Achieving Sustainable Site Design through Low Impact Development Practices

LEED®

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INTRODUCTION

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A. Definition of Low Impact Development (LID)

Low Impact Development (LID) is a sustainable storm water management strategy that is gaining rapid acceptance in the United States to meet regulatory compliance and resource protection goals and is practiced extensively in Europe. The increased use of LID is in response to burgeoning infrastructural costs of new development and redevelopment projects, more rigorous environmental regulations, concerns about the urban heat island effect, and the impacts of natural resources due to growth and development. The frequency of droughts and concern about water quality issues have also prompted interest in the treatment and the reuse of storm water as a viable resource and has resulted in a shift in the way planners, developers, architects, engineers, and the public approach the control of storm water and conservation of rainwater. Many municipalities across the nation have embraced LID due to its holistic approach to site design and overall sustainable design. There are countless examples of jurisdictions that have proactively revised their development policies, codes, growth and management plans and implemented LID technologies to manage storm water at its source and collect rainwater for secondary use.

The LID strategy controls water at the source—both rainfall and storm water runoff—which is known as 'source-control' technology. It is a decentralized system that distributes storm water across a project site in order to replenish groundwater supplies rather than sending it into a system of storm drain pipes and channelized networks that control water downstream in a large storm water management facility. The LID approach promotes the use of various devices that filter water and infiltrate water into the ground. It promotes the use of roofs of buildings, parking lots, and other horizontal surfaces to convey water to either distribute it into the ground or collect it for reuse.

The LID approach differs from conventional conveyance systems as it promotes the highest and best use of the intrinsic land form and built structure(s) to both distribute storm water and collect rainwater. The uniqueness of LID is the interaction and function of water on a site. It capitalizes on the integration of infrastructure, architecture, and landscape in order to create a balanced, hydrologically functional and sustainable site. The LID approach handles water like the valuable and viable resource that it is, for the water that reaches a project site is a valuable commodity and can be used in innumerable ways.

LID encompasses the use of structural devices (engineered systems) and non-structural devices (vegetated, natural systems). It uses a combination of these technologies, or a "suite of technologies," to maintain or restore the natural hydrologic functions on a site with the goal of reducing the impact of development. The goal is to structure the development of a site so that the pre-development conditions are not altered excessively. Of particular concern are the rate of storm water runoff, the pollutants in the water, and recharge of water into the ground. By reducing water pollution and increasing groundwater recharge, LID helps to improve the quality of receiving surface waters and to stabilize the flow rates of nearby streams. The integrated LID devices that are available allow the designer to restructure the built environment to control storm water and capture rainwater in order to minimize the impact of development. The integration of LID devices permits the developer and designer to use an array of storm water management devices that are both cost-effective and environmentally sound. The LID strategy is not a static design approach, however, is very dynamic and adaptable. LID has been proven to reduce development and infrastructure costs, minimize operations and maintenance costs, and improve the marketability of projects.

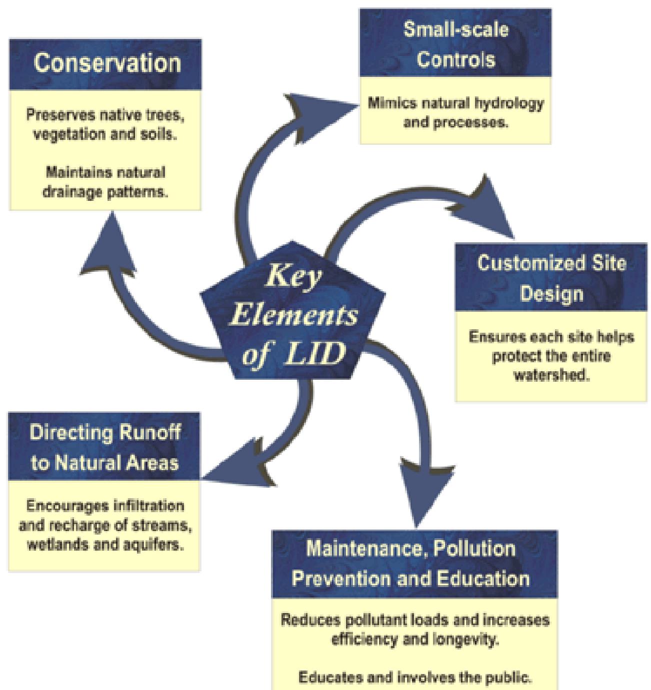


Fig. 1: Key Elements of LID

B. Background of LID

LID was pioneered in the 1990's by the Prince George's County, Maryland Department of Environmental Resources. The LID effort in Prince George's County began with the development and use of bioretention cells. The County's initial experience with bioretention led to a full-scale effort to incorporate LID into the County's resource protection program. In 1998, the County produced the first municipal LID manual. This was later expanded into a nationally distributed LID manual that was published in 2000. A feasibility study was prepared by the LID Center in 2002 that provided guidance on how LID could be used to retrofit urban areas. Since then the LID Center, other water research organizations, and universities have been developing tools, strategies, and techniques to incorporate LID into research and regulatory programs.

C. The Benefits of LID

The primary benefits of LID are:

1. To prevent degradation of water quality and natural resources,
2. To manage storm water more efficiently and cost effectively,
3. To protect groundwater and drinking water supplies, and
4. To help communities grow more attractively.

D. Models of Ingenuity

There still are many barriers to using LID technologies, primarily because of unfamiliarity with the technologies, and obstacles in the administrative and permitting process. However, many models already exist that illustrate the ingenuity of municipalities across the country to incorporate sustainable practices into their development codes and policies to protect their natural resources and manage storm water. Many communities have streamlined processes and revised their regulations and development codes to promote LID storm water management applications.

One popular practice among planning departments is extending provisional variances or waivers of standards to developers, engineers, and architects for projects that demonstrate the use of LID technologies. Many areas of the country that are progressive with respect to alternative storm water management applications are beginning to adapt their local codes and zoning laws as a result of successful pilot programs. Demonstration projects have repeatedly stimulated interest in LID practices and have prompted the passage of ordinances, revisions to development policies and codes, amendments to storm water management guidelines, and often influenced modifications to growth and management goals or Comprehensive Land Use Management Plans. Municipalities have used the pilot projects to:

- Demonstrate sustainable materials and products,
- Monitor storm water runoff,
- Measure the impact to adjacent waterways,
- Determine cost benefits,
- Streamline permitting and administrative approval processes, and
- Evaluate public involvement and acceptance.

E. The Challenge of LID

LID is in the early stages of adoption in the United States and a challenge exists to assist municipalities in adapting these approaches and techniques. Although the technologies are relatively new to planners in this country and innovative in their response, they have been successfully used in Europe and Asia for many years. The technologies are not experimental; rather they are proven and tested. The challenge is to implement these technologies in inventive configurations. However, the pursuit of innovative technologies is not a foreign concept to developers, engineers, and architects that advocate and promote green building and sustainable design.

F. Case Studies and Pilot Projects

There are many exemplary programs that have used a broad range of planning methods and systematic approaches to develop policies, practices, and procedures to meet local water quality regulations and environmental challenges. Municipalities such as Portland, Oregon have incorporated LID techniques into their urban resource protection programs. Local governments throughout the Puget Sound (Washington State) have revised ordinances, or passed new ordinances, to allow for and encourage LID practices. Several successful pilot projects have been constructed locally and nationally and have demonstrated the effectiveness of managing runoff, reducing construction and maintenance costs, and enhancing communities. As a result, they have created significant interest in LID. *Refer to Section IV for more detailed descriptions on case studies and pilot projects.*

DESCRIPTION

A. LID Site Design Goals

The goal of LID site design is to minimize the generation of storm water runoff and to treat pollutant loads where they are generated. This is accomplished by directing storm water towards small-scale systems that are dispersed throughout the site with the purpose of managing water in an evenly distributed manner. These distributed systems allow for downsizing or elimination of storm water ponds, curbs, and gutters, thus saving on infrastructure and storm conveyance costs. Eliminating (or reducing the size of) ponds makes available additional land for open space, lots, or supplementary building footprint.

Because LID embraces a variety of useful techniques for controlling runoff, designs can be customized according to local management requirements and site constraints. Designers and developers can select the LID technologies that are appropriate to a site's topographic and climatic conditions and are appropriate to meet storm water control requirements. New projects, redevelopment projects, and capital improvement projects are all candidates for implementation of LID.

B. LID Site Design Strategies

Site design strategies for every design project address the arrangement of buildings, roads, parking areas, site features, and storm water management plans. LID builds on conventional design strategies by exploiting every surface in the infrastructure—natural and hardscape—to perform a beneficial hydrologic function. The surfaces are used to retain, detain, store, change the timing of, or filter runoff in a number of different configurations and combinations. Some of the more prevalent site design techniques include:

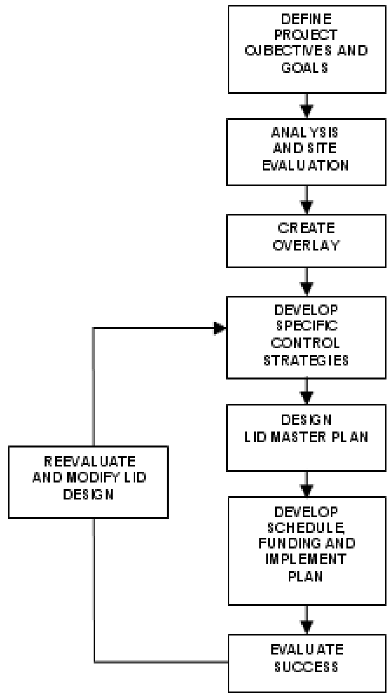
- Reduce imperviousness by using permeable paving or landscaping to break up expanses of impervious surfaces.
- Direct runoff into or across vegetated areas to help filter runoff and encourage groundwater recharge.
- Preserve, or design into the infrastructure, naturally vegetated

areas that are in close proximity to parking areas, buildings, and other impervious expanses in order to slow runoff, filter out pollutants, and facilitate infiltration.
- Reduce street widths.
- Remove curbs and gutters from streets, parking areas, and parking islands to allow storm water sheet flow into vegetated areas.
- Use devices such as bioretention cells, vegetated swales, infiltration trenches, and dry wells to increase storage volume and facilitate infiltration.
- Grade to encourage sheet flow and lengthen flow paths to increase the runoff travel time in order to modify the peak flow rate.
- Disconnect impervious areas from the storm drain network and maintain natural drainage divides to keep flow paths dispersed.
- Disconnect roof downspouts and direct storm water into vegetated areas or into water collection devices.
- Install cisterns or sub-surface retention facilities to capture rainwater for use in irrigation and non-potable uses.
- Install vegetated roofs or garden roofs.
- Use native plants (or adaptable species) to establish an adaptable and low maintenance landscape that requires less irrigation and are appropriate for the climatic conditions.
- Use naturally occurring bio-chemical processes in plants located in tree box filters, swales, planter boxes.
- Divert water away and disconnect from the storm drain or CSO using correctional drainage techniques.

C. LID Site Planning Process

This following is a model LID design strategy. It is important to have a clear idea of the sustainability goals in order to develop an effective LID storm water management program. Once strategies and LID technologies are identified, a master plan can be prepared.

Fig. 2: LID Design Development and Planning



Process

A step-by-step process for LID design development is described below:

Step 1: Define Project Objectives and Goals

a. Identify the LID objectives for the entire project.
b. Determine the goals and feasibility for water quality, water quantity, peak runoff control, and on-site use of storm water.
c. Determine project character/aesthetic. Identify the baseline principles from which LID design decisions will be made by defining the LID technologies that support the concept and visual aesthetic. Determine if it is a goal to irrigate open space with captured rainwater, or whether rain barrels are a suitable aesthetic for front or back yards. Determine if it is important to offer residential homeowners the ability to use rain barrels for private irrigation needs, or use subsurface detention facilities for carwashes. Consider whether green roofs or roof gardens are consistent with the envisioned architectural design.
d. Prioritize and rank basic objectives.

Step 2: Analysis and Site Evaluation

A site evaluation will facilitate LID design development by providing infrastructural, contextual, cultural, and community clues that will assist in the development of a LID program.

a. Conduct a detailed investigation of the site through collected materials such as drainage maps, utilities information, soils maps, land use plans, and aerial photographs.
b. Perform an on-site evaluation highlighting opportunities and constraints, such as pollutant hot spots, potential disconnects from Combined Sewer Overflows (CSOs), slopes, critical drainage areas, sunlight, shade, wind, habitat, potential green corridors, circulation, power lines, and storm drains. Make note of potential

LID practices and areas where water quality and quantity controls could be installed.

Step 3: Create Overlay

a. Classify the land use on the project site.
b. Review the proposed architectural plan to identify buildings and structures, open or vegetated space, parking lots, parking lot islands, side yards, vegetated strips adjacent to sidewalks, and buffer areas.
c. Create an overlay that identifies opportunities for LID devices.

Step 4: Develop LID Control Strategies

a. Develop a list of LID control strategies that potentially fulfill the objectives. Determine the appropriate number of LID controls needed. Identify specific LID technologies for the project site and determine how to integrate them, keeping in mind the optimum location, to meet their design objectives.
b. Specify LID technologies for each land use component.

Step 5: Design LID Master Plan

a. Sketch a design concept that distributes the LID devices uniformly around the project site. Keep in mind that some LID technologies can be used to capture storm water from adjacent impervious areas. Consider where public recreation areas can be provided, such as networks of open space or green corridors. Take into account using all surfaces (built, hardscape, and landscape). Keep in mind the multifunctional aspect of LID technologies (i.e., parking lot with sub-surface detention facility).
b. Develop a master plan that identifies all key control issues (water quality, water quantity, water conservation) and implementation areas. Specify specific LID technologies and any connections they have to storm water overflow units and sub-surface detention facilities.
c. Finalize the plan.

Step 6: Develop Schedule, Funding, Construction, and Implementation Plans

The development process is not a linear or static process but one that is dynamic and adaptable.

Step 7: Evaluate Success or Modify Design

Developing a storm water management program using LID principles and practices is a dynamic process. Evaluate the design to see if it meets project storm water management objectives. This will be achieved by:

a. Conducting modeling and/or calculations to determine if the master plan meets storm water control objectives. If the design does not meet the requirements, consider alternative strategies and repeat Steps 4, 5, and 6.
b. Periodically reevaluate the plan during the implementation process to determine if revisions need to be made to the storm water management program.

D. LID Technologies and Water Conservation

The following example addresses a way to determine the goals for on-site reuse of rainwater and water conservation. Determine which level of on-site reuse and water conservation is consistent with project objectives. A list of suitable LID technologies is suggested for the different water conservation levels.

1. ***Level One: Distribution***
   Storm water runoff is distributed using open and vegetated areas to increase infiltration and reduce the amount of storm water that enters the storm drains. This requires minimal infrastructural modifications/additions.
   LID Technologies: Sheet flow to rain gardens, bioswales, bioretention cells, tree box filters, soil amendments, structural soil, native and sustainable ornamental plants

2. ***Level Two: Hardscape Materials and Curbs***
   Replace hardscape materials with permeable materials. Construct sidewalks, parking bays, and internal alleys with materials, such as permeable concrete or green grids, that allow water to infiltrate. Slope roads in the directions of the parking lot islands, and construct curb-less islands to allow water to flow into the island. Minimal infrastructural alterations/additions are required.
   LID Technologies: Permeable paving, curb-less parking lot islands, porous concrete parking bays, and above listed technologies

3. ***Level Three: Recycling Rainwater and Runoff***
   This level uses above-ground LID devices to channel and collect rainwater from roofs, and uses sub-surface facilities to treat and collect runoff from roads and sidewalks. The recycled and stored water is used for irrigation and other non-potable purposes. The devices are integral with the buildings and infrastructure. Significant infrastructural alterations/additions are required.
   LID Technologies: Disconnected roof drains, cisterns, sub-surface storm water retention facility (below parking lots), rooftop channels, rain barrels, and above listed technologies

LID can be thought of as a component of the larger approach to sustainable design and water conservation. LID makes use of the rainfall and storm water that reaches a site, filtering it and directing it for reuse. LID site design technologies can be incorporated into the overall LEED Water Efficiency and Innovative Wastewater Technology goals pertaining to water use, recycling grey water, and water sewage treatment.

This analysis was compiled through a grant through the National Fish and Wildlife Foundation.

APPLICATION

LID Implementation Examples

Many municipalities in the U.S. have been very proactive in using on-site source control methods to manage storm water, such as in

Maplewood, Minnesota. In 1995, Birmingham Street, in Maplewood, was retrofitted with rain gardens adjacent to curb-less streets, instead of conventional curb and gutter, and became a precedent for future streetscape improvement projects in the county. The City of Olympia, Washington, has been very proactive in requiring certain sustainable storm water management practices to reduce the impact of impervious areas (e.g., narrower streets and permeable parking bays) and have adopted new codes and development guidelines. The City of Portland, Oregon, has revised zoning codes for parking lots to reduce the minimum size of parking bays and increase the required interior landscaping. Santa Monica, California, has modified its municipal code to encourage the use of sustainable practices including a number of site, landscape and water conservation technologies.

Some successful LID design and program development models include:

1. Olympia, Washington—Green Cove Basin

Key Goals:

- Designate Green Cove Creek as a sensitive drainage basin.
- Adopt low impact development regulations within designated sensitive drainage basins which may include storm water standards, critical area regulations, zoning designations, and other development standards.
- Protect critical areas in designated sensitive drainage basins.
- Direct development away from sensitive areas.

Key Elements:

- Increases allowable residential densities from single-family to duplex and multi-family uses.
- Limits maximum impervious surface coverage per lot.
- Reduces lot widths and setbacks.
- Increases maximum building heights.
- Changes zoning to allow multiple uses.
- Allows use of pervious materials on driveways and sidewalks.
- Requires use of pervious materials on new parking areas.
- Reduces width of local access streets to 18 feet.
- Reduce width of neighborhood collector streets to 25 feet.
- Increases width of sidewalk planters to 25 feet.
- Requires use of a rock infiltration gallery/conveyance system on roads where street slopes are less than 5 percent.
- Increases minimum tree density to 220 trees per acre (approx. 55%).

Comments:
The ordinance requires the use of one technique to handle street runoff, rather than providing a suite of technologies that might be more adaptable to different situations. The ordinance does not specifically address the treatment or capture of runoff from buildings.

2. Portland, Oregon—Amendments to Zoning Code

Objective:

To promote integration of storm water management facilities into parking lot layouts, to decrease the size of parking stalls and aisles, and to increase parking lot landscaping.

Key Elements:

- Promotes management of parking lot runoff within parking lot landscaping.
- Reduces parking space dimensions to 16 feet x 18½ feet for 90-degree parking.
- Reduces aisle width to 20 feet.

Comments:
An effort was made to permit and promote the management of parking lot runoff within interior landscaping, but to avoid creating excessive complications for retrofits of existing parking lots. The zoning code does not explicitly require that storm water runoff be managed within parking lot landscaping. The regulation of storm water management is left to the Bureau of Environmental Services. Specific requirements for parking lot runoff management are included in the city's *Storm Water Management Manual*.

3. Santa Monica, California

Objective:
To reduce runoff volume and contamination from both existing properties and future developments.

Key Elements:

- Establishes "Good Housekeeping Requirements" for existing properties, including the removal of hazardous substances from areas susceptible to runoff and restrictions on the washing down of paved areas.
- Requires all new developments and substantial remodels to submit an "Urban Runoff Mitigation Plan", and to reduce projected runoff for a project site by twenty percent. Provides a list of recommended design elements, including, but not limited to:
    - Maximize infiltration using:
        - biofilters
        - green strips
        - swales
        - permeable materials in lieu of hardscapes
    - Maximize amount of runoff directed permeable areas
    - Orient roof runoff toward permeable surfaces or structural BMPs
    - Modify grading to divert flow to permeable areas
    - Design curbs to minimize isolation of permeable or landscaped areas
    - Maximize storm water reuse
    - Use cisterns, retention structures or green rooftops to store runoff for reuse
    - Install BMPs to remove pollutants from runoff
    - Urban Runoff Mitigation Plan must include maintenance plan and applicant's signed statement accepting responsibility for

all BMP maintenance.

- Downspouts and subsurface pipes directing storm water to the curb must be fitted with a French drain system of perforated pipe and gravel.

Comments:
Substantial differences exist between the ordinance as adopted in 1992 and the most recent revision (2000). Both versions are included for the purpose of comparison. At some point, it may be instructive to research the reasons for changes in language and specific requirements.

4. King County, Washington-LID / Built Green™ Demonstration Projects

Objective:
To create three safe, healthy, and diverse communities that are sustainable and affordable, and to study the efficiency of the development review process as it affects project affordability.

Key Goals:
The three (3) pilot projects will:

- Demonstrate environmentally-friendly storm water management techniques (low impact development) that use landscaping and small-scale hydrologic devices to capture, filter, and infiltrate storm water runoff.
- Demonstrate ecologically sound approach to managing the built environment using Built Green™ construction principles.
- Feature recycled materials, energy efficiency, and natural habitat protection.

The three projects are:

1. *Hope VI Park Lake Homes in White Center:* An urban infill mixed-use redevelopment site of 900 units: new single family and multi-family housing units; developed by King County Housing Authority
2. *Shamrock in Renton:* An urban single family residential project of 100 single family housing units developed by Camwest, a private developer
3. *Sunflower Development on Vashon Island:* A housing project of 14 single family homes

Key Elements:
The modifications and waivers to standard development regulations that may be modified for the low impact development and Built Green™ demonstration projects may include:

- Zoning
- Density and dimensions
- Design requirements
- King County road standards
- Parking and circulation
- Landscaping and water use
- Drainage review requirements
- Environmentally sensitive areas
- Signs

5. Maplewood, Minnesota

Objective:
Adopted LID storm water management techniques as an alternative to conventional curb and gutter infrastructure in a 1950s residential community slated for a street improvement project.

Key Goals:

- Retrofit two blocks of existing streets and front yard municipal storm water easements with rain gardens that infiltrate storm water.
- Reduce capital costs for municipal infrastructure by avoiding curb and gutter installation.
- Build an ecologically friendly landscape that supports biodiversity.
- Create a culturally sustainable landscape through community involvement.
- Enhance the aesthetic of the neighborhood.

Key Elements:
The landscape retrofits include:

- Grassed swales in storm water easements.
- Rain gardens in front yards of volunteer residents. Residents selected from seven types of garden designs that use native plants, such as "easy shrub," "butterfly and friends," or "Minnesota prairie garden". The city provided the landscape design and all of the plants required for their garden.
- French drains installed at key locations to increase infiltration capacity.
- The front yard gardens create a landscape corridor up and down the street.
- An abandoned lot was used as a storm water retention area and has become a community nature garden.
- The program is supported by community education and outreach programs and promotes public involvement.
- Questionnaires address homeowners' uncertainties about design, the use of the storm water easement in their front yard, maintenance, and care.
- Annual community "planting days" are scheduled where city personnel and residents demonstrate how to plant and maintain rain gardens.

This analysis was compiled through a grant through the Summit Fund of Washington.

Low Impact Development Technologies

Refer to the Low Impact Development Technologies Resource Page for more detailed descriptions about specific LID technologies, cost comparisons, benefits, and their use.

RELEVANT CODES AND STANDARDS

Regulatory Compliance

Chesapeake Bay Agreement 2000
Clean Water Act

- Section 303. Total Maximum Daily Loads
- Section 311. Spill Prevention, Control and Countermeasure Requirements
- Section 319. State Non-Point Source Management Program
- Section 401. Certification and Wetlands
- Section 402. National Pollutant Discharge Elimination System (NPDES) Program
- Section 404. Regulation of Dredged or Fill Material

Safe Drinking Water Act Wellhead Protection Program
Coastal Zone Management Act
Energy Policy Act of 1992
Estuaries and Clean Waters Act of 2000
National Environmental Policy Act of 1969
Sikes Act

Federal Directives

Executive Order 13423, "Strengthening Federal Environmental, Energy, and Transportation Management"

ADDITIONAL RESOURCES

WBDG

Design Objectives
Sustainable, Sustainable—Protect and Conserve Water

Product and Systems
Building Envelope Design Guide: Below Grade Systems, Foundation Walls, Floor Slabs, Plazas, Tunnels, Vaults
Federal Green Construction Guide for Specifiers
32 10 00 (02700) Bases, Ballasts, Paving
32 12 43 (02795) Porous Paving
32 90 00 (02900) Planting
31 25 73 (02635) Stormwater Management by Compost
32 71 00 (02670) Constructed Wetlands
07 33 63 (02930) Vegetated Roof Covering
33 16 20 (11201) Rainwater Harvesting

Associations

National Association of Homebuilders-Low Impact Development Practices for Storm Water Management

Organizations

Low Impact Development Center, Inc.
Puget Sound Action Team
Sustainable Buildings Industry Council (SBIC)
U.S. Green Buildings Council (USGBC)

Publications

GSA LEED® Applications Guide
GSA LEED® Cost Study
Natural Approaches to Storm Water Management (PDF 1.2 MB)
The Practice of Low Impact Development publication (NAHB for the Dept of HUD); order 1-800-245-2691; helpdesk@huduser.org or NAHB
"Reducing Combined Sewer Overflows—Toward Clean Water in Washington, DC" (PDF 415 KB)
"Out of the Gutter—Reducing Polluted Runoff in the District of Columbia" (PDF 1.4 MB) (NRDC)
Low Impact Development
Low Impact Development—Protecting Water Resources as Our Cities Grow (PDF 2.7 MB)

Design and Analysis Tools

Bioretention Design Software
Bioretention Facility Design References
LID Design Software
Low Impact Development Urban Design Tools
Prince Georges County—Low Impact Development

Training

American Society of Civil Engineers (ASCE) Training
Applied Stormwater Management Design Training
Low Impact Development Conferences
Low Impact Development Conference 2001 (Puget Sound)
Low Impact Development Training Workshops

Other

Environmental Protection Agency (EPA)
EPA—Low Impact Development
EPA—Storm Water Management
EPA—Storm Water Management at the EPA Headquarters Office Complex
National Association of Homebuilders Research Center LID Web Resources
Puget Sound Action Team LID Web Resources

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