North Carolina National Estuarine Research Reserve
Technical Paper Series:

Stormwater Runoff from Impervious Surfaces

Why is Urban Stormwater a Problem?

When rainwater washes over farmlands or urban streets, it collects a wide variety of pollutants from the surface of the land and carries them into streams, lakes, and estuaries. Runoff from developed areas, construction sites, rooftops, roads, and highways is categorized as urban stormwater runoff. As areas become more densely developed, a larger percentage of land is covered by these paved or hardened surfaces, and the severity of water pollution grows worse.

A typical family house covers about 5,000 square feet with impervious surfaces—including a roof, driveway, and maybe a deck or patio[1]. In addition, an enormous system of roads, highways, and parking lots expands to serve new facilities. Roads and parking lots contribute a far greater amount of paved surfaces; 60 to 70 percent of all impervious surfaces are related to the automobile[2].

Figure 1. This stenciled storm drain educates the public about where stormwater flows. **Photo courtesy of the City of Kinston.**

Paved areas and rooftops are impervious surfaces—impenetrable materials that prevent infiltration of water into soil. Increasing impervious coverage is a significant threat to North Carolina water quality. Rain that would have been absorbed by plants or filtered into groundwater aquifers instead flows into stormdrains. Though many people believe that storm drains carry water from streets to wastewater treatment plants, these drains usually carry runoff directly to nearby streams, rivers, lakes, or coastal waters. Our extensive network of parking lots, rooftops, and especially roads, creates a 'stormwater superhighway' that carries pollutants quickly into the aquatic environment.

Rain that would have been absorbed by plants or filtered into groundwater aquifers instead flows into local waterbodies

Because there is no opportunity for plants to absorb the moisture that falls on pavement, a much larger volume of stormwater drains into streams that flow from urban areas. This large quantity of water reaches streams too quickly, flowing across roads and through pipes that do not offer the resistance to surface flow that the natural vegetation of meadows and forests would.

During dry periods, streambase flow is substantially reduced. Because none of the past rains were able to saturate the ground, shallow groundwater storage is diminished. As a result, less water is available to gradually percolate into streams. Drastic fluctuations in stream and river flow levels increase the potential for destructive flooding.

To understand just how much stormwater reaches streams from impervious surfaces, compare an acre of undeveloped land to a parking lot. The stormwater runoff from one inch of rain falling on one acre of meadow would fill a room with two feet of standing water. The same amount of rainfall on an acre of parking lot would generate enough runoff to fill three rooms with water from floor to ceiling[2].

The Center for Watershed Protection has found that stream degradation occurs at relatively low levels of imperviousness—only 10 or 20 percent impervious coverage[2]. Cumulative effects from increasing stormwater runoff include public health threats, economic losses in commercial fisheries and tourism, and damaged aquatic environments.

What Contaminants are found in Stormwater Runoff?

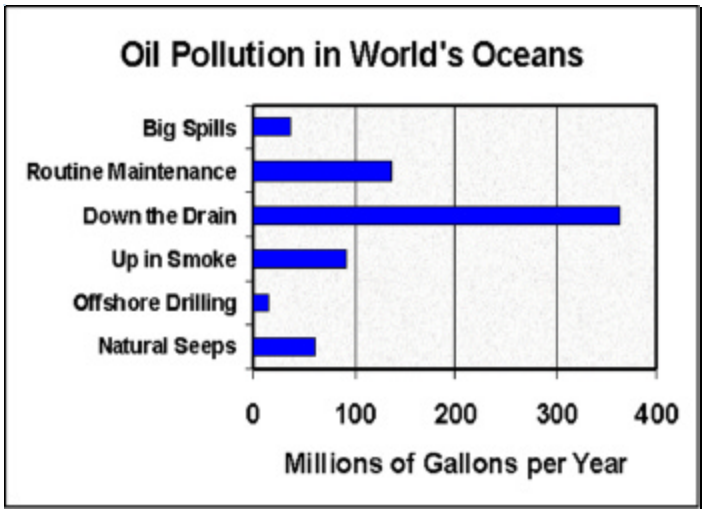
When stormwater sweeps along roads and rooftops, it carries many types of pollutants to streams and estuaries. Each of these pollutants negatively affects the coastal environment individually, but even graver ecological damage may result from the combination of many different pollutants.

- **SEDIMENT** *(from construction, erosion, agriculture)* Emerging into estuaries or lakes as a large plume of cloudy water, sediment-laden runoff may block light from penetrating through to seagrasses. Suspended sediments prevent submerged plants from photosynthesizing—depleting food sources and habitat for other aquatic life.

- **NUTRIENTS** *(from fertilizers, failing sewer or septic tanks)* Though nutrients like nitrogen and phosphorus are beneficial to plants in certain quantities, increased development of land and use of concentrated fertilizers have caused elevated nutrient content in natural waterbodies. High nutrient levels stimulate algae blooms. As bacteria consume the abnormally large algae population, oxygen levels in the water can dip dangerously low—endangering fish important to the ecosystem and to our economy.

- **MICROBES** *(from failing sewer or septic tanks, animal wastes; includes bacteria, viruses and protozoa)* The more urbanized and intensively developed an area is, the more microbes will infiltrate into stormwater. This is true because older wastewater systems are more likely to leak, and because more people and their pets live in these densely developed neighborhoods.

- **ORGANIC MATERIALS** *(like lawn clippings or leaf litter)* Even seemingly harmless yard waste (like grass clippings or leaf litter) can degrade water quality. Organic materials—including yard waste, paper, plastic, and other trash—decay when they are washed into water bodies. As bacteria decompose waste materials, they consume oxygen in the water that would have sustained larger, healthier fish populations.



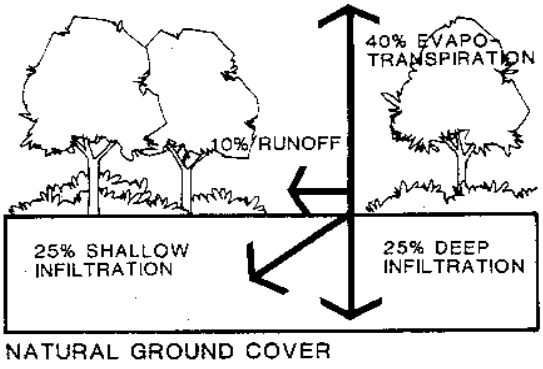
- **OIL & GREASE** *(from cars on roads and parking areas)* The National Research Council estimates that **363 million gallons of oil** per year enter the coastal ocean from storm drains alone[3] (see graph). At high concentrations, all petroleum-based products can cause mortalities of aquatic plants and animals. Some hydrocarbon compounds (like polynuclear aromatic hydrocarbons or PAHs) are toxic to aquatic organisms even in very small concentrations.

- **METALS** *(like copper, lead, chromium, cadmium, zinc or mercury)* Trace metals also enter urban runoff from exhaust, fluid leaks, weathering of paint and wood preservatives, industrial spills, atmospheric deposition, and illegal dumping. Atmospheric deposition should not be underestimated: air pollution is responsible for almost one-third of toxic contaminants and nutrients that enter coastal oceans[1]. Metals are not only potentially toxic to aquatic life, but also ruin drinking water supplies and contaminate shellfish stocks.

- **TOXIC & SYNTHETIC CHEMICALS** *(from pesticides, residential or industrial solvents)* About 65,000 chemicals are sold commercially in the United States, but only about 300 of these have been effectively tested to determine their effects on the environment[4]. Synthetic chemicals may be lethal to some organisms in concentrated dosages; for example herbicides or pesticides may kill aquatic plants and microorganisms.

What can Local Governments do?

The traditional approach to stormwater management has used a structural approach—drains, pipes or culverts for example—to carry water off the land as fast as possible. Structural methods of controlling stormwater runoff may include construction and maintenance of ditches, retention ponds, or wastewater treatment plants. Because these engineered solutions can cause downstream flooding and speed the delivery of contaminants to the environment, a newer perspective on stormwater management focuses instead on preventing stormwater problems by reducing runoff volumes and reducing pollutant loads.



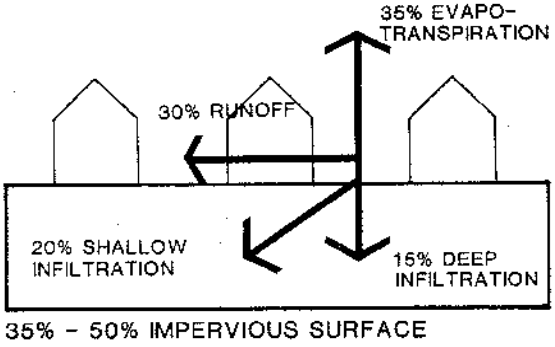
NATURAL GROUND COVER

Measures to reduce water pollution from urban stormwater runoff are only effective with good government and community support. Local governments must design the best combination of engineered structures, public participation and education, land use planning, and land use controls to meet their water quality goals and fit their budget.

Preventative Measures

Local governments may find that adopting preventative management practices will achieve the same water quality goals with less capital investment and fewer maintenance costs than traditional systems. Stormwater prevention programs are not free, however, and water quality improvements will come only from firm political and economic commitment. Often called Best Management Practices, prevention strategies include a wide variety of programs like public education efforts, recycling centers for used oil, preservation of wetlands, and land use controls.

Public education—teaching citizens about the problem and how they can help—may be the most cost-effective way to reduce contaminated runoff. Communities may employ brochures, newsletters, newspaper articles, television or radio programming, videos, or workshops. One way to involve and educate the public is to stencil storm drains with a warning that it drains directly to a specific creek (see Figure 1).



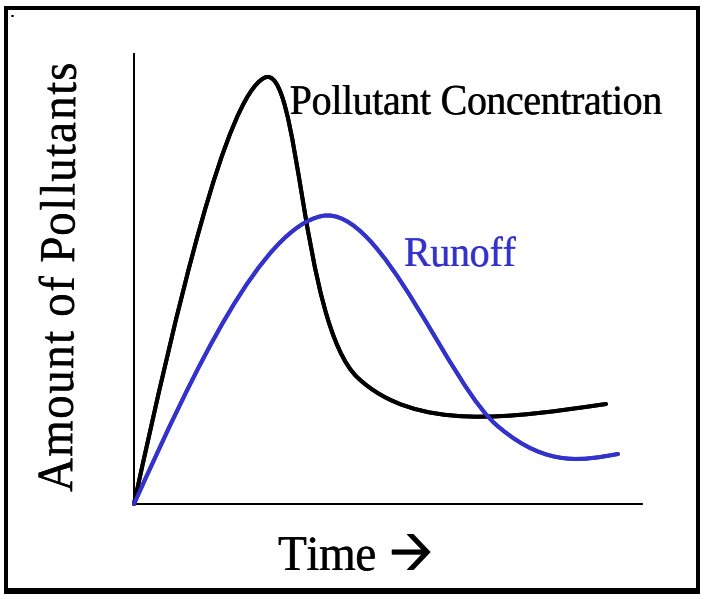
35% - 50% IMPERVIOUS SURFACE

Governments can also use municipal or county controls like zoning ordinances, floodplain regulations, or watershed protection ordinances. A community can increase the amount of vegetated cover directly by implementing Impervious Surface Limitations or Open Space Requirements. These are ordinances that require developers to set aside a certain percentage of natural area.

Additional measures include Tree Protection Requirements and Downspout Controls. Because trees soak up a larger amount of rain than grass or shallow vegetative covers, limits on cutting trees during construction or in developed areas will reduce stormwater runoff. Local building codes or development ordinances can also require gutter downspouts to discharge into landscaped areas rather than onto paved sidewalks or streets. This very easy practice should be encouraged whenever possible to increase infiltration of stormwater.

Controlling the First Flush

Pollutants accumulate on impervious surfaces during dry weather. When the first drops of rain fall, this pollution is quickly collected in stormwater runoff. The initial volume of stormwater with high concentrations of pollutants is often called the 'first flush.' Since about 90% of pollutant loading is thought to occur within a storm's first flush, controlling the initial surge of runoff can drastically reduce transport of contaminants to water bodies. The figure to the right, from Livingston[5], shows the initial spike in pollutant concentration as this first flush washes off of impervious surfaces like parking lots, roads, or rooftops.



Additional Stormwater Resources

- U.S. Environmental Protection Agency, Polluted Runoff (Nonpoint Source Pollution): **www.epa.gov/owow/nps/**
- U.S. Environmental Protection Agency, Nonpoint Source Pointers (Factsheets): **www.epa.gov/owow/nps/facts/**
- Stormwater and General Permits Unit, Division of Water Quality (DWQ), Department of Envrionment and Natural Resources (DENR): **http://h2o.enr.state.nc.us/su/stormwater.html**
- North Carolina Nonpoint Source Management Program, DWQ, DENR: **http://h2o.enr.state.nc.us/nps/**
- North Carolina Coastal Nonpoint Source Management Program, DWQ, DENR: **http://h2o.enr.state.nc.us/nps/CNPSCP/cnpcp.htm**
- Water Resources Research Institute (WRRI) of the University of North Carolina: **www2.ncsu.edu/ncsu/CIL/WRRI/index.html**
- Nonpoint Education for Municipal Officials (NEMO): **http://nemo.uconn.edu/**
- Center for Watershed Protection (CWP): **www.cwp.org**
- Stormwater Resources for Officials, Developers and Homeowners, NC State University: **www.bae.ncsu.edu/stormwater/**

Literature Cited

[1] 1000 Friends of Washington. "Land Use and Water Quality: Water Pollution." *www.1000friends.org/waterq.htm*, visited September 2000.

[2] Schueler, Importance of Imperviousness. 1994. "The Importance of Imperviousness." Watershed Protection Techniques Quarterly. Vol. 1, No. 3. Center for Watershed Protection.

[3] National Research Council. 1985. Oil in the Sea. National Academy Press. Washington, D.C.

[4] Benchley, Peter and Judith Gradwohl. 1996. Ocean planet: Writings and Images of the Sea. New York. Harry N. Abrams, Inc.

[5] Livingston, E.H. and E. McCarron. 1991. "Stormwater Management: A Guide for Floridians." Stormwater/Nonpoint Source Management, Florida Department of Environmental Protection. Tallahassee, FL.

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