**Low Impact Development – Sustainable Stormwater Management**

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## Introduction:

The Clean Water Act (CWA) was adopted by the United States in 1972 to address point source discharges of pollutants into the many rivers and lakes in the United States. Over the 41 years, the CWA has had the desired result of restoring the water quality in these water bodies which were often so polluted that they were unsuitable for use by the public.

However, another problem soon became very apparent. This new issue was pollutants found in stormwater that were not the result of a point discharge, but seemed to come from everywhere. Ultimately, these discharges became known as non-point source discharges and were the result of rainfall washing accumulated pollutants off the many different types of impervious surfaces, such as building roofs, road networks, parking lots and even landscaped areas. These pollutants were being discharged to streams, rivers, and lakes and over time, these water bodies were experiencing undesirable aquatic vegetation as a result of phosphorous discharges. Aquatic species were being reduced by the presence of metals and hydrocarbons in the water, which can be toxic even at very low concentrations. Sediment was being deposited on the bottom of cold water streams preventing benthic organisms from reproducing and thus adversely affecting the entire aquatic food chain.

In addition to the water quality impacts, the approach to dealing with stormwater from developed sites caused a significant unintended consequence on small receiving streams. Starting in the late 1970's, the concept of peak rate reduction of post-development stormwater became the rule in many areas of the United States. It was simple enough in theory; reduce the peak rate of runoff for post-development conditions to the peak rate of runoff for pre-development conditions for a certain size rainfall event by using a detention basin to hold back and meter out the accumulated runoff over a longer period of time. "This is easy to do and will protect the environment", was the prevailing thought of regulators and designers of this approach. What no one considered was the fact that the small streams were now seeing long flow durations for a full channel condition from the increased volume of runoff that caused erosion of the stream channels with the resultant discharge of sediment farther down the stream channel or into a larger water body. The discharge of sediment created turbid water, which reduced the ability of sunlight to penetrate the water column resulting in other adverse aquatic impacts to plants and fish. While the point source discharges were eliminated, the non-point source discharges were proving to be very difficult to identify, quantify and correct.

In the early 1990's, Prince Georges County in the State of Maryland started looking at solutions to the non-point source issue as the pollutant discharges into Chesapeake Bay were adversely affecting the blue crab population and the economic health of the many communities which depended upon the resources of Chesapeake Bay.

Larry Coffman, the Associate Director of Prince George's County, Maryland's Department of Environmental Resources, started looking for solutions to non-point source discharges. He began observing how natural environment systems such as woods and meadows handled rainfall. He also studied the rainfall events themselves and found that most of the rainfall events only generated a small of amount of rain within a 24 hour period.

He realized that rainfall which occurred in these natural systems was attenuated in many ways by these systems. Leaves on trees intercepted rainfall preventing it was ever reaching the ground, the dense litter layer on the ground dissipated the velocity of the falling raindrop, preventing erosion of the soil surface and lastly, any runoff which made to the ground surface simply infiltrated into the soil. The rainfall which infiltrated into the soil was filtered through physical, chemical and biological processes within the soil. What a great system; reduce or eliminate runoff, filter runoff by infiltration through the soil and maintain the integrity of ecosystems. Could these natural processes be recreated to treat non-point source runoff? The answer was a resounding *yes*. When these observations were coupled with research by Dr. Robert Pitt of the University of Alabama for the National Urban Runoff Program on how pollutant loads were occurring on impervious surfaces, the framework for Low Impact Development (LID) was created.

**What is LID?**

LID is an ecologically friendly approach to site development and stormwater management that aims to mitigate development impacts on the land, water and air. The LID approach emphasizes the integration of site design and planning techniques that conserve the natural systems and hydrologic function on a site. LID also embraces the philosophy that rainfall is a resource to be reused and recycled in the environment and not something to be gotten rid of.

LID works to manage rainfall at the source using uniformly distributed decentralized micro-scale controls. The primary goal of LID is to mimic a site's pre-development hydrology by using design techniques that infiltrate, filter, store, evaporate, and detail runoff close to its source, thus creating a site which demonstrates "Hydrologic Transparency". Hydrologic Transparency is defined as "The use of LID design strategies and stormwater treatment systems for a development scenario that yields hydrologic conditions matching or in extremely close proximity to the hydrologic conditions of the natural site prior to development".

In the past twenty years, the concept of LID and the various types of treatment systems have been the subject of research at Villanova University ( http://www3.villanova.edu/VUSP/ ) under the direction of Dr. Robert Traver, North Carolina State University ( http://www.bae.ncsu.edu/stormwater/ ) under the direction of Dr. Bill Hunt, University of Maryland ( http://www.waterresources.umd.edu/ ) under the direction of Dr. Allen Davis, and the University of New Hampshire Stormwater Center ( http://www.unh.edu/unhsc/ ) under the leadership of Dr. Tom Ballestero and the former director Dr. Robert Roseen to name a few of the predominant research facilities. The research conducted by these institutions have not only proved that the concept of LID works, but have refined the design standards and processes for the treatment systems to ensure long term functionality.

LID is an approach to creating sustainable developments that work with the natural land form while reducing, or in some cases eliminating the adverse impacts associated with development. The first step is the application of Environmental Site Design strategies which identify sensitive environmental resources on a site and places the development on the land most suitable for development while preserving these environmental resources. By the preservation of these resources, other environmental benefits are realized, such as the sequestering of carbon in the vegetation and undisturbed soils. Forests will also absorb carbon dioxide and give off oxygen as a result of photosynthesis.

LID is a performance based upon to stormwater management which is in direct contrast to the prescriptive approach used to design stormwater management systems over the past 35 years. From a stormwater management perspective, the focus of LID is on what is termed the "90% storm event". This is the amount of rainfall which occurs over 24 hours and storms this size and smaller that constitute approximately 90% of the total annual rainfall for an area. While the size of the 90% storm event varies geographically, it is generally 1.25 cm (1.0") of rainfall in 24 hours. In Arid regions, it may be only 0.62 cm.

Another goal of LID is to mimic the natural infiltration rates for the 90% storm event for the different soil types. Sandy soils will infiltrate most, if not all of the 90% event, while a clay soil will infiltrate very little. By the installation of LID treatment systems such as Bioretention, Filter Strips, Bioswales and Permeable Pavement systems, the goal is to have a developed site act like the natural site from a hydrologic standpoint for the 90% storm event. By mimicking the natural environment, surface runoff volumes are reduced, which minimizes the risk and extent of flooding from these small rainfall events.

**Types of LID Treatment Systems:**

The most commonly used LID treatment system is the Bioretention system. A Bioretention system is a depressed landscaped area with a specified soil media which is planted with native grasses and shrubs. Runoff from the first 1" of rainfall is directed to the Bioretention system and the runoff will temporarily pool in the depression and then infiltrate into the native soils. Pollutants found in the runoff are reduced by the physical, chemical and biological processes of the soil and plants in the Bioretention system. Metals and hydrocarbons from in stormwater have an affinity to attach themselves to sediment particles, so if sediment being trapped in a Bioretention system, so were these pollutants. Nutrients, both in soluble and particulate forms are taken up by the vegetation for growth purposes.

**Figure 1 - Bioretention System (Trinkaus Engineering, LLC)**

A variation of the Bioretention system is the Bioswale (aka Linear Bioretention or Dry Swale). A Bioswale can be used along roadways to convey and filter runoff just like a Bioretention cell. A key design aspect of all types of LID infiltration systems is obtaining a comprehensive soil evaluation in the area of the proposed system. The types of soil must be identified as well as potential limiting factors such as the depth of groundwater or bedrock. In addition, infiltration testing is required of the soil layers at or below the bottom of the Bioretention facility to ensure that a minimum infiltration rate of 1.25 cm/hr (0.5"/hr) is obtained.

While LID infiltration systems can be installed in soils with infiltration rates slower than 1.25 cm/hr, the design must be modified to address the slower infiltration rate by increasing storage volume or adding an underdrain to the system.

**Figure 2 - Bioswale (Trinkaus Engineering, LLC)**

There are many types of permeable pavement systems that can be used to reduce impervious areas, reduce runoff volumes and provide water quality improvement. If the soil conditions are not adequate to fully infiltrate the runoff from the 90% storm, then a filter course must be included in the base material of the pavement section to provide the water quality benefit. This filter course is a layer of well graded sand and gravel or medium to course sand.

**Figure 3 – Porous Concrete (at left), Paver Stones with Gravel Infill (at right)**
**(Photo by S. Trinkaus of Cincinnati, Ohio LID Demonstration Project)**

**Figure 4 – Paver Bricks with Coarse Sand Infill (at left) and Ornamental Pavers with Stone Infill (at right)**
**(Photo by S. Trinkaus of Cincinnati, Ohio LID Demonstration Project)**

## LID in the United States:

In the United States, there are certain areas on both coasts where LID has generally been embraced by the regulatory community, designers and most importantly the public. However, we are still experiencing resistance to the implementation of LID in other areas due to a lack of knowledge and education about the adverse impacts of stormwater on our environment. Public education and outreach to all of the stakeholders in the development process is extremely important to overcoming resistance to LID and to facilitate the widespread acceptance and implementation of LID approaches on a local, regional, or national basis.

LID is easy to apply for new developments as there is inherent flexibility when working with vacant land. LID strategies can consist of the following: Environmental site design, Site fingerprinting, impervious area disconnection, Vegetative filter strips, Bioretention systems or rain barrels for roof runoff and Green roofs. There are many LID tools available to create sustainable projects.

Addressing stormwater volume and water quality issues in the urban environment are more challenging, but can be addressed by the creative application of LID. While there are typically many potential barriers to LID in the urban environment, such as space constraints, utility conflicts and urbanized (disturbed & compacted) soils, these barriers can be overcome to implement LID. Infiltration systems such as Bioretention and Permeable Pavers can be designed with underground storage systems to account for slow infiltration rates.

The City of Portland, Oregon (http://www.portlandoregon.gov/bes/34598 ) has pioneered the implementation of LID in the urban environment by the creation of "curb bump outs" which locate Bioretention systems along the gutter line of a street. LID planters are Bioretention systems installed in a portion of a sidewalk to not only treat stormwater, but create more "green space" in the urban area. Water quality improvement is the primary goal for the implementation of LID in an urban area as the disturbed soils are generally not suitable for infiltration. Permeable pavement systems can be utilized for on-street parking lanes to reduce the impervious area.

There are many proprietary LID treatment systems which can also be considered for the urban area. The Filterra system (http://www.filterra.com/ ) is a tree filter with a high flow rate media to reduce pollutant loads. The Modular Wetland System (http://www.modularwetlands.com/ ) is an inlet system with a subsurface gravel flow wetland in a concrete box. Native wetland plants are used to enhance pollutant load reductions.

A common misconception about LID is that the treatment systems are expensive to construct and maintain. This has been proven to be false. LID treatment systems have been shown to be less expensive to construct and maintain when compared to Conventional stormwater management systems, such as catch basins and pipe and standard detention systems. While the installation of Permeable Pavement is more expensive than standard pavement, a cost saving is still realized because no Conventional drainage systems are needed when Permeable Pavement is used. On average, the use of LID treatment systems will result in an infrastructure cost saving of 10 – 30% over Conventional designs. In urban areas, the cost saving may not be as high due to the more site constraints, but the improvement of water quality is well worth the cost.

The maintenance of Bioretention systems is not only simple, but is needed less frequently than in Conventional practices. Basically, Bioretention systems are depressed landscape areas, so weeding and the removal of leaves in the fall constitute the typical maintenance requirements. Depending upon the location of the system, accumulated sediment will need to be removed from the soil surface and can readily be done by hand once or twice a year. Maintenance of permeable pavement systems generally consists of cleaning on a quarterly basis using a regenerative vacuum truck at an annual cost of $ 1,200.

**LID Applications in Chinese Cities:**

During a recent visit to Guangzhou, China in December 2012, I observed that water is a predominant feature in a Chinese city and is enjoyed by the citizens and visitors alike. I noticed that there are substantial landscaped areas along many of the roads in the city. These landscaped islands are typically higher than the road surface and are very similar to the ones found in the United States. One approach to implementing LID is to make these raised landscaped islands into depressed Bioretention systems with the same amount and type of native plants. The benefit of this approach is maintaining the green space in a city while treating the stormwater runoff from the impervious areas.

Another approach is to use either permeable asphalt or porous concrete for portions of large parking areas for hotels and convention facilities to reduce the extent of impervious areas. LID strategies can be implemented almost everywhere to improve water quality of stormwater and create a sustainable environment for all.