runoff or attached to sediments. Researchers in Wisconsin have found that phosphorus concentrations in residential yards were higher than any other urban source area (Bannerman *et al.*, 1994). Since residential lawns produced only a fraction of the total runoff of impervious areas, however, they only generate about 20% of the total phosphorus load (despite the fact they comprised some 66% of total watershed area).

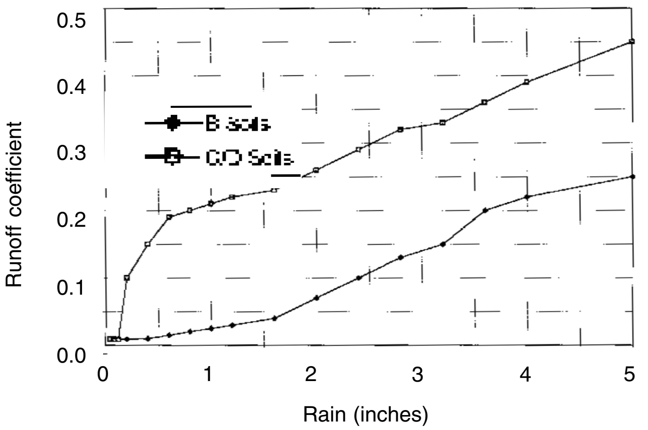

Figure 5: Runoff Coefficients for Lawns of Two Soil Types (Pitt, 1992)

Many forms of fertilizer nitrogen take a different path to the stream, leaching into soil water and eventually migrating to the stream in groundwater. In particular, leaching of nitrogen fertilizers into the soil is enhanced when lawns are over-watered (see article 38). Consequently, stream monitoring should reveal higher concentrations of nitrate during dry weather periods. Various stormwater monitoring agencies have detected nitrate at the one to two ppm level in dry weather stream flow, but have been unable to directly link stream nitrate concentrations to prior lawn fertilization applications.

Fertilizers are but one of many nutrient inputs to the yard. Many homeowners are unaware that lawns receive an annual nitrogen and phosphorus subsidy via atmospheric deposition of 17 and 0.7 lbs/ac/yr, respectively (MWCOG, 1983). Other "free" sources of nutrients include the dilute concentrations of N and P present in municipal water used for irrigation, as well as nutrient concentrations in stormwater that may runon from rooftops and roads.

Pest Control

The link between the application of lawn pesticides and impacts on urban streams is not entirely clear. There is no question that a great number and quantity of herbicides and insecticides are applied to urban lawns. There is also strong evidence that most pesticides remain on the lawn until they eventually degrade. At the same time, recent monitoring efforts are routinely detecting commonly used weedkillers and insecticides in urban streams, albeit at the low part per billion level. The

Table 1: Comparative Runoff, Nutrient and Sediment Concentrations from Six Different Pervious Surfaces After 24 Hour Simulated Rain (Total 3.7 Inches) (Ross and Dillaha, 1993)

Pervious Surface	Rv	Nitrate	Soluble P	TSS
Gravel Driveway	0.51	0.03	0.06	692
Bare Soils	0.33	0.32	0.79	1935
Cool Season Grass, Sodded	0.05	0.31	1.12	29
Warm Season turf	0.03	0.44	0.33	43
Mulched Landscape	0.00	None	None	None
Meadow	0.00	None	None	None

possible significance of these low pesticide concentrations on aquatic life are only just beginning to be studied. Several recent California studies strongly suggest that insecticide such as diazinon and chlorpyrifos pose a significant risk to aquatic health in residential watersheds (Connor, 1995). More research into the pathways and impacts of these highly toxic insecticides is needed to gauge the significance of the risk in other regions of the country.

Peculiarity and the Public

This article summarizes the limited research that has been conducted on the runoff and pollutant dynamics of pervious areas in urban watersheds. Clearly, the impact of our management of pervious areas on urban streams is not fully understood. Given this uncertainty, do we really have a strong enough foundation to justify the public outreach programs that encourage homeowners to reduce lawn inputs and change long-held behaviors? Watershed managers are actively promoting the presumed water quality benefits of alternative lawn care methods in nearly every region of the country. Will this outreach result in meaningful water quality improvements in our urban streams?

A full answer cannot be made until more research is performed. The evidence does generally suggest that chemicals applied to a relatively small fraction of the urban landscape (i.e., high input turf) do show up in urban streams, where they may exert some influence on the overall health of the aquatic ecosystem. It is also clear that management of pervious areas strongly influences the hydrology of urban watersheds. Indeed, many opportunities to protect streams through better understanding and management of our pervious areas have yet to be fully exploited.

-TRS

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