Low Impact Development –National Resources Defense Council

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).

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

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

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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