RETAIN, DON'T DRAIN

A Review of LID Stormwater Management Strategy
Focused on Preserving the Hydrologic Integrity of the Site and the Watershed

by David Venhuizen, P.E.

The full range of available stormwater management strategies should be considered in each circumstance to determine the most workable, cost efficient and sustainable approach. However, consideration of low-impact development (LID) management strategies is urged by various factors related to each of these measures. Sustainability begins with the form and function of the development design, and when it comes to stormwater management, the LID strategy is the very embodiment of that principle.

The basics of LID strategy and the reasons for favoring it are well encapsulated by the following excerpt from "Low-Impact Development Design: A New Paradigm for Stormwater Management Mimicking and Restoring the Natural Hydrologic Regime" by Larry Coffman, former director of the Prince George's County (Maryland) Department of Environmental Resources, which developed much of the LID strategy:

> "LID stormwater management technology can maintain or restore a watershed's hydrologic regime by fundamentally changing conventional site design to create an environmentally and hydrologically functional landscape that mimics natural hydrologic functions (volume, frequency, recharge and discharge). This is accomplished in four ways. First: minimizing impacts to the extent practicable by reducing imperviousness, conserving natural resources and ecosystems, maintaining natural drainage courses, reducing the use of pipes and minimizing clearing/grading. Second: recreating detention and retention storage dispersed and evenly distributed throughout a site with the use of open swales, flatter slopes, depression storage, rain gardens (bioretention), water use (rain barrels), etc. Third: maintaining the predevelopment time of concentration by strategically routing flows to maintain travel time. Fourth: providing effective public education and socioeconomic incentives to ensure property owners use effective pollution prevention measures and maintain management measures. With LID, every site feature is multifunctional (green space, landscaping, grading, streetscapes, roads and parking lots) and helps to reduce stormwater impacts or provide/maintain beneficial hydrologic functions. The cumulative beneficial impact of using the wide array of distributed LID techniques allows the site designer to maintain or restore a watershed's natural relationship between rainfall, runoff, infiltration and evaporation.
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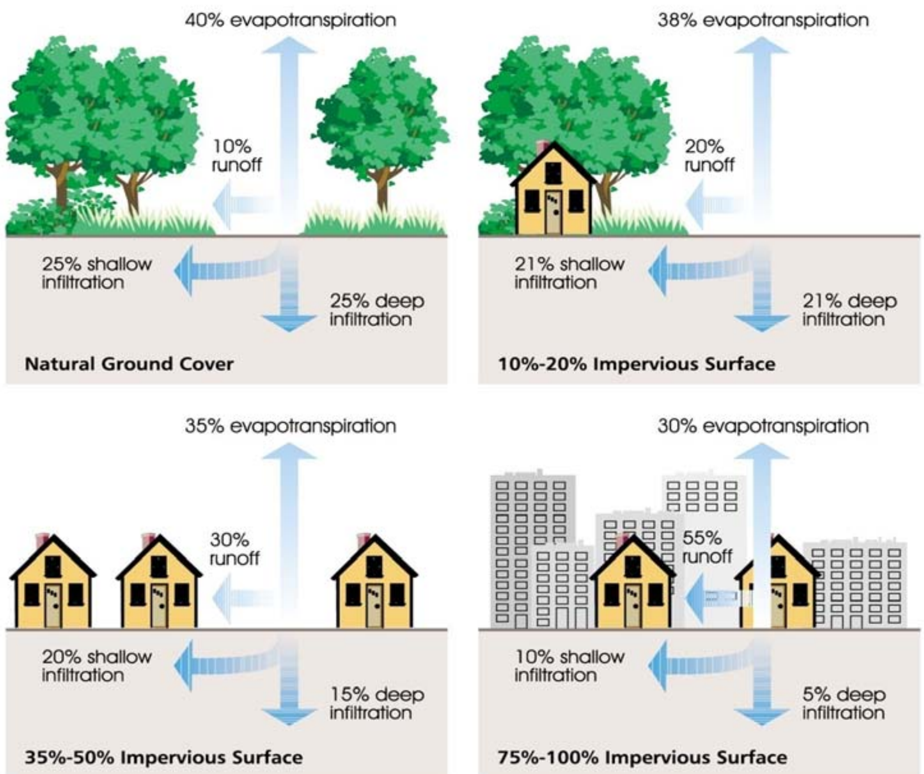
> "The effective use of LID site design techniques can significantly reduce the cost of providing stormwater management. Savings are achieved by eliminating the use of stormwater management ponds, reducing pipes, inlet structures, curbs and gutters, less roadway paving, less grading and clearing. Where LID techniques are applicable, and depending on the type of development and site constraints, stormwater and site development design, construction and maintenance costs can be reduced by 25% to 30% compared to conventional approaches."

That last statement is likely the major incentive for the development principals to investigate LID. As Coffman describes, LID also offers an environmentally superior management strategy, by maximizing site values and by distributing detention/retention devices throughout the drainage area. This latter practice contrasts with the conventional practice of gathering flow from a large area into end-of-pipe ponds and filter beds – devices that are typically unsightly and take up space that could offer additional development yield and/or site beautification.

In any case, the focus of those conventional end-of-pipe strategies is to intercept, detain, treat and then drain. This addresses the water *quality* impacts of the project (to the extent that the BMPs used, and indeed this whole "gross" end-of-pipe strategy, does "adequately" address the water quality impacts), but development also increases the *quantity* of runoff, as illustrated in Figure 1. The more sustainable LID strategy would address this problem as well. This would better maintain the hydrologic integrity of the site and—by the cumulative impact of these practices—of the watershed, as noted by Coffman.



HYDROLOGIC CHANGES DUE TO DEVELOPMENT
FIGURE 1

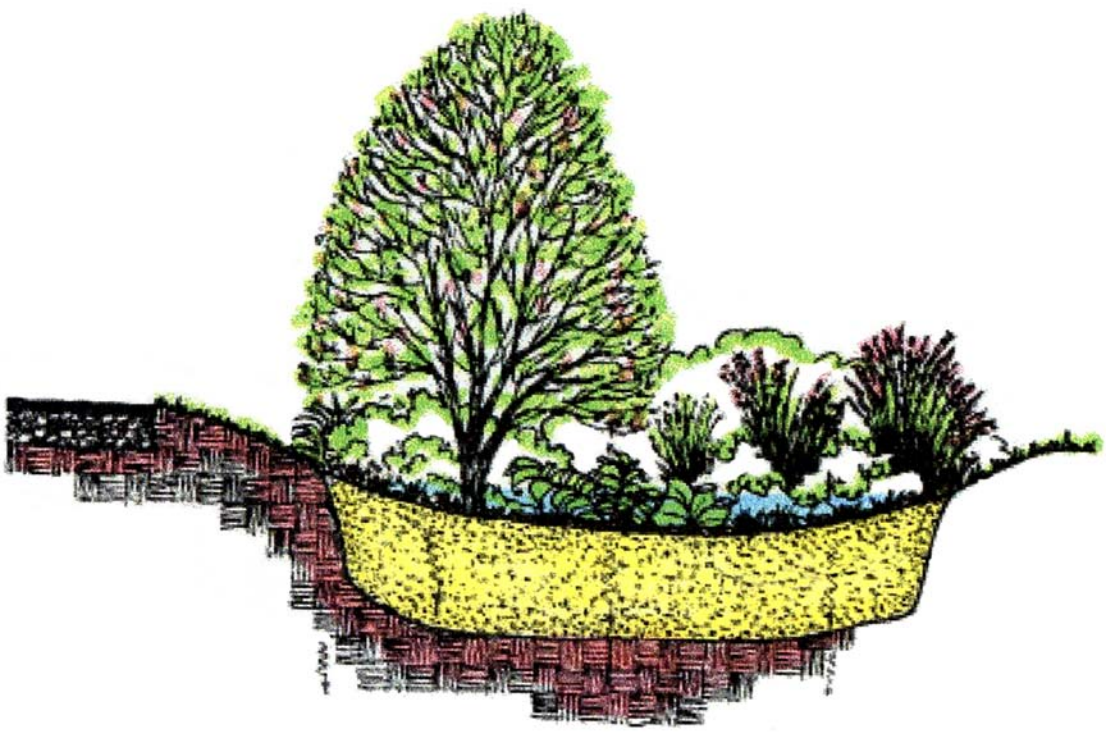
This broad concept must of course be focused down to the explicit strategies that would best meet the needs in each project. Understanding that the essence of this strategy is that management methods would be "worked in" to the site design, the details must await the acquisition of detailed site information and firming up of the development plans. However, it is expected that stormwater management would center on these strategies:

- Treating runoff close to where it is generated with distributed methods, expected to be mainly bioretention beds, which are reviewed below.
- Maintaining the natural level of quickflow runoff. This would be accomplished with those distributed retention/detention methods by maintaining time of concentration close to the natural condition, by minimizing impervious cover with "green" design standards (e.g., narrower streets, green roofs, porous pavement), and by minimizing the increase in "effective" impervious cover by catchment and sequestration of rainwater from rooftops.
- Maximizing and enhancing existing drainage channels. Drainageways which convey flow from a sizeable area may be left largely undisturbed and bordered by a buffer zone. Where appropriate smaller drainageways might be "improved" and beautified.

The LID strategy may employ a range of what are termed "integrated management practices" (IMPs), so called because they are integrated into the site improvement plan. These include bioretention, dry wells, filter strips, vegetated buffers, level spreaders, porous pavement, green roofs, grassed swales, rain barrels, cisterns, and infiltration trenches.

Duly noting the potential contribution of the building-scale rainwater harvesting strategy (reviewed in the "Rainwater Harvesting" section of this web site), the most versatile and useful of these tools is expected to be the bioretention bed. This device can be deployed in a highly distributed manner to intercept runoff at its source, which would minimize the need for any hard-pipe conveyance. Where that is more expeditious, it can also be deployed as essentially an end-of-pipe strategy for small drainage areas.

A generalized schematic of a bioretention bed is shown in Figure 2. The essential components of the bed are an underdrain (if required), the soil mix/filter media, an organic mulch layer, and the plants. Bioretention in general employs a simple, site integrated, terrestrial-based design that provides opportunity for runoff infiltration, filtration, storage and water uptake by vegetation. The bed captures runoff to be filtered through a prepared soil medium. Once the pore space capacity of the medium is exceeded, stormwater begins to pool at the surface of the mulch layer.



SCHEMATIC OF BIORETENTION BED
FIGURE 2

As shown in the figure, the planting bed is in a depression to provide some detention/retention storage until the water level builds up to the overflow depth, typically specified as 6-12 inches. The bioretention bed is typically sized so that it holds the "water quality volume" (as that is defined in the applicable regulations) once the water has ponded to this maximum allowable depth. The overall drainage plan must provide a drainage path for the overflow. Ideally this would be a natural or newly constructed vegetated channel so that installation of hard pipe conveyances is minimized.

If the permeability of the soil is high enough, the bioretention bed does not have to be underdrained, and the bed acts as a retention device for all the water retained at or below the water quality volume. If the permeability of the soil is too low to allow the retained volume to infiltrate within a specified time, then the bed must be underdrained. If the bioretention bed is underdrained, there must be an outlet and flow path available for the drainage. Again, this would ideally be into the same natural or newly constructed vegetated channel that would convey the overflow, again to minimize installation of hard pipe conveyances.

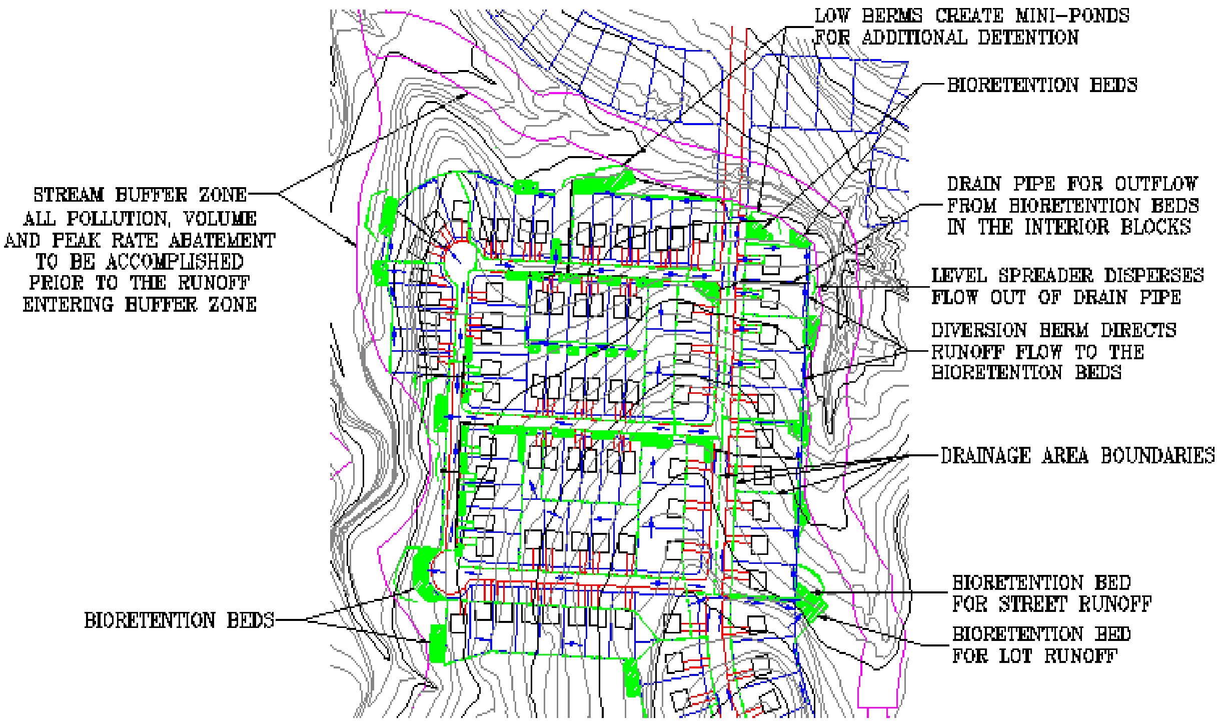
With or without underdrainage, however, bioretention beds significantly reduce the increase in quickflow from a site brought about by an increase in impervious cover. (This is reviewed in another document in the "Low-Impact Development" menu of this web site.) Without underdrains, much of the water infiltrates and never flows off the site. With underdrains, some of the water is retained – the amount required to raise soil moisture in the bed from ambient condition to field capacity, which analyses show may be the full amount of runoff from the majority of storms – and the release of the rest is significantly delayed, so it is more like baseflow than quickflow.

Bioretention beds function by the operation of all the processes that occur in the natural environment which the bed mimics. As indicated above, depending on the design of the facility, different processes can be maximized or minimized. The major processes operating in a bioretention bed include interception, infiltration, settling, evaporation, filtration, absorption, transpiration, assimilation, adsorption, nitrification, denitrification, volatilization, thermal attenuation, degradation, and decomposition. As indicated by this list, bioretention is a complex process, not just a simple filtering device. Bioretention beds retain, break down, and assimilate pollutants, thereby protecting the receiving waters.

When deployed in a high distributed manner to receive runoff from small areas, bioretention beds can also help restore some of the "hydrologic roughness", the depression storage in a natural landscape that is typically destroyed by the development process, which creates smooth grades. An example of a stormwater management strategy based on highly distributed bioretention beds is illustrated in Figure 3. As shown, there are a large number of small bioretention beds, each receiving runoff from small drainage areas, in essence mimicking—perhaps even enhancing—the hydrologic roughness of the native site.

Two other aspects of this sort of strategy bear attention. One is its ability to capture and sequester runoff on a highly distributed basis so that, no matter how little infiltration potential there may be in the soils on this site, infiltration "losses" are maximized, enhancing soil moisture storage and the amount of water that, instead of running off directly as quickflow, percolates to a bedrock plane and may emerge at seeps along stream channels. This sequestering and slow release of quickflow would minimize the loss of baseflow typically imparted by the installation of impervious surfaces in a watershed.

The other aspect is a decrease in the overall vulnerability of the stormwater management function. The "conventional" manner of providing stormwater treatment would be to place a large-scale end-of-pipe pond/filter near, or even in, the stream channel (noting that some rules may restrict what can be placed in channels), a situation that "places all the eggs in one basket", so to speak. No matter how well thought out, designed and constructed a control may be, it is sure that nature will conspire to produce at some point conditions that would "pop the cork" and cause a release of pollution. By instead distributing the controls among many sites, each receiving flow from a small area, the vulnerability of the overall system is greatly reduced, as any such event would result in only a very small release from a minor portion of the total area rather than a large release from all of it. In any case, the likelihood of a "cork popping" event is much higher in a device where a very large volume of water gathers than it would be in one where the volume at overflow is very small.



EXAMPLE BIORETENTION-BASED STORMWATER MANAGEMENT SYSTEM
FIGURE 3

As noted, bioretention is a highly versatile concept. To illustrate that bioretention could be integrated into the landscaping scheme in any number of ways, consider these variations of this method listed in "The Bioretention Manual" published by Prince George's County:

- Curbless parking lot perimeter bioretention – a bed located along the low edge of a paved area like a parking lot, into which the water sheet flows along the pavement edge.
- Curbed parking lot perimeter bioretention – a similarly arrayed bed which receives inflow through curb cuts, requiring flow dissipation/spreading devices be added to the design.
- Parking lot island and median bioretention – similar to the above, except arrayed in parking lot islands or in roadway medians, in which case it may be very long and thin.
- Swale-side bioretention – installed along the side of a drainage swale to intercept the water quality volume from the upstream contributing area.
- Rooftop bioretention – essentially a "green roof".
- Residential On-Lot Bioretention, Landscaped Garden, Shallow-Dish Design – various names used to describe what are often referred to by the catch-all name of "rain garden", which covers any sort of retention area, typically on a residential lot, that is designed to capture and retain runoff, whether or not "formally" designed as a bioretention bed.
- Tree and shrub pits – a shallow ponding area created around a tree or shrub by depressing rather than mounding the soil around the plant, using the improved planting soil placed in the excavation as a bioretention bed.
- Sloped "weep garden" – a bioretention bed design adapted to a sloping site, which allows the water to weep out through a wall that retains the bed along the downslope side.
- Bioretention trap areas – any area created by a depression behind a site feature such as a curb or sidewalk, whether or not "formally" designed as a bioretention bed.
- Natural forest site – a forested area in a high permeability soil which is left largely undisturbed, except for a berm on the low side of the area to create a shallow ponding area.

It should be stressed that bioretention can be employed in higher intensity settings like a town center, not just in areas with lower development intensity. As an example, consider a block and the surrounding streets in a town center setting. Assume a block measures 300' x 400', so covers 120,000 sq. ft. Even in this setting, it is to be expected there would be some landscaping incorporated into the development. A guess at the maximum impervious cover is 80%. Therefore, landscaping would cover 20% of the block area, or 300 x 400 x 0.2 = 24,000 sq. ft. The other 80%, 96,000 sq. ft., is impervious. According to the Prince George County sizing criteria, a 100% impervious area would require a bioretention bed area equal to 10% of the drainage area. So the required area of the bioretention bed would be 96,000 x 0.1 = 9,600 sq. ft., leaving 24,000 – 9,600 = 14,400 sq. ft. Assume that the R.O.W. is 70' wide and 100% impervious, and the adjacent half – 35' wide – drains to this block. The street impervious cover is 400 x 35 x 2 + (300+35+35) x 35 x 2 = 53,900 sq. ft. Bioretention bed area required for this impervious area would be 53,900 x 0.1 = 5,390 sq. ft. This leaves 14,400 - 5,390 = 9,010 sq. ft. of "unencumbered" landscaped area. This illustrates that, even at this intensity, bioretention can “fit” into the site plan.

Again noting that the essence of the LID strategy is that the methods are integrated into the site design, costs of bioretention facilities in a project cannot be meaningfully estimated until a further definition of how and where they may be deployed is available, and until local cost factors for the bioretention bed components are researched. However, some case studies have indicated that integrating bioretention across a site can achieve a net reduction of between 15% and 50% of site development costs compared with conventional BMP’s. Key fiscal/economic advantages of using bioretention for stormwater management include:

- Design costs and complexity may be significantly reduced.
- Safety and risk factors lower during construction, maintenance and operation.
- Grading and sediment controls reduced by preserving dispersed drainage flow patterns.
- Installation costs reduced by the use of a non-structural design.
- Credit for subdivision landscaping.
- Reduction or elimination of storm drainage infrastructure.
- Reduction in runoff quantity.
- Reduction/elimination of land area to control stormwater by placing bioretention on-lot.
- Reduction/elimination of large-scale end-of-pipe treatment areas.
- Superior aesthetics of bioretention beds over large-scale end-of-pipe devices enhances overall value of the development.
- Maintenance responsibility manageable/may be largely shifted to lot owner, since this activity is essentially just maintenance of landscaping features.

This uncertainty in costs applies to the entire LID stormwater management strategy since, once again, these methods are designed in to the site plans. They are not, as dominates prevailing practice, devices that are simply appended on to a site plan that was developed without regard to stormwater impacts, as a remedial process rather than as an integral aspect of the design process. Thus, construction details are highly site specific rather than standardized “cookie cutter” designs. Again, however, the experience in many applications, covering a range of development types, is that an LID strategy would reduce overall costs of the stormwater management function.

The proposed strategy would also maximize water resources utilization efficiency by retaining more moisture on the site and—in the case of direct catchment and sequestration off rooftops—providing the opportunity to defray demands on the general water supply, whether that water is utilized to satisfy interior demands or only to defray irrigation demands. Again, a very basic idea is *to address stormwater as a resource, not as a nuisance*. It remains to investigate the opportunities and liabilities of these strategies in the context of each project and so derive the actual costs in this setting. As noted, based on what has been observed in many applications, it is to be expected that the ***planning/engineering costs incurred to do this would be repaid many times over by the savings***.