Low Impact Development as a Stormwater Management Technique

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The Rocky Mountain Land Use Institute

Sustainable Community Development Code
Research Monologue Series:
Environmental Health & Natural Resources

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About the Research Monologue Series

The Sustainable Community Development Code, an initiative of the Rocky Mountain Land Use Institute, represents the next generation of local government development codes. Environmental, social, and economic sustainability are the central guiding principles of the code. Supporting research for the code is represented by a series of research monologues commissioned, presented and discussed at a symposium held at the University of Denver in September of 2007. RMLUI and the University of Denver's Sturm College of Law extend its gratitude to the authors of the papers who have provided their talents and work pro bono in the service of the mission of RMLUI and the stewardship of the creation.

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About the Author

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This paper is geared to those involved in any aspect of land development: the public, land developers, engineers, planners, land use decision-makers, builders, and those who are interested in promoting low impact development (LID) in their communities. This paper includes an introduction on urban hydrology and typical stormwater management practices so the connection and associated costs between land development, water quality and waterway stabilization needs are clearly understood. Also included are the elements of LID, guidelines and techniques on how to promote LID and strategies to develop a low impact development land use code.

Introduction

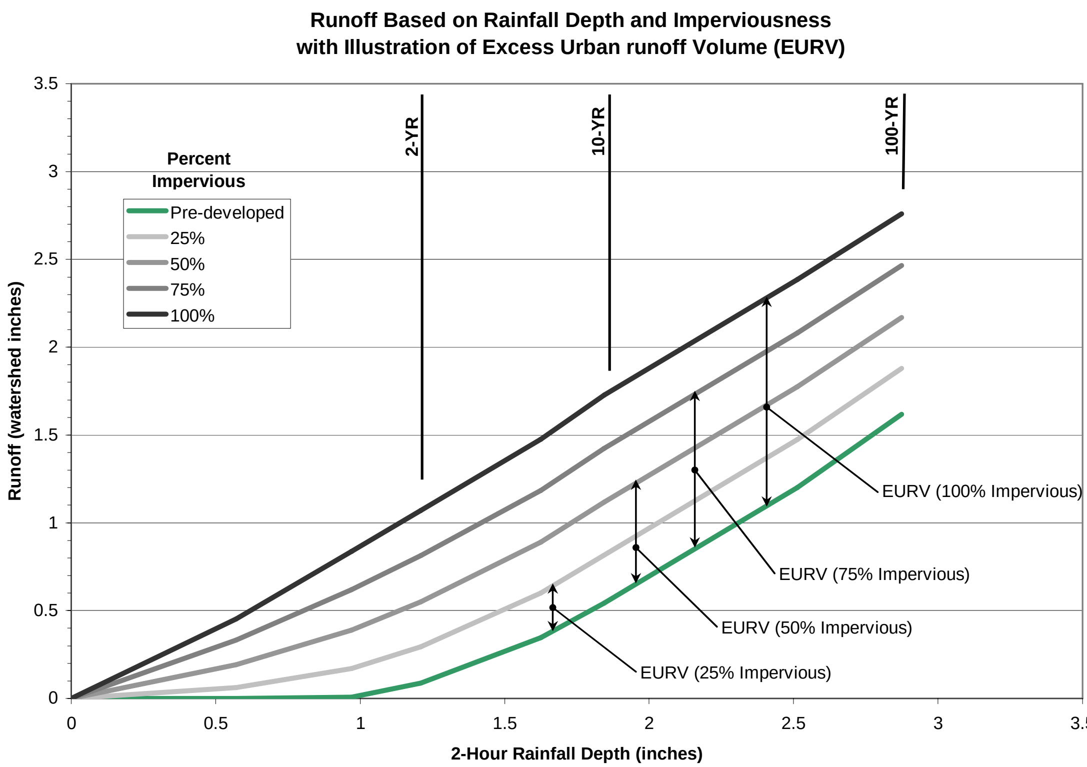
A 2004 study by Christopher Elvidge of the National Oceanic and Atmospheric Administration's National Geophysical Data Center in Boulder, Colo. revealed that the United States has added enough roads, buildings, parking lots and other impervious areas to nearly cover the state of Ohio, and is adding a million new single-family homes and over 10,000 miles of new roads a year.[1] A more recent analysis of Landsat satellite data indicates there are 296 square meters, or approximately 3200 square feet, of impervious surface area for each U.S. resident**.** For comparison, there are 3843 square feet of impervious area for each person in Canada, 1109 square feet per person in Germany, 1389 square feet per person in the United Kingdom and 721 square feet of impervious area for each person in China.[2] Elvidge's 2004 study also noted the effects on waterways as impervious area is added in a watershed. The effects include: water temperature changes from urban heat island effects, water quality impacts from increased pollutant loads and waterway structural changes such as scour and downcutting from increasing rate and volume of stormwater runoff. Some communities are acknowledging these effects and are trying to grow in a manner that continues to provide economic gain while protecting and enhancing public benefits. Low Impact Development (LID) offers options to help achieve these goals.

This waterway shows little evidence of scour or downcutting. The riparian area is hydraulically connected to the water as indicated by the relationship between the level of the water and the vegetated banks.

The Low Impact Development Center defines low impact development as, "a new, comprehensive land planning and engineering design approach with a goal of maintaining and enhancing the pre-development hydrologic regime of urban and developing watersheds." [3] Low Impact Development is a manner of land development that seeks to mimic predevelopment hydrology to protect waterways, habitat, baseflow, and groundwater recharge. It also protects water quality by minimizing the pollutant loading to waterways from developed areas. To understand more thoroughly why it is beneficial for communities and watersheds to incorporate LID techniques, it is helpful to first understand the effects of traditional stormwater management, which have marked land development and altered waterways and water quality for decades.

What is stormwater runoff?

Stormwater runoff occurs when rain falls or snow melts at a rate that is more than the surface can absorb. This excess water flows off the surface of land into gullies, gulches and waterways. Depending on several factors, such as vegetation, soils, geology, slope and climate, undeveloped and undisturbed land typically has the ability to absorb small, frequent storms and a substantial portion of larger storms before runoff occurs. For example, in the Denver Front Range, there is less than one runoff event a year from undeveloped property.[4] The chart below illustrates that when one inch of precipitation falls on undeveloped land in the Denver Front Range, it is almost completely absorbed. When the same property becomes developed with 100% impervious area, approximately 0.8 inches of runoff is generated from the same one inch of precipitation. When two inches of precipitation falls on an undeveloped property, approximately 1.3 inches is absorbed and 0.7 inches runs off. After development, with 100% impervious area, the runoff from the same storm more than doubles at 1.8 inches.[5] This is called Excess Urban Runoff Volume and is the extra runoff that is generated when impervious area is added to property. After development there are 20 to 30 runoff events a year because directly connected impervious area blocks absorption and converts much of the precipitation to runoff.[6]



This chart illustrates that natural undeveloped property absorbs all or much of the precipitation from small storms and increased impervious area generates additional runoff. The chart is based on Full Spectrum Detention research by Jim Wulliman at Muller Engineering and Ben Urbonas at Urban Drainage and Flood Control District.

Water Quality Impacts from Excess Stormwater Runoff

Designing communities in a manner that generates excess stormwater runoff has caused undesirable effects.

- the watershed loses more water after development because impervious area blocks the soil from absorbing water;
- pollutants flow across impervious surfaces and wash into waterways; and
- waterways become eroded and scoured from increased flows (rate and volume).

A 2002 report by American Rivers, Natural Resources Defense Council and Smart Growth America titled "Paving Our Way to Water Shortages" estimates the billions of gallons of groundwater recharge loss, annually, from 18 large cities in the United States.[7] The model indicated that some cities such as Boston lose 44 -102 billion gallons or 135,000 - 313,000 acre-feet of recharge annually. Detroit loses 8 -18 billion gallons or 24,000 - 55,000 acre-feet of recharge annually.

Secondly, precipitation flowing on impervious surfaces picks up pollutants and washes them into our waterways during the drainage process. Metals, salts, grease, oil, and sediment from roads and parking lots; bacteria from parks (e.g. dogs, geese); and lawn fertilizer are common pollutants. Allowing stormwater to soak into the soil would remove many of the pollutants from the stormwater runoff.

Connected impervious areas and trickle channels convey low flows and associated pollutants, which were previously absorbed, offsite directly to a waterway.

Additionally, as more water is removed from land and rapidly conveyed to waterways, the waterways become scoured by the increased flow. Even in areas with detention ponds, riparian corridors become damaged because detention facilities are designed to collect runoff from impervious areas, detain it and release it slowly to reduce downstream flooding. The goals of detention facilities are to provide time for some pollutants such as sediment settle out and to mimic historic RATES of flow but not the volume, which is far greater than before because of increased impervious surfaces. Additionally, the outlet structures in detention ponds are typically designed to detain only the large storm events (10- to 100-year events), but the rate and volume of more frequent, smaller storms (10-year and smaller event) flow off the property at a much greater rate and volume than before development.

Increased runoff rate and volume contribute to scour and downcutting in waterways.

Creating runoff from small storm events, which did not previously generate runoff, has a profound destabilizing effect on receiving waterways. Small precipitation events draining from multiple properties combine and behave as if they were from a much larger storm event in the waterway. Waterways become scoured, often with steep, destabilized banks. Waterway stabilization projects, which are a direct result of such damage, are often funded by a city's or county's general fund, a stormwater utility fee paid by property owners and/or a developer impact fee. Many communities have adopted stormwater fees that link the level of "responsibility" to pay for the stormwater system to the amount of impervious area on a property. A property owner with more impervious area pays a higher fee. In Colorado, many Front Range cities including Denver, Fort Collins, Golden, Lakewood, Parker, and Westminster have stormwater utility fees that pay for the construction and maintenance of the stormwater drainage system and associated program requirements.[8] Jefferson and Boulder Counties, in Colorado are examples of communities that fund stormwater needs from the general fund. Stormwater program funding is often between several hundred thousand to several million dollars a year depending on community size and needs.

Example of waterway scour and destabilization from excess urban runoff.

Bank stabilization repair project.

Addressing water quality and waterway protection with restoration and repair projects exclusively in the waterway limits options and produces limited results. This is simply because a riparian corridor is narrow when compared to the developed land area draining into it. Additionally, when a section of waterway is stabilized while upstream development with connected impervious area continues to occur, it is likely that added runoff from the more recent upstream development will continue to destabilize the receiving waterway. The result is continuing and cascading drainageway projects to increase channel capacity and restabilize channels throughout a region. LID protects waterways and water quality by starting at the source – the developed land – with techniques tailored to the site.

No Adverse Impact [9]

Low impact development techniques also have an emerging role in reducing flood risk and related damage. The “No Adverse Impact” (NAI) approach to land development and stormwater management is based on legal standards that property owners cannot use their property in a manner that does harm to another property. It is similar to the “Do no more harm than formerly” doctrine, which explains that an upstream property can drain onto a downstream property but stormwater cannot be released in a manner, character, strength or flow to do more harm than formerly.[10] Since land development with impervious area generates increased runoff, potential harm may be exported off site. The standard technique of mitigating harm has been for governments or taxing districts to manage increased runoff volume by constructing and maintaining drainage structures, and completing channel stabilization projects in the right-of-way. LID techniques used on individual properties throughout the watershed reduce excess urban runoff volume and have the potential to reduce subsequent flooding risk.

Low Impact Development – What does it look like and what are common barriers?

Only runoff reduction and infiltration techniques on developed land can reduce stormwater runoff volume and mimic predevelopment hydrology. Developed land must look and function differently than traditional development to protect and restore water resources. Seemingly minor design elements, including the following, are barriers to water resources protection:

- elevated landscape islands in commercial parking areas;
- solid, elevated curbs that prevent runoff from flowing off a street or parking lot and onto landscaped areas;
- roof drains directly connected to an under drain storm sewer system; and
- minimum parking requirements that create large, impervious parking areas with vacant spaces much of the time.

Some of these elements such as minimum parking and raised curbs may be required in a community’s land development code. Codes typically do not require elevated landscaping or solid curbs, but they may inadvertently encourage designs that promote excess runoff. For example, the landscaping regulation in one Colorado County states, “Each landscaped island proposed shall…have raised curbs or wheel stops.” [11]

The following are common elements that are typically used in combination to achieve a low impact development site:

1. Integrating site planning, architecture, engineering and construction:

   Integrated site design is crucial to ensure that LID goals are included with building design, and followed through during the civil engineering design, construction and landscaping stages of the project. For example, if a porous


The PLD on the left should allow water to flow into it at the curb cut however the asphalt surface is not installed in a manner that allows water to flow through the curb cut. This causes the next PLD to receive excess flow.

   landscape detention area or rain garden is designed by the civil engineer, it is important that the architect daylight the roof drains instead of connecting the roof to an under drain system, which bypasses the porous landscape detention area.

2. Minimizing directly connected impervious area: [12]

   This is a key element to reduce stormwater runoff rate and volume and includes a variety of techniques. Regulatory controls such as creating narrower street templates, removing minimum parking standards, or adopting maximum parking standards can be used. Alternative paving surfaces such as porous pavement and permeable pavers are structural techniques to increase porosity on developed land. Providing sumped grass buffers and grass swales instead of raised landscaping areas are other functional design elements that reduce stormwater runoff.

Photo Courtesy AWARE Colorado

This parking area combines several LID elements: flush curbs with wheel stops, block pavers, porous gravel parking spaces and sumped landscaping to reduce runoff.

Photo Courtesy Chuck Taylor - Advanced Pavement Technologies

Runoff from a narrow driving lane can sheet flow onto a permeable paver system to reduce road runoff.

3. Daylighting:

   Allowing stormwater to remain on the surface takes advantage of absorption, infiltration and evaporation opportunities. For example, roof drains may discharge to a landscaped area or road runoff may drain to roadside swales instead of into drop inlets that deliver the stormwater below ground.[13] A swale should be used instead of a pipe where ever possible.

SEA Streets project in Seattle has reconstructed some street sections to provide surface detention in swales to reduce runoff volume.

4. Split flow method:[14]

   A weir or other flow control device is used to separate the high and low storm flows. Small precipitation events, or the “first flush” which contains the highest pollutant load, are directed to infiltration and absorption structures. The split flow structure also includes an overflow bypass to divert less frequent, large storms down stream or to a detention area. This technique addresses the shortcomings of both detention and infiltration techniques. Detention does not adequately protect receiving waterways because it does not reduce stormwater volume and infiltration structures have not adequately addressed flood control needs.

A large flow bypass (drain) or weir provides a method of separating flow sizes. Low flows are absorbed and high flows are provided a bypass to reduce flooding or scouring in structures that are designed for frequent small storm flows.

LID Code Examples

The Low Impact Development Center lists numerous examples of LID projects in the country including establishing LID design criteria for U.S. Department of Defense and the Environmental Protection Agency (EPA).[15] Perhaps the most comprehensive project profiled to date is the LID initiative in Puget Sound. In 2005, the Puget Sound Action

Team initiated a project to assist Puget Sound cities and counties to adopt LID codes. The Action Team hired an engineering firm that is skilled in LID techniques and then advertised for local communities to apply and participate in the code revision process. The engineering firm and community staff identified regulations, reviewed development standards, rewrote regulation and developed new ordinances, maintenance guidance and engineering drawings. Staff brought the LID work products and recommendations back to their elected officials to start the process of adopting the changes.[16, 17]

Land Use Code Strategies

Regulatory Obstacles

- Zoning Regulations: Specific regulations regarding parking and landscaping such as removing parking minimums or establishing parking maximums, allowing or recommending curb cuts or wheel stops and sumped landscaping and allowing or recommending permeable paver and porous pavement systems for parking areas, should be reviewed.

- Public Works: Typically, only drainage and conveyance structures such as ditches, inlets and storm sewer are allowed in the right-of-way. LID techniques that reduce runoff volume should be allowed in the right-of-way.

- Land Development Regulations: Communities often have detailed drainage regulations and drainage sizing criteria, but lack corresponding information or guidance on LID techniques. Such guidance should be incorporated into the land development code with criteria for using and applying LID techniques.

Incentives for LID

- Agencies can reduce stormwater utility fees for property owners who reduce impervious area or include LID structures.
- LID-educated land developers can increase buildable area and project profitability by reducing required detention volume and incorporating stormwater function into landscape and parking areas.
- Developers and property owners can reduce potential liability and meet “No Adverse Impact” goals by using LID techniques to mimic predevelopment hydrology.
- Reduced heat island effect and reduced watering for landscaping lowers building operation costs.
- Agencies can provide density bonuses to land developers who include LID.

Regulations

- Assess stormwater fees and developer impact fees that reflect the true cost of offsite impacts such as the costs for waterway restoration, water quality projects and stormwater maintenance.
- Require land development to mimic predevelopment hydrology by including runoff reduction practices and minimizing directly connected impervious area.
- Establish a LID overlay or master plan to provide a community vision and articulate goals.
- Include a LID chapter in the land development regulations to establish general requirements and standards.
- Establish native landscaping requirements.
- Adopt maximum parking regulations or revise zoning code to allow reduced parking.
- Include LID engineering details in the land development and/or drainage regulations.
- Adopt LID standards for rights-of-way, public road and parks projects.

Strategic Success Factors

- Awareness: Education about the effects of land development on waterways and benefits of LID is needed for each sector involved in the land development process, which includes the public, land developers, design engineers, architects, landscape architects, local government staff, builders and land use decision-makers.

- Public Works Standards: LID can be included in street design by allowing narrower rights-of-way, reduced impervious pavement surface, alternative surfacing methods for shoulders and walkways, alleys, curb cuts, and landscape detention/infiltration facilities in roadside swales.

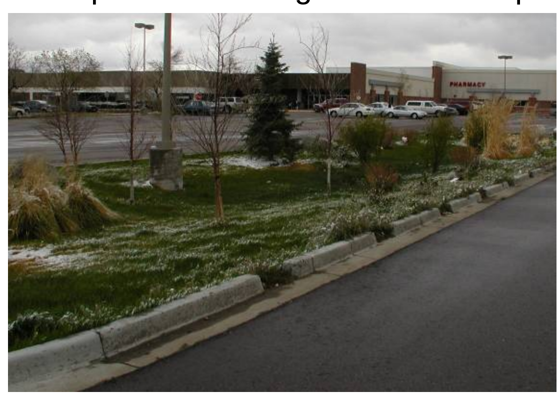
- LID Engineering Details: Many communities have engineering details and guidance available for conveyance to a single detention structure. Regionally-accepted engineering details are needed for LID structures such as porous landscape detention (rain gardens), porous pavement, permeable block paving, tree boxes, green roofs and LID street templates.

- Multiple Structure Sizing: LID typically combines many techniques as a treatment train approach. While communities may provide guidance on constructing some LID structures such as a porous landscape detention, it is less clear how much the required detention volume can be reduced when multiple structures are used. Instructions should be provided for calculating the runoff reduction achieved or detention capacity provided when LID techniques are combined.

Maintenance

This PLD has a single valley pan inlet instead of multiple curb cuts. This property may benefit from more frequent sediment sweeping to reduce the sediment load that can flow into this structure.

Even though low impact development techniques are intended to mimic natural processes or have the appearance of a more natural system, LID structures, like other stormwater management structures, must be maintained. It is thought that typical stormwater management, which often consists of inlets, storm sewer pipe and a detention pond, creates fewer structures and areas to maintain. Since low impact development decentralizes stormwater structures to achieve volume reduction and reduced offsite impacts, maintenance is also decentralized. Related concerns about LID techniques are that there will be more structures on private properties and that this decentralization will pose difficulties for a regulatory agency to ensure long-term function and maintenance. However, there is also the perspective that LID structure maintenance can be managed with the same observation and inspection oversight that Municipal Separate Storm Sewer System (MS4) permit holders are required to provide for all permanent stormwater structures, including detention ponds. Additionally, an operations and maintenance (O&M) manual with information on the type, frequency, estimated cost of maintenance activities can be provided to commercial property owners and HOAs to facilitate proper long-term function and maintenance of stormwater structures. [18]



Multiple inlets may help reduce the erosion and sedimentation of a PLD.

Designing with Maintenance in Mind

An understanding of flow and pollutant character of stormwater runoff is helpful in optimizing the design of LID structures to facilitate maintenance activities. For example, a porous landscape detention (PLD) area that receives parking lot runoff may be designed to allow sheet flow through curb cuts into the structure. This inlet design allows more sediment to remain on the parking lot side of the curb, where it is easier to remove. Alternatively, a single valley pan will flush water and potentially more sediment into the structure and accelerate clogging of the filter media. If there is a valley pan delivering concentrated flow to the PLD, the property owner should conduct more frequent, preventative sweeping maintenance to reduce the potential sediment load that can flow into the system.

The vegetation and materials used in LID structures must be critically examined. For example, grass or bark mulch may give a desired appearance, but grass clipping and mulch will likely float and clog an overflow pipe or may wash out of the structure during large flow events. Instead, large cobbles, a material that will not float, may be used along the bottom of the structure to provide a surface that can carry flow. It should also be determined whether the maintenance must be done by hand or if the structure can accommodate mechanical maintenance without damaging the structure or its treatment capabilities. Permeable pavers and porous concrete or asphalt systems also need to be cleaned to maintain permeability. A vacuum sweeper is used for this task and its use is recommended annually.

Summary

The process to include Low Impact Development in communities is as varied as the communities themselves. Some communities are adding LID elements or requirements to reduce offsite impacts and costs associated with increased runoff volume. Some developers have realized that LID techniques save them money because the size and cost of stormwater collection and conveyance infrastructure, as well as detention volume, is reduced. Additionally, because of the functionality and attractiveness of LID structures such as green roofs, bioswales or paver systems, there are increased opportunities to offer a “green” or more “sustainable” property. The added value that LID elements bring may more than offset the costs of construction or maintenance. Once these benefits are understood, stakeholders in the land development process may begin to seek out LID elements. A land developer may seek LID design services from an architectural or engineering company. Citizens may ask for LID features such as swales, narrower streets, sumped landscape islands, rain gardens or permeable paver systems during the public hearing process and seek regulation changes to guide future development.

Constructing runoff reduction and infiltration structures during development and redevelopment reduces pollutant discharges into waterways and minimizes in-channel impacts associated with imperviousness of the built environment. As communities are increasingly regulated for surface water quality impacts from stormwater runoff and are struggling to fund waterway repair and stabilization projects, Low Impact Development offers timely and promising options.

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17. AHBL - Low Impact Development Local Regulation Assistance Project
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Additional Resources:

1. Colorado Association of Stormwater and Floodplain Managers – Stormwater Quality Committee. LID photo database of LID structures in Colorado. http://www.casfm.org/stormwater_committee/default.htm
2. International Stormwater BMP Database: http://www.bmpdatabase.org/

3. New England Environmental Finance Center: Promoting Low Impact Development in your Community. http://efc.muskie.usm.maine.edu/docs/LID_Fact_Sheet.pdf
4. Municipal Guide to Low Impact Land Development. http://www.toolbase.org/PDF/DesignGuides/Municipal_LID.pdf
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