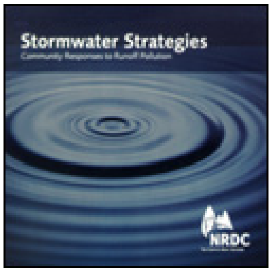

Stormwater Strategies
Community Responses to Runoff Pollution

National Resource Defense Council

Chapter 2

THE CAUSES OF URBAN STORMWATER POLLUTION

Runoff pollution occurs every time rain or snowmelt flows across the ground and picks up contaminants. It occurs on farms or other agricultural sites, where the water carries away fertilizers, pesticides, and sediment from cropland or pastureland. It occurs during forestry operations (particularly along timber roads), where the water carries away sediment, and the nutrients and other materials associated with that sediment, from land which no longer has enough living vegetation to hold soil in place.

This report, however, focuses on runoff pollution from developed areas, which occurs when stormwater carries away a wide variety of contaminants as it runs across rooftops, roads, parking lots, baseball diamonds, construction sites, golf courses, lawns, and other surfaces in our cities and suburbs. The oily sheen on rainwater in roadside gutters is but one common example of urban runoff pollution.

This chapter discusses some of the causes of stormwater runoff and pollution, which are important to understand before adopting management strategies.

The United States Environmental Protection Agency (EPA) now considers pollution from all diffuse sources, including urban stormwater pollution, to be the most important source of contamination in our nation's waters. [1] While polluted runoff from agricultural sources may be an even more important source of water pollution than urban runoff, urban runoff is still a critical source of contamination, particularly for waters near cities -- and thus near most people. EPA ranks urban runoff and storm-sewer discharges as the second most prevalent source of water quality impairment in our nation's estuaries, and the fourth most prevalent source of impairment of our lakes. [2] Most of the U.S. population lives in urban and coastal areas where the water resources are highly vulnerable to and are often severely degraded by urban runoff.

Urban stormwater continues to impair the nation's waterways, 29 years after passage in 1972 of the law now known as the Clean Water Act. The main reason why urban stormwater remains such an important contributor to water pollution is the fact that in most areas, stormwater receives no treatment before entering waterbodies. The storm-sewer system merely collects the urban runoff and discharges it directly to the nearest river, lake, or bay.

Over the past 29 years, water pollution control efforts have focused primarily on certain process water discharges from facilities such as factories and sewage treatment plants, with less emphasis on diffuse sources. While these efforts have led to many water quality improvements, new efforts are now needed to address the remaining sources of water pollution, including urban runoff pollution.

Comprehensive stormwater regulation has been slow to develop (see box: "History of Stormwater Regulation in the United States"). Since 1992, cities with a population over 100,000, certain industries, and construction sites over 5 acres have had to develop and implement stormwater plans under Phase I of the National Pollutant Discharge Elimination System (NPDES) stormwater regulations. As of May 1999, states and the EPA have issued more than 260 permits affecting some 850 operators, including larger cities operating separate storm sewer systems, which require them to develop stormwater management plans. A number of stormwater discharges from industrial activities are also subject to NPDES stormwater permit requirements.

On December 8, 1999, EPA promulgated a rule requiring smaller municipalities, those with populations of fewer than 100,000 people located in urbanized areas (where population density is greater than 1,000 persons per square mile) to develop stormwater plans. Municipalities not in urbanized areas that have more than 10,000 residents and a population density greater than 1,000 persons per square mile will also have to develop stormwater plans if the state so designates. Under this so-called "Phase II" rule, the EPA and states will develop "tool boxes" from which the smaller local governments can choose particular stormwater strategies, including the strategies presented in this report, to develop their stormwater plans.

Stormwater must be distinguished from other urban sources of pollution largely caused by wet weather since each separate source is regulated differently. In addition to stormwater runoff, which is the focus of this study, there are two other significant sources of urban wet weather pollution: sanitary sewer overflows (SSOs) and combined sewer overflows (CSOs). SSOs occur when sanitary sewers, often because of leaks and cracks, become surcharged in wet weather and overflow, often through manholes or into basements. CSOs occur when flows into combined sewer system (systems that receive stormwater, sanitary sewer discharges from residences and businesses, and wastewater discharges from industrial facilities and transport it all through a single pipe) exceed the treatment and storage capacity of the sewer system and waste treatment facility. At that point, this combined waste stream overflows into creeks, rivers, lakes or estuaries through designated outfalls usually without treatment. CSOs and SSOs are more of a problem with older systems while stormwater is an issue for all metropolitan areas, especially growing areas. Moreover, while prevention programs can be very important to efforts to reduce CSOs and SSOs, structural changes are usually necessary. By contrast, much stormwater pollution can be *prevented* with proper planning in growing or redevelopment areas.

Remarkably, studies have shown that stormwater alone can be almost as contaminated as these sewage/stormwater mixtures.[3] Yet stormwater runoff remains to be regulated in most of the nation's populated areas. While many CSO and SSO control measures may overlap with stormwater pollution control measures, strategies that deal with stormwater specifically must be implemented if the quality of America's waterbodies is to improve. These strategies are the focus of this report.

HISTORY OF STORMWATER REGULATION IN THE UNITED STATES

The history of stormwater regulation began over 25 years ago. It has been in and out of the courts, Congress, EPA and is now in the hands of states and local governments.

1972: EPA issues exemptions from the federal Clean Water Act NPDES permit program for most sources of stormwater. NRDC sues EPA to require permits for all point sources, including urban storm sewers (applications by 1973 and permits by 1974).

1975–1977: The U.S. District Court finds that EPA exemptions are contrary to the Clean Water Act (NRDC v. Train).[a] This decision is upheld by U.S. Court of Appeals in 1977 (NRDC v. Costle).[b]

1980: EPA issues rules responding to the court's decision that exempt cities outside "urbanized areas from needing NPDES permits for their storm sewers." NRDC and industry sue EPA over the rules (NRDC v. EPA).[c]

1980–1990: During this period, EPA struggled with developing stormwater rules, and extends the stormwater permit deadlines for large cities until 1987 and 1989. EPA also issues "nonenforcement letters" informing cities that EPA would not take enforcement actions against cities with permit applications and proposes narrowing the definition of stormwater discharges. In 1983, EPA issues a final report on the Nationwide Urban Runoff Program. In 1984, NRDC and the states negotiated with EPA to reject narrowing coverage and revoke letters.

1987: In Clean Water Act amendments, Congress requires EPA to issue by 1989 "Phase I" rules addressing stormwater from cities with a population over 100,000 and from industrial sites, and to issue by 1992 "Phase II" rules for other significant sources of stormwater pollution.

1990: EPA promulgates "Phase I" NPDES stormwater regulations and extends compliance beyond those dates in the 1987 law. NRDC sues EPA for illegally extending deadlines and excluding certain sources from regulations (NRDC v. EPA).[d]

1992: A U.S. Court of Appeals ruling prohibits further stormwater dead-line extensions (NRDC v. EPA)[e] and invalidates certain provisions of the Phase I rule. EPA and the states issued initial general permits for storm-water discharges.

1992: Congress provides an additional extension to small cities for storm-water permit applications.

1995: EPA is sued for its failure to conduct study, file report, and issue regulations concerning Phase II stormwater pollutant sources (NRDC v. Browner).[f] EPA issues Report to Congress on "Storm Water Discharges Poten-tially Addressed by Phase II of the NPDES Storm Water Program." NRDC and EPA enter into consent decree requiring EPA to issue a final rule by March 1999 (later extended to October 1999) addressing both Phase II stormwater and Phase I issues remanded by the court. In 1996, EPA convenes a federal advisory committee.

1997: EPA issues draft Phase II stormwater rules.

a 396 F.Supp. 1393 (D.D.C. 1975), aff'd by NRDC v. Costle, 568 F.2d 1369 (D.C. Cir. 1972).
b 568 F.2d 1369 (D.C. Cir. 1972).
c 673 F.2d 392 (D.C. Cir. 1980) (per curiam).
d 915 F.2d 1314 (9th Cir. 1990).
e 966 F.2d 1292 (9th Cir. 1992).
f No. 95-634 PLF (D.D.C.) (consent order signed April 6, 1995).

The Water Cycle

To fully understand the stormwater pollution problem, it is helpful to step back and review the water cycle, also known as the hydrologic cycle. The water cycle is simply the constant movement of water from the sky to the ground and back again. The main components of the water cycle are precipitation, infiltration, evapotranspiration (evaporation and transpiration, the process by which plants release water they have absorbed into the atmosphere), surface and channel storage, and groundwater storage. As part of that cycle, when rainwater falls to the ground, or when snow or hail on the ground melt, that water may take several paths, as illustrated in Figure 2-1 (print report only).

While the magnitude of these effects varies across the country depending on the precipitation patterns, soil types and other factors, the underlying principles remain the same. [4] In a typical Midwestern undeveloped area, for example, with natural ground cover such as forests or meadows, a large fraction -- perhaps 50 percent -- of the water infiltrates the soil. Much of this water may remain near the surface from which it often resurfaces into lakes or streams. Other infiltrated water descends to a deeper level, perhaps recharging an underground aquifer used for drinking water. A significant share -- 40 percent in this example -- of the water returns to the atmosphere through evapotranspiration. Only a small amount of the water -- the remaining 10 percent, in this example -- typically remains on the surface of undeveloped land to run off into streams and other waterbodies.

Urbanization can dramatically alter this water cycle, increasing runoff and reducing, at times to almost zero, infiltration. This can completely alter the physical and chemical character of the receiving waterbody.

The Causes of Stormwater Pollution

The stormwater pollution problem has two main components: the increased volume and velocity of surface runoff and the concentration of pollutants in the runoff. Both components are directly related to development in urban and urbanizing areas. Together, these components cause changes in hydrology and water quality that result in a variety of problems including habitat loss, increased flooding, decreased aquatic biological diversity, and increased sedimentation and erosion, as well as affects on our health, economy, and social well-being. These consequences will be discussed in Chapter 3; the following is a discussion of the sources of these problems.

Table 2-1
Impacts from Increases in Impervious Surfaces

	Resulting Impacts				
Increased Imperviousness Leads to:	**Flooding**	**Habitat Loss (e.g., inadequate substrate, loss of riparian areas, etc.)**	**Erosion**	**Channel Widening**	**Streambed Alteration**
Increased Volume	•	•	•	•	•
Increased Peak Flow	•	•	•	•	•
Increased Peak Flow Duration	•	•	•	•	•
Increased Stream Temperature		•			
Decreased Base Flow		•			
Changes in Sediment Loadings	•	•	•	•	•

Source: *Urbanization of Streams: Studies of Hydrologic Impacts,* EPA 841-R-97-009, 1997

INCREASED VOLUME AND VELOCITY: THE IMPERVIOUS COVER FACTOR

Types of Impervious Cover

Some impervious cover, such as exposed rock or hardpan soil, is natural. Land development, however, greatly increases it. Human-made impervious cover comes in three varieties: rooftop imperviousness from buildings and other structures; transport imperviousness from roadways, parking lots, and other transportation-related facilities; and impaired pervious surfaces, also known as urban soils, which are natural surfaces that become compacted or otherwise altered and less pervious through human action. Examples of the hard soils include the base paths on a baseball diamond or a typical suburban lawn.

Transport imperviousness generally exceeds rooftop imperviousness in urban areas of the United States.[5] "Cumulative figures show that, worldwide, at least one third of all developed urban land is devoted to roads, parking lots, and other motor vehicle infrastructure. In the urban United States, the automobile consumes close to half the land area of cities; in Los Angeles the figure approaches two thirds."[6] The city of Olympia, Washington, also found that transport imperviousness constituted approximately two-thirds of total imperviousness in several residential and commercial areas.[7] This distinction is important because rainfall on transportation surfaces drains directly to a stream or stormwater collection system that discharges to a waterbody usually without treatment, whereas some roofs drain into seepage pits or other infiltration devices. Research has also found a strong relationship between curb density and overall imperviousness in residential areas suggesting that roads lead to the creation of other impervious surfaces.[8]

The creation of additional impervious cover also reduces vegetation, which magnifies the effect of the reduced infiltration. Trees, shrubs, meadows, and wetlands, like most soil, intercept and store significant amounts of precipitation. Vegetation is also important in reducing the erosional forces of rain and runoff. In one study, conversion of forest to impervious cover resulted in an estimated 29 percent increase in runoff during a peak storm event.[9]

Imperviousness Thresholds

Research has shown that when impervious cover reaches between 10 and 20 percent of the area of a watershed, ecological stress becomes clearly apparent.[10] After this point, stream stability is reduced, habitat is lost, water quality becomes degraded, and biological diversity decreases. Figure 2-3 (print report only) shows that as the amount of impervious surface in a watershed increases infiltration and evapotranspiration both drop substantially. As a result, more water, having nowhere else to go, runs off the surface picking up pollutants from activities occurring on the impervious surfaces.

To put these numbers into perspective, typical total imperviousness in medium-density, single-family home residential areas ranges from 25 percent to nearly 60 percent.[11] Total imperviousness at strip malls or other commercial sites can approach 100 percent.

Increased Volume of Runoff

The effect of impervious surfaces on the volume of stormwater runoff can be dramatic. For example, a 1-inch rainstorm on a 1-acre natural meadow would typically produce 218 cubic feet of runoff, enough to fill a standard size office to a depth of about 2 feet. The same storm over a 1-acre paved parking lot would produce 3,450 cubic feet of runoff, nearly 16 times more than the natural meadow, and enough to fill three standard size offices completely.[12]

On a larger scale, the effect is even greater. In a 620-square-mile portion of the watershed of the Des Plaines River in Illinois, in 1886, when agricultural or urban development covered 10 percent of the land area, the river's median annual discharge was 4 cubic feet per second. Today, when development covers approximately 70 to 80 percent of that same area, the median annual discharge has been 700 to 800 cubic feet per second, 175 to 200 times the earlier discharge level.[13]

Greater Stream and Runoff Velocity During Storm Events

Impervious surfaces increase the speed of runoff as it drains off the land. Unlike grassy meadows or forests, hard, impervious cover, such as parking lots and rooftops, offers little resistance to water flowing downhill, allowing it to travel faster across these surfaces.[14] In addition, the faster rate of runoff delivers more water in a shorter time to receiving waters than would occur under natural conditions. The increased velocity and delivery rate greatly magnifies the erosive power of water as it flows across the land surface and once it enters a stream.

Increased Peak Discharges

Increased imperviousness not only changes the volume of stormwater flows, but also the distribution of flows over time. When land is undeveloped, the initial stormwater flow following a rain event is relatively small, since the land absorbs and infiltrates much of the water. However, impervious cover forces rainwater or snowmelt to run off the land immediately, causing a sharp peak in runoff immediately following the rain event, as illustrated in Figure 1-5 (print report only). Impervious cover can double, triple, quadruple or even quintuple peak discharge.[15] Streams receiving these increased urban peak flows are described as "flashy," meaning that they are prone to sporadic and unstable discharges including flash floods or sudden high pulses of storm flows. An increase in peak flow can have significant impacts on the human and natural environment. Greater peak flows lead to increased flooding, channel erosion and widening, sediment deposition, bank cutting, and general habitat loss as discussed in Chapter 3.

Reduced Stream Base Flow

Because impervious cover reduces infiltration and forces stormwater to run off the land immediately, it also typically reduces the amount of groundwater available to recharge streams when there is no rain.[16] Hydrologists often refer to groundwater zones under urban areas as "starved" since they are not replenished. This groundwater-charged stream flow, known as base flow, can fall to 10 percent of the regional average when the level of imperviousness in the stream watershed reaches 65 percent.[17] Prolonged low flow can have a significant impact on aquatic life and, in some cases, a greater impact than extreme peak flows.[18] Reduced infiltration can also lead to shortages of drinking water supplies.

Decreased Natural Stormwater Purification Functions

Government flood control agencies often replace the beds of creeks, streams, and other drainage ways with concrete open channels, or completely replace those drainage ways with subsurface concrete storm drain lines. These changes degrade or eliminate habitat and dramatically alter hydrology. Channelizing, diking, and levying disconnects a river from its floodplain and reduces its ability to modify floods naturally. Similarly, this and other development fills, converts, or otherwise eliminates swamps, marshes and other wetlands. Eliminating these natural drainage ways reduces flow storage and detention and soil moisture maintenance and can increase overall flooding and erosion. In addition, natural streambeds and floodplains provide a hydrologic link between groundwater and surface water and can naturally clean waters. By capturing and slowing stormwater, these areas trap sediment, trace metals, and soluble forms of nutrients.[19] Studies have shown that wetlands can retain up to 100 percent of the metals present in water.[20] Wetlands reduce nitrogen discharges, both through the process of bacterial denitrification and through plant uptake, but less effectively reduce phosphorous when soils are saturated.

Similarly, other natural areas can reduce pollutant loads. One riparian forest in the Chesapeake Bay region removed 89 percent of the nitrogen and 80 percent of the phosphorus from runoff.[21] Forests also typically absorb 70 to 80 percent of atmospherically deposited nitrogen.[22] Trees and other plants stabilize the soil, giving it structure that prevents erosion, and reduce runoff by intercepting and storing precipitation. When rapid stormwater flows have already created erosion on bare soils, plants on downhill slopes slow those flows and allow sediment, as well as other pollutants, to settle onto the land rather than in a waterbody.

However, use of wetlands, streams, and other natural systems is not desirable unless stormwater is delivered at a rate at which pollutants can be assimilated. Natural wetlands, while playing an important role in managing the quality and quantity of runoff, should not be viewed as a sink for polluted runoff. While wetlands help remove pollutants from runoff, some pollutants can accumulate in wetlands or be converted to more potent forms, thereby degrading the natural ecosystem functions and values of these systems and impact the organisms living there.[23] Furthermore, the US EPA recommends protection for any wetland or riparian area which removes pollutants from runoff to coastal waters.[24] Therefore, use of these systems for stormwater management should be carefully considered, realizing that these systems need quality water delivered at an appropriate rate to function properly.

INCREASED DEPOSITION OF POLLUTANTS

The second aspect of urbanization that contributes to urban stormwater pollution is the increased discharge of pollutants. As human activity increases in a given area, the amount of waste material deposited on the land and in drainage systems increases. The principal contaminants of concern for stormwater fall into seven categories. The following table lists these categories and provides examples.

While all activities can be a source of some contaminants, certain activities are particularly large contributors. Industrial sites can be major sources of metals and organic chemicals. Feedlots are a large source of pathogens, nutrients, and BOD. Agricultural and timber operations discharge high quantities of sediment. This report focuses on those activities in urbanized and urbanizing areas, practices of homeowners, businesses, and government agencies that also contribute many of these contaminants.

TABLE 2-2
Categories of Principal Contaminants in Stormwater

Category	**Examples**
Metals	zinc, cadmium, copper, chromium, arsenic, lead
Organic chemicals	pesticides, oil, gasoline, grease
Pathogens	viruses, bacteria, protozoa
Nutrients	nitrogen, phosphorus
Biochemical oxygen demand (BOD)	grass clippings, fallen leaves, hydrocarbons, human, and animal waste
Sediment	sand, soil, and silt
Salts	sodium chloride, calcium chloride

Vehicle Use

Driving a car or truck contributes a number of different types of pollutants to urban runoff. Pollutants are derived from automotive fluids, deterioration of parts, and vehicle exhaust. Once these pollutants are deposited onto road and parking surfaces, they are available for transport in runoff to receiving waters during storm events. One landmark study estimated that cars and other vehicles contributed 75 percent of the total copper load to the lower San Francisco Bay through runoff.[25] Brake pad wear contributed 50 percent of the total load, and 25 percent came from atmospheric deposition -- the eventual settling of metals from tailpipe emissions onto the ground. Other car- and truck-related sources of metals include tire wear, used motor oil and grease, diesel oil, and vehicle rust.[26] Tire ware is a substantial source of cadmium and zinc; concentrations at outfalls often exceed acute toxicity levels. Engine coolants and antifreeze containing ethylene glycol and propylene glycol can be toxic and contribute high BOD to receiving waters.

Vehicle exhaust contributes the nutrient nitrogen to our nation's waters. Studies estimate that deposition of nitrogen from power plant and vehicle exhaust contributes 17 pounds per year of nitrogen and 0.7

pounds per year of phosphorus to a typical acre of land in the metropolitan Washington, DC, area.[27] In general, fossil fuel combustion is the largest contributor of nitrogen to the waters of the northeastern United States, and is a very large contributor elsewhere.[28]

Oil, grease, and other hydrocarbons related to vehicle use and maintenance also contaminate our waters. These come from disposal of used oil and other fluids on the ground or into storm drains, spills of gasoline or oil, and leaks from transmissions or other parts of automobiles and trucks. The stormwater discharge from one square mile of roads and parking lots can yield approximately 20,000 gallons of residual oil per year.[29] Runoff from residential car washing also contributes oil, grease, grit, and detergents to the stormwater system. Even gas vapor emitted when filling tanks can subsequently mix with rain, contributing significantly to polluted runoff.[30]

Roads and Parking Lots

In many communities, most impervious cover is related to the transportation system.[31] Material accumulates on these surfaces during dry weather conditions, only to form a highly concentrated first flush during storm events. One study found streets to be the impervious surface with the highest pollutant loads in most land use categories.[32] Another found that transportation related land uses have the second highest level of pollutant concentrations; only piped industrial sources were higher.[33]

Table 2-3
Sources of Heavy Metals from Transportation

Source	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Gasoline	•			•				•	•
Exhaust							•	•	
Motor Oil & Grease		•			•		•	•	•
Antifreeze					•				•
Undercoating								•	•
Brake Linings				•	•		•	•	•
Rubber	•			•				•	•
Asphalt				•			•		•
Concrete				•			•		•
Diesel Oil	•								
Engine Wear					•	•	•	•	•

Source: Local Ordinances: A Users Guide, Terrene Institute and EPA, Region 5, 1995.

Home Landscaping and Public Grounds Maintenance

Landscaping practices are another potential source of pollutants in urban runoff. Turf management chemicals including fertilizers used at home and on golf courses, cemeteries, and public parks can add nutrients to runoff.[34] Monitoring has shown a direct link between the chemicals found in lawn care products and urban water quality.[35] While there remain questions on some details of the contribution of turf management to receiving water quality, it is clear that the type, quantity, and timing of materials used make a significant difference.

One important variable is the quantity of chemicals being applied. Over or improper application at homes and other places is far too common.[36] Experts estimate that residential fertilizer use accounts for one-third of the excess nitrogen entering the Sarasota Bay watershed in southwest Florida.[37] Of particular concern is the application of fertilizers and pesticides just before an intense storm event, since they may not have had time to become fixed in the soil and thatch.

Similarly, harmful pesticides found in stormwater, such as chloropyrifos, 2,4-D, and diazinon come from golf courses, municipal parks, highway medians and roadsides, and residential lawns and gardens.[38] The percentage of pesticide lost in runoff can be large; one study found up to 90 percent of the herbicide 2,4-D was lost in runoff after being applied a few hours before a storm event.[39]

Since organic matter contains nutrients, raking autumn leaves or grass clippings into gutters or streets for municipal collection or otherwise facilitating the entry of these materials into the storm-sewer system also adds nutrient loads and oxygen-demanding substances to stormwater. Poorly maintained garden beds or lawns can be a source of sediment as well.

Table 2-4
Six Pesticides Found Frequently in Stormwater Samples

Pesticide Name	**Human Health and/or Environmental Effects**
2,4-D	Associated with lymphoma in humans; testicular toxicant in animals.
Chlorpyrifos	Moderately toxic to humans; neurotoxicant; can be highly toxic to birds, aquatic organisms, and wildlife.
Diazinon	Moderately toxic to humans; neurotoxicant; can be highly toxic to birds, aquatic organisms, and wildlife.
Dicamba	Neurotoxicant; reproductive toxicity in animals; association with lymphoma in some human studies.
MCPA (Methoxane)	Low toxicity to non-toxic in test animals, birds, and fish; suspected gastrointestinal, liver, and kidney toxicant.
MCPP (Mecoprop)	Slightly to moderately toxic; some reproductive effects in dogs; suspected cardiovascular, blood, gastrointestinal, liver, kidney, and neurotoxicant.

Sources: T.R. Schueler, quot;Urban Pesticides: From the Lawn to the Stream,quot; Watershed Protection Techniques, vol. 2, no. 1, Fall 1995, pp. 247, 250 and Extoxnet: Extension Toxicology Network Pesticide Information Profiles, http://ace/orst.edu/info/extoxnet, and Environmental Defense Fund, Scorecard Chemical Profiles, http://www.scorecard.org/chemical-profiles.

Construction Sites

Construction activity is the largest direct source of human-made sediment loads.[40] quot;Results from both field studies and erosion models indicate that erosion rates from construction sites are typically an order of magnitude larger than row crops and several orders of magnitude greater than rates from well-vegetated areas, such as forest or pastures.quot;[41] Since erosion rates are much higher for construction sites relative to other land uses, the total yield of sediment and nutrients is higher.[42] Studies indicate that poorly managed construction sites can release 7 to 1,000 tons of sediment per acre during a year, compared to 1 ton or less from undeveloped forest or prairie land.[43] Construction activity can also result in soil compaction and increased runoff.

Like nutrients, soil and sediment are, to a certain degree, a naturally occurring and functional component of all waterbodies. Yet human activities usually increase the amount of sediment entering our waterbodies to such an extent as to turn sediment into a water quality problem.

Illicit Sanitary Connections to Storm Sewers From Homes and Businesses

Illicit connections from toilets to storm sewer pipes can add pathogens to stormwater.[44] [45] Pathogens are viruses, bacteria, and protozoa harmful to human health. Coliform bacteria, which come from human waste, is commonly used as an indicator that harmful pathogens may be present in the water.[46] Studies have found high levels of coliform bacterial in stormwater.[47]

Illicit sanitary connections can also add nutrients such as nitrogen and phosphorus to stormwater. Human waste also contributes to bod. Leaking sanitary sewer lines located near storm sewer lines can pose the same problems as illicit connections.[48]

Septic Systems

Effluent from poorly maintained or failing septic systems can rise to the surface and contaminate stormwater.[49] Septic systems can be important sources of pathogens and nutrients, especially nitrogen, that are not effectively removed from the waste stream. Bathing beach and shellfish bed closures are frequently the result of septic system effluent. One study found that 74 percent of the nitrogen entering the Buttermilk Bay estuary in Massachusetts originated from septic systems.[50] Fecal coliform and BOD can be present in stormwater if the system is improperly sited, designed, installed, or maintained.

Illicit Industrial Connections to Storm Sewers

Businesses that illicitly connect pipes containing wastewater from industrial processes to the storm sewer system rather than to the sanitary sewers can add metals, solvents or other contaminants to stormwater. In Seattle, one industrial facility's discharge of lead to the storm sewer system resulted in sediment so contaminated that it could be sent to a smelter to be refined.[51] Floor drains, dry wells, and cesspools are also frequent sources of illicit industrial discharges and connections.

Uncovered Materials Stored Outside

Rain or melting snow can erode piles of bulk material, such as sand, loose topsoil, or road salt if left uncovered, adding sediment, salts or other pollutants to nearby waterbodies. Likewise, precipitation can wash contaminants off leaking or dirty objects left outdoors. For example, water quality monitoring showed that untreated runoff collected from auto recycling facilities near Los Angeles frequently exceeded EPA benchmark figures, for biochemical oxygen demand, nitrogen, oil and grease, phosphorus, and sediment.[52]

Street, Sidewalk, and Airport De-icing

In colder parts of the country, salts used to keep roads, parking lots and sidewalks free of ice often drain into our waterbodies as snow and ice melt and spring rain falls. While some salt and ice treatment is necessary to keep roads safe in winter, measures can be taken to reduce or prevent the impacts from de-icing. The principal salts used are sodium chloride and calcium chloride, although materials such as calcium magnesium acetate and other commercial products are also used.[53] Some municipalities spread sand to maintain road traction on snow and ice, and this sand eventually may increase sediment loads. Airports de-ice runways and planes, usually with glycol mixtures that can be both toxic to fish, wildlife, and humans and exert high BOD on receiving streams.

Landfills

Because the soil cover on landfills is not stabilized with vegetation or other retaining cover while the landfill is operational, soil can erode from landfills as it does from construction sites. Additionally, improperly maintained hazardous-waste landfills can allow toxic contaminants to reach or stay on the surface of the landfill, allowing stormwater to carry these pollutants to nearby waterbodies.

Pets and Wild Animals

Waste from domestic and wild animals is a source of pathogens, nutrients and BOD in stormwater.[54] The Northern Virginia Soil and Water Conservation District estimates that each day, dogs leave 180,000 pounds of waste on the ground in Fairfax County, Virginia, alone.[55] Waste from birds such as pigeons, geese, and gulls that are attracted to human activity can also be a problem. Wild geese that congregate in large numbers on cultivated turf adjacent to bodies of water also contribute to pathogen, nutrient and BOD loadings.[56]

Littering

Not only does stormwater frequently receive no treatment, it also often does not even have the benefit of simple filtering or screening for visible objects. As a result, paper cups, cigarette butts, virtually anything made of styrofoam, newspaper, and other materials that people toss on the ground are carried into storm sewer systems -- and eventually into lakes, streams, and oceans.

This list, exhaustive as it is, is incomplete. Galvanized roofs, unpaved roads, the dust that collects on paved streets, and countless other aspects of daily life in urban areas contribute to polluted runoff. The first step in stormwater management is not to memorize any particular list, but rather to recognize the breadth of opportunities for pollution prevention and the need to think holistically about the entire chain of human activities that affect runoff quantity and quality. The case studies presented in this report demonstrate a wide variety of effective and efficient strategies for addressing stormwater runoff at the source.

Notes

1. U.S. Environmental Protection Agency, *Nonpoint Source Pollution: The Nation's Largest Water Quality Problem*, www.epa.gov/OWOW/NPS/facts/point1, January 21, 1997.

2. U.S. Environmental Protection Agency, *National Water Quality Inventory: 1996 Report to Congress*, EPA841-R-97-008, April 1998, p. ES-13.

3. Haile, R. W. et al, *An Epidemiological Study of Possible Adverse Health Effects of Swimming in Santa Monica Bay,* Santa Monica Bay Restoration Project, 1996. 70 pp.; Novotny V. H. and H. Olem, *Water Quality: Prevention, Identification, and Management of Diffuse Pollution*, Van Nostrand Reinhold, New York, 1994, p. 36; Pitt, R., *Stormwater Quality Management,* CRC Press, forthcoming 1999; Moffa

and Associates, R. Pitt, and SAVIN Engineers, Assessment of Decision Criteria used to Determine Benefits of CSO/SSO/SW Investments, WERF-sponsored report, forthcoming 1999.

4. Approximately 60 percent of rainfall infiltrates in the Olympia, Washington, area, for example, while approximately 50 percent infiltrates in the Connecticut area. City of Olympia Public Works Department, *Impervious Surface Reduction Study: Final Report*, May 1995, p. 9; University of Connecticut Cooperative Extension System, *NEMO Project Fact Sheet 3: Impacts of Development on Waterways*, undated brochure.

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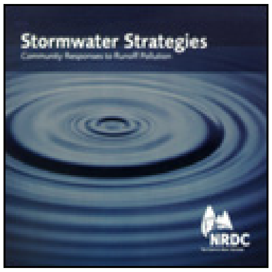

Stormwater Strategies Community Responses to Runoff Pollution

National Resource Defense Council

Chapter 3

THE CONSEQUENCES OF URBAN STORMWATER POLLUTION

The degradation caused by urban stormwater pollution is serious, and affects a significant proportion of the nation's population. Changes in land use that increase impervious cover lead to flooding, erosion, habitat degradation, and water quality impairment. Everyday activities such as driving, maintaining vehicles and lawns, disposing of waste, and even walking pets often cover impervious surfaces with a coating of various harmful materials. Construction sites, power plants, failed septic systems, illegal discharges, and improper sewer connections also contribute substantial amounts of contaminants to runoff. When these contaminants enter lakes, streams, and estuaries they result in stormwater pollution. This pollution, in turn, impacts important natural resources as well as other, equally important activities such as commercial and recreational fishing, swimming, and boating. While urban stormwater runoff is not alone in causing these impacts (industrial and agricultural runoff are equal or greater contributors to water quality impairment on a national scale), the environmental, aesthetic, and public health impacts outlined in this chapter will not be eliminated until urban stormwater pollution is controlled.

Flooding and Property Damage

The most dramatic consequence of increases in the volume and rate of stormwater runoff is flooding and property damage. As discussed in the preceding chapter, undeveloped areas such as forests and wetlands serve as sponges for excess rainwater, so when these areas are eradicated, filled in, or replaced with impervious cover such as asphalt, the volume of water entering streams and rivers increases. One study estimated that because of the increase in impervious cover in a watershed a flood event that should be expected once in 100 years could occur once every 5 years when the impervious cover reaches 25 percent, and could become an annual event when impervious cover reaches 65 percent.[1]

Conventional urban stormwater management, with its emphasis on engineered flood control measures such as dams, dikes and levees, and detention facilities, has in many areas helped to mitigate some of the worst flood damage. But it has been vastly outstripped by the pace of flood-producing urbanization. Furthermore, by quickly channeling stormwater away from certain areas via paved channels, stormwater pipes, and stream bank stabilization techniques (e.g., riprap, cutbacks, plantings, and bulkheads) rather than providing for retention or infiltration, conventional stormwater management can simply transfer hydrologic impacts downstream.[2] At times, downstream areas experience greater habitat loss, increased channel widening and erosion, and worse flooding due to the reduced storage and facilitated runoff upstream.

An Announcement from the Experts: "No One Safe From Flooding," FEMA Says

WASHINGTON April 1, 1997 -- Destructive floods can -- and do -- occur in -- every state in the nation, according to recent statistics issued by the Federal Emergency Management Agency (FEMA).

While some communities are less likely to experience flooding than others, nowadays very few, if any, are entirely safe from this threat, which is by far the most common type of natural disaster in the United States. "About 90% of our natural disasters involve flooding in one way or another," FEMA Director James Lee Witt said, "and the impression many people have that floods seem to happen more frequently now than they used to is quite accurate."

"As more and more land is cleared for development and paved over, there is less and less available to soak up excess water," Witt said. "The runoff has to go somewhere, and places that never flooded before are now at risk."

The records of the Federal Insurance Administration indicate that approxi-mately $1.1 billion in claims under the National Flood Insurance Program were paid in each of fiscal years 1995 and 1996. Those same records indicate that the Federal Insurance Administration paid flood insurance claims in every state of the union during that two-year period.

Source: "No One Safe from Flooding, FEMA Says" FEMA News Desk, April 1997, http://www.fema.gov/home/NWZ97/97095.htm

Streambank and Streambed Erosion

The increased volume and rate of urban stormwater runoff erodes streambanks and streambeds, dislodging and suspending sediment that might otherwise have remained in place. Erosion can be gradual, or can occur rapidly through a sudden collapse of a streambank.[3] Changes in hydrology also affect the shape and dimension of river channels, thereby altering aquatic habitat and channel stability.[4]

Siltation and Sedimentation

Rapidly flushing stormwater can increase erosion from all land, not just streambanks and streambeds. Stormwater then transports the eroded sediment downstream into the receiving waters. Eventually, when sediment-laden water is stilled, that sediment settles to the bottom of the stream, river, lake, or estuary. When sediments settle out, they may cover or destroy important habitat such as spawning beds or submerged aquatic vegetation. Pollutants such as phosphorus attach to sediment particles and become suspended or dissolved in receiving waters. The magnitude of the sedimentation problem is staggering: one study estimates that each year erosion from construction sites puts 80 million tons of sediment into receiving waters.[5]

Siltation and sedimentation has economic impacts as well. These excess deposits of sediment clog harbors and other water transport routes and reduce the storage capacity of reservoirs, obliging governments to spend billions of dollars each year to dredge and maintain those channels and facilities.[6] The U.S. Army Corps of Engineers dredges 83 million cubic yards of sediment linked to pollution sources each year at an annual cost of $180 million.[7] In many cases, these dredged sediments are laden with nutrients, heavy metals, and toxic chemicals -- making disposal expensive. Siltation can also affect commercial and recreational fishing by degrading necessary habitat and can impede recreational boating by creating obstructions.

Increased Water Temperature

Aquatic organisms have specific water temperature preferences and tolerance limits. Changes in water temperature can have a serious impact on aquatic ecosystems.[8] Water that infiltrates the ground and flows beneath the surface is usually much cooler than surface runoff. Not only do impervious surfaces prevent infiltration, they often warm stormwater as it runs off. Unshaded rooftops, parking lots, and other impervious areas can be 10–12° F warmer than fields and forests and consequently can heat the stormwater passing over them, often to 90° F or more, even before it reaches a stream or lake.[9] Research has found that the average stream temperature increases directly with the percentage of impervious cover in the watershed.[10] One study documented a temperature difference of almost 20° F between a wooded section of a Maryland stream and an open section of the same stream 7/10ths of a mile downstream.[11] Furthermore, trees shade waterbodies keeping them cool, while development often replaces tress with impervious surfaces.

Harm to Aquatic Life

Urban runoff can harm aquatic life in many ways due to changes in water chemistry and habitat loss.[12] The metals and organics that stormwater carries are toxic to fish and other forms of aquatic life. For example, untreated urban runoff collected from an auto recycling facility near Los Angeles over several years repeatedly killed 20 percent or more of the minnows exposed to it.[13] Urban stormwater is also often toxic to several species of aquatic insects, on which fish, frogs and other higher life forms feed.[14] For example, organic chemicals may have effects on the immune systems and early development of aquatic life.[15]

Stormwater can also bring toxic levels of road salt to urban waters. In certain streams draining roadway areas, studies have measured concentrations of chloride at levels 25 or even 60 times the level harmful to trout.[16] Even the trash that stormwater carries harms wildlife. The plastic loops that hold six-packs of beer or soda together can strangle gulls.

Sediment in stormwater has a number of harmful effects on aquatic life. Sediment still suspended in water increases infection and disease among fish by irritating their gills.[17] A number of fish species, including endangered species such as the log perch or blue shiner, cannot tolerate sediment levels in the water above certain threshold levels, and thus disappear from waterbodies under those conditions.[18] Suspended sediment scours submerged plants attached to rocks, as well as blocks sunlight that aquatic plants use to produce growth through photosynthesis.[19]

When sediment settles, it can bury and smother bottom-dwelling insects and reduce the survival rate of fish eggs.[20] At the same time, sediment deposition fills in the spaces between the gravel in stream beds that fish use to spawn and raise their young and in which invertebrate food sources live.[21] Furthermore, sediment may carry nutrients, bacteria, toxic metals and organic chemicals to the water.[22]

The increase in surface runoff associated with land development also dramatically increases runoff of the nutrients phosphorus and nitrogen, causing receiving waters to suffer. Many nutrients, which cling to soil particles in natural settings, are dislodged by development and other activities making them free to run off with stormwater.[23] For example, in a comparison between two Maine watersheds, phosphorus export was 10 times greater in a developed watershed than a forested watershed.[24] In highly developed areas these increases are usually permanent.

The enrichment of waters with nutrients is termed eutrophication and is a concern for several reasons. Excess phosphorus causes elevated growth of algae and aquatic vegetation in lakes and streams. Excess nitrogen can have a similar effect in marine waters. The excessive plant growth interferes with the use of waterbodies for recreation, fisheries, industry, agriculture, and drinking water supply. It can also lead to foul odors, noxious gas, and poor aesthetic quality of the receiving water.[25] In marine systems, nutrient enrichment can lead to red and brown tides that are a threat to marine organisms and human health. Perhaps most dramatically, eutrophication can cause fish kills.[26] When the vegetation dies and decomposes, it consumes oxygen dissolved in the water. Fish and other aquatic organisms cannot tolerate dissolved oxygen concentration below certain thresholds. As a result, eutrophic waters are typically devoid of most life.

Organic material discharged to a lake or stream also consumes oxygen when decomposing thereby reducing the dissolved oxygen content of the receiving water. As with nutrient enrichment, sudden additions of such material, perhaps in a storm or through illicit dumping, frequently causes fish kills.[27] Longer term impacts include changes in fish populations and reductions in shellfish.

The increase in water temperature compounds the oxygen-depletion problem. The warmer the water, the less dissolved oxygen it can carry. Research indicates that the thermal changes caused by urban runoff can increase visible algae blooms and have severe impacts on cold-water fish and other aquatic life.[28]

Changes in hydrologic patterns also have a significant effect on aquatic life. Urbanization increases both the magnitude and frequency of extreme low and high flow events. It also leads to a decrease in infiltration resulting from decreased base flow, an increase in water temperature, and declines in upland, riparian, and instream habitat quality. Research indicates that larger flood events significantly reduce populations of young fish such as trout and salmon as well as invertebrate populations.[29]

These impacts -- sedimentation, contaminant loadings, hydrologic instability, oxygen depletion and temperature increases -- not only threaten individual animals, but also reduce the diversity of life living in these waterbodies.[30] Studies have shown a sharp drop in the diversity of insect populations, which serve as food for higher life forms such as frogs and fish, as the amount of impervious cover in an urbanizing watershed passes 10 or 15 percent.[31] Other research has shown that the variety of fish species drops as well, with the disappearance of sensitive fish such as trout and salmon.[32] In short, stream biological health declines as watershed imperviousness increases.

Harm to Coastal Shellfisheries

Pathogens in stormwater also contaminate shellfish beds, and this contamination, along with pollution from other sources, causes closure of shellfish beds nationwide. Data collected from five coastal states indicate that urban runoff and storm sewers are the most pervasive source of shellfish harvesting restrictions, contaminating over 30 percent of the area reported as subject to such restrictions in those states.[33] A key contributing factor is the fact that levels of bacteria and viruses are usually much greater -- 100 to 1,000 times greater -- in the bottom sediment, where shellfish live, than in the water above.[34]

Harm to Sport Fishing

The harm to fish leads quickly to harm to fisheries. Sport fishing is a big business in the United States, and many of the species that are most sensitive to degraded water conditions, such as brown trout and salmon, are the species anglers prize most. Quality fisheries can be an important economic asset to the surrounding communities.[35] The U.S. Fish & Wildlife Service estimates that over 35 million anglers spent over $38 billion dollars in pursuit of their pastime in 1996, money that would not be spent if there were no fish to be caught.[36]

Human Illness

Stormwater carries disease-causing bacteria, viruses, and protozoa. Swimming in polluted waters can make you sick.[37] A study in Santa Monica Bay found that swimming in the ocean near a flowing storm sewer drain during dry weather conditions significantly increased the swimmer's risk of contracting a broad range of health effects. Comparing swimming near flowing storm-drain outlets to swimming at a distance of 400 yards from the outlet, the study found a 66 percent increase in an group of symptoms indicative of respiratory disease and a 111 percent increase in a group of symptoms indicative of gastrointestinal illness within the next 9 to 14 days.[38] Increased sediment in receiving water is also related to human illness: sediment prolongs life of pathogens and makes it easier for them to reproduce.

Impacts to Drinking Water Supply

In urbanized areas, runoff pollution is a serious concern for water supply agencies. Over 90 percent of the people in the United States rely on public supplies of drinking water. Of that 90 percent, 19 percent are served by systems with reported health violations.[39] A nationwide survey of surface drinking water supply utilities found that with an increase in urbanization there arose an increased concern among managers over runoff pollutants, particularly nutrients, bacteria, and toxic organic chemicals.[40] The costs can be astronomic. For example, runoff pollution from suburban and agricultural sources is one of the largest threats to New York City's currently unfiltered drinking water supply. If this pollution cannot be prevented, New York City may need to filter its water supply at a capital cost of perhaps $5 billion or more.[41]

Aesthetic Losses

Even if stormwater does not cause illness in humans from direct exposure or through dining on contaminated shellfish, it can cause other annoyances or intrusions. The cigarette butts, polystyrene cups, and other trash that storm sewers dump in neighborhood waters are an obvious eyesore. Sediment loads reduce the clarity of water, which not only reduces its attractiveness but can also increase the likelihood of boating, swimming, and diving accidents.[42] Excess nutrient loads can cause severe algal blooms, which coat the surface of water with an unpleasant scum, cloud the water, and add unpleasant odors and taste to water used for swimming or drinking.[43] The fish kills that urban stormwater pollution can cause are also community nuisances.

Harm to tourism and recreation. The combination of potential human illness and aesthetic losses can cause loss of revenues from tourism and recreational activities. Urban stormwater runoff was a documented contributing factor to approximately 25 percent of the approximately 1,651 beach closings reported in 1997, and was probably a factor in many more beach closings for which the contaminant sources were undocumented.[44] Coastal tourism is a major component of local economic activity across the nation, adding, for example, some $54 billion dollars and more than 320,000 jobs to the economies of nine California counties alone.[45] Inland, along rivers and lakes, tourism and recreational activities dependent on clean water provide municipalities with tax revenues and employment opportunities. Each year, water-based recreation adds $26 million to $31 million and a minimum of 650 to 750 jobs to the economies of 13 New Hampshire towns along the Connecticut River, and over $13 million and 290 jobs to the economy of the upper Delaware Valley between New York and Pennsylvania.[46]

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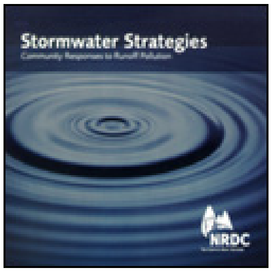

Stormwater Strategies Community Responses to Runoff Pollution

National Resource Defense Council

Chapter 12

LOW IMPACT DEVELOPMENT

Introduction

Low Impact Development (LID) has emerged as a highly effective and attractive approach to controlling stormwater pollution and protecting developing watersheds and already urbanized communities throughout the country.[1] Several LID practices and principles, particularly the source control approach and the use of micro-scale integrated management practices have the potential to work effectively as stormwater quality retrofits in existing ultra urban areas as well.[2] Developments in and application of LID techniques that have occurred since the original publication of *Stormwater Strategies* motivated this new section, which is an addendum to the discussion of strategies for addressing stormwater in new development and redevelopment covered in Chapters 5 through 11.

LID stands apart from other approaches through its emphasis on cost-effective, lot-level strategies that replicate predevelopment hydrology and reduce the impacts of development. By addressing runoff close to the source, LID can enhance the local environment and protect public health while saving developers and local governments money.

Below is a discussion of LID, its principles, practices, and benefits followed by 13 new case studies. The case studies provide examples of several LID practices and describe how they are being applied throughout the country. These practices are the building blocks of LID design and, when integrated in a systematic way, provide substantial benefits to the developer and community.

What is Low Impact Development?

LID is simple and effective. Instead of large investments in complex and costly engineering strategies for stormwater management, LID strategies integrate green space, native landscaping, natural hydrologic functions, and various other techniques to generate less runoff from developed land. LID is different from conventional engineering. While most engineering plans pipes water to low spots as quickly as possible, LID uses micro-scale techniques to manage precipitation as close to where it hits the ground as possible. This involves strategic placement of linked lot-level controls that are "customized" to address specific pollutant load and stormwater timing, flow rate, and volume issues. One of the primary goals of LID design is to reduce runoff volume by infiltrating rainfall water to groundwater, evaporating rain water back to the atmosphere after a storm, and finding beneficial uses for water rather than exporting it as a waste product down storm sewers. The result is a landscape functionally equivalent to predevelopment hydrologic conditions, which means less surface runoff and less pollution damage to lakes, streams, and coastal waters.

LID is economical. It costs less than conventional stormwater management systems to install and maintain, in part, because of fewer pipe and below-ground infrastructure requirements. But the benefits do not stop here. The associated vegetation also offers human "quality of life" opportunities by greening the neighborhood, and thus contributing to livability, value, sense of place, and aesthetics. This myriad of benefits include enhanced property values and re-development potential, greater marketability, improved wildlife habitat, thermal pollution reduction, energy savings, smog reduction, enhanced wetlands protection, and decreased flooding.[3] LID is not one-dimensional; it is a simple approach with multifunctional benefits.

LID Runoff Control Objectives:[6]

- minimize disturbance
- preserve and recreate natural landscape features
- reduce effective impervious cover
- increase hydrologic disconnects
- increase drainage flow paths
- enhance off-line storage
- facilitate detention and infiltration opportunities

LID is flexible. It offers a wide variety of structural and nonstructural techniques to reduce runoff speed and volume and improve runoff quality. LID works in constrained or freely open lands, in urban infill or retrofit projects, and in new developments. In a combined sewer system, LID can reduce both the number and the volume of sewer overflows.[4] Opportunities to apply LID principles and practices are infinite -- almost any feature of the landscape can be modified to control runoff (e.g., buildings, roads, walkways, yards, open space). When integrated and distributed throughout a development, watershed, or urban drainage area, these practices substantially reduce the impacts of development.

As urbanization continues to degrade our lakes, rivers, and coastal waters LID is increasingly being used to reverse this trend, resulting in cleaner bodies of water, greener urban neighborhoods, and better quality of life. LID offers a strong alternative to the use of centralized stormwater treatment. It aims to work within the developed and developing environment to find opportunities to reduce runoff and prevent pollution. LID controls stormwater runoff at the lot level, using a series of integrated strategies that mimic and rely on natural processes.[5] By working to keep rainwater on site, slowly releasing it, and allowing for natural physical, chemical, and biological process to do their job, LID avoids environmental impacts and expensive treatment systems.

Low Impact Development Principles and Practices

LID is grounded in a core set of principles based on the paradigm that stormwater management should not be seen as stormwater disposal and that numerous opportunities exist within the developed landscape to control stormwater runoff close to the source.[7] Underlying these principles is an understanding of natural systems and a commitment to work within their limits whenever possible. Doing so creates an opportunity for development to occur with low environmental impact. The principles are:[8]

- integrate stormwater management early in site planning activities
- use natural hydrologic functions as the integrating framework
- focus on prevention rather than mitigation
- emphasize simple, nonstructural, low-tech, and low cost methods
- manage as close to the source as possible
- distribute small-scale practices throughout the landscape
- rely on natural features and processes
- create a multifunctional landscape

LID uses a systems approach that emulates natural landscape functions. A near limitless universe of runoff control strategies, combined with common sense and good housekeeping practices, are the essence of a LID strategy.

These basic strategies, also known as integrated management practices, rely on the earth's natural cycles, predominantly the water cycle, to reduce land development impacts on hydrology, water quality, and ecology. Integrated management practices combine a variety of physical, chemical, and biological processes to capture runoff and remove pollutants at the lot level (See Insert).

Ten Common LID Practices

1. Rain Gardens and Bioretention
2. Rooftop Gardens
3. Sidewalk Storage
4. Vegetated Swales, Buffers, and Strips; Tree Preservation
5. Roof Leader Disconnection
6. Rain Barrels and Cisterns
7. Permeable Pavers
8. Soil Amendments
9. Impervious Surface Reduction and Disconnection
10. Pollution Prevention and Good Housekeeping

Several strategies focus on disconnecting roofs and paved areas from traditional drainage infrastructure and conveying runoff instead to bioretention areas, swales, and vegetated open spaces. LID also strives to prevent the generation of runoff by reducing the impervious foot print of a site, thereby reducing the amount of water that needs treatment. The end hydrological results are a reduction in runoff volume, an increased time of concentration, reduced peak flow and duration, and improved water quality.

Developers apply most LID strategies on the micro-scale, distributed throughout the site near the source of runoff. They customize strategies according to site conditions in order to reduce specific pollutants and to control runoff, a technique known as site foot-printing. LID is particularly effective when practices are integrated into a series of linked, strategically placed and designed elements that each contribute to the management of stormwater.

Bioretention, a core LID practice, provides a good example of how LID management practices work. What looks like a nicely landscaped area is in fact an engineered system that facilitates depression storage, infiltration, and biological removal of pollutants. Developers usually place bioretention areas in parking lot islands, at the edge of paved areas, at the base of buildings, or in open space areas. Runoff is directed to these low-tech treatment systems instead of conventional stormwater infrastructure. Bioretention areas use plants and soil to trap and treat petroleum products, metals, nutrients, and sediments. Bioretention areas, also know as "rain gardens," are relatively inexpensive to build, easy to maintain, and can add aesthetic value to a site, without consuming large amounts of valuable land area.[10]

LID Practices Use Natural Functions to Trap and Treat Runoff.[9]

Physical: increases interception, infiltration, and evapotranspiration; facilitates sediment removal, filtration, and volatilization; stabilizes soils to reduce sedimentation and erosion.

Chemical: facilitates adsorption, chleation, ion exchange, and organic complexing.

Biological: increases transpiration, nutrient cycling, direct uptake, and microbal decomposition.

LID includes integrating land and infrastructure management. Activities such as street sweeping, toxic-free and low-impact landscaping, frequent cleaning of catch basins, sediment control, and downspout disconnection all reduce runoff contamination. LID works equally well in new development and redevelopment projects and is easily customized to complement local growth management, community revitalization, and watershed protection goals.[11]

LID is much more than the management of stormwater -- it is rethinking the way we plan, design, implement, and maintain projects. Comprehensive programs usually complement LID practices with broader issues such as: considering where growth disturbance should occur; increasing awareness of the cumulative impacts of development; involving the community and raising watershed awareness; developing direct social marketing of LID retrofit actions to households, institutions and commercial establishments; creating a rational institutional framework for implementing stormwater management, and establishing an authority to guide and administer stormwater management activities.[12]

LID and Retrofitting the Ultra Urban Environment

The fundamental approach of using micro-scale management practices and source control has great potential to generate substantial benefits in existing urbanized watersheds.[13] LID principles and practices are particularly well-suited to ultra urban areas because most LID techniques, like rain gardens and tree planter boxes, use only a small amount of land on any given site.[14] Many LID practices, including bioretention, are good for urban retrofit projects since they are easily integrated into existing infrastructure, like roads, parking areas, buildings, and open space.

LID practices can be applied to all elements of the urban environment. For example, bioretention technology can effectively turn parking lot islands, street medians, tree planter boxes, and landscaped areas near buildings into specialized stormwater treatment systems.[15] Developers can redesign parking lots to reduce impervious cover and increase stormwater infiltration while optimizing parking needs and opportunities. Innovative designs for urban areas may also include roof gardens, methods for capturing and using rainwater, and use of permeable pavement in low traffic areas, parking areas, and walking paths.[16] Furthermore, LID strategies can help beautify the urban environment and create desirable public open space.

Seven Benefits of Low Impact Development

Effective. Research has demonstrated LID to be a simple, practical, and universally applicable approach for treating urban runoff.[17] By reproducing predevelopment hydrology, LID effectively reduces runoff and pollutant loads. Researchers have shown the practices to be successful at removing common urban pollutants including nutrients, metals, and sediment. Furthermore, since many LID practices infiltrate runoff into groundwater, they help to maintain lower surface water temperatures. LID improves environmental quality, protects public health, and provides a multitude of benefits to the community.

Economical. Because of its emphasis on natural processes and micro-scale management practices, LID is often less costly than conventional stormwater controls. LID practices can be cheaper to construct and maintain and have a longer life cycle cost than centralized stormwater strategies.[18] The need to build and maintain stormwater ponds and other conventional treatment practices will be reduced and in some cases eliminated. Developers benefit by spending less on pavement, curbs, gutters, piping, and inlet structures.[19] LID creates a desirable product that often sells faster and at a higher price than equivalent conventional developments.

Flexible. Working at a small scale allows volume and water quality control to be tailored to specific site characteristics. Since pollutants vary across land uses and from site to site, the ability to customize stormwater management techniques and degree of treatment is a significant advantage over conventional management methods. Almost every site and every building can apply some level of LID and integrated management practices that contribute to the improvement of urban and suburban water quality.[20]

Adds value to the landscape. It makes efficient use of land for stormwater management and therefore interferes less than conventional techniques with other uses of the site. It promotes less disturbance of the landscape and conservation of natural features, thereby enhancing the aesthetic value of a property and thus its desirability to home buyers, property users, and commercial customers. Developers may even realize greater lot yields when applying LID techniques.[21] Other benefits include habitat enhancement, flood control, improved recreational opportunities, drought impact prevention, and urban heat island effect reduction.

Achieves multiple objectives. Practitioners can integrate LID into other urban infrastructure components and save money. For example, there is a direct overlap between stormwater management and Combined Sewer Overflow (CSO) control such that municipalities can use LID to help remedy both problems.[22] Lot level LID applications and integrated stormwater management practices combine to provide substantial reductions in peak flows and improvements in water quality for both combined and separated systems.

Follows a systems approach. LID integrates numerous strategies, each performing different stormwater management functions, to maximize effectiveness and save money. By emulating natural systems and functions, LID offers a simple and effective approach to watershed sensitive development.

Makes sense. New environmental regulations geared toward protecting water quality and stabilizing our now degraded streams, rivers, lakes, and estuaries are encouraging a broader thinking than centralized stormwater management. Developers and local governments continue to find that LID saves them money, contributes to public relations and marketing benefits, and improves regulatory expediencies. LID connects people, ecological systems, and economic interests in a desirable way.

Low Impact Development Strategies

Vegetated Roof Helps Green City

Philadelphia, PA
Population: 1,585,577
Area: 135 square miles

Highlight: Green roof uses Low Impact Development principles to capture and treat runoff at the source.

Roofs cover a significant portion of the urban landscape and generate large volumes of stormwater runoff. By the same token, they provide an excellent opportunity to control runoff if they are covered with plants. Europeans have been using vegetative roof covers for more than 25 years to control runoff, improve air quality, and save energy. Extensive roof gardens or "green roofs," as they are often called, are beginning to appearing on commercial, industrial, institutional, and residential buildings in the U.S., opening new territory for stormwater management.

Green roofs offer an exciting chance to apply low impact development (LID) principles. They are typically composed of growth media and vegetation on a high-quality waterproof membrane. This veneer of living vegetation is highly effective at capturing, retaining, and filtering runoff. The waterproof membrane prevents leaking. By controlling runoff at the source and absorbing pollutants, green roofs prevent stormwater pollution.

The benefits, however, extend beyond water quality. Green roofs conserve energy by keeping roofs cool in the summer and insulated in the winter. They save money by reducing land area needed for stormwater management practices, which is especially important in densely populated areas with high real estate values, and by extending the life of a roof. Vegetated cover reduces ware and tear caused by temperature related expansion and contraction and protects the roof from ultraviolet (UV) radiation and cold winds that break down traditional roofing materials.[24] Roof gardens typically have a 50-year life expectancy. Extensive green roofs cost between $5 and $12 per square foot to install; add an additional $10 to $20 for roofs that need waterproofing. Green roofs also have substantial aesthetic benefits. They make a building or cityscape more pleasant to look at and some vegetated roofs, known as "intensive" green roofs, can be designed to be accessible and used as park and building amenities.

The green roof project at the Fencing Academy of Philadelphia is a 3,000-square-foot extensive roof garden installed and monitored by Roofscapes, Inc. on top of an existing building. The system makes use of natural processes to detain and treat a 2-year 24-hour storm event. The vegetated roof cover is on average 2.75 inches thick, and includes a synthetic under-drain layer, a thin, lightweight growth media, and a meadow-like planting of perennial *Sedum* varieties. The designers selected plants appropriate for the region and setting. The system weighs less than 5 pounds per square foot when dry and less than 17 pounds per square foot when saturated. The light weight allows installation on existing conventional roofs without structural adjustments.

The roof system can reproduce open-space runoff characteristics for rainfall events up to 3.5 inches. Little or no immediate runoff occurs for rainfall events delivering up to 0.50 inches. For these events, modeling predicts a 54 percent reduction in annual runoff volume. Actual monitoring using 14- and 28-square-foot trays over a nine-month period showed that the trays captured 28.5 inches of the 44 inches of rainfall recorded during this period. The roof garden is also effective at reducing the temperature of runoff that does occur since the temperature of the green roof stays cooler than conventional roofs in warm months. This helps reduce "thermal shock" caused by flash runoff from hot roof surfaces, which can have a significant impact on aquatic ecosystems.

Green roofs are easily incorporated into both new and existing development. Some factors that must be considered, however, are the load-bearing capacity of the roof deck, the moisture and root penetration resistance of the roof membrane, roof slope and shape, hydraulics, and wind shear. Roof gardens like the one described at the Fencing Academy of Philadelphia are excellent opportunities to apply LID principles and achieve multiple benefits. Widespread use of roof gardens would substantially reduce stormwater runoff and urban water pollution problems while helping to improve air quality, conserve energy, reduce urban heat island effects, and add beauty and green space to urban settings.

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LID Subdivision Reduces Peak Discharge[25]

Frederick County, MD*
Population: 195,277
Area: 633 square miles

Highlight: Total low impact development (LID) site design reduces runoff, saves developers money, and provides downstream peak discharge control.

* This case study was provided by Michael Clar, President, Ecosite, Inc., 2001.

Developers conceived the Pembroke Subdivision using a low-impact approach right from the start. In doing so, they created an economically desirable development that protects the environment and exhibits the benefits of a multifunctional landscape. Pembroke is a half-acre plot residential development located in northern Frederick County, Maryland. It is the first low impact development (LID) subdivision permitted in Frederick County and one of the few comprehensive LID subdivisions in the country. To date, most projects that have incorporated LID practices and principles are limited to a single lot in scope and therefore, do not realize the greater environmental benefits of the management practices spread across a drainage area.

In Pembroke, developers addressed runoff using "volume control" techniques as opposed to the more traditional "peak discharge" approach that uses a network of catch basins and pipes to convey runoff from an entire development to stormwater management ponds. The volume control approach allowed developers to replicate predevelopment runoff patterns using micro-scale integrated management practices that capture and treat rainwater close to where it hits the ground. The use of LID practices and principles throughout the development enabled developers to eliminate the use of two stormwater management ponds that they had envisioned in an earlier site conception. This elimination represented a reduction in infrastructure costs of roughly $200,000. In place of the stormwater management ponds, the developer preserved two-and-a-half acres of undisturbed open space and wetlands, which aid in the control of stormwater runoff. This also resulted in a considerable saving in wetlands mitigation impacts.

Extensive use of LID site foot-printing techniques allowed the site design to preserve approximately 50 percent of the site in undisturbed wooded condition. This design feature was very beneficial to maintaining pre-development hydrologic conditions. Site foot-printing also enabled developers to gain two additional lots by using a LID design, increasing the 43-acre site yield from 68 to 70 lots. This "density-bonus" added roughly $100,000 in additional value to the project.

Developers also reduced effective impervious cover and saved money by converting approximately 3,000 linear feet of roads from an "urban road" section to a "rural road." They did so by replacing curbs and gutters with vegetated swales and reducing paving width of the road from 36 to 30 feet. The use of swales saved the developers $60,000 in infrastructure construction and the reduced road width lowered paving cost by 17 percent, while at the same time reducing overall imperviousness.

In order to satisfy County criteria for adequate downstream conveyance, developers conducted a downstream impact analysis. The analysis examined the ability of a LID site design to maintain predevelopment peak discharge conditions for a range of storms including the 1, 2, 10, 50 and 100-year storms This analysis was important because many public works personnel perceive innovative LID stormwater management techniques to be capable of addressing water quality issues, but insufficient to provide downstream peak discharge control for the larger flood flows. The developers had initially based site LID hydrologic analysis on the 1-year storm (2.5 inch rainfall), which is part of the criteria for water quality control in Frederick County. The downstream analysis revealed, however, that the 1-year storm design was not sufficient to maintain predevelopment peak discharges for the 10, 50 and 100-year storms. They then used an incremental iterative procedure to determine additional control requirements to provide necessary downstream control. This analysis showed that increasing the design storm to a 2-year storm (3.0 inches of rainfall), provided required downstream protection over the complete range of flood events (10, 50 and 100 year storms).

The results of this study have great significance for future stormwater management policy and design criteria. These results clearly illustrate tremendous advantages achieved by incorporating a runoff volume control approach and LID technology. It also demonstrates that conventional stormwater management designs that use a peak-discharge detention approach along with stormwater management ponds are not as effective as a LID approach. The hydrologic flaws associated with the peak-discharge detention approach are numerous, and include:

- Peak discharge control does not typically address the maintenance of groundwater recharge.
- Peak discharge approaches alter the frequency and duration of flood flows resulting in stream channel degradation.
- Peak discharge approaches can actually exasperate downstream flooding conditions due to the super-positioning of runoff hydrographs.
- Peak discharge approaches, particularly the use of regional facilities, provide no protection for streams above the regional facilities.

Using an integrated LID stormwater management approach reduces or eliminates many of these problems.

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LID at the Washington Naval Yard[26]

Washington, DC
Population: 606,900
Area: 61.4 square miles

Highlight: The Navy demonstrates Low Impact Development (LID) effectiveness and applicability by installing a number of LID retrofits throughout the Washington Navy Yard, helping to protect the Anacostia and Potomac Rivers and Chesapeake Bay.

Polluted urban runoff is a serious environmental and public health problem in the District of Columbia (the District). As in other urban areas, the hydrology of District waters is changed and contaminated by pollution borne by stormwater. Pollutants from everyday activities degrade the rivers, posing health risks, destroying habitat, and limiting citizen and visitor enjoyment. Surface runoff that discharges through separate sewer systems and combined sewer overflows are the most significant sources of pollutants to District waters, causing almost 70 percent of their overall impairment.[27]

Approximately 65 percent of the District's natural groundcover has been replaced with impervious surfaces, which generate large quantities of surface runoff and cause severe water pollution problems.[28] For example, dissolved oxygen levels in the Anacostia become so low during the summer that fish kills can occur.[29] Bacteria levels are sometimes hundreds to thousands of times higher than the allowable levels, putting the health of those whom come in contact with the water at risk.[30] Monitoring shows that District waters are too polluted to allow swimming.[31] Neither the natural drainage systems nor the stormwater system are capable of adjusting to the dramatic hydrologic changes that are occurring in the District as a result of urban development.

As part of an overall effort to help protect and restore the quality of the Anacostia and Potomac Rivers and the Chesapeake Bay, Naval District Washington adopted a low impact development (LID) approach to stormwater retrofit and new facilities construction projects. This LID effort complements the Navy's effort to update the 150-year old separate-storm sewer system. Video investigations, cleaning, and system modernization led the way to the installation of ten Naval District Washington pilot projects that demonstrate the use of LID techniques in ultra-urban areas. Researchers will document and evaluate construction costs, maintenance requirements/costs, and pollution control effectiveness.

The project employs a variety of LID practices and principles, focusing on existing parking lots, roads, rooftops, and landscaped areas throughout the Washington Navy Yard. The LID practices collect runoff from these surfaces, filter pollutants, and control runoff volume and timing before discharging to the Anacostia River through the existing storm sewers. Engineers designed the bioretention retrofits to intercept stormwater preferential pathways and to treat the first one-half inch of rain at a minimum. Each unit treats about 0.5 acres of impervious surface.

The two main areas of LID retrofits are in the Willard Park and Dental Clinic parking lots. Naval District Washington installed several bioretention and detention cells to retrofit the parking area at Willard Park as part of the replacement and repair of existing parking structures. Some sections of the parking lot are specially designed to store water and release it slowly to reduce peak discharge. To save space and maximize parking, Naval District Washington installed bioretention strips between parking areas. Additional features include rain barrels that collect and store roof runoff for later irrigation and storm drain inlets that prevent trash and debris from entering the river. The retrofit of the Willard Park lot resulted in minimal disturbance and no loss of parking spaces.

As part of major reconstruction of the Dental Clinic parking area, Naval District Washington installed bioretention islands, sand filter gutter strips, and permeable pavers between parking rows. Permeable pavers are a matrix of paving blocks and gravel that allow stormwater to infiltrate into a stone filled water storage area beneath the surface. Where the future use of the existing surface could not be altered, Naval District Washington installed underground storage cells. These detention cells help slow runoff and reduce peak discharge but do not offer any water quality treatment.

Additional LID practices are distributed throughout the Navy Yard. For example, disconnected building downspouts infiltrate rooftop runoff and storm drain inlet structures trap sediment, litter, and debris. The

Navy Yard also installed a tree-box filter at the 9th Street gate. Tree-box filters are mini bioretention areas installed beneath trees that can be very effective at controlling runoff, especially when distributed throughout the site. Runoff is directed to the tree-box, where it is cleaned by vegetation and soil before entering a catch basin. The runoff collected in the tree-boxes helps irrigate the trees. Finally, Naval District Washington amended soils in some open space areas with aggregate gravel, although generally subsurface conditions are not conducive to infiltration.

Of the 60 acres of impervious surfaces at the Navy Yard, these demonstration projects addressed runoff from about 3 acres. Other end-of-pipe treatment systems are in place that treat an additional 10 acres. About 25 percent of the facility has stormwater controls in place. In addition, Naval District Washington has repaired the storm sewer system to stop leaks and prevent interaction between surface water and groundwater at the site. Naval District Washington is preparing a region-wide LID plan to address stormwater runoff at their satellite facilitates.

Future plans call for LID retrofitting of other naval facilities in the Chesapeake Bay watershed. LID concept plans have already been completed for the following naval installations:

1. Potomac Naval Annex
2. US Naval Observatory
3. Nebraska Avenue Naval Annex
4. Anacostia Naval Annex
5. US Naval Academy

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Urban Stormwater Control Project at the Environmental Center of the Rockies[32]

Boulder, CO
Population: 83,312
Area: 22.6 square miles

Highlight: Strategic landscaping and micro-scale stormwater management that mimics natural systems reduce runoff and harvest rain water for irrigation.

When it learned that 70 percent of pollutants reaching nearby Boulder Creek were the result of nonpoint sources, the Land and Water Fund of the Rockies (the LAW Fund) took initiative and enacted corrective measures. They had already retrofitted a building to house the new Environmental Center of the Rockies using "green" architecture strategies, which included reflective windows, a new roof made from recycled materials, and roof mounted solar collectors. The LAW Fund saw the Environmental Center with its highly visible, urban setting as a perfect place to take sustainable design a step further. They decided to "green" the landscape surrounding the building and retrofit its parking lot using Low Impact Development (LID) techniques. The project created an aesthetically pleasing setting that performs natural stormwater functions and conserves water.

The LAW Fund, with the help of Denver's Wenk Associates and Joan Woodward, professor of landscape architecture, created a "closed loop" landscape that captures and treats runoff on-site instead of conveying it to city waterways. To accommodate the site's location in a semi-arid climate (annual average precipitation depth is about 18.6 inches) the design focused on detention and infiltration practices that incorporate native drought-resistant plants. The system uses integrated management practices such as retention grading, vegetated swales, and bioretention cells (rain gardens) to capture and treat runoff. It uses these features in conjunction with a smaller parking lot, disconnected roof leaders, water harvesting, and landscaping that emphasizes native vegetation. These practices work together to:

1. conserve water and energy
2. decrease stormwater runoff discharge to city sewers and
3. decrease transport of water-born pollutants from the facility.

Project designers created this system of swales and rain gardens, amended with sandy loam to increase infiltration, to infiltrate and cleanse up to one-half the volume of a hundred-year flood event. The system should also effectively treat the first flush of runoff, which picks up most of the pollutants deposited on impervious surfaces. Strategic grading of the parking lot directs all runoff through two infiltration swales along the edge of the paved area. Designers engineered the swales to filter both coarse materials and finer particles and pollutants. A buried permeable landscape barrier prevents clogging of filter media in the bottom of the swale. Then, the swales convey runoff to vegetated areas in the parking lot itself and at the front of the building, or to nearby bioretention areas. This depression storage allows excess runoff to be stored for later evapotranspiration.

In addition, the LAW Fund reduced the amount of effective impervious cover at the site by eliminating 22 percent of the parking spaces, removing an extra sidewalk, disconnecting roof leaders, and landscaping the open space around the building. Before the retrofit, the 24,108 square-foot site was predominately irrigated turf grasses and impervious parking, pedestrian, and building surfaces. Now, more than 30 percent of the site is pervious, landscaped surfaces.

A water balance study indicated that the landscape system infiltrates between 70 and 80 percent of the water applied to the site as either precipitation or irrigation water, with less than one percent of the applied water leaving the site as runoff. Vegetation plays an important role in this process, using the remaining 20 to 30 percent of the applied water. Water quality monitoring has not been a focus of this project. However, researchers believe the system is protecting local water quality since it retains and infiltrates almost all runoff on site.

The LAW Fund wanted to harvest as much runoff as they could to irrigate the vegetated portions of the site. For example, harvested roof runoff goes directly to planter boxes, which overflow onto the parking lot if capacity is exceeded. This reduces irrigation demand substantially. Landscaped garden terraces provide a pleasant place for outdoor meetings and educational programs and help to buffer the building from the adjacent road that handles more than 30,000 cars daily. This multifunctional system also uses shade trees throughout the parking lot to intercept precipitation and help reduce surface runoff.

The City of Boulder, Wright Water Engineers, US EPA, and Colorado University continue to monitor the site and evaluate the system. The Colorado University is also monitoring the site and analyzing data through the Boulder Area Sustainability Information Network (BASIN) project. The LAW Fund is developing a long-term maintenance plan for the site, which will be cheaper than conventional landscape maintenance requiring mowers, extensive irrigation, weed trimmers, and pesticides. A 16-minute video presentation of the project is available through The City of Boulder's Channel 8 television station.

The Environmental Center of the Rockies project is one of 25 projects selected by the National Forum on Nonpoint Source Pollution. The National Geographic Society and the Conservation Foundation started the forum, which addresses issues by identifying innovative, nonregulatory options that balance economic and environmental needs. A list of the 25 projects can be found on the World Wide Web at: http://www.lawfund.org/ecr/ecr25demo.htm. Funding and support of the project came, in part, from The National Geographic Society, The Conservation Fund, and the U.S. Geological Survey.

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T.R.E.E.S. Reduces Runoff[33]

Los Angeles, CA
Population: 3,485,398
Area: 469 square miles

Highlight: The Hall House demonstration site uses lot level low impact development practices designed to capture and treat all the runoff from this residential site.

Water and air pollution, drought, flooding, youth unemployment, urban blight are some of the challenging issues that a coalition of Los Angeles government agencies and environmentalists are addressing through the T.R.E.E.S project. T.R.E.E.S., an acronym for Trans-Agency Resources for Environmental and Economic Sustainability, uses an innovative, inexpensive, and integrated approach to address these issues simultaneously. Working together, the groups involved developed a series of Best Management Practices (BMPs) for industrial sites, commercial buildings, schools, and single family homes that create a "blueprint for an ecologically, socially, and economically sustainable Los Angeles." Project managers identified the following BMPs as being most applicable and cost-effective:

- strategic planting
- other tree planting
- tree maintenance
- mulching
- cistern installation
- dry well installation
- graywater system installation
- pavement removal

The T.R.E.E.S. Project began in 1997 with a design charrette that included city planners, landscape architects, engineers, urban foresters, and public agency staff. The goal of the charrette was to identify and design retrofit opportunities for Los Angeles that cost-effectively reduce the environmental effects of urbanization. To promote their efforts, T.R.E.E.S. created a demonstration site at a single-family residence in south Los Angeles. The Hall House site uses several of the selected strategies including a cistern collection system, redirection of roof-top runoff, vegetated/mulched swales, and retention grading to reduce runoff pollution. By design, the BMPs used should capture all runoff from the site, reusing some for irrigation and returning the rest to the groundwater.

The design directs rooftop rainwater to a cistern collection system that stores runoff in two 1,800-gallon tanks for irrigating the site during dry months. To further promote sustainability, the cisterns are constructed with recycled polypropylene, a plastic that is plentiful in the Los Angeles waste stream. In addition, the cistern can double as a flood control device when the overflow is connected to the storm drain system. The widespread use of cisterns throughout a community can regulate flow of water into the stormwater drainage system by creating a network of strategically drained and filled reservoirs. By capturing and retaining rooftop runoff close to the source, cisterns help reduce pollution while conserving water for later use.

The swales, composed of recycled yard waste, slow the flow of stormwater allowing for infiltration and pollutant removal. They are an attractive, low-cost, low-maintenance, on-site stormwater treatment system that use limited yard space. In addition, the yard is graded to direct runoff to depressed garden areas that also retain water until it can be absorbed into the ground. These rain gardens can capture and retain a 10-inch flash flood with the probability of occurring once every 100 years. If necessary, excess runoff can be bypassed to the existing drainage system. This strategy works best in highly permeable soils, as is the case with the Hall House site, or if soil is amended with a layer of crushed aggregate rock to achieve higher infiltration rates.

Most of the BMPs are relatively inexpensive, and several are within the ability of the average homeowner to install. The two cistern tanks at the Hall House were prototypes requiring custom manufacturing and installation. With widespread application of the technology, a do-it-yourself design, and mass production, the cost is expected to be an achievable 50-cents per gallon. Other cost estimates are listed below:

BMP	Cost Using Contractor	Cost "Do it Yourself"
Retention Grading of Lawns Biofiltration Swales Downspout Extensions	$2,500 $250 $75 each	$1,250 minimal $40 each
Note: costs are estimates and include materials and installation		

The T.R.E.E.S. demonstration site uses natural systems and functions to reduce the effects of urbanization. These site-level techniques have significant potential to reduce pollution if applied throughout a watershed. They are cost effective and successful at capturing, cleaning, and storing runoff, reusing water, preventing floods, improving air quality, reducing energy demand, and creating urban forestry and watershed management jobs. If applied throughout the city, project managers anticipate reducing water imports by 50 percent, cutting the solid waste stream by 30 percent, decreasing energy dependence, and creating thousands of new jobs.

The T.R.E.E.S. project has developed an implementation plan that uses public policy and financial strategies to encourage widespread use of these BMPs. One example of this effort is a partnership between T.R.E.E.S. and the Los Angeles Department of Water and Power's *Cool Schools* program. Students help to reduce the heat island effect and lower energy consumption at their campuses by replacing asphalt with grass and trees. At Broadous Elementary, designated a *Sustainable School ,* T.R.E.E.S. coordinated the design and construction of a stormwater separator and infiltration basin to foster groundwater recharge and solve a campus flooding problem. Program participants are developing a monitoring plan and outdoor classroom curriculum.

The Hall House demonstration site is also in the early stages of a comprehensive two-year monitoring study. Researchers from University of California at Davis and USDA Forest Service have selected a control site next door, mapped and tested soils; and installed flow meters and set up a micrometeorological station to measure runoff from roof surfaces, the use of irrigation water, and runoff to the street. At this point, researchers do not have any results to report. However, this study will eventually help determine how much runoff is actually being captured and treated by the BMPs.

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Note: Tree People's sponsors in the T.R.E.E.S Project include the USDA Forest Service, the City of Los Angeles Stormwater Management Division and Department of Water and Power, the City of Santa Monica, the U.S. Environmental Protection Agency, the Los Angeles County Department of Public Works, the Metropolitan Water District of Southern California, the Los Angeles Urban Resources Partnership, the Southern California Association of Governments, and Environment Now.

SEA Streets Leaves Legacy [34]

Seattle, WA
Population: 516,259
Area: 84 square miles

Highlight: Street improvements incorporate low impact development practices to reduce runoff and enhance the neighborhood.

The Seattle Millennium Project is celebrating the light, water, and woodland resources that residents cherish as important quality-of-life features. As part of the Millennium Project, Seattle Public Utilities has initiated the Urban Creeks Legacy program. This program focuses on creek restoration as well as improved drainage and water quality. Goals of the program are to promote public awareness, educate citizens, foster collaboration, involve volunteers, and celebrate Seattle's creek systems.

One element of the Urban Creeks Legacy Program is a pilot project call SEA Streets, which aims to reduce the impact that "street-scapes" have on local stream watersheds and salmon habitat. SEA Streets is a comprehensive approach that manages stormwater, minimizes impervious surfaces, and eases traffic. It complements an ongoing effort by Seattle Public Utilities and Seattle Transportation to address street improvements in areas that do not have traditional piped drainage systems. Seattle Public Utilities has found these areas to be significant contributors to runoff quality and quantity problems.

The SEA Streets Project focuses on Broadview, a residential section of ultra-urban northwest Seattle located in the Pipers Creek Watershed. Seattle Public Utilities selected Broadview through a neighborhood petition process after receiving 94 percent approval from the neighborhood for the pilot project. Six neighborhoods had achieved the 60 percent resident support needed to be considered for the pilot site, which the city also evaluated for technical feasibility.

SEA Streets examines street drainage alternatives with the following objectives:

- Decrease runoff peak flow and volume
- Minimize impervious area
- Document effects of alternative design
- Minimize maintenance through design and stewardship
- Design watershed and neighborhood friendly streets
- Change the paradigm that curb gutter/sidewalk is necessary

The key elements of SEA Streets are drainage improvements, street improvements, landscaping, and neighborhood amenities. Landscaping and tree preservation provide rainfall management, runoff treatment, and aesthetic benefits. Sidewalk design focuses on attracting pedestrians and balancing transportation and parking needs with runoff reduction and treatment. Vegetated swales, gardens, and bioretention areas are used in conjunction with traditional drainage infrastructure to collect and treat runoff close to the source.

The drainage improvements focused on reducing surface runoff by integrating engineering practices commonly used in ultra-urban areas with practices that mimic and use natural processes. System designers combined traditional drainage features (culverts, catch basins, flow control structures, and slotted pipes) with interconnected swales, vegetation, and soil amendments to manage stormwater flow and discharge. The swales contain native wetland and upland plants to treat runoff and beautify the site. The entire site is multifunctional and designed to function like a natural ecosystem. In some areas, however, infiltration practices can not be used due to existing groundwater intrusion problems in some homes. In these situations, the emphasis was on biofiltration treatment of stormwater and not infiltration. They also increased the time that water travels through the drainage area by increasing the length of flow paths, using vegetated surfaces for conveyance (and biofiltration), and maximizing use of all areas within the right-of-way without hard surfaces for detention. Any water not infiltrated flows into a temporary pool where it is treated and detained before being conveyed into the downstream stormwater network.

City engineers designed the system to reduce the peak discharge rate and volume from a two-year 24-hour storm event (1.68 inches) to predevelopment conditions. In addition, the system meets City of

Seattle requirements to convey runoff from a 25-year, 24-hour storm event. The system is capable of controlling runoff from the entire 2.3-acre drainage area, an important for protecting habitat for threatened and endangered salmon species in the Pipers Creek watershed. To verify these design goals, for a two-year period, the city will monitor effluent during each storm and compare it to data collected prior to the enhancement of SEA Streets.

Street improvements are one of the most important and interesting components of the SEA Streets project. The original street consisted of a straight, 60-foot right-of-way with parking on both sides -- there were no sidewalks or drainage controls. To improve stormwater management, designers created a curvilinear roadway with only 14-foot wide paved sections (18 feet at intersections), which remains wide enough for two cars to pass slowly. The longer flow path and reduced impervious cover help limit the volume and speed of runoff. Designers addressed emergency access by eliminating curbs and creating grass shoulders that can accommodate heavy vehicle loading. They further reduced effective imperviousness through efficient parking configurations and the use of alleys. Parking spaces are limited but accommodate the needs of property owners. Sidewalks also follow the curvilinear pattern and are only located on one side of the street.

Strategic landscape elements reduce and help treat runoff while making the street more attractive and pedestrian friendly. As part of SEA Streets, the city planted more than 100 deciduous and coniferous trees and 1,100 shrubs. Prior to this project, there was not a single tree in the right-of-way. Designers worked with homeowners to create functional transitions between private and public property and informed them about water quality sensitive landscaping practices.

All together, the design features of the site provide numerous neighborhood amenities. In addition to those mentioned above, tree conservation and vegetation help reduce summer heat and absorb air pollutants, curvilinear streets keep traffic volume and speed down, and pedestrian friendly design helps reduce automobile use.

This innovative project cost $850,000, funded completely by Seattle Public Utilities using money collected from drainage fees. The city estimates that conventional drainage methods and street improvements would have cost between $600,000 and $800,000. However, they expect the significant research, design, and communications budgets needed for this pilot project to be lower for future projects, making the SEA Street approach even more economical and competitive.

The success of the Broadview pilot project has already led to the planning of a second SEA Street, which will include additional LID practices such as permeable pavers and pavement and focus more on water quality monitoring. Seattle Public Utilities' long term goal is to retrofit the ditch and culvert drainage system that currently dominates the northern part of the city using SEA Streets and other natural approaches to manage runoff.

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City Partners with Property Owners to Promote LIDs[35]

> **Portland, OR**
> *Population: 437,329*
> *Area: 125 square miles*
>
> ***Highlight:*** To help clean up the city's waters, Portland initiated a pilot program that provides money for low impact development retrofits that control runoff in combined sewer areas.

Faced with severe pollution in the Willamette River, poor watershed health, and loss of habitat for endangered salmon, Portland decided to take action. The city developed the Clean River Plan-a comprehensive approach to improve water quality in urban streams that promotes low impact development (LID) strategies among property owners and developers.

The Clean River Plan offers solutions to eliminate combined sewer overflows (CSOs) and local basement flooding, including techniques for controlling urban runoff from commercial, industrial, and institutional properties. CSOs are a major source of pollution in the Willamette. Almost every time it rains in Portland, stormwater fills the combined sewers, which carry both sanitary sewage and surface runoff, causing overflows. CSOs discharge raw sewage along with contaminated runoff from streets, lawns, and parking lots directly into the river. The Clean River Plan uses a variety of strategies for removing stormwater from sewers and restoring beneficial natural processes. These strategies are intended to help downsize or displace single-purpose infrastructure such as large pipes, expanded treatment plants and pump stations.

To jump start participation in one facet of the program, Portland's Bureau of Environmental Services initiated the Willamette Stormwater Control Program, providing technical and financial assistance for a limited number of pilot projects that control stormwater runoff. The program focuses on LID techniques that capture runoff close to the source, allowing it to infiltrate into groundwater. These landscape practices also enhance neighborhoods, reduce air pollution, and reduce basement flooding. These projects will demonstrate the technical feasibility, cost, and performance of retrofits that incorporate LID practices and principles.

The Bureau will support 15 demonstration projects to retrofit existing commercial sites, industrial properties, schools, religious institutions, and apartment complexes in targeted areas of Portland. These projects are to focus on strategies such as:

- disconnecting roof downspouts and directing runoff to vegetated swales, planters, or other landscape features
- removing or replacing pavement with porous materials that allow stormwater to soak into the ground
- re-grading some paved areas so they drain into new or existing landscaping
- installing roof gardens that reduce stormwater flow into the sewers and also improve air quality

In return, pilot program participants can receive up to $30,000 for design and construction for their projects. In addition, the projects will receive extensive publicity. To be accepted for financial assistance, projects must be part of an existing development, they must be located in the city's combined sewer target area, and that must remove runoff from at least 10,000 square feet of paved or roof area. Projects must be completed by December 31, 2002.

The first project funded is a retrofit of a Boys and Girls Club building using LID to provide complete on-site treatment and disposal of runoff draining from its 21,000 square-foot roof. Runoff from two thirds of the roof will go directly to planters and landscape bioretention areas that provide infiltration and treatment. The other third of the roof area will drain to a traditional soakage trench system with treatment provided by a sand filter. The total project cost is approximately $35,000 and is expected to be completed by the end of 2001. The Willamette Stormwater Control Program continues to evaluate a number of proposals for project to be implemented over the next couple years.

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Stormwater Treatment System is a Work of Art[36]

St. Paul, Minnesota
Population: 272,235
Area: 58 square miles

Highlight: Rain garden captures runoff and attracts residents to improve water quality and promote stewardship in their neighborhood.

The Maria Bates Rain Garden located in St. Paul's East Side is an excellent example of the multiple opportunities and benefits achievable through creative stormwater management. The Maria Bates Rain Garden is an urban greenspace that uses low impact development (LID) principles and practices to improve water quality and promote environmental stewardship.

The Upper Swede Hollow Neighborhood Association initiated the rain garden as an offshoot of their Lower Phalen Creek Project, which aims to build watershed stewardship through community based initiatives. One objective was to protect a recently restored wetland area along the Mississippi River. Another was to promote urban beautification. The rain garden was a perfect solution, performing multiple functions that include: controlling surface runoff, cleaning the water, and preventing downstream erosion while also creating desirable public open space.

Two vegetated swales are at the core of the garden's design. The design redirects stormwater from a residential street to the rain garden, or bioretention cell, through a specially installed catch basin. It captures runoff from a one-acre drainage that is 75 percent impervious cover, removing oil, grease, heavy metals, nutrients, and sediment. The 900 square-foot rain garden treats runoff from the 1-inch 24-hour storm. Overflow from larger storms discharges to the storm sewer system.

Once captured by the rain garden, runoff seeps into the ground, preventing polluted runoff from traveling through storm drains to the Mississippi River. The soils and native vegetation that make up the garden should filter and remove pollutants in the runoff. A monitoring program is planned for the near future. Project managers also plan to redirect water from a nearby office building roof into the swales once ongoing renovations are completed.

As with many LID practices, the garden has attractive features that extend beyond water quality management. Designers used it as an opportunity to create needed public open space. Local artists Chris Baeumler and Kevin Johnson created a meandering "rainwater walkway" through the garden that helps convey water and illustrate the garden's function. Additional features include an ornamental railing, benches, and a boulder that is carved-out to capture water and inscribed with text explaining the purpose of the garden.

The garden also serves as an outdoor classroom. Community Design Center of Minnesota organized local students to help plant the garden and learn about pollution prevention. Nearly 200 students from Dayton's Bluff Elementary School learned about native plants, water quality, and erosion control during a workshop at the garden that was sponsored by the Community Design Center along with other organizations and institutions.

The Upper Swede Hollow Neighborhood Association managed the Maria Bates Rain Garden project. Barr Engineering provided the design and engineering services. Construction and design costs totaled approximately $19,000. Financial support from city, state, and federal agencies as well as local and national charitable organizations made this project possible.

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Additional Examples

Jordan Cove Urban Watershed Study[37]
Waterford, CT

The Jordan Cove Urban Watershed Study is a comprehensive monitoring project that uses a "paired watershed" approach to evaluate water quality from two sections of a new development site. One of the sections is following traditional subdivision requirements to develop 10.6 acres of land while the other 6.9-acre site is taking a low impact development (LID) approach. Researchers are comparing monitoring results to a control site, a 43 lot, 13.9-acre established subdivision across the street that uses conventional stormwater management. They are applying management practices to the LID drainage area only. Currently, researchers are monitoring the construction phase of the low impact development and are beginning to evaluate the post-construction phase of the traditional site, which has 14 of 17 home completed. The developer has five homes under construction in the low impact development and has installed two residential rain gardens. To control erosion and sedimentation, they are applying construction best management practices at this site such as phase grading, pervious pavers on the access roads, sediment detention basins and swales, and rapid reseeding.

Project managers plan to use a wide variety of LID practices in the low impact development including grassed swales, roof runoff rain gardens (bioretention cells), detention areas, pervious pavement, conservation zones, a pervious road with a central bioretention, and state-of-the-art oil/grit separators in conjunction with pollution prevention and good housekeeping practices. The LID site has the following objectives:

1. retain sediment on site during construction
2. reduce nitrogen, bacteria, and phosphorus export by 65, 85, and 40 percent respectively and
3. maintain post-development peak rate and volume and total suspended sediment load at predevelopment levels.

The traditional site grades all runoff to the street and uses conventional curb, gutter, and pipe drainage without treatment. Furthermore, the low impact development reduces the overall impervious footprint by clustering houses, narrowing roads, and minimizing paved areas.

The Jordan Cove Urban Watershed Study is currently in the third of a proposed six-to ten-year monitoring period. Project managers for the sites have collected base-line data from all sites and are monitoring the construction phases of the two new developments. Prior to development, the traditional site was used for poultry farming and the BMP site was a closed-out gravel pit. To date, monitoring has revealed the following:

1. Concentrations of pollutants in the runoff from the control site are somewhat lower than results of a nationwide monitoring program.
2. In the LID watershed during construction weekly storm flow and peak discharge have decrease significantly.
3. Runoff from the LID site has lower concentrations of most water quality parameters than the control site. However, the results are preliminary and inconclusive.
4. Monitoring at the traditional site indicates increases in most parameters when compared to the control.
5. Storm flow increased during construction of the traditional site but decreased during construction of the LID site.

6. Researchers hypothesize that change in the landscape features of the traditional watershed have caused the hydrologic response at the site. Researchers hypothesize that it is hydrologic response, rather than erosion and increased sediment, that is the cause of increased pollutant export from the site.

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Www.nemo.uconn.edu/res&ap/resapjordan.htm

Florida Aquarium Stormwater Research/Demonstration Project[38]

Tampa, Florida

The Florida Aquarium Stormwater Research/Demonstration Site project is an both effort to document the benefits of low impact development (LID) strategies and inform the public as part of the process. In 1993, the Southwest Florida Water Management District and the Florida Aquarium partnered to evaluate the effectiveness of alternative parking lot design and materials to reduce runoff and improve water quality.

The study site is an 11.5-acre asphalt and concrete parking area in mid-town Tampa, Florida (about half of the parking lot has been recently converted to a construction area for cruise ship terminals). The original parking lot served approximately 700,000 visitors annually. Researchers modified the parking lot by installing the following integrated LID practices throughout the site:

- End-of-island bioretention cells
- Bioretention swales around the parking perimeter
- Permeable paving
- Bioretention strips between parking stalls
- A small retention pond to supplement storage and pollutant removal

The distributed LID practices can be considered a stormwater treatment train that treats runoff from the building roof, parking lots, and access streets.

Monitoring has demonstrated that the LID practices significantly reduce runoff volume and protect water quality. Researchers collected samples from 30 storm events over a one-year period. They collected data that allowed comparisons between both treatment techniques and paving surfaces (asphalt paving with and without a swale and swale areas with cement, permeable pavement, and asphalt). The LID practices achieved between 60 and 90 percent reduction in runoff volume. Researchers also documented pollutant removal efficiencies with the highest load reduction coming from the basin with permeable pavement and swales (see table below).

Pollutant Removal Efficiencies for Various Treatment Types			
Constituent	Percent pollutant reduction compare to the asphalt non-swaled area		
	Asphalt with Swale	Cement with Swale	Permeable with Swale
Ammonia	45	73	85
Nitrate	44	41	66
Total Nitrogen	9	16	42
Ortho Phosphorus*	-180	-180	-74
Total Phosphorus*	-94	-62	3
Suspended Solids	46	78	91
Copper	23	72	81
Iron	52	84	92
Lead	59	78	85
Manganese	40	68	92
Zinc	46	62	75

*The efficiencies for phosphorus are negative, indicating an increase in phosphorus loads in the swaled basins. The permeable swale continues to exhibits the best performance. Researchers believe that grass clippings leftover from swale maintenance are the likely source of phosphorus since there is no phosphorus in rainfall or asphalt and very little in automobile products.

Researchers compared loads from this site to other studies done in Florida and found that the loads were much lower than reported at other urban sites using conventional stormwater management.

Throughout this project, public involvement has been an important attribute. Aquarium visitors receive information about the project and the connection between rain, urban development, and water quality. A brochure gives tips on how residents can prevent pollution on a daily basis. Students and general aquarium visitors are encouraged to visit the research station to learn more about the project and stormwater runoff.

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Gap Creek Subdivision[39]

Sherwood, AR

A low impact development (LID) approach can yield significant benefits to developers as well as the environment and community. Terry Paff, developer of the 130-acre Gap Creek subdivision in Sherwood, Arkansas, looked to create something unique in the marketplace. He decided to take a "green" approach by implementing a variety of practices to reduce the environmental impact of development. The approach he took resulted in significant economic benefits derived from a combination of lower development costs, higher lot yield, and greater lot values. The developer had not counted on any cost savings but has since learned that "that just comes with the territory."

Gap Creek is one of the fastest growing neighborhoods in the North Little Rock area. Developers attribute its growth and popularity to the sustainable design that buyers prefer over the traditional, "cookie-cutter" suburban development. Specific features include streets that flow with the existing landscape, minimal site disturbance and preservation of native vegetation, preservation of natural drainage features, and a network of buffers and greenbelts that protect sensitive areas. However, Paff still used some conventional stormwater management practices at this development for conveying and removing street runoff. These LID features allow stormwater to flow naturally and be controlled close to the source, as well as providing passive recreation and aesthetic benefits. The developer took advantage of this conservation approach to maximize the number of lots that abut open space areas, thus enhancing marketability and increasing property values.

The LID approach also yielded substantial savings and financial success for the developer. Its sustainable plan required significantly less site clearing and grading, which cut down on site preparation costs. The use of natural drainage features meant less money spent on drainage infrastructure (i.e. piping, curbs, gutters, etc.) Shorter and narrower streets reduced imperviousness and also saved money. For example, Paff reduced street width from 36 to 27 feet and retained trees close to the curb line realizing savings of almost $4,800 per lot -- a saving higher than originally expected. The greater lot yield and high aesthetic curb appeal also resulted in larger profits. Paff was able to sell lots for $3,000 more than larger lots in competing areas and sold nearly 80 percent of the lots within the first year. He estimates that the economic benefits will exceeding $2 million over projected profits. Additional benefits of the LID design include lower landscaping and maintenance costs and more common open space and recreational areas.

LOW IMPACT DEVELOPMENT
A COMPARISON OF TWO DIFFERENT LAND PLANS*

Projected Results From Total Development		
Total Site	**Conventional Plan**	**Sustainable Plan**
Lot Yield	358	375
Linear Feet Street	21,770	21,125
Linear Feet Collector Street	7,360	0
Linear Feet Drainage Pipe	10,098	6,733
Drainage Structures Inlets/Boxes/Headwalls	103	79
Estimated Total Cost	$4,620,600	$3,942,100
Estimated Cost per Lot	$12,907	$10,512

Actual Results from First Phase of Development		
Phase 1	**Conventional Plan (Engineer's Estimated Figures)**	**Sustainable Plan (Actual Figures)**
Lot Yield	63	72
Total Cost	$1,028,544	$828,523
Total Cost Per Lot	$16,326	$11,507

Economic and Other Benefits From Low Impact Development	
Higher Lot Yield	17 additional lots
Higher Lot Value	$3,000 more per lot over competition
Lower Cost Per Lot	$4,800 less cost per lot
Enhanced Marketability	80 percent of lots sold in first year
Added Amenities	23.5 acres of green-space/parks
Recognition	National, state, and professional groups
Total Economic Benefit	More than $2,200,000 added to profit

* Tyne & Associates, North Little Rock, Arkansas

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LID for Optimum Water Quality Protection of Water Supply Reservoir[40]

High Point, NC*

Due to its proximity to a proposed regional water supply reservoir, the City of High Point, North Carolina is faced with the implementation of very stringent water quality controls related to nutrients control (i.e., phosphorus) and limitations on total impervious area. As part of a watershed wide assessment and development of a comprehensive stormwater management plan,[41] an evaluation of the benefits of using LID technology was conducted.

The evaluation revealed that the use of LID, particularly the incorporation of bioretention techniques, could optimize the removal of phosphorus by approximately 50 percent over conventional pond based BMPs. The bioretention cells can achieve phosphorus removal levels ranging from 75 to 90 percent compared to the reported levels for stormwater management ponds, which range from 40 to 50 percent.

The LID evaluation also reinforced another advantage of the LID technology with respect to the total impervious area limitation requirement. A number of jurisdictions have begun to place total impervious area limitations on a watershed scale as a surrogate for water quality control. This approach is based on the total impervious area threshold concept reported in a number of publications.[42] For a specific site, however, the LID concept can provide a win/win strategy, which optimizes water quality objectives while allowing higher impervious cover for a given site. This dual strategy is accomplished in two ways. First the LID design methodology provides procedures and techniques to hydraulically disconnect impervious areas so that, for example, a site with 70 percent impervious cover will be hydrologically equivalent to a site with 40 to 50 percent impervious cover. The second part of this strategy results from the fact that the LID micromanagement practices can be incorporated into elements of the landscape providing a dual function for site features and thus preclude the need to dedicate and disturb (clear, grub, etc.) 8 to 10 percent of the total site for a stormwater management pond.

* This case study was provided by Michael Clar, President, Ecosite, Inc., 2001.

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Zero Impact Development Ordinance[43]
Lacey, WA*

Recently, several communities have developed innovative ordinances to eliminate legal and institutional barriers to and facilitate the use of lot level stormwater controls. Lacey, Washington is one such community. Lacey adopted a Zero Impact Development Ordinance in August of 1999 -- the direct result of a conference called "Salmon in the City." The conference was sponsored by the American Public Works Association and thirty other local, state, and federal entities. The conference called attention to the impact of development on aquatic life -- a message that was of particular relevance due to the fact that the National Marine Fisheries Service had just announced that northwest chinook salmon were "threatened" under the Endangered Species Act. The ordinance facilitates waivers of requirements that conflict with the use of LID practices. The ordinance is still in early stages of implementation and to date, no developers have taken advantage of it.

The primary goal of the Zero Impact Development Ordinance is to retain the hydrologic functions of forests after a site is developed such that there is near "zero effective impervious surface." The ordinance works by providing developers with the opportunity to demonstrate zero effective impervious surfaces and to use watershed-sensitive urban residential design and development techniques. The ordinance makes LID a legal alternative to conventional site design. However, actions are voluntary and to date, no other incentives exist to encourage zero impact developments in Lacey.

The Lacey ordinance is designed to protect receiving waters and aquatic resources. It established criteria that a development project must meet in order to qualify for deviations from certain current development standards. The city used criteria taken directly from the "Salmon in the City" conference research, which describe the fundamental characteristics of a healthy watershed. The Lacey ordinance criteria have since become known as the 60/0 standard. In other words, at least 60 percent forest must remain after development and impervious surface must be made "ineffective" or established as zero effective impervious surface area (also known as the "zero impact" standard). Developers can make impervious surfaces ineffective by disconnecting them from conventional drainage infrastructure and installing LID integrated management practice to capture and treat runoff. The ordinance also requires monitoring and evaluation designed to measure the performance of steps taken to ensure zero impact.

Lacey's innovative low impact development law is based on specific monitoring criteria that documents the negatives effects development has on water resources and aquatic life. The Zero Impact Development Ordinance is specifically intended to provide post-development conditions that stay below the threshold of impacts on aquatic life.

* This case study was modified from original information provided by Tom Holz, SCA Consulting Group, August, 2001.

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