King County
Department of Natural Resources and Parks
Water and Land Resources Division

Model Low Impact Development Strategies for Big Box Retail Stores

THE GREENING OF SURFACE WATER MANAGEMENT METHODS FOR LARGE FORMAT RETAILERS

FINAL
July 2007

Model Low Impact Development Strategies for Big Box Retail Stores

The Greening of Surface Water Management Methods for Large Format Retailers

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July 2007

This report was prepared by

King County

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Water and Land Resources Division
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KING COUNTY DEPARTMENT OF NATURAL RESOURCES & PARKS

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Executive Summary

In balancing business and environmental needs, investment and convenience, consumerism and sustainability, our society makes choices between development, healthy watersheds and clean water. Are these choices mutually exclusive? We hope that this study demonstrates that development choices that protect the environment are compatible with business operations.

The purpose of this project was to investigate methods to reduce the environmental impact of "Big Box" retail stores through the application of Low Impact Development (LID) principles of stormwater management. "Big Box" refers to an adaptation of retail that focuses on volume, among other commonalities. The industry calls it "large-format retail"; in some places it's known as "big box retail". LID is a more natural approach to land development and stormwater management that uses a site's natural features and best management practices to mimic natural hydrologic patterns and thereby limit stormwater runoff and pollutant generation.

With their headquarters in King County Washington, Costco Wholesale Corporation was a natural partner for this project and generously provided insight to the planning, design and operational considerations of large-format retail businesses. They also offered valuable input to our evaluation of LID approaches and made their staff and consultants available for many hours of meetings and discussions. By using their specific challenges as an example, we have examined standard large format development methods, barriers to the use of LID methods, and benefits of site-specifically designed best management practices (BMPs). We have attempted to identify and quantify a viable suite of alternative stormwater management methods to apply to intensive developments. Costco has an interest in making their operations "greener", and this collaboration demonstrates another step in that direction.

Purpose of this Report

This report is intended to be used as an introduction for anyone interested in how LID could be applied to new development projects with high levels of impervious surface as well as a reference and guide for the proponents, designers and reviewers of such projects. Our goal is to demystify LID to decision makers. Although this work focused on Costco as a case study, it has general applicability to shopping centers and other developments with large parking lots and other areas of significant impervious surface.

This report is not intended to be a design manual or regulatory document. It is a general reference, and as such cannot cover all situations that may be encountered nationwide. We have attempted to consider a wide range of stormwater standards from jurisdictions that require only conveyance of storm flow to highly restrictive standards such as the 2005 Stormwater Management Manual for Western Washington. The guidance provided here must be supplemented with a good knowledge of local code and development practices and sound engineering judgment.

Organization

This report details a number of LID strategies that have been considered using Costco as an example to outline typical big box development practices and quantifies their effectiveness at managing stormwater. It also describes LID application and limitations of typical large format retail sites. Lastly, this report summarizes conclusions and recommendations for furthering the promotion of LID on development-intensive sites.

During the course of this project our interviews and research brought out material that enhances the value of the information provided within this report to the big box developer. A series of appendices document the outcomes of these various paths. Appendix A captures the ideas discussed with Costco and their consultants through several meetings on this topic, including Costco's thoughts on particular LID strategies. Appendix B outlines more ideas for the 'greening' of big box retail developments including energy efficiency, solar power and others. In Appendix C, stormwater engineers and those keen on detail will find information regarding hydrologic modeling methods, scenarios and details about the performance of various BMPs in different conditions.

Appendix D describes key considerations regarding the operation and maintenance of LID BMPs which are essential to the success of these strategies. And lastly, Appendix E offers a suite of stormwater pollution prevention BMPs specifically designed for big box retailers.

Results

It is of no surprise to find that one of the biggest challenges in applying LID BMPs to big box retail sites is the developer's willingness to consider alternative development scenarios. The very definition of big box denotes a large warehouse-style building surrounded by a great deal of parking that includes a great deal of impervious surface. But this, in itself, is not a limitation to using LID. Our work with Costco revealed the use of a very standardized development design used to keep their schedule and costs predictable and tight. Deviation from the standard model is certainly feasible, but in some cases requires an investment and some risk to try new things. For these reasons and others, Costco is not uniformly receptive to all LID BMPs. They have, however, identified a number of LID strategies that focus on their parking lot design to include a mix of pervious and impervious paving materials, and various types of distributed bioretention systems.

Predictably, the other big challenge in using LID BMPs is finding and designing the right strategy for any particular site conditions. The very nature of LID BMPs require that must be specifically designed to respond to the natural conditions on a site. The hydrologic analysis conducted in concert with this project shows that LID can be effectively used on big box projects: in the best of conditions LID methods could manage all stormwater; in more challenging circumstances LID can be used in combination with more traditional stormwater methods. In either case there are many additional benefits to using LID strategies that include overall aesthetic and community acceptance. Developers interested in LEED certification can also look to LID methods in design and development. Overall, the relative ease of using LID is a function of local site constraints including soil and groundwater conditions, climate, topography, as well as local regulations.

Conclusions

There are barriers, both perceived and real, to the use of LID in large commercial development due to existing regulations and current development practices. With increasing awareness of the benefits and effectiveness of LID, these barriers will be overcome. Successful transition to this new mode of stormwater management will require change and effort on the part of government, engineers, and the public, as well as project proponents themselves.

Government needs to lead the way by providing new standards, education and incentives. Engineers have a responsibility to keep abreast of current trends and produce designs that are sustainable. The general public has a responsibility to stay informed and demand that their government respond to the challenge of balancing development with resource protection. And last but not least, project proponents such as large-format retail owners need to be willing to accept some risks, try new things and look at economic, social and environmental costs and benefits when designing projects.

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Impacts of Urbanization

Development choices have a profound effect on the way water moves through our watersheds. As new development creates impervious surfaces, disturbs soil and removes vegetation, less rain infiltrates into soils, more water runs off the surface and pollutants are transported by runoff. This increased runoff causes flooding and erosion, degrading our waterways and natural habitat.

A considerable body of research has shown that conventional development methods used in the past have not been effective at managing stormwater to prevent damage to water quality and natural resources. Removing natural vegetation and adding as little as a few percent impervious surface within a watershed can cause significant measurable habitat degradation.

Conventional methods of managing stormwater are flood-control focused and emphasize the collection and conveyance of runoff from developed areas to centralized facilities where water can be treated, infiltrated or slowly released. These end-of-pipe facilities are effective at reducing some pollutants leaving the site and in controlling the flow rates during larger storm events but they have limited ability to mitigate runoff volume, flashiness, altered base flow, reduced groundwater recharge and other more subtle development impacts to hydrology.

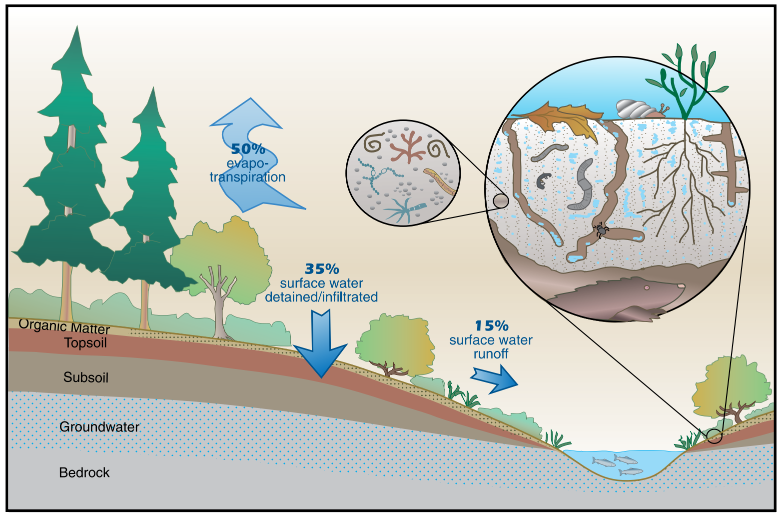


Figure 1. In healthy watersheds forest and plant cover buffer rainfall, thick forest duff absorbs accumulated rain, and water is slowly transported to groundwater or nearby streams.

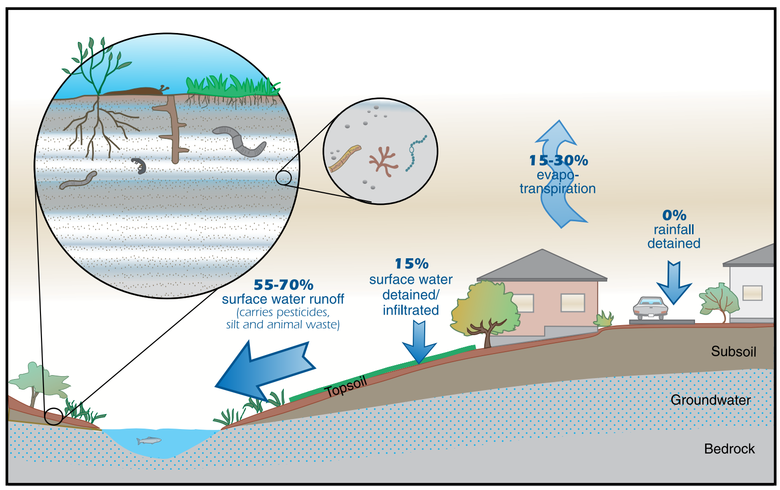


Figure 2. In developed watersheds there is no forest duff and little vegetation to absorb rainfall. The result is an increase in runoff, a decrease in groundwater recharge, and less healthy soils and streams.

These hydrologic alterations can cause significant impacts to the health of aquatic ecosystems. For example, changes in the timing and amplitude of water level fluctuations in wetlands can negatively impact plant health and amphibian breeding. Changes in timing and amplitude of stream flow can impact food sources, breeding and rearing of fish species. Ineffectively managed stormwater flows can cause stream bank erosion, channel incision, sedimentation and other habitat impacts. Stormwater runoff has resulted in degradation of fresh and saltwater habitat around the country.

Water quality impacts of stormwater to aquatic systems are widely documented, but poorly understood. End-of-pipe stormwater treatment systems have been shown to be effective at reducing sediment and pollutants that are bound to sediment, but the effective removal of very fine particulates and dissolved pollutants is more variable, depending on the target pollutants and the system type. Where combined sanitary/stormwater systems exist, LID has great potential for reducing storm-induced overflow. LID can also reduce thermal impacts to water resources that result from conventional development.

The LID Difference

Low Impact Development (LID) strategies offer methods to manage stormwater differently: by focusing on the natural site condition, minimizing impervious surfaces and the effect of impervious surfaces, and infiltrating rather than collecting and conveying stormwater, runoff is managed at the source. Most constructed LID Best Management Practices (BMPs) function to reduce pollutants as well as runoff volume, through filtering and biological treatment. Organizations and agencies nation-wide have focused largely on applying LID methodologies to residential development, focusing both on technical methods as well as on social barriers and incentives. However, commercial centers also offer significant opportunity to change the way stormwater runoff is managed in our watersheds.

The "Big Box" Challenge

There are many national and multi-national corporations that follow a common development model that is automobile-oriented, located along a major roadway with high visibility, surrounded by large parking lots, with a one-story floor plan of 100,000 square feet or more. Development like this works well for companies with large-scale distribution networks and purchasing power, and who can provide one-stop shopping with a variety of goods under one roof at lower prices than their smaller competitors. But it also results in vast amounts of impervious surface and associated stormwater runoff.

There are known methods to reduce impervious surface – in total quantity or total relative perviousness – but these methods are not common or standard development practice, especially in commercial development. As a result, there are many challenges that private developers and corporations face when considering the investment of changing their development practices or trying new methods. By looking at the barriers that Costco faces in embracing LID, we hope to find LID strategies that will work for them, AND we expect to learn how the public sector can support changes to these development practices.

When End-of-Pipe is Appropriate

While the stormwater literature includes numerous studies showing that development impacts are not adequately mitigated by end-of-pipe facilities, these facilities still have a place in addressing stormwater on development sites. On sites where soils drain well and infiltration is feasible, end-of-pipe facilities can be quite effective at mitigating most impacts. Unfortunately, most sites do not have soil and groundwater conditions that are conducive to large-scale infiltration facilities, and on these sites the LID approach can help address the impacts that standard, end-of-pipe facilities cannot. It is our belief that both conventional end-of-pipe facilities and LID BMPs have a place in managing stormwater from development projects.

Where impervious cover is low as in low-density urban and rural residential settings, conventional stormwater facilities may be largely unnecessary and may be replaced entirely with LID BMPs. With high impervious-cover urban projects, a combination of LID BMPs and conventional end-of-pipe facilities may be the most feasible and cost-effective approach to providing flood control and more completely mitigating the hydrologic impacts of development. In cases where site conditions are favorable and/or mitigation requirements are not too high, it may be feasible to control runoff on high intensity sites completely using LID techniques.

Related Work

There are a number of LID design manuals that have been developed for local jurisdictions. There have been many studies of the feasibility of applying LID to development projects. In addition, there have been numerous studies of the performance of LID BMPs on specific project sites. The number of websites containing LID information has expanded tremendously in the last several years. That work has been considered in the course of this project. All of that work is valuable and may be useful to anyone interested in LID. A list of suggested references and further reading follows the text of this report. Two of these references warrant special mention:

- The "Low Impact Development Technical Guidance Manual for Puget Sound", published by the Puget Sound Action Team and Washington State University in 2005, is an excellent resource as both an introduction to Low Impact Development and a "how-to" manual. It is intended specifically for use in the Puget Sound area, but the techniques are more generally applicable. *http://www.psat.wa.gov/Publications/LID_tech_manual05/lid_index.htm*

- "Low Impact Development for Big Box Retailers", published by the Low Impact Development Center in 2005, is very similar in scope to our study and also funded by an EPA grant. This study used Target Corporation as an example and is very easy to understand with many examples and figures. *http://www.lowimpactdevelopment.org/bigbox/lid%20articles/bigbox_final_doc.pdf*

LID Strategies

The goal of LID is to prevent development sites from causing measurable harm to streams, lakes, wetlands, and natural systems (as well as the built environment). This is achieved by using a variety of best management practices to match pre-development (usually forested) hydrologic conditions over the full range of rainfall intensities and durations. Water quality treatment and pollution prevention needs can also be met by LID.

There are several critical phases of development at which to consider LID strategies. **Site evaluation** itself is based on a multitude of assumptions and has a clear influence on how much site alteration is needed. **Site design** is a critical time to carefully fit the needs to the site and identify which types of strategies to use and where. The **construction** phase requires careful execution to minimize soil compaction and set up all the selected BMPs for success. Lastly, after construction is completed, it is the day-to-day **operation and maintenance** choices that ensure the success of various best management practices.

Before looking more in depth at strategies employed during these phases, it is helpful to understand two basic LID goals and common BMPs that are used to achieve these goals:

LID Goal #1. Reduce Impervious Surface:

Limiting Footprint is the most direct, effective way to reduce impervious surface. Using multi-story buildings, particularly with incorporated parking garages is the most effective way to reduce impervious surface. Other strategies include shared parking, smaller stalls and narrower drive aisles.

Permeable Pavement is any kind of pavement constructed of material that allows water to penetrate and drain into the underlying soil. Commonly used materials are porous asphalt, porous concrete, concrete unit pavers, reinforced soil/grass and confined gravel grid systems. These materials prevent runoff while still providing stable surfaces for pathways, driveways, parking, etc.

Open Grid Decking consists of metal grating, recycled plastic lumber or wood decking installed over a soil system that will absorb runoff.

Vegetated Roofs, also called green roofs are engineered roof cover systems that include plants, a storage medium and a drainage layer. Green roof systems reduce runoff volume by evapotranspiration and provide detention storage that reduces flow rates. They also increase the service life of roofing materials, conserve energy

Permeable pavers are used to retrofit a Park & Ride.

PHOTO CREDIT: Curtis Hinman

Porous concrete can be used for aesthetically pleasing & functional parking areas.

for heating and cooling, and mitigate urban heat-island effects. Green roofs can be combined with other functions such as skylights and solar panels.

Soil Amendment is the addition of compost and/or other soil materials to on-site soils to improve the water storage, drainage characteristics and pollutant removal capacity. Soil amendment can also reduce the need for water, fertilizer and pesticides.

LID Goal #2. Manage Stormwater as Close to Origin as Possible

Rainwater Harvesting is a system for collecting, storing, treating and using rainwater. These systems include a catchment surface, filtration, storage and distribution elements. Rainwater can be used as an alternate source for irrigation, non-potable or potable water supply.

PHOTO CREDIT: ERICA GUTTMAN

Green roof with sedums and grasses on the Multanomah County building in Portland, Oregon.

PHOTO CREDIT: SEATTLE PUBLIC LIBRARY WEB SITE

Green roof and solar panels on the Ballard Public Library in Seattle.

Clockwise from top: King County stores roof runoff in cisterns at the King Street Center in Seattle, uses it to flush bathroom fixtures and irrigate landscaping.

Bioretention, also called rain gardens, is a stormwater management system that uses soil and plants to absorb stormwater runoff and to capture pollutants. Bioretention systems typically use soil materials that are amended with compost, and may incorporate liners and underdrains. These systems are very effective at holding stormwater. If properly designed and installed, they require very little maintenance, and last for decades.

Amended soils and plant materials hold & absorb runoff and capture pollutants.

Conveyance swales in a Seattle Public Utilities project are 98% effective at storing and absorbing wet season runoff.

Dispersion into Native Vegetation consists of constructed systems that disperse runoff into natural vegetated areas, where soils and plants absorb and treat runoff and pollutants.

Open Conveyance Swales allow the treatment of stormwater onsite through filtration, biological uptake, infiltration and evaporation. These processes do not take place in piped systems. Open swales with amended soils can also function as bioretention systems.

Perforated Conveyance Systems are an alternative approach to traditional solid pipe that allows runoff to infiltrate. These can include both perforated pipe bedded in washed aggregate and bottomless chambers. These systems may not be suitable for untreated runoff in highly pervious soils due to the potential for groundwater contamination.

Applications and Limitations

Table 1 summarizes BMPs, their uses and constraints. Any one site is likely to benefit from a variety of BMPs to address its specific conditions.

Site Evaluation Considerations

The first step toward developing an approach to using LID on a project is to evaluate the conditions on and near the proposed project site, and the other parameters that will directly affect how the site could be developed. The outcome of this evaluation can be used to answer the primary question, whether the site is well-suited for the project. An excellent model for site evaluation may be found in Chapter 2 of the LID Technical Guidance Manual for Puget Sound. Some key parameters are discussed below.

Site Characteristics

Site characteristics can also have a major impact on project design. The site topography, whether the ground is sloped or the site contains closed depressions, has a major impact on site grading and drainage design. The presence of floodplains can also impact grading and drainage design. The presence of aquatic resources on and off the site must also be considered.

When the project site contains or drains to streams or wetlands, the stormwater management system may need to be designed to minimize impacts to these resources. Impacts to stream flow regime, erosion potential, temperature, and water quality

Table 1. **BMP Selection and Limitations**

BMP TYPE	USES	LIMITATIONS
Preserve Native Vegetation	Minimize runoff, can be used for bioretention	Limits available area of developable land
Protect/Amend	Minimize runoff, reduce need for water, fertilizer	No limitations within landscape areas
Limit Impervious Surface	Reduce runoff, pollutant transport	Higher cost of multi-story buildings, parking
Vegetated Roof	Reduce runoff, reduce temperature impacts	Initial cost, more difficult repairs, different maintenance required. Limited effectiveness in controlling largest events.
Bioretention	Reduce runoff volume, remove pollutants	Available area, poorly drained soils
Rainwater Harvesting	Reduce runoff volume, offset potable water use	High initial cost, complexity of treatment if used in buildings
Permeable Pavement:	All types effective at reducing runoff, capturing pollutants	Less effective in clay soils, high water table
Grass/gravel systems	Low-traffic areas	Not well suited to high traffic areas, difficult to roll carts; high heel problem
Porous Asphalt	Low-medium traffic areas	Some durability problems in past
Porous Concrete	Low, medium and high traffic areas	Usually most expensive
"Good Housekeeping" Practices: Other structural and non-structural BMPs that minimize generation of pollutants such as covered storage, selecting less toxic alternatives, spill response plans and sweeping	Limiting pollutants at source is most effective way to prevent impacts, can be applied to any site and can be very low cost	Varies

could destroy fish habitat and therefore may require mitigation. Similarly, for wetlands, the impact of runoff on wetland water level fluctuation may need to be controlled. If the site drains to a large lake, river or to saltwater, flow control may not be necessary. Preventing groundwater contamination while preserving recharge is another factor that must be considered. The use of LID BMPs on a project will tend to reduce impacts to all these aquatic systems.

The presence of unique vegetation, habitat and species may also impact the design of a site and the stormwater management system. For example, no-touch buffer areas may need to be set aside that in some cases could be used to help manage runoff. Features of cultural or historic significance may also impact stormwater management design.

In redevelopment projects, some of the existing buildings or parking areas may be retained. In this case, the existing development may dictate the site layout. Retrofitting existing pavement and buildings to incorporate LID can be done, but the options available will be more limited.

The availability of public transit may help to reduce impacts by reducing the need for parking. The cost and availability of water may impact design; high cost and low availability may make use of stormwater for irrigation or other purposes more attractive. If sanitary sewer service is not available, on-site wastewater disposal systems could also limit stormwater management options.

Climate

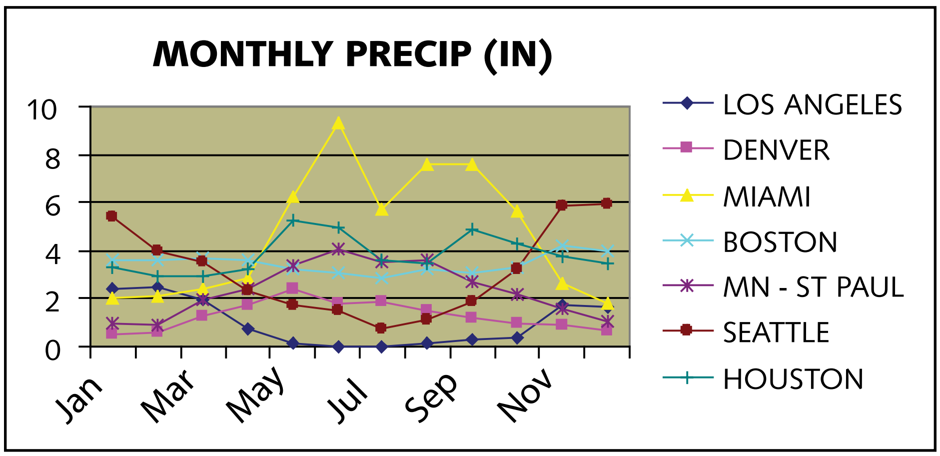
The climate at the project site will also impact stormwater management system design. The seasonality of temperature range, evaporation potential, precipitation patterns and rainfall intensity impact the type of BMPs that will be effective and the design of the system. Frozen ground may prevent infiltration of runoff. Systems dependent on evapotranspiration (ET) may work very well in climates where rainfall occurs during the warm season, and poorly when rainfall occurs during the cold season. **Figure 3** shows the wide variation in the seasonal distribution of precipitation in different parts of the US. It is interesting to note that Seattle has an unusually small proportion of precipitation during months when temperatures are high enough to promote ET.

Figure 4 compares precipitation with evaporation in Seattle and Denver. Clearly evaporation will play a much more important role in a bioretention system in Denver than it will in Seattle.

Soil Conditions

The infiltration rate of the soils on the site needs careful evaluation. It should be noted that traditional small-scale on-site infiltration tests can predict rates that greatly exceed full-scale BMP performance. In the case of large-scale infiltration facilities, measured facility infiltration rates have been measured as low as only 10% of small-scale test rates. The performance of small, shallow, linear bioretention systems should be less sensitive to size effects, but larger-scale testing or appropriate design

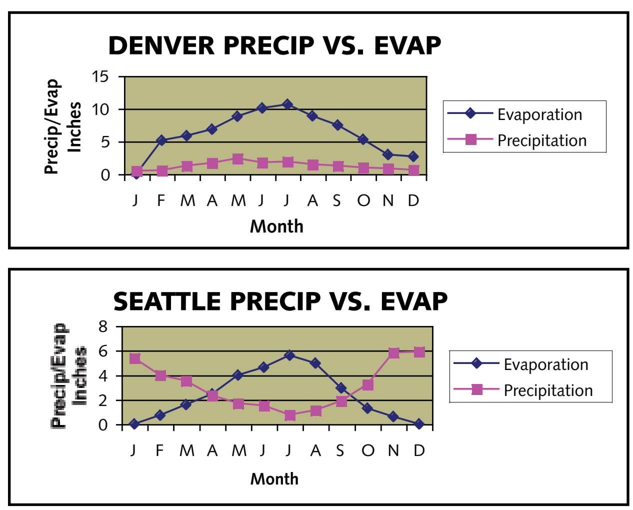
Figure 3. **Monthly Precipitation in Selected U.S. Cities**



Above: Note wide variation in seasonal distribution of precipitation around U.S.

Figure 4. **Comparison of Precipitation and Evaporation in Denver and Seattle**

Note that evaporation always exceeds precipitation in Denver and evaporation is highest when precipitation is highest. The opposite is true in Seattle.



conservatism is needed. Generally speaking, if the design infiltration rate is on the order of 0.5 inches per hour or less, infiltration of all runoff with a centralized facility will probably not be feasible, but distributed bioretention may perform adequately. If the design infiltration rate exceeds 2 inches per hour, any system based on infiltration should be feasible.

The infiltration rate in soils is a function of the wet-season water table, the water/soil temperature and the geometry of the system. As well, performance can be greatly impaired by improper construction techniques and by the long-term migration of fines into the system. Arriving at an accurate prediction of the long-term performance of a large-scale system is difficult, and calls for careful analysis and considerable experience.

The depth to the water table needs careful evaluation to determine the feasibility of infiltration, bioretention and permeable pavements. If the maximum water table is less than 3 feet below finish grade, small-scale infiltration and bioretention may not be feasible. If the maximum water table is less than 2 feet below finish grade, permeable pavement systems may not be feasible.

Sites with very shallow impervious soil/bedrock, very high water tables or steep slopes may not be suitable for permeable pavement and bioretention. In these cases, it may not be possible to use LID BMPs alone to meet required flow control standards. Some benefit can still be realized on these sites through other techniques such as vegetated roofs, rainwater harvesting and reduced impervious coverage. The use of these BMPs with end-of-pipe facilities will help to mitigate some of the runoff volume increase and flashiness of hydrologic response that results from development.

The potential for groundwater contamination needs to be carefully evaluated where soils infiltrate well. Shallow unconfined aquifers in gravel soils are most susceptible and will require a high level of treatment and spill control. Similarly, regions with limestone/Karst formations can also be highly susceptible to groundwater contamination. Finer grained soils with great depth to the water table are much less susceptible to groundwater contamination and may not need a high level of treatment prior to infiltration. Bioretention systems can provide a high level of pollutant removal and may be an excellent choice where there is a high level of concern about potential contamination.

Frost depth should be considered when selecting and designing BMPs. Frozen soil and ice coating of pavement will affect the performance of open swales and permeable pavement in cases where local climate conditions include frequent cold spells followed by rain. However, studies show that permeable pavements can reduce ice formation, deicing costs and increase transit safety.

Unusual soil conditions such as expansive soils, collapsing soils or chemical contamination may preclude the use of BMPs that rely on infiltration such as bioretention and permeable pavement. The degree of consolidation and the structural capacity of soils may also affect BMP selection. Where a large thickness of crushed rock, sand or gravel is needed to stabilize the subgrade, permeable pavement may be more attractive since the rock or sand can serve as an underground reservoir. Cuts into native soil, uncontrolled fill and controlled fill imported to the site will change the hydraulic properties of the soil from what is found on the undeveloped site and must be considered. Geologic hazards such as earthquake liquefaction and unstable slopes should also be considered.

Local Regulations

Local zoning regulations can greatly affect the project design. Impervious cover limits affect the amount of area available for bioretention. Landscape standards can also affect the design of bioretention systems. Parking requirements have a major impact on the amount of impervious area that a project needs.

Local drainage standards vary tremendously around the US. Some jurisdictions do not require that any measures be taken to address the impacts of stormwater runoff, rates, volume, or pollutants. Other jurisdictions have highly restrictive standards that allow little or no surface discharge or require that the pre-development runoff rates not be exceeded. Most jurisdictions typically require conveyance of stormwater without overflow for storms up to some theoretical design event, for example a storm that is expected to occur only once every 10 or 25 years.

While at present only a few jurisdictions require or encourage the use of LID techniques, the number is rapidly increasing. Some jurisdictions discourage the use of LID because of lack of knowledge or flexibility in standards, which tends to drive applicants to simply meet standard code requirements. In many cases it is possible to get LID designs approved by showing that they can provide treatment that meets or exceeds code requirements through a variance process or exception process. While this typically requires some increased review time and cost, given the benefits of LID, going through the variance process is potentially very worthwhile.

It is worthwhile to note that there seems to be a gradual trend in which stormwater standards are becoming more restrictive around the country and knowledge of new methods of stormwater management will be needed to cope with new standards.

Site Design Considerations

Designing an LID project includes careful evaluation of business needs, site design, BMP design, pollution prevention practices and maintenance. As discussed in previous sections, the goal of LID is to minimize discharge of stormwater runoff and pollutants from the site. The first principle for achieving that goal is to limit impervious surface, particularly surface that generates high levels of pollutants.

Evaluation of Needs

When considering the approach to site design and BMP selection, attention should be paid to limiting impacts at the site scale and at the watershed scale. At the site scale, limiting stormwater runoff and mobilization of pollutants are important. At the watershed scale, preserving water resources, open space and buffers, and limiting the total imperviousness within the watershed become important.

The first place to begin is a careful assessment of the needs of the project. The easiest way to prevent stormwater impacts is to prevent runoff. It cannot be overemphasized that limiting impervious surface and pollutant generation at the source is the single most effective strategy for minimizing stormwater impacts. If the project can be made smaller and still provide the same function, impacts will be reduced. This includes impacts on the site and off the site, impacts of construction, energy and resource consumption, and pollutant generation. If the building footprint can be made smaller and still meet the project need, make it smaller. If the project can meet parking needs with fewer spaces, build fewer spaces.

A development strategy that includes concentrating development and resultant impervious surface in less sensitive portions of the watershed while preserving open space in the remaining, more sensitive areas can more effectively reduce impacts to water resources than developing the whole watershed at lower density. In particular, infill development and redevelopment where transportation infrastructure is already in place (as opposed to new development of outlying greenfield areas) can significantly reduce total watershed imperviousness. As well, redevelopment of existing abandoned, brownfield or underused sites using an LID approach can result in reducing runoff from what exists under current conditions.

Aesthetic Values

Design of the site should include aesthetics and corporate preferences in the selection and placement of BMPs. Integrating LID BMPs into the project design can substantially improve the project aesthetics. Alternative pavement materials and vegetated surfaces can give the architect a broader palette of color and texture than standard pavement and roofing materials, can soften the visual impact of acres of parking, and can address other needs like wayfinding and traffic control. Vegetation and lighter colored pavement also can create a significantly cooler local environment in the summer, increasing customer comfort. Green roofs add insulation and reduce heat build-up in the summer, and can result in significant energy savings.

Parking Management

According to the Victoria Transportation Policy Institute's book, "Parking Management Strategies, Evaluation and Planning," off-street parking typically requires 300-400 square feet per stall. A multi-story building with indoor or covered parking could reduce total impervious surface by 80% or more and could virtually eliminate transport of automobile-generated pollutants from parking areas. Similarly, reducing the need to construct parking by locating where there is good public transportation, instituting or encouraging ride-sharing and carpooling, and sharing parking areas with adjacent development can substantially reduce the need to construct parking spaces. Reducing vehicle demand in this way is called transportation demand management (TDM). It is an inescapable fact that fewer and smaller stalls reduce the size of parking lots.

Manage Stormwater at Origin

Once the minimum amount of hard surface needed for the project is established, the next step is to consider how to take maximum advantage of the site characteristics to limit and manage runoff on-site. There are three ways to control the volume of surface runoff leaving the site: infiltrate it into the ground, evaporate it directly or through plants (evapotranspiration), or collect and use the water on the site (rainwater harvesting).

Infiltrate runoff to the extent feasible by situating runoff-generating surfaces next to landscaped and native-vegetation areas where stormwater can be absobed. Where soils and grades allow the use of permeable pavements they can be used to limit runoff by infiltration. Where soil conditions are favorable, bioretention may be used to manage runoff by a combination of infiltration and evapotranspiration (ET). Similarly, maintaining or increasing tree cover can also provide increased ET. When soils are less favorable, amending soil with compost, the use of mulch and careful plant selection can greatly improve the ability of soils to accept and treat runoff. The use of small or large surface ponds or subsurface structures, including gravel trench systems or bottomless chambers under parking areas or within landscape areas can be considered where surface features are not feasible.

Consider the movement of foot and vehicle traffic through the site. Bioretention features should be designed and situated so that they are not impacted by traffic. Provide clear paths, curbs, striping to confine traffic to appropriate areas. Provide bridges, pavers or grid systems for crossing of bioretention areas.

Vegetated roofs and rainwater harvesting are alternative ways of reducing runoff and may be particularly useful in settings where soil and groundwater conditions severely limit the ability of soils to accept runoff, and in ultra-urban settings where there is virtually no vegetated area. Vegetated roofs utilize ET to reduce runoff volume and also slow the rate of runoff.

Where irrigation costs are high and/or where sewer rates are tied to water use, rainwater harvesting is more likely to be cost-effective. Since the impervious areas are large in big box projects and since most of the annual rainfall becomes runoff, a large water demand is needed in order to use all the harvested rainfall. For example, in the Seattle area the annual rainfall of about 36 inches produces about 30 inches of runoff, or about 20 gallons per square foot per year.

An initial simple water budget and hydrologic analysis should be conducted to consider potential benefits of these different approaches, some of which will have multiple benefits. During design, more detailed analysis considering soil and climate conditions can be done to more accurately quantify benefits of different approaches.

Water Quality Treatment and Pollution Prevention

Water quality treatment standards vary widely across the US. Many jurisdictions require treatment of a design storm volume, in many cases 0.5 inches. King County, Washington requires treatment of 95% of the average annual runoff volume. King County water quality treatment requirements are a function of land use and protection of the downstream resource. For example, high-intensity land use triggers a higher treatment standard. If the downstream resource is a lake that is phosphorus-sensitive, facilities and BMPs that remove phosphorus are required. Facility design may be based on a flow rate, as in the case of biofiltration swales or filter systems or on a treatment volume as required for wet ponds.

The minimum treatment goal is to remove 80% of total suspended solids (TSS); for the other standards the goals include removing metals or phosphorus, or controlling alkalinity and pH.

Different types of treatment facilities and BMPs target different pollutants. For example, filtration with compost can be very effective at removing metal, but not phosphorus.

Selection of the water quality treatment strategy for the project involves identifying local standards and target pollutants, then finding facilities or BMPs that can control the target pollutants. In general, BMPs that contain runoff on-site will also retain the pollutants on-site. For example, permeable pavement and bioretention will retain pollutants in the soil, where they may undergo degradation and conversion to less toxic forms. Where soils are very coarse and water tables are shallow, careful analysis is needed to provide designs that will not allow pollutants to be transported directly into groundwater. Some LID strategies and water quality management BMPs can be implemented on any site.

Of course, the best strategy for limiting the discharge of pollutants from any project is to prevent their generation and release. A more comprehensive discussion of pollution prevention BMPs is presented in the Operations and Maintenance Considerations section below and in the Stormwater Pollution Prevention BMPs for Big Box Retail Operations section in Appendix E.

Constructability

In order to select the most cost-effective design strategy, the cost and availability of local materials needs to be evaluated, as well as the availability of local contractors with experience installing the selected BMPs. For example the cost of aggregate (crushed rock and gravel) varies considerably around the country. Where these materials are particularly expensive, BMPs such as permeable pavement systems that require very large quantities may be too costly; substituting sand may be an effective strategy to reduce cost. Similarly, without experienced contractors, a vegetated roof would be a poor choice. Where land is cheap, bioretention may be more attractive; where land is expensive, multi-story structures (with less impervious surface) may be the most effective way to limit impacts.

Planning for Maintenance

Finally, the operation and maintenance needs of the LID BMPs must be assessed. If it is necessary to use sand, salt or other deicing materials on parking areas in the winter, permeable pavement may not be a good choice due to the risk of clogging the pavement or contaminating groundwater. Green roofs, bioretention and rainwater harvesting are not impacted by sanding of parking and can be used instead of permeable pavement. Permeable pavement will perform best if it is regularly vacuum swept, ideally with high-efficiency vacuum sweepers. If corporate maintenance standards call for regular sweeping by a contractor, this BMP might be a good fit.

Vegetated roof systems require particular care. It is very important that maintenance staff do not use sharp implements to remove weeds and debris from a vegetated roof. Leaks from punctures can be very hard to locate without special leak detection systems. Although the vegetation and drainage layer provides the underlying roof membrane protection from ultraviolet light and temperature extremes and can lengthen the life of a roof, if repairs become necessary they can be difficult and costly.

Maintenance of landscapes in bioretention areas and vegetated open space does not require highly trained staff or contractors. It is very important to limit the use of fertilizers and pesticides in these areas, and ideally none should be used. Excessive or improper application of these chemicals can cause bioretention, biofiltration or open space areas to be sources of pollutants rather than BMPs providing treatment of pollutants. If properly maintained, these systems can last decades.

When the site design has been finalized, operation and maintenance manuals need to be created for the selected BMPs. Besides regular maintenance, a pollution prevention and spill response plan needs to be incorporated into the operation and maintenance plan (see Operation and Maintenance section below).

Construction Considerations

The single biggest concern during construction of an LID project is preserving and improving the hydrologic characteristics of the site. This is primarily a function of the ability of the soils and vegetation on the site to prevent surface water runoff and the availability of storage for stormwater on the site. Soil permeability is determined by porosity and structure, as well as by the particle size distribution.

Typical practice is to strip topsoil and grade the entire site, which compacts the soil and decreases its infiltrative capacity. Vehicle and equipment traffic needs to be prevented or strictly limited on those areas on the site that will remain in native vegetation, be landscaped, covered with permeable paving, or designed with open swales and bioretention systems. Heavy loads and soil disturbance compacts soils, reducing their porosity and structure, which will decrease soil permeability. This effect is particularly important for soils that contain any silt and clay-size particles. Coarse-grained (sand and gravel) soils are much less sensitive to disturbance. Similarly, coarse-grained soils are much less sensitive to disturbance when wet than finer-grained soils.

For areas that will be covered with conventional pavement or buildings, vehicle and equipment traffic may not be a concern; therefore, such traffic could be routed over these areas during construction to protect soil elsewhere on the site.

Where soil will be removed, enhanced or replaced it will be necessary for equipment to traverse the area. Disturbance to the soil that is left in place can be limited by using wide-tracked equipment with low ground pressure, by limiting earthwork to periods when the soil is drier and by working at "arm's length" with excavators. In addition, where coarse-grained soil is imported, pushing a thick initial lift over the more sensitive subsoil can help to reduce disturbance. Where disturbance to sensitive soils is unavoidable or inadvertent, it may be possible to restore soil permeability by tilling or amending the soil with compost. Tilling or mixing needs to be done when the soil is relatively dry.

Preventing transport of sediment into areas that are intended to absorb post-construction runoff is also important. Good erosion and sediment control practice will help preserve the drainage characteristics of the soils on the site as well as protecting off-site areas from sediment impacts. Construction erosion and sediment control is an important part of any development, regardless of whether LID is part of the project design. Erosion control design and implementation is beyond the scope of this report.

Install porous asphalt and concrete after the site has been completely stabilized to minimize the transport of sediment onto the pavement. During construction, do not allow construction or heavy vehicles to traverse excavated recharge beds or areas of completed porous pavement. Erosion and sediment introduction from surrounding areas must be strictly controlled during and after construction to prevent clogging of void spaces in base material and permeable surfaces.

Operation and Maintenance Considerations

Proper operation and maintenance programs are essential for all businesses. Well designed and implemented programs can reduce repair and replacement costs and better protect the environment. In addition, the potential for costly cleanup and liability can be reduced through effective O and M programs. If the use of the site is considered holistically, pollution prevention practices can be seen to include maintenance of the features on the site and preventing the release of pollutants on the site.

All stormwater management systems require some maintenance to perform properly. A regular program of inspection and maintenance is needed to correct and prevent problems that impair performance. As with all facility maintenance, regular maintenance can avoid costly damage to stormwater systems. Educating staff about LID systems is essential. Awareness of intended and proper function increases the chances that LID systems will operated effectively and efficiently. Well informed landscape and maintenance staff will not use herbicides or fertilizers in bioswales or inappropriately cut or prune vegetation, as examples.

All staff should also be trained in pollution prevention practices appropriate to the activities they perform. Simple practices can keep toxins out of stormwater management systems, and thereby protect water quality. Appendix E contains lists of practices for specific activities that can be used in employee training.

The following discussion outlines BMP operations and maintenance needs. More detailed O and M standards are presented in Appendix D.

Perhaps the most effective strategy for reducing facility and BMP maintenance needs is preventing sediment, trash and chemical pollutants from entering the system. This strategy includes structural and non-structural BMPs. The following list of practices can be applied to all commercial settings to help reduce the generation of pollutants that can be picked up by stormwater.

Locate Activities as Far as Possible From Surface Drainage Paths

Locating pollution generating activities on high ground, far from drainage paths, ditches, gutters, and storm drains allows more time to recognize spills and act to prevent water contamination.

Avoid the Activity or Reduce its Occurrence

Often an alternate production process or material application process can be used to substitute for another, more polluting process. Ideally, a polluting activity can be avoided altogether, or its frequency of occurrence reduced. An example is washing vehicles less often or taking vehicles to commercial car washes or detail shops that recycle water and do not discharge to surface water rather than washing on site.

Use Less Material

Improper disposal of excess material or increased application of materials simply because excess is available can cause pollution. Purchase only the amount of material that will be needed for foreseeable use. In most cases you will see cost savings in both purchasing and disposal.

Use the Least Toxic Materials Available

All applications of solid and liquid materials should use the least toxic products and raw materials available, whether in production, cleaning, pesticide applications, or other uses.

Create and/or Maintain Vegetated Areas Near Activity Locations

Grass and other types of vegetation can filter out many pollutants in stormwater runoff. Vegetated areas should be maintained around areas where polluting activities occur, especially down slope of activity areas. Routine maintenance will keep vegetated areas healthy and capable of filtering pollutants.

Recycle as Much as Possible

Recycling is always preferable to disposal of unwanted materials. Leftover paints, finishes, cleaning materials, building materials, etc. may be used by someone else, so don't throw them away. Many empty containers and other common items are recyclable. Recycling and proper waste management prevents spills or other inadvertent pollution of surface water.

Vacuuming and Sweeping/Permeable Pavement Maintenance

Regular vacuuming and sweeping of paved surfaces helps to reduce the amount of sediment and associated pollutants that can be transmitted by stormwater runoff. The use of high-efficiency vacuum sweepers can collect a larger portion of the sediment that is deposited on paved surfaces than conventional sweepers. This will reduce the amount of sediment reaching stormwater facilities and BMPs and reduce the need for sediment removal in these systems. High-efficiency sweepers are particularly effective at maintaining the performance and extending the life of permeable pavement systems. Note also, with permeable pavement systems, maintenance personnel must be instructed not to apply sealants or repave with non-porous materials.

Prevent Release of Pollutants

The use of structural pollution prevention BMPs such as covering dumpsters, storing toxic materials indoors and storing liquids in tanks with secondary containment that will contain spills is another effective way to prevent the release of pollutants into stormwater. A pollution prevention plan that includes proper training of staff in the handing of these materials and spill response protocols is also essential to having an effective pollution prevention program. The spill response plan should include materials that are handled as a regular part of business operations as well as materials that may be accidentally or deliberately spilled on the property. The most common accidental spills are likely to be fluids from vehicles including fuel, coolant and hydraulic fluid. Deliberate dumping of toxic chemicals poses substantial health risks. Response to this deliberate dumping should be handled by professionals, and staff should be educated about both the risks of toxic substances and who to contact in the event of a chemical release.

Maintain Conveyance Systems

Stormwater conveyance system elements including catch basins, pipes and swales should be regularly inspected and cleaned of sediment. If the pollution prevention BMPs described above are implemented, the amount of sediment that accumulates in the conveyance system should be minimal. Properly designed pipes are self-flushing, so sediment should not generally accumulate in pipes, but catch basins are designed to collect coarse sediment and will require periodic cleaning. Sediment that is removed must be properly disposed of in accordance with local regulations. With an effective pollution prevention plan in place, the need for inspection and cleaning should be substantially reduced.

For a more complete, detailed list of operations BMPs for typical large-format retailers, please see Stormwater Pollution Prevention BMPs in Appendix E. These pollution prevention BMPs are described in stand-alone documents that cover specific activities that are likely to be performed in retail operations. They are intended to be used to educate staff and can be used as training aids or integrated into operations manuals.

Costco Wholesale: A Case Study

In order to realistically analyze LID methods for use in the large format retail application, we have analyzed a typical Costco store using conventional stormwater management and some LID practices. Costco Wholesale generously offered information about their business model, site selection, standard development practices and operations. While each retailer has its own niche, the general style of most if not all big box development is similar to Costco: a very large single-story building surrounded by acres of parking.

Background

Costco Corporation is a large format retailer that has undergone rapid growth since its inception over 20 years ago. Costco has a very active building program, with new stores being developed around the US, Canada, Britain and Japan. Development scenarios range from Costco purchase of an undeveloped site to lease of a developed site with utilities including stormwater in place.

Costco has developed a very successful business model based on highly standardized store designs. From groundbreaking to ribbon cutting, Costco constructs a new store in about 110 days. Being automobile focused, they want very large parking areas to accommodate the maximum number of customers. Their developments provide more parking than local codes require in some cases.

The Costco Way: Standard Development Specifications

The typical store site is 15 acres, flat, with a 148,000 square-foot single story store, 750-800 parking stalls and a gas station. In highly urbanized areas such as Vancouver and London, multi-story stores have been built. Sites are typically about 85% impervious and 15% landscaping. Stormwater facilities vary widely from conveyance pipes only to open pond or underground storage and treatment systems, depending on local regulations.

Costco Wholesale under construction, Woodinville, WA

PHOTO PROVIDED BY COSTCO WHOLESALE CORPORATION

Customers typically arrive in large vehicles and after shopping are pushing very large shopping carts or platforms with large quantities or sized products. Costco likes to have very smooth pavement, which constrains the selection of alternative pavement materials, and Costco limits grades to 2%. Ease of movement through the parking area and access into and out of vehicles is important. Yet the mixture of vehicular and pedestrian traffic is a major safety concern. All these factors make it difficult for Costco to consider smaller parking stalls.

Traffic circulation becomes an issue when stores are busy. Costco parking is fully utilized and management would generally like to have more than the minimum amount of parking provided. During peak hours, Puget Sound-area Costco stores' parking lots are used well in excess of 90%, with cars waiting for stalls to become available. When parking lots are relatively empty, Costco considers it to be desirable to have vehicle and cart access across delineated parking stalls.

Costco stores are constructed with standing-seam metal roofs, which are extremely light and are assumed to be incapable of carrying significant additional loads. Placing a vegetated roof over this type of roof raises concerns for Costco about constructability, waterproofing, possible corrosion and difficulty of long-term maintenance. However, other developers have successfully constructed vegetated roofs on metal roofs and on similarly designed buildings, indicating that the concerns Costco has may be able to be addressed.

Parking

The typical Costco site has 750-800 parking spaces covering about 9.5 acres, an average of 550 square feet per stall. This is an average of 5 spaces per 1000 gross square feet of retail space. The space per parking stall is quite high and the parking ratio is also high.
A summary of stall sizes and area required to provide 750 parking stall is shown below. Reduced stall and aisle dimensions can substantially reduce impervious surface coverage, as shown in **Table 2**.

Table 2. **Parking Space Sizes**

PARKING LOT DESIGN	Stall Width	Stall Depth	Aisle Width	Area (acres)	Area %
Costco Standard	10'-0"	20'-0"	24'-0"	9.5	100
King County Standard	9'-0"	18'-0"	24'-0"	8.8	93
King County Compact	8'-0"	16'-0"	20'-0"	8.3	87

Standard Stormwater Management

Costco's current approach to stormwater management is to base designs on local standards and meet or exceed local requirements. One area in which local standards may be exceeded is in conveyance of stormwater runoff. Costco prefers not to allow stormwater to be stored in parking areas during large events, and they prefer to not have overflow of conveyance systems in less than 25-year events. Conveyance for up to 100-year events is also checked to confirm that no serious flooding will occur.

If flow control and water quality treatment facilities are required by local codes, they are designed to meet local standards. Local codes vary tremendously around the US, with many areas requiring no more than conveyance of runoff. Costco recognizes the limitations of this approach and the Corporation is interested in using a more environmentally sustainable approach.

On a typical Costco site in the Seattle area the average annual volume of runoff generated is roughly 11 million gallons, enough to fill 1200 tanker trucks or to fill a Costco store to a depth of about 10 feet.

Based on data obtained from a 1994 study, pollutant loads for a 15-acre commercial site with no water quality treatment can vary widely. The approximate expected annual loads would be as shown in **Table 3**.

Table 3. **Approx. Expected Annual Runoff Loads**

Constituent	Annual Load in Lbs/Year
Total suspended solids	700 – 11,000
Total phosphorus	1 - 12
Total nitrogen	17 - 150
Total lead	2 - 15
Total copper	1 - 2
Total zinc	3 - 6

Efforts to Date

Costco has experience with differing stormwater standards across the country, and has experimented with different strategies to comply. In one Washington State store, meeting a strict new stormwater standard required a buried detention system consisting of 1 mile of 8-foot pipe.

Costco has also made efforts to try out some LID strategies. On one site in Connecticut, they tried concrete cellular grassed paving. This system could not meet their need for a smooth surface for rolling carts, nor did it drain properly so the grass did not survive well and the pilot area became very muddy. In North Carolina, Costco experimented with some test areas of pervious concrete paving. Every change to the standard development model has an increase in near-term construction costs. Although long-term lifecycle costs have not been fully analyzed, there may be cost advantages over the life of the LID practice.

Cellular grass paving doesn't meet Costco's need for smooth surface for carts.

PHOTOS PROVIDED BY COSTCO WHOLESALE CORPORATION

A Costco pilot project using pervious concrete has worked well.

Drivers for Change

Driven by stakeholder interest, potential savings, value-added marketing and compliance with changing regulations, Costco continues to pursue a "greener" approach to their developments and remains interested in evaluating possible LID strategies based on the triple-bottom-line: economic, environmental and social values.

BMPs that Make Sense for Big Box Retail

Based on the analysis of Costco development standards as typical of the industry, the following BMPs were identified as being most viable for big box retailers:

1. preserving native vegetation,
2. reducing impervious surface coverage,
3. using pervious surfaces in place of impervious surfaces,
4. using distributed stormwater management systems rather than a central facility,
5. using soil/plant systems to convey, treat and control runoff,
6. minimizing the generation of pollutants
7. harvesting rainwater

The use of any one of these methods will reduce the amount of surface water that has to be managed through conventional approaches, and there are value-added benefits to most of these methods. Items 1 and 2 require no further explanation, but it should be noted that planning and zoning codes, land cost and economics strongly drive big box retailers to maximize site coverage.

Pervious surface strategies that make sense include permeable pavement systems and vegetated roofs. These strategies can significantly improve the aesthetics of a development and also have some improved effect on micro-climates, cooling temperatures.

Many vegetated roof technologies exist, ranging from modular grid systems that snap in place over an existing roof to thin vegetated mats somewhat like carpet that can be rolled out over a metal roof. The key feature is actually in the growing medium, and many abound, specifically designed to be effective for different applications. Some jurisdictions in the country and around the world are requiring green roofs be used in new construction. With the vastness of the typical big box roof, vegetated roofs are a great way to retain and evapotranspirate rainfall.

Scuppers and raingardens can easily and artfully manage overflow.

Concerns about the rough texture of permeable paving systems can be overcome by using mixtures of materials on a site: smoother surfaces in key pedestrian and cart pathways, and more pervious systems in drive aisles or at the outer edges of a development. Similarly, strength and durability concerns can be addressed by using stronger conventional materials in high-traffic areas.

A project built in Snohomish County, Washington by a big box retailer used pervious asphalt in the parking stalls and a standard mix in the drive aisles. (*See below*.) The lot was sloped to have runoff flow to the parking stalls and infiltrate there. The site also used some bioretention cells with landscaping, a good example of using a combination of distributed systems.

In an asphalt parking lot in Snohomish County Washington, pervious asphalt is used in the parking stalls (foreground) and smoother more impervious asphalt is used in the drive aisles (top of photo near cone).

Distributed systems spread the management of stormwater across the site. These can include bioretention areas such as rain gardens and swales (*see below*), permeable pavement and distributed underground infiltration systems. Appropriate design using soil amendments and gravel reservoirs can make these methods viable in many conditions, thereby allowing design creativity to overcome most obstacles. It should be noted that Costco has experienced situations in some jurisdictions where local landscape standards are so restrictive that this creativity is limited.

Soil and plant systems like bioretention and swales can convey, treat and control runoff.

Lastly, the harvesting of rainwater is a viable possibility for big box stores to reduce stormwater runoff, given the vast size of their buildings. Using a typical Costco roof of 148,000 square feet as an example, an average of 8100 gallons would be generated per day or 3 million gallons per year in the Seattle area. Rainwater harvest requires more of an investment of capital up front for storage, filtration and pump systems. Many technologies for storage exist, including modular grid systems that

Vegetated roofs can be used in conjunction with solar power, a green building technology that has a quick return on investment.

store runoff under parking lots. Storage allows for the detention of a stormwater pulse to be balanced with the end use of the runoff. Since storage cost is high, systems that have constant demand require less storage and are therefore may be cost-effective.

Harvested rainwater could be used, as previously discussed for internal non-potable uses, and/or landscape needs. A typical Costco building uses about 5500 gallons per day. In order to utilize harvested rainwater for all interior use, at least some of the water would need to be treated to drinking water standards. Separate systems could be created for potable service from municipal and harvested sources. If water use is low in the buildings, and if a low-water-use landscape is used, rainwater harvesting may not be a feasible approach. Modeling of a Costco rainwater harvesting scenario for potable water use in the Seattle area indicated that the volume of an end-of-pipe stormwater system would be reduced by an amount that exceeds the volume of the rainwater storage system thus offsetting much of the system construction cost.

The investment in rainwater harvest must be weighed for its entire value: economic, environmental and social, which may vary by site. As noted in the Modeling of Rainwater Harvest section of Appendix C, installation and maintenance costs may be offset by possible reductions in sewerage, water supply and/or stormwater fees in some areas, but not others.

As formerly mentioned, selection of the appropriate LID BMPs for any site involves balancing the site characteristics and local building code standards with the local material cost and contractor capabilities. As well, aesthetics, commitment to reducing impacts and maintenance capabilities will influence BMP selection.

After initial screening to determine which BMPs are most likely to meet performance goals, calculations will need to be done to determine the size of BMPs that would be needed to meet performance goals. In some cases, a combination of LID BMPs and conventional end-of-pipe stormwater facilities may be the approach selected to balance cost, site constraints and performance.

Rethinking Re-development

Every development project does not begin at the 'beginning'. Sometimes the ideal location is one that has previously been developed: an old shopping center or industrial area for example. For redevelopment projects, replacing any unneeded impervious surface with bioretention or landscaping with amended soils can still be done, but opportunities may be more limited than on an undeveloped site. BMPs that may be most easily adapted to a redevelopment project that retains existing building and parking areas include vegetated roofs, bioretention and rainwater harvesting. Existing grades will limit the use and locations for open bioretention systems, but in many instances swales with amended soils can be added and landscape areas can be converted to bioretention features. In many jurisdictions, reuse, overlaying or replacement of existing impervious surface will not trigger flow control requirements and may also not trigger water quality treatment requirements. If there are no requirements from the local jurisdiction, then the designer will have a free hand to use any LID BMPs, with the knowledge that impacts will be less than under current site conditions.

Effectiveness Modeled

In order to evaluate the effectiveness of various LID strategies and to compare them with each other and with conventional end-of-pipe facilities for big box retailers, a series of more than 40 different scenarios were modeled for this study. These scenarios all considered a 15-acre site with a typical large format retail development as described previously. The results are outlined here, while Appendix C offers more detail of the selected scenarios and results.

The modeling can generally be summarized as follows:

- When conditions are favorable for the use of LID BMPs, stormwater standards can be met using only LID.
- Parking areas account for the largest fraction of runoff from a big box site.
- Permeable pavement and bioretention are the primary LID tools for managing parking lot runoff.
- How well the soil drains is the primary determinant of permeable pavement and bioretention performance.

Poorly drained soils limit BMP performance; if the soil is well-drained or moderately well-drained, the BMP performance is acceptable. These soil conditions can be summarized roughly as having a minimum design infiltration rate of about 0.25 inches per hour in regions where low-intensity, moderate-volume rainfall is typical and having a minimum design infiltration rate of about 0.5 inches per hour in regions of high-intensity, high-volume rainfall. Figure 5 demonstrates the comparative effectiveness of various combinations of LID techniques on the same site.

As these results indicate, infiltration rates do not need to be very high for LID systems to perform. Nevertheless, design professionals must be cautious about assuming properties of soils, particularly soils with more than a few percent silt and clay. A very careful determination of infiltration rates is necessary to assess performance of permeable pavement and bioretention systems.

Cost

The volume of end-of-pipe flow control facilities to meet the performance standards modeled varied widely, reflecting the very large differences in local stormwater control standards, from as little as 0.72 acre-feet to 5.25 acre-feet. We assumed a rough cost of $5 per cubic foot of storage to represent the cost of installing either an underground system under the parking lot or an open pond which makes the land unusable for building or parking. This means the cost of a flow control facility, not including the cost of the stormwater conveyance system or a water quality treatment facility can range from about $150,000 to $1,150,000, depending on the local stormwater requirements. This represents a cost of about $10,000 to $75,000 per acre or $0.25 to $1.75 per square foot. Note also, the smallest of the facilities can often be fit within required open space/landscape area and may therefore have lower cost. This implies that where standards are low, using LID methods to just eliminate a pond may not be cost effective. However, if surface swales are substituted for the usual pipe system, savings can be much greater and studies have shown that the use of LID can be cost effective.

Where more stringent requirements apply, the money saved on the stormwater flow control system can be much greater and can much more easily offset the additional cost of using permeable pavement systems and bioretention. Similarly, local water quality treatment requirements and the cost of end-of-pipe water quality treatment systems to meet those requirements vary greatly. Where treatment requirements can be met using permeable pavement and bioretention, there is another potential large cost offset. While the costs for each individual project will vary, there is a potential for significant construction cost savings using LID rather than end-of-pipe solutions.

Modeling of rainwater harvesting to consider cost/benefit indicates that rainwater harvesting for potable use could be cost effective in some settings. In the scenario modeled, the storage for the rainwater harvesting system reduced the size of the end-of-pipe stormwater system significantly enough to offset much of the construction cost. The saving in annual water supply cost was estimated to be about $5000 per year and there would be reduced sewerage cost as well where sewer rates are tied to metered water consumption.

Implications for Big Box Retail Development

The modeling indicates that it is possible to substitute LID techniques for end-of-pipe stormwater systems to achieve similar or better mitigation of impacts. Where conditions are favorable, the standard large format retail layout would not need to change much to use LID. The same size building and the same number of parking spaces could be provided as in the current practice. Landscapes would be laid out differently and planting schemes would change to accommodate bioretention. With the available selection of permeable pavement materials, the appearance of parking areas would not have to change, but new materials would allow more creative approaches incorporating varied textures and color.

An alternative LID approach for large format retail operations could be taken that differs substantially from the current approach. This approach would be based on a greatly reducing the footprint of the operation by using one or a combination of the following techniques:

- multi-story building with garage parking,
- shared parking or transportation demand management approach,
- shifting business model to internet-based or delivery of goods approach.

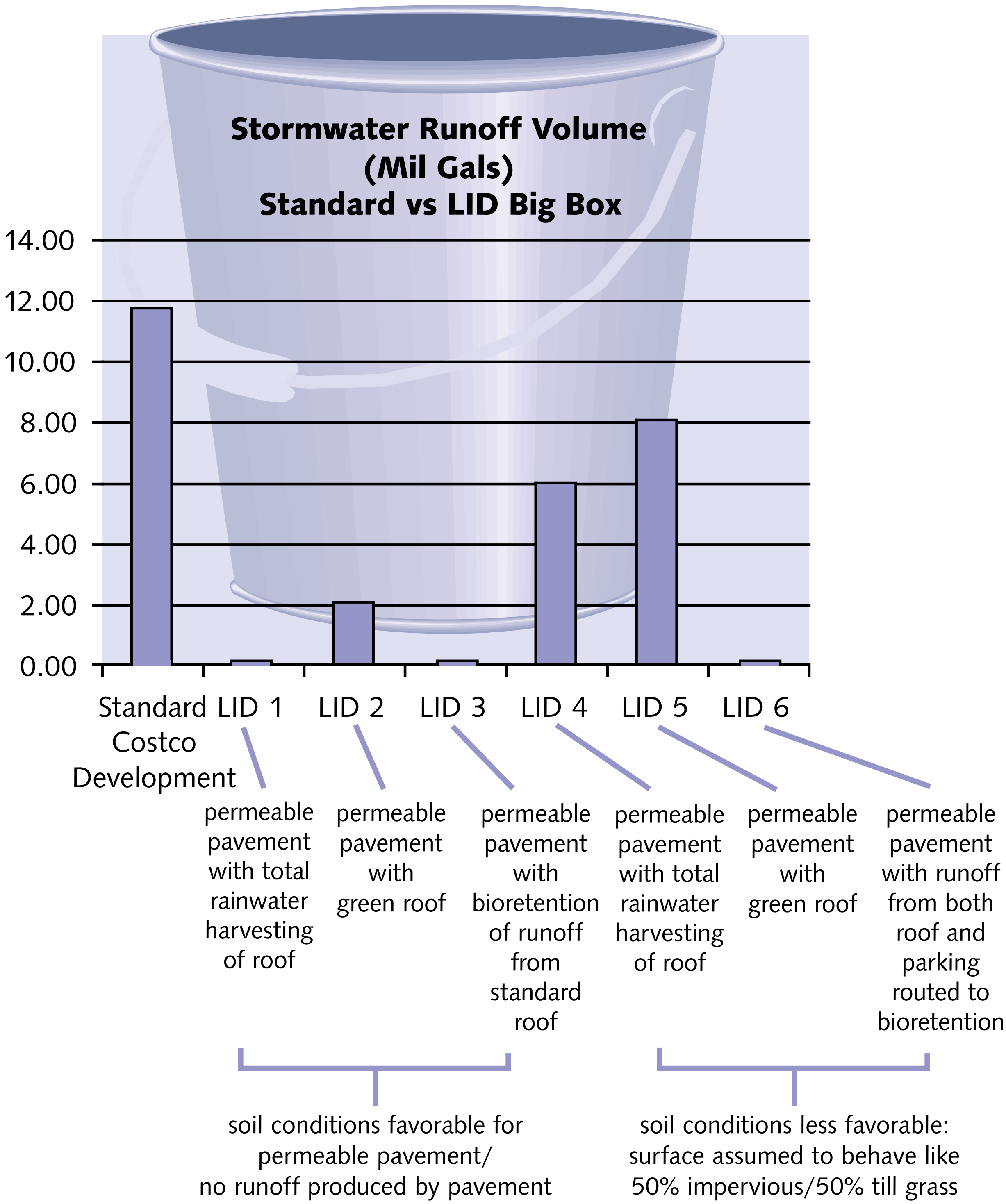
In effect, this approach represents a shift away from the large format retail model.

Costco's Response to Potential Big Box LID BMPs

Each of the LID strategies and BMPs suggested as plausible for big box retail operations was discussed with Costco and their consultants. While they acknowledged that many or all of these concepts would work for some in their industry, some would be a good match for Costco and others would not. Their responses to each of the potential LID BMPs for big box retail stores are summarized here, and outlined in more detail in Appendix A.

Regarding the preservation of native vegetation and soils, Costco indicates they use native

Figure 5. **Comparative Effectiveness of Various LID Strategies**



Note that scenarios 1, 3 and 6 produce no surface runoff and 2, 4 and 5 greatly reduce the volume of surface runoff.

Table 4 outlines viable conditions for various LID BMPs.

Table 4. **BMP Selection Considerations**

BMP Type	Slope >10%	Well Drained Soil	Poorly Drained	Climate Soil	Shallow Ground Water	Contractor Experience
Bioretention	C	CE	OK, 1	2	C	NA
Permeable Pavement	M, 3	CE	C, 1	NA	C	REQ
Vegetated Roof	NA	NA	NA	2	NA	REQ
Limit Impervious Surface	NA	NA	NA	NA	NA	NA
Rainwater Harvesting	NA	NA	NA	NA, 4	C, 5	NA
Retain Native Veg	NA	NA	NA	NA	NA	NA
Protect, Enhance Soil	NA, 6	NA	NA, 6	NA	NA, 6	NA

KEY TO SYMBOLS

OK Usually feasible with this condition
C Caution
M May be used under limited circumstances
REQ This BMP requires an experienced contractor to insure proper installation
CE More cost-effective
NA this parameter has little or no influence

1 May not be suitable with clay and expansive soil.
2 Most effective when wet season has high evapotranspiration
3 May be used for short distances on steeper slope, particularly with well drained soils
4 May be more cost-effective with low annual precipitation
5 May make underground storage more difficult, reduced irrigation need
6 Steep slope, clay soils and shallow groundwater can make this BMP difficult to implement

plants wherever possible, but that because their standard construction methods include a 2% grade requirement, implementation of this type of BMP difficult.

Some LID BMPs focused on reducing impervious surface coverage are reasonable for Costco to consider, others would require a much larger shift of their current development model. The use of multi-story buildings or parking is not consistent with Costco's standard development and would not be likely unless required by code or a cost-effective option resulting from land prices and availability (as in Tokyo, Japan or Vancouver, Canada). In order to consider a site design that shared parking with other adjacent developments and thereby reduce their footprint, Costco would need to find a partner that had compatible peak hours. Much easier to consider would be the redesign of standard parking lots by changing circulation patterns, stall size and driveways which could all result in an overall reduction pervious surface. Also attractive to Costco is the use of pervious asphalt or concrete, particularly where a smooth surface can be achieved for rolling carts.

Green roofs would be an LID BMP that would be more difficult for Costco to embrace. They use lightweight standing seam metal roofs spanning a vast warehouse space. Engineering and maintenance concerns are many, and would take a significant investment in research to overcome. On the other hand, rainwater harvest is perceived by Costco to be a much more feasible alternative for managing roof runoff.

Distributed stormwater management systems like open swales and infiltration areas are easy to embrace BMPs where they are feasible, as they can be shaped around parking requirements.

With creative parking lot design bioretention and bioswales, whether done with native or imported soils are a good match for Costco sites.

Costco's Use of LID

Based on the modeling of various BMPs considered for application in big box retail developments, Costco and their designers have developed some conceptual ideas that they are interested in integrating into their comprehensive store designs. Details still need to be worked out and as always will depend on site conditions, but also on performance goals. Their preferred strategies are discussed focus on the parking lot: using pervious paving or distributed bioretention systems.

Pervious Paving

On the previously mentioned Wilmington, North Carolina project Costco experimented with the use of pervious concrete. **The result has addressed their concern for a smooth rolling surface and has performed exceptionally well.** In this application, the pervious concrete design included a perforated under-drain which would presumably be connected to a collection system and would reduce the overall ability for stormwater to infiltrate. Pervious asphalt has also been successfully used by big box retailers in parking lot applications. On sites with appropriate native soils, Costco will be willing to further experiment with the use of pervious paving.

Distributed Bioretention Systems

As noted in the modeling analysis, stormwater generated from Costco's parking lots could be fully infiltrated if the entirety of their landscaping were used as bioretention. Effective bioretention requires that runoff can be detained and allowed to pond while it infiltrates. The depth of ponding would need to be resolved, and again is site specific dependent on native or engineered soils. Several illustrations provided by Costco's design team exemplify a variety of bioretention ideas. Common to all is an expectation that parking stall depth would be reduced a little allowing overhang into vegetated areas. These concepts could be applied individually or in combination across a site.

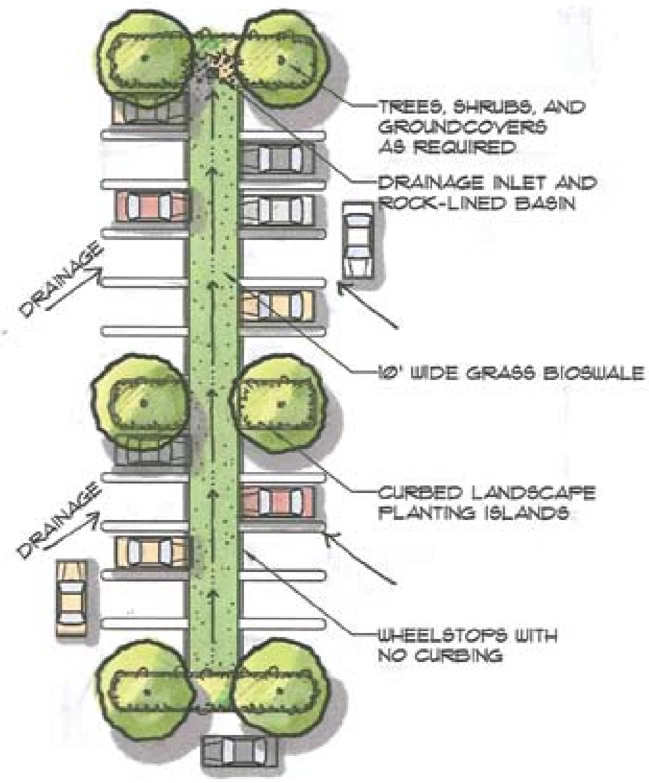
In **Figure 6A**, Costco has conceptualized a ten-foot wide bioswale area in the center of a parking aisle. This example provides raised beds to meet landscape requirements for trees, shrubs and groundcover to prevent them from being inundated in the wet season. By using wheelstops with no curbing parking lot runoff can sheet flow into the bioswale area. The wheelstops are also placed so cars could overhang into the bioswale, potentially reducing the overall length needed within parking stalls. As noted in the cross section 6B, engineered and amended soils are intended absorb and hold water while it infiltrates to deeper soils. As conceptualized, this bioswale is designed to flow to a rock-lined basin and drainage inlet. The elevation of the inlet would control the ponding capacity and therefore the ability for stormwater to infiltrate. The overall performance of this bioswale could be improved by increasing the depth of engineered soils and by increasing the capacity for ponding. The later could be achieved by building cells or weirs into the swale and or raising the drain to parking surface level or removing it altogether.

A narrower infiltration trench would also be desirable to Costco, requiring less square footage overall, as demonstrated in **Figure 7A** and **7B**. The trench could be two to three feet wide and placed between rows of cars, and allow curbed landscape planting islands to meet vegetation requirements. In this example, a concrete curb is used to provide more strength at the edge of the pavement, but those curbs would be cut every 10 feet or so to allow runoff into the trench. Again, cars can overhang into the trench reducing the necessary length of a parking stall. As with the conceptualized bioswale, Costco's designers have proposed a drainage inlet at one end of the trench to control overflow. The overall performance of this trench could be enhanced by amending soils beneath the rock to improve stormwater treatment and infiltration.

Another way to introduce bioretention to Costco parking lots was conceptualized by their designers in **Figures 8A** and **8B**. In this idea, vegetation requirements would be concentrated in areas of the parking lot to form bioretention features that spanned the space of approximately eight parking stalls. A lack of curbing (or curb cuts) would allow runoff from the surrounding parking lot to sheet flow into the bioretention area. Soils beneath could be engineered and amended to varying depths. The larger planting area would provide opportunity to use a larger variety of plant material adding aesthetic benefits and providing some cooling. As conceptualized, this design also includes a drainage inlet, and as previously mentioned, the height of this overflow determines the ability of the bioretention area to pond, and therefore its ability to hold water while it infiltrates. Performance could be maximized by amending soils to significant depth and/or raising the drain to parking surface level or removing it altogether.

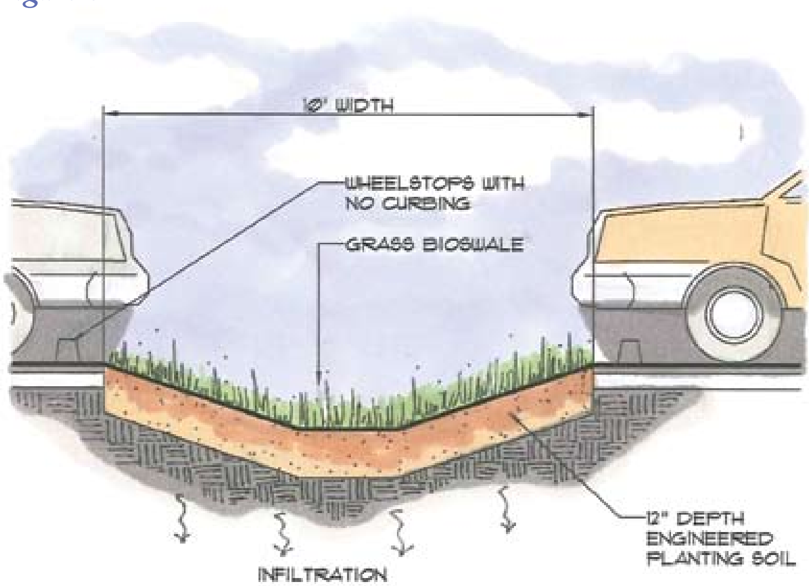
The final concept Costco designers have considered uses bioswales located at the outer edges of the parking lot adjacent to a retaining wall. **Figures 9A** and **9B** show ten-foot wide swales that accept sheet flow from the parking lot, again using wheelstops rather than continuous curbing, planting areas surrounding the parking lot, and concentrating trees and shrubs in islands connected by swales. This configuration uses the same strategies as the other concepts: engineered and amended soils, in combination with vegetation, concentrated landscaped areas and drainage inlets. Aesthetic benefits could be achieved by this concentration of landscaping. This layout would work well where local zoning codes require landscaping at the project boundaries. As with all the concepts, overall performance will be maximized by the soil's ability to hold and infiltrate and the feature's ability to pond water while it can infiltrate, making the depth of soil amendment and the height of the drainage inlet key specifications.

Figure 6A



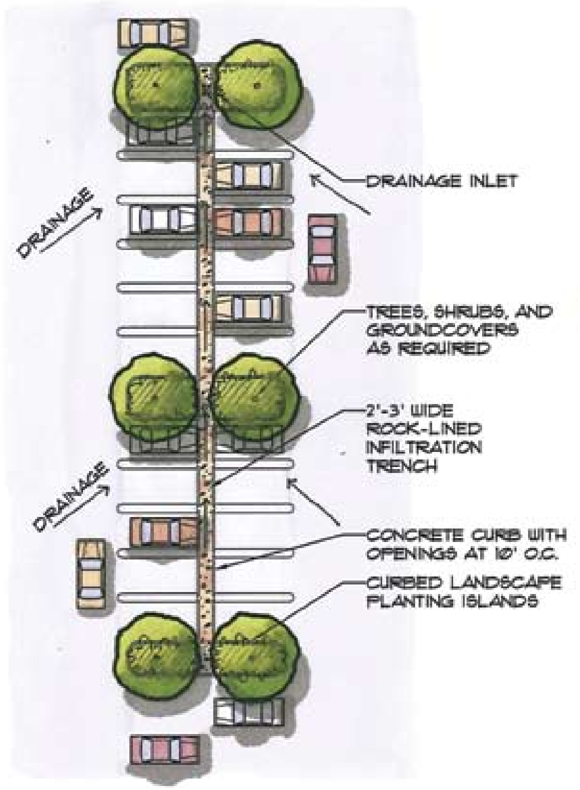
LINEAR BIO-SWALE PLAN

Figure 6B



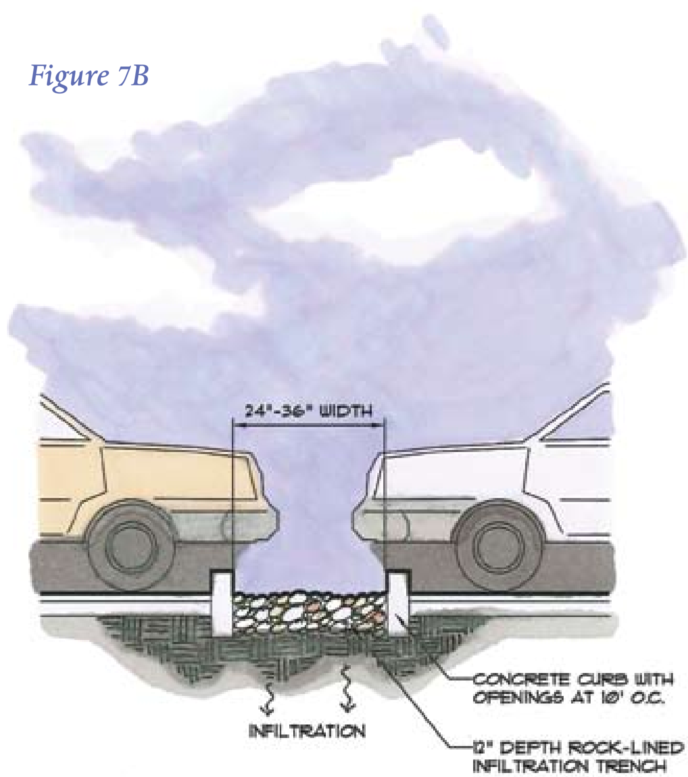
LINEAR BIO-SWALE SECTION

Figure 7A



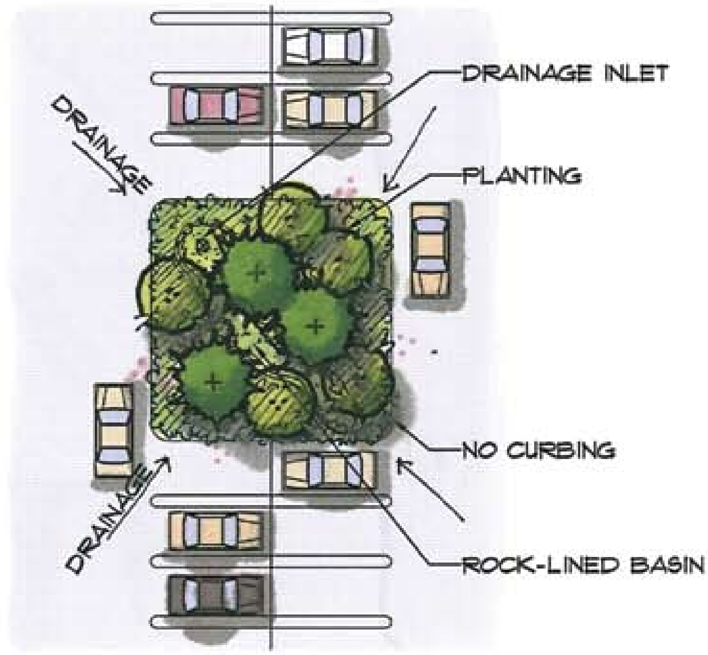
ROCK-LINED TRENCH PLAN

Figure 7B



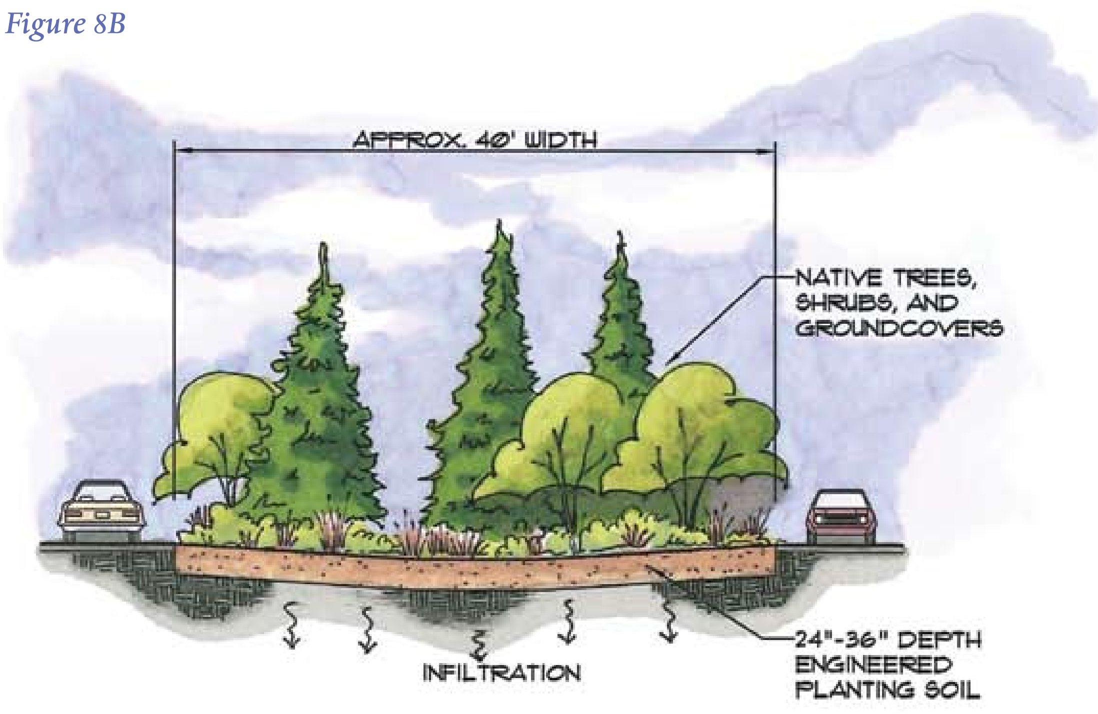
ROCK-LINED TRENCH SECTION

Figure 8A



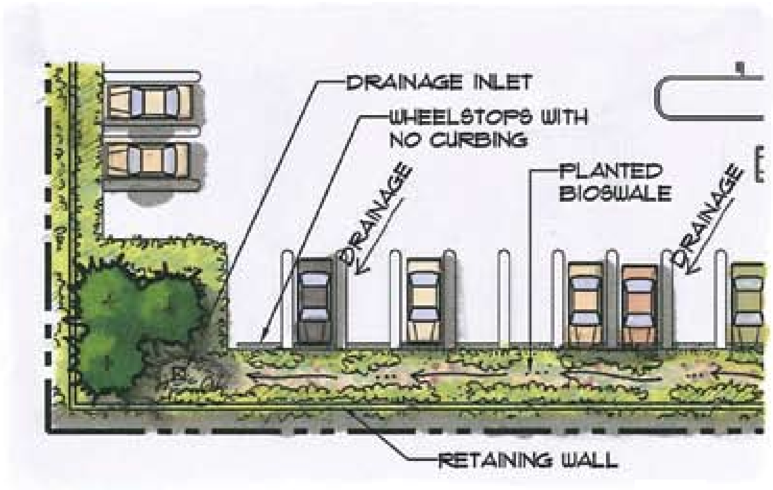
BIO-RETENTION AREA PLAN

Figure 8B



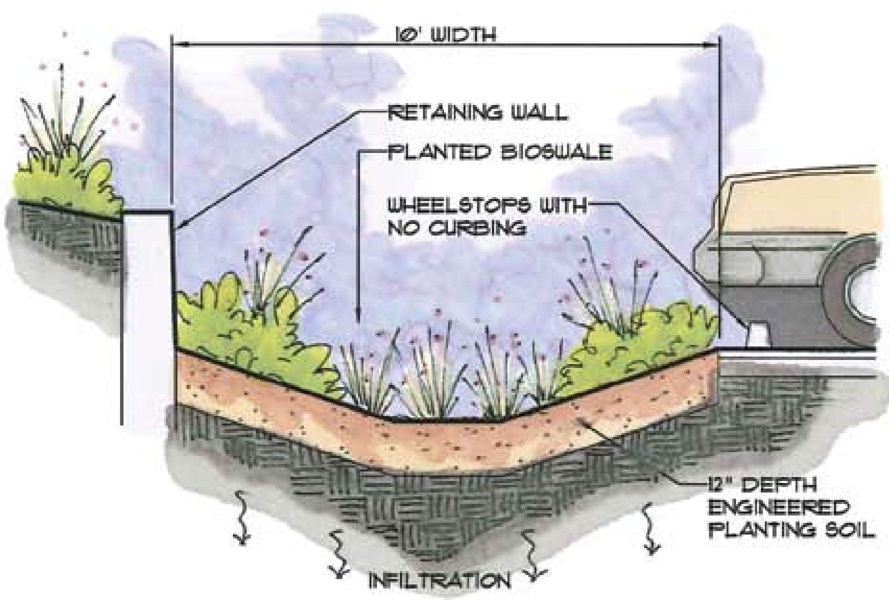
BIO-RETENTION AREA SECTION

Figure 9A



BIOSWALE AT WALL BASE PLAN

Figure 9B



BIOSWALE AT WALL BASE SECTION

Conclusions

There are barriers to the use of LID in large commercial development: some caused by existing regulations and some by development choices. Assumptions about customer needs and management of liabilities also effect development and design decisions that limit the use of many BMPs.

Using LID to reduce impacts from big box retail stores presents difficult challenges. Some LID approaches have limited application on high-intensity urban sites, for example preserving large amounts of native vegetation to limit impacts. For a project with 13 acres of building and parking, preserving 65% of a site in native vegetation and limiting total impervious surface to less that 10% of the site would require a 130 acre site.

On a regional watershed scale, this type of low-density development can result in higher total impervious cover in the watershed and much less of the watershed that can be left "undeveloped". To illustrate this concept, consider a 100-square mile watershed with 100,000 residents and associated housing, schools, businesses, etc. If development is concentrated in 20 percent of the watershed using a moderately high urban density (5,000 people per square mile) and the remaining area is undeveloped, far fewer miles of roadways would be required than if the development were spread over the whole watershed. Similarly, much larger intact areas of habitat can be preserved than if the watershed is broken up into many parcels, each with disconnected set-aside areas. The new EPA publication "Protecting Water Resources with Higher-Density Development" presents an excellent analysis of this problem.

Parking accounts for about 75% of the impervious surface cover on a Costco site, and this is fairly typical of big box retail development. In addition, parking areas typically produce significantly higher pollutant loads than roof or landscape. Therefore, in order to truly reduce impacts, parking has to be considered. The most effective way to do this is to integrate the parking and retail into one multi-story building, which would require a major change in the way large-box retailing is done and would be very costly. Strategies to reduce parking needs are another way to limit impervious cover, at the same time reducing land consumption and development cost. As discussed in the modeling results above, using permeable pavement and/or bioretention to limit runoff are other strategies that can be effective. If soil conditions are favorable, all runoff can be managed on site using these LID BMPs.

From Costco's perspective there are several barriers to embracing LID:

- Permitting is more difficult
- Cost and construction time are less certain
- Long-term durability and maintenance costs are uncertain
- Deviation from a successful and standardized development model is an economic risk.
- Without a strong push from new regulations, management directive or some kind of incentive program, Costco is very reluctant to change.

There are potential benefits for Costco and other large commercial developers to adopt the LID approach. Some projects have reported cost savings by using LID rather than a conventional stormwater management system. Any cost analysis should consider not only initial construction costs and ongoing maintenance costs, but also the environmental and social benefits. Regulations are changing and it is likely that more jurisdictions will require the use of LID: it is best to prepare for this change by gaining experience with LID gradually rather than being forced to react to new standards. There is a limited amount of money available from some government entities to assist developers using green strategies (for example this EPA grant and King County's grant program for developers seeking LEED certification). There is increasing public (and stockholder) pressure for corporations to take more action to protect the environment. Many companies have successful "green marketing" strategies, and the use of LID in new construction is a very visible means of outreach.

Recommendations

Government Needs to Provide Incentives

Government officials need to recognize that the old techniques of managing stormwater that rely only on end-of-pipe controls have not done an adequate job of protecting aquatic resources. LID offers an opportunity to do better. Many agencies have actively embraced this new model and have led the way. What can government do to facilitate LID projects?

- Regulations: local governments can upgrade codes to include LID standards either as allowed alternatives to end-of-pipe designs or as requirements. Since LID technology is evolving rapidly, a rapid, low-cost process for evaluating and permitting alternative approaches to stormwater management would greatly encourage the use of new techniques.
- Regulations: local governments can make landscaping and other site development standards more flexible to make it easier to create designs with LID strategies such as bioretention.
- Incentives: local governments can provide incentives to encourage the use of LID. These can include grants, fee reductions, density bonuses, priority permitting, free technical assistance, free publicity through awards and recognition, and public-private partnerships to assist with infrastructure construction.
- Education: governments can provide training for review staff, private design engineers and the general public to promote acceptance and use of LID.
- Monitoring: governments can monitor the installation of BMPs to see that they are properly constructed and maintained, and measure their effectiveness over time. Results should be shared broadly.
- Feedback: since the use of LID will be new for most jurisdictions, it will be particularly important that there be a process for refining standards as local performance data become available.

Design Professionals Have a Responsibility

Design professionals, especially licensed engineers, have a responsibility to keep their skills up-to-date. Over the last few years state licensing laws have been updated to encourage and require this. Engineers doing stormwater management should strongly consider becoming better informed about the latest trends in stormwater management including LID. Learning about the benefits and pitfalls of LID methods is needed in order to successfully employ this new paradigm. Advocating for LID with project proponents, identifying viable opportunities and long term benefits is an important role of the design professional.

The General Public Has a Major Role

Citizens need to be informed about what is happening in the world around them, sharing their concerns with community leaders, service providers and favorite businesses. Change happens slowly, but government does respond to input from citizens. Citizens can ask their local governments what they are doing to protect aquatic resources and whether they are encouraging the use of LID stormwater management strategies. People can also choose LID for their own projects, creating a demand for these strategies.

Large Format Retailers Can Make a Difference

In order for lower impact strategies to be implemented, the owners of projects need to be willing to try new things and accept some risk. Analysis and demonstration projects have shown that LID is feasible and has significant benefits. The long-term costs of the LID approach are not well known and will not be well known for a number of years. Until more large format retailers and other commercial project developers gain experience with the LID approach, some uncertainty will remain. There is also a risk associated with not keeping abreast of these new trends in stormwater management. These techniques are being allowed in many jurisdictions and more jurisdictions are beginning to require this approach. A gradual, voluntary program of LID implementation may be preferable to an enforced one.

Glossary

Bioretention a stormwater management system, often termed a rain garden, that uses soil and plants to reduce the volume of surface water runoff and to capture pollutants. Bioretention systems with liners and underdrains may more properly be called bio-detention, since they may not retain a significant fraction of the runoff.

Best Management Practice (BMP) a schedule of activities, prohibitions of practices, physical structures, maintenance procedures, and other management practices undertaken to reduce or prevent increases in runoff quantity and pollution.

Detention storing and slowly releasing surface runoff, thereby reducing flow rate. The total volume of runoff is not reduced by detention.

End-of-pipe Facility a conventional engineered facility that is at the end of a system of ditches and pipes that is intended to treat or control polluted stormwater after it has been routed to the facility.

Evapotranspiration (ET) the process by which rain water, surface water and groundwater are transformed to vapor and enter the atmosphere. This includes direct evaporation of rain and surface water, sublimation of snow and ice, and transpiration of groundwater by plants.

Green Roof or Vegetated Roof is an engineered roof cover system that includes plants, a storage medium and a drainage layer. Green roof systems reduce runoff volume by evapotranspiration and provide detention storage that reduces flow rates.

High-Efficiency Sweeper a self-propelled mechanical sweeping system that includes a high-efficiency vacuum system for removing fine particulates from paved surfaces.

Infiltration to allow water to soak into the ground (commonly referred to as percolation) to dispose of surface and storm water runoff.

Low Impact Development (LID) the use of site design and on-site Best Management Practices (BMPs) for the purpose of limiting surface water runoff and pollutant generation from a development site in order to more closely mimic the flow regime and water quality parameters found on an undisturbed site.

Permeable Pavement is a pavement constructed of material that allows water to penetrate and drain into the underlying soil. Commonly used materials are pervious asphalt, pervious concrete, concrete unit pavers, reinforced soil/grass and confined gravel.

Raingarden see bioretention

Rainwater Harvesting a system for collecting, storing, treating and using rainwater.

Retention collecting and retaining runoff by long-term storage and evaporation (including transpiration by plants), by infiltrating runoff into the ground or by a combination of the two. Retention reduces the volume of stormwater runoff leaving the site.

Soil Amendment the addition of compost and/or other soil materials to on-site soils to improve the drainage characteristics and pollutant removal capacity. Soil amendment can also reduce the need for water, fertilizer and pesticides.

Vegetated Roof see green roof.

Resources and Suggested Reading

Better Site Design: A handbook for Changing Development Rules in Your Community, The Center for Watershed Protection 1998.
An excellent document outlining basic LID principles.

Guidelines and Resources for Implementing Soil Quality and Depth BMP T5.13, Soils for Salmon, 2005. www.SoilsforSalmon.org

Impervious Surface Reduction Study, City of Olympia, Washington, 1995.
A very relevant evaluation of how impervious surface can be reduced for different project types.

King County, Washington Surface Water Design Manual, King County, Washington, 2005.
A stormwater manual that includes both end-of-pipe facilities and LID BMPs. Standards are tailored to Puget Sound conditions, particularly limiting stormwater impacts to anadromous fish habitat.

Long Term Stormwater Quantity and Quality Performance of Permeable Pavement Systems, Brattebo and Booth, 2002. http://depts.washington.edu/cwws/Research/Reports/permeableparking.pdf

Low Impact Development for Big Box Retailers, The Low Impact Development Center, Inc., 2005.
This document is very similar in scope to our study and also funded by an EPA grant, is very easy to understand with lots of examples and figures. The authors use a somewhat different hydrologic analysis approach than used in the King County study and consider flow rate control of only a 10-year design storm.

Low Impact Development Guidance Manual for Puget Sound, Puget Sound Action Team, 2005. http://www.psat.wa.gov/Publications/LID_tech_manual05/lid_index.htm
An excellent resource as both an introduction to Low Impact Development and a how-to manual. This manual is intended specifically for use in the Puget Sound area, but the techniques are more generally applicable.

Massachusetts Nonpoint Source Pollution Management Manual, Massachusetts Department of Environmental Protection, 2006. http://projects.geosyntec.com/NPSManual/NPSManual.pdf

Natural Approaches to Stormwater Management, Puget Sound Action Team, 2003. http://www.psat.wa.gov/Publications/LID_studies/LID_approaches.htm

Parking Management Strategies, Evaluation and Planning, Victoria Transport Policy Institute, 2006.
Very useful for analysis of parking needs and ways to reduce paved area.

Protecting Water Resources with Higher-Density Development, US EPA Publication No. 231-R-06-001, 2006

Transportation Demand Management - Transit Oriented Development - Department of Transportation, King County, Washington, King County web site www.metrokc.gov/kcdot.

Water Quality: Prevention, Identification, and Management of Diffuse Pollution, Novotny, Vladimir & Harvey Olem, 1994, Van Nostrand Reinhold

Suggested Web Sites

City of Seattle Natural Drainage Systems Website:
http://www.seattle.gov/util/About_SPU/Drainage_&_Sewer_System/Natural_Drainage_Systems/index.asp

EPA LID page
http://www.epa.gov/nps/lid/

LID Urban Design Tools, LID Center
http://www.lid-stormwater.net/

LID Center
http://www.lid-stormwater.net/

Puget Sound Action Team LID Website
http://www.lid-stormwater.net/

Massachusetts LID Toolkit Webpage
http://www.mapc.org/LID.html

HUD Publication: The Practice of Low Impact Development
http://www.huduser.org/publications/destech/lowimpactdevl.html

US Green Building Council Homepage
http://www.usgbc.org/

Pavement Busters Guide, Victoria Transportation Institute
http://www.vtpi.org/pavbust.pdf

APPENDIX A
Costco Thoughts on Possible LID Strategies

King County

Department of Natural Resources and Parks
Water and Land Resources Division

LID Strategies	Opportunities / Practices	Comments	Constraints	Costco response
Protect & restore native soils and vegetation	Retain native vegetation— preserve and use in landscaped areas	Native vegetated surfaces generally produce less runoff and provide absorb runoff from developed surfaces Native vegetation is generally adapted to the local environment and needs less water, fertilizer and pesticides than non-native species.	Costco's standard design and construction methodologies may not easily adapt to these BMPs	High feasibility, they can easily do. They currently use native plants when possible.
	Preserve and amend soils— preserve native soils and use in landscaped areas amend soil where degraded	Healthy soil can reduce the need for fertilizer, pesticides and watering as well as enhance the infiltration of stormwater on the site; amendments like compost, sand and mulch can improve soil drainage characteristics and fertility.	Costco's standard design and construction methodologies may not easily adapt to these BMPs; Standard site grade is no more than 2%.	
Reduce development envelope	Multi-story buildings and parking garages— effectively compacting Costco footprint while still accommodating volume, reduces stormwater runoff.	Costco has used multi-story buildings and parking garages on a few projects. Approach may be driven where land cost is high or where large parcels are not available.	Outside of Costco's standard design and construction procedures. Would require creative and functional solutions to circulation of carts, people and vehicles.	Not likely to use multi-story buildings except where required by code or cost-effective.
	Share parking with adjacent development—	Would require Costco to rely on adjacent developments to accommodate peak parking volumes.	Directly conflicts with Costco standard policy of 750 parking stalls on site.	They can share parking. The issue is compatible peak hours. For Costco movie theatres and health clubs don't work well, other retail is better. Average customer stay 1 hr.
Reduce impervious surfaces & eliminate effective impervious area	Maximize parking lot density—	By changing circulation patterns, stall size, and driveways could reduce the amount of property needed for parking	Large parking stalls are important to Costco to ease transfer of bulk goods into customer vehicles; Costco wants customers to be able to move carts between aisles through empty parking stalls, which limits the use of wheel stops and landscaping in overhang areas between the front of stalls	This approach could be used. An example design would be helpful.
Reduce impervious surfaces & eliminate effective impervious area (continued)	Pervious pavement— Using paving methods that allow infiltration, reduces effective impervious area.	Costco has tried a grassed modular pavement system once, but was unhappy with the results. Other types of pervious pavement including pervious asphaltic concrete, pervious Portland cement concrete and concrete unit pavers could be considered either exclusively or in combination with less pervious material.	Costco prefers to use asphaltic concrete mix designs that produce smoother surfaces than typically used surfacing materials in order to produce a smoother surface where shopping carts will roll more easily.	High feasibility. Would consider pervious asphalt or concrete, perhaps perco-crete because of smoothness. Unit pavers are also possible. Need to pass the "high heel test".

LID Strategies	Opportunities / Practices	Comments	Constraints	Costco response
	Green roof— addition of an organic layer to roof system that depending on design and depth can fulfill varying functions with varying success, from retaining rainfall to reducing heat island effect.	Green roofs have been shown to result in significant reduced energy consumption and can result in longer roof life. Green roofs may as a result have lower life-cycle costs, but at present they are only beginning to see much use the US.	Costco uses standing seam metal roofs. Placing a green roof over this type of roof presents significant concerns with constructability, waterproofing, possible corrosion and difficulty of long-term maintenance. Using a green roof system would probably require using a different roof system that would be more costly to install, both for the roof materials and the supporting structure. Design, review and construction time may be extended where green roofs are selected.	Required in Chicago. Would do only if required. Would prefer rainwater harvesting.
Manage stormwater as close to its origin as possible	Open swale conveyance— using open drainage systems increases the opportunity for runoff to infiltrate, evaporate and to be treated by vegetation.	By careful grading, the use of amended soil and appropriate plant selection, open conveyance can be designed to maximize the opportunity to treat and reduce surface runoff.	Current Costco design is driven by parking space requirements. This BMP may require creative redesign and compromise, and may result in additional environmental and social benefits.	Not a problem. Was used on the Woodinville and Coeur D'Alene projects.
	Infiltrate runoff to extent feasible— use small or large surface or subsurface structures, including gravel trench systems or bottomless chambers under parking areas or within landscape areas	Where soils are highly infiltrative, a centralized facility may manage all runoff; where soils have limited infiltration capacity, dispersed smaller facilities will be more suitable.	Site specific	Good where feasible. Concern about contaminants in dry wells without pre-treatment.
Manage stormwater as close to its origin as possible (continued)	Rainwater Harvesting— collect, store and pump rainwater for non-potable uses indoors and out, and/or treat rainwater for potable uses.	By storing water collected from roof structures, could be used for non-potable uses like toilets and landscape irrigation. Via filtration systems rainwater could be used for non-potable uses + potable uses like dishwashing, sinks, etc.	Requires initial investment, which may reduce some water supply costs over time. Using non-potable water would require separate supply systems. A backup potable water supply to supplement the non-potable system uses may also be needed. Filtred system for potable uses may require more management, more permits as well as backup system.	Interested. Easily done. Covington store is a possible candidate. Covington has a two-tier water rate system with much higher rates for landscape use. Covington requires a separate meter for landscaping irrigation with $10k hookup fee.
	Bioretention— runoff from roofs or parking lots could be routed into tree planter boxes, bioretention strips or ponds.	Using runoff from parking areas has the advantage of providing good pollutant removal for the most polluted runoff.	Again, would require creative parking lot design to accommodate parking requirements.	

LID Strategies	**Opportunities / Practices**	**Comments**	**Constraints**	**Costco response**
	Reduce pollutant generation— structural and non-structural BMPs to reduce the transport of pollutants into surface water.	Could include a landscape management plan with integrated pest management to limit the application of fertilizers and pesticides; Could also include sweeping rather than washing parking lots, and not dumping any pollutants into storm drains,	More of a function of Operations and Maintenance of the property.	Interested in information we could provide. Note that parking lots are swept weekly. Use of high efficiency sweepers may be a good option to reduce pollutant loading.
Other strategies with environmental and social benefits beyond the site	Built green/LEED—	By using green building principles other than LID, such and energy conservation, materials selection, etc, we can reduce impacts to resources and habitat that we are trying to protect by using LID.	Beyond the scope of this project, though clear multifunctional, lifetime cost, environmental and social benefits.	
	Broaden business model— to reduce need for parking and pollutant generation	Further develop internet-based shopping, delivery of goods to customers, drive-up shopping and pick-up, shuttles from remote parking or other locations and orienting development to maximize the availability of public transit.	Beyond the scope of this project, though clear multifunctional, lifetime cost, environmental and social benefits.	Carpooling to reduce vehicle trips; could do public education. Costco provides bus passes and shuttle service to employees. Some shoppers do use public transit and Costco does try to locate near transit lines or stations. Costco does $500 M in online business and expects to do $1 B soon. Business model limits staff and does not include "back of house" storage, so drive-up approach would not work. Business center delivers orders over $300.
Other strategies with environmental and social benefits beyond the site (continued)	Careful site selection— Protecting critical/sensitive and hydrologically functional habitat	By avoiding development of, and even protecting properties that are functioning well hydrologically in a natural state, and specifically selecting sites that are highly impacted, while simultaneously minimizing stormwater runoff through LID BMPs, Costco may effect a net gain in hydrologic function.	Beyond the scope of this project, though clear multifunctional, lifetime cost, environmental and social benefits.	

Above BMP opportunities and practices are likely to have varying additional benefits of multifunctionality, lower lifetime costs, and additional environmental and social benefits.

APPENDIX B
Additional Considerations: Further “Greening” of the Big Box

King County
Department of Natural Resources and Parks
Water and Land Resources Division

Appendix B. Additional Considerations: Further "Greening" of the Big Box

Developments that cover 85% of the site with impervious surface cause more than just stormwater impacts. Business constraints including customer convenience, construction and operating cost, and uncertainty about use of new approaches make application of LID practices for big box retailers particularly difficult. Development impact evaluation should look beyond local stormwater impacts and take a more global view. There are connections between water use, energy use, construction materials and water resources. By using green building principles other than LID, we can reduce impacts to resources and habitat that we are trying to protect by using LID. The Leadership in Energy and Environmental Design (LEED) system is an excellent measuring tool for green design of commercial buildings.

Listed below are a few examples of how green building principles could be applied to big box development to help protect resources:

Considering all the benefits. In selecting BMPs for any particular site it is important to note that some BMPs have benefits beyond managing stormwater. For example, native vegetation, bioretention and vegetated roof systems can result in:

- Cooler temperatures and higher humidity, achieved through natural evaporation
- A more aesthetically pleasing landscape
- Habitat for wildlife
- Reduction of the "heat island" effect in cities

In addition, vegetated roofs also offer:

- Decreased heating and cooling costs
- Improved air quality (up to 85 percent of dust particles can be filtered out of the air)
- Increased life of the conventional roof underneath the vegetated roof
- Replacement of the vegetated area displaced by the structure

Water Conservation. Reduced recharge means reduced groundwater supply, drying of wetlands and reduced stream base flow. Increased withdrawal of groundwater and surface water for human consumption can have the same impact. The use of water-saving plumbing fixtures and landscapes that require little water can help limit the same impacts that we are trying to limit using LID.

Pumping groundwater and pumped diversion of surface water uses energy. Reducing water consumption and avoiding designs that require pumping can reduce energy consumption.

Material Selection. Concrete, asphalt and steel production consume vast quantities of water and energy. The use of recycled materials or material content can help reduce these impacts. Similarly more efficient layout and design can also reduce material consumption.

Forest habitat can be preserved when timber is harvested sustainably. Preserving forest preserves natural hydrology more effectively than any other approach (where forest is the native land cover). The use of sustainably-harvested lumber can help to reduce the impacts of new construction.

Energy Efficiency. Energy production and transmission consume resources and destroy habitat. Most energy consumption results in CO_2 emission which causes climate change. Climate change is negatively impacting habitat and species, and is likely to negatively impact water supply in many areas. The use of more insulation, energy-efficient lighting, heating and cooling systems in new projects can greatly reduce energy consumption with its attendant impacts. Alternative energy sources that eliminate CO_2 emissions can also be used.

Solar. Solar energy can be harnessed with varying technologies and varying applications. The large flat roof of typical commercial buildings is a great location for solar panels. Photovoltaic systems can be used alone or combined with vegetated roofs and/or rainwater harvest for multiple benefits. With the ability to sell power to local utilities and incentives provided by some agencies, solar panels have been shown to have fairly quick pay-back in sunny climates. The cost per watt of solar cell generating capacity has been declining and this trend is expected to continue.

Challenging assumptions: An altogether different approach to limiting impacts from large developments is to modify the business model. Using internet-based retailing, remote ordering and delivery to supplant the need for new stores is an alternative approach that could reduce the demand for construction of new impervious surface. It should be noted that Costco's internet sales have been increasing rapidly and that Costco does now deliver orders to business customers.

Climate change: The latest information about climate change indicates that it is happening more rapidly than was previously thought. While this may generally mean warming, more intense storms and sea level rise, local areas may see more or less precipitation and changes in seasonal distribution of precipitation. While there is no easy way to evaluate the impact of climate change on the effectiveness of BMPs, the following general tendencies should be expected. Warmer temperatures should increase evaporation and plant transpiration, which could increase the effectiveness of vegetated roofs and bioretention systems. Increased rainfall during the winter could leave soils more saturated and reduce the effectiveness of vegetated BMPs; increased summer rainfall could be more effectively handled with vegetated systems. Higher rainfall intensity and larger storm volume would generally require larger BMPs to provide flood control. Changes to water supply and irrigation needs could significantly alter the cost and availability of potable water, thus making rainwater harvesting more economically feasible.

APPENDIX C
Hydrologic Analysis of LID and the Big Box

King County

Department of Natural Resources and Parks
Water and Land Resources Division

Appendix C. Hydrologic Analysis of LID and the Big Box

In order to evaluate the effectiveness of various LID strategies and to compare them with conventional end-of-pipe facilities, a series of scenarios was modeled using a continuous hydrologic model and a single event model. For areas with long-duration, lower-intensity precipitation patterns, a continuous model is needed to accurately simulate runoff events and evaluate BMP performance. When short-duration, high-intensity runoff events dominate, a single event model may adequately simulate runoff and BMP performance. In the former case, research has shown that single-event models seriously overestimate the performance of stormwater facilities. Because of their simplicity, single-event models based on runoff curve numbers are still widely used around the US.

The continuous model used for this evaluation was the King County Runoff Times Series (KCRTS) model. This model was developed in the early 1990s for application in King County, Washington. The KCRTS model uses runoff files created using Hydrologic Simulation Program-Fortran HSPF with 50 years of local precipitation data, using regionalized parameters that have been shown to accurately simulate runoff in the area. HSPF is a widely-used continuous runoff simulation model that was developed by EPA and USGS. The model incorporates precipitation records, evaporation records, soil properties and land cover. The model calculates surface runoff, interflow, and discharges to groundwater.

KCRTS contains routines for creating hydrograph time series, analyzing flow frequency and duration, computing runoff volume, and sizing flow control facilities. KCRTS runoff is the sum of surface flow and interflow; the model does not provide output for other HSPF parameters.

The single event model used was King County's HYD program, developed in the 1980s, that uses the Santa Barbara Urban Hydrograph (SBUH) method for generating runoff hydrographs. The SBUH method is based on the SCS curve number methodology. The curve numbers are adjusted for local conditions.

KCRTS Model Scenarios

A large number of scenarios were modeled using KCRTS that included differing land cover, soil types, LID techniques and stormwater regulations. The results are summarized in the four tables below. Model scenario descriptions can be viewed in **Table C-4**.

The model runs considered a typical 15-acre site with four possible pre-development land cover and soil type scenarios. The pre-developed land cover types used were forest (F) and pasture (P). The soil types were glacial till (T), a hydrologic group C soil and glacial outwash (O), a hydrologic group A/B soil. The post-development land cover was assumed to be 3.25 acres of building, 9.5 acres of parking and 2.25 acres of landscape, representing a typical Costco store. A standard development scenario using imperious surfaces and no LID BMPs was run for both soil types to establish baseline runoff conditions. A variety of LID approaches were then modeled.

The KCRTS Modeling scenarios looked at the size of conventional stormwater facilities needed to meet different development standards, the reduction in conventional facility size allowed using LID BMPs and the reduction in runoff volume resulting from use of LID BMPs. For outwash soil, infiltration was assumed to be feasible with a design infiltration rate of 2 inches per hour, and the facility was designed to infiltrate all runoff events in the model. Since infiltrating all runoff is relatively easy to do with Group A and B soils, both runoff rate and volume changes are easily mitigated. Therefore, the rest of the KCRTS model runs considered till (Group C) soils, where controlling runoff, particularly volume increases, is more difficult. Two runoff control standards were considered, matching the 2 and 10-year peak pre-developed peak flow rates and matching the duration of flows from 50% of the 2 through the 50-year runoff events. Note that in a continuous model the concept of a design storm event is replaced with the runoff event frequency, since the continuous model uses many years of continuous rainfall data rather than a single synthetic storm event.

All LID model scenarios assumed using permeable pavement, either with the pavement assumed to infiltrate all runoff if over outwash soils, or with a more conservative assumption in the case of till soils that the pavement behaves as if it were 50% impervious and 50% grass. Scenarios using one each of three methods of controlling roof runoff were modeled: a vegetated roof system, collection and use of all rainwater falling on the roof, or routing roof runoff into a bioretention system. The vegetated roof was modeled as 50% grass, 50% impervious to simulate attenuation of large runoff events. The bioretention system was considered to cover 15% of site (2.25 acres) and was modeled with 0.5 inches per hour infiltration rate, a 12-inch storage depth, with surface discharge though a riser overflow.

With any open stormwater facility, ponded water behaves as impervious surface in the sense that whatever rain falls on the water surface is volume added directly to the facility. Consequently, it is desirable to minimize the wetted surface of a bioretention facility. When the rate of rainfall is less than the infiltration rate, then water does not pond and the surface can be modeled the same as other pervious surface. One way to accomplish the goal of minimizing the ponded surface is to connect a series of bioretention cells that overflow from one to the next. That way during smaller events, a smaller ponded surface is created. This can have other advantages in that plants that have less tolerance for inundation may be used in downstream cells that hold water less frequently. In practice, distributing the bioretention cells across the site will improve effectiveness by distributing the hydraulic load over a greater area. An alternative approach would be to design the bottom of the bioretention areas with varied grade so that smaller runoff events cover a limited amount of the bioretention surface.

The ponded surface effect was considered in the modeling. For smaller, more frequent runoff events, the bioretention area was modeled as pervious surface; for the largest runoff events ponding was assumed and the area was modeled as impervious surface. This behavior is similar to green roofs and to pervious pavement where infiltration rates are limited. With these BMPs, little or no runoff is produced during smaller events and runoff is less attenuated during large events. In the Northwest, the critical design rainfall events occur in the winter when ET is low. Unlike most of the US, only a small portion of the precipitation occurs in the summer (see Figure 3, page 8), so ET is much less important for bioretention facilities than in most of the country. When calculating the size of conventional facilities needed to control discharge from the project site, runoff from the roof systems was routed through the bioretention facility, then a conventional flow control facility was sized to meet the stormwater control standard considered in the given scenario.

The following is a description of the assumptions used for the various KCRTS model scenarios. LID site scenarios 1,2, and 3 assume using permeable pavement, a green roof, rainwater harvesting or bioretention, and outwash soils. These cases assume a best-case pavement with zero runoff and rainwater harvesting of all roof runoff. The green roof is assumed to behave as 50% impervious/50% grass. The bioretention is modeled as a infiltration facility covering 15% of the site, with a 12 inches depth and with an infiltration rate of 0.5 inches per hour and no underdrain or orifice control.

- LID 1 Post is permeable pavement over outwash soils with total roof rainwater harvesting (no runoff)
- LID 2 Post is permeable pavement over outwash soils with green roof
- LID 3 Post is permeable pavement over outwash soils with bioretention of runoff from standard roof
- LID site scenarios 4, 5 and 6 are the same as 1, 2 and 3 above except that the permeable pavement is over till soils with runoff equivalent to 50% impervious/50% till grass; for scenario 6 runoff from both roof and parking are routed to bioretention.
- LID 1 Post through LID Post 6 show runoff leaving the site without a conventional end-of-pipe facility.
- Cases 1-20 show the volume of an end-of-pipe facility required in addition to the LID BMPs to meet the given flow control target, matching 2-year and 10-year pre-developed peak flows or matching pre-developed runoff durations from 50% of the 2-year through the 50-year event.

The results of these model scenarios are summarized in **Tables C-1** and **C-2**. **Table C-1** shows the average annual volume of runoff and the peak flow rates for pre- and post-development scenarios without conventional stormwater flow-control facilities. **Table C-2** shows the size of conventional end-of-pipe ponds that would be required in addition to the LID BMPs in order to meet given runoff control standards. **Table C-3** summarizes the LID assumptions that underly these scenarios.

Table C-1. Hydrologic Modeling of Typical Costco Site Scenarios Using KCRTS: Runoff Volume and Rate for Seattle Area

Land Cover	Average Annual Volume of Runoff Leaving Site - Ac-Ft	2-year Peak Flow CFS	10-year Peak Flow CFS
Outwash Forest Pre-dev	0.017	0.003	0.004
Outwash Pasture Pre-dev	0.039	0.003	0.115
Till Forest Pre-dev	8.87	0.417	0.726
Till Pasture Pre-dev	14.01	0.539	0.965
Std Dev Post - Outwash	33.0	3.18	3.78
Std Dev Post – Till	36.0	3.29	3.97
LID 1 Post - Outwash	0.0	0.0	0.0
LID 2 Post - Outwash	6.3	0.53	0.634
LID 3 Post - Outwash	0.0	0.0	0.0
LID 4 Post – Till	18.4	1.55	1.85
LID 5 Post – Till	24.7	2.08	2.48
LID 6 Post – Till	0.0	0.0	0.0

Table C-2. Hydrologic Modeling of Typical Costco Site Using KCRTS, Cases 1-20: End-of-Pipe Facility Size

Land Cover	6′ deep facility volume - Ac-Ft
Case 1 - std dev, outwash, infiltrate all runoff (2″/hr)	2.67
Case 2 - std dev, till forest, match durations	5.25
Case 3 - lid dev 1, match till forest durations	0.0
Case 4 - lid dev 2, match till forest durations	0.13
Case 5 - lid dev 3, match till forest durations	0.0
Case 6 - std dev, match till forest peaks	3.72
Case 7 - lid dev 1, match till forest peaks	0.0
Case 8 - lid dev 2, match till forest peaks	0.13
Case 9 - lid dev 3, match till forest peaks	0.0
Case 10 - lid dev 2, match till pasture peaks	0.0
Case 11 - lid dev 3, match till pasture peaks	0.0
Case 12 - lid dev 4, match till forest durations	1.12
Case 13 - lid dev 5, match till forest durations	2.49
Case 14 - lid dev 6, match till forest durations	0.0
Case 15 - lid dev 4, match till forest peaks	0.93
Case 16 - lid dev 5, match till forest peaks	1.65
Case 17 - lid dev 6, match till forest peaks	0.0
Case 18 - lid dev 4, match till pasture peaks	0.58
Case 19 - lid dev 5, match till pasture peaks	1.28
Case 20 - lid dev 6, match till pasture peaks	0.0

Note: peak matching is 2, 10-year only

Assumptions:

For LID site scenarios 1,2, 3, assume using permeable pavement; green roof, rainwater harvesting or bioretention. Assume best case pavement is zero runoff, rainwater harvesting is total (size needed?) and green roof has large storage (use 50% EIA). Treat bioretention as a facility with 0.5 inches per hour infiltration rate. Model bioretention on 15% of site (2.25 acres) with 12 inches of storage, riser overflow only, route roof runoff into bioretention. Model green roof as 50% till grass, 50% impervious.

LID Dev 1 is permeable pavement with total rainwater harvesting (no runoff)

LID Dev 2 is permeable pavement with green roof

LID Dev 3 is permeable pavement with bioretention of runoff from standard roof

For LID site scenarios 4, 5, 6, same as 1, 2, 3 above except that permeable pavement runoff is equivalent to 50% impervious/50% till grass; for scenario 6 runoff from both roof and parking routed to bioretention

LID 1-6 Post is runoff leaving the site without a conventional engineered facility.

Cases 1-20 show the volume of the engineered facility required to meet the given flow control target.

Bioretention Sensitivity Modeling:

Following the evaluation of the previous scenarios, another series was run to test the sensitivity of the infiltration rate in the bioretention facility. This series, Cases 21 through 26 showed that given 15% of the site area used for bioretention with a maximum ponding depth of 12 inches, runoff control targets were met for the additional scenarios when the infiltration rate was reduced to 0.25 inches per hour without the need for an end-of-pipe facility. (see Table C-3.)

Table C-3. Bioretention Lower Infiltration Rate Scenarios Using KCRTS, Cases 21-26

Case 21 - lid dev 3, match till forest durations........... 0.0*

Case 22 - lid dev 6, match till forest durations........... 0.0*

Case 23 - lid 3, match till forest peaks....................... 0.0*

Case 24 - lid 6, match till forest peaks 0.0*

Case 25 - lid 3, match till pasture peaks 0.0*

Case 26 - lid 6, match till pasture peaks 0.0*

*no end-of-pipe facility needed

Note: peak matching is 2, 10-year only

Assumptions:

Cases 21-26 show the volume of the engineered facility required to meet the given flow control target, assume bioretention infiltration rate is reduced to 0.25 inches per hour.

Table C-4. KCRTS Modeling Scenario Key

Scenario	permeable pavement % runoff managed	rainwater harvesting from roof	green roof	bioretention
OF Pre				
OP Pre				
TF Pre				
TP Pre				
Std Dev Post – Outwash				
Std Dev Post - Till				
LID 1 Post – Outwash	100%	y		
LID 2 Post – Outwash	100%		y	
LID 3 Post – Outwash	100%			roof
LID 4 Post - Till	50%	y		
LID 5 Post - Till	50%		y	
LID 6 Post - Till	50%			roof and parking
Case 1 - std dev, outwash, infiltrate all runoff (2"/hr)	0			
Case 2 - std dev, till forest, match durations	0			
Case 3 - lid dev 1, match till forest durations	100%	y		
Case 4 - lid dev 2, match till forest durations	100%		y	
Case 5 - lid dev 3, match till forest durations	100%			roof
Case 6 - std dev, match till forest peaks	0			
Case 7 - lid dev 1, match till forest peaks	100%	y		
Case 8 - lid dev 2, match till forest peaks	100%		y	
Case 9 - lid dev 3, match till forest peaks	100%			roof
Case 10 - lid dev 2, match till pasture peaks	100%		y	
Case 11 - lid dev 3, match till pasture peaks	100%			roof
Case 12 - lid dev 4, match till forest durations	50%	y		
Case 13 - lid dev 5, match till forest durations	50%	y		
Case 14 - lid dev 6, match till forest durations	50%			roof
Case 15 - lid dev 4, match till forest peaks	50%	y		
Case 16 - lid dev 5, match till forest peaks	50%		y	
Case 17 - lid dev 6, match till forest peaks	50%			roof
Case 18 - lid dev 4, match till pasture peaks	50%	y		
Case 19 - lid dev 5, match till pasture peaks	50%		y	
Case 20 - lid dev 6, match till pasture peaks	50%			roof and parking
Case 21 - lid dev 3, match till forest durations	100%			roof
Case 22 - lid dev 6, match till forest durations	50%			roof and parking
Case 23 - lid 3, match till forest peaks	100%			roof
Case 24 - lid 6, match till forest peaks	50%			roof and parking
Case 25 - lid 3, match till pasture peaks	100%			roof
Case 26 - lid 6, match till pasture peaks	50%			roof and parking

Rainwater Harvesting Modeling

After the various LID scenarios were modeled, additional work was done to look at the cost-effectiveness of rainwater harvesting for big box stores. A scenario assuming collection of runoff from a 148,000 square foot roof with potable water usage in the building of 5500 gallons per day was modeled using 50 years of SeaTac rainfall. The modeling indicated that a 10,000 cubic foot (80,000 gallon) vault supplied by roof runoff would supply 68% of the average annual need and result in a 11,655 cubic foot reduction of the end-of-pipe stormwater facility size.

This scenario resulted in a savings of about $11,000 per year in water and sewer costs. The cost of the rainwater storage vault should be offset by the reduction in cost for the stormwater detention system. The cost of treating the rainwater to potable standards was not calculated, but the savings in water and sewer costs would provide a substantial offset to treatment cost.

Harvesting rainwater for irrigation in the northwestern US is problematic, given that very little rain falls during the irrigation season resulting in the need for very high storage volumes. Water storage costs on the order of $500 per 100 cubic feet and public water costs on the order of $3 per 100 cubic feet. In the southwestern US rainfall patterns, longer irrigation seasons and limited water supplies may make harvesting rainwater for irrigation more cost-effective.

SBUH Modeling Scenarios

The model scenarios using SBUH were much less extensive than the continuous model simulations. These were run for comparison purposes. The pre-developed site conditions were assumed to be pasture with till (Group C) soils, and a 2% slope across the site. Curve numbers of 85 for pasture, 86 for grass and 98 for impervious surface were used. Times of concentration were calculated to be 38.9 minutes for the pre-developed condition and 7.0 minutes for the post-developed condition. Since the event model does not allow calculation of the average annual runoff volume, the volume of a 2-year, 24-hour storm event was calculated to compare pre- and post-development runoff volume. Pre- and post-development peak runoff rates for a 2-year and 10-year, 24-hour storms were calculated using a Type 1A distribution and precipitation totals of 2 and 3 inches, respectively. The volume required for a detention pond to match pre-development peak flow rates and of an infiltration pond to infiltrate all runoff (assuming an infiltration rate of 2 inches per hour) were then calculated. These results are presented in **Table C-5**.

In addition, a scenario was run with the SBUH model to test managing runoff from a conventional pavement and roof with bioretention only. Using a 2.25 acre bioretention area with a storage depth of 1.1 feet and an infiltration rate of 0.25 inches per hour, the model indicated that all of the runoff generated by a 3-inch, 24-hour type 1A storm was infiltrated. The runoff volume stored at 1.1 foot depth is 2.49 acre-feet, with a water surface area of 2.25 acres. If freeboard is added, the area needed for bioretention would increase somewhat. This result indicates that with moderately favorable soil conditions, stormwater runoff can be effectively managed with shallow bioretention BMPs using about 15% of the total site area.

Runoff from parking and roof areas were calculated separately to compare runoff rates and volumes from developed areas. Considering these results, it can be seen that controlling all runoff from only the parking area would reduce the peak flow and volume leaving the site to levels similar to a pre-developed site. For example, the use of a permeable pavement system for the parking lot that retained all runoff along with a landscape system that retained precipitation falling on landscaped areas would reduce runoff volume and rates to close to an undeveloped site.

Table C-5. **Hydrologic Modeling of Typical Costco Site Using SBUH**

Land Cover	2-year Storm Volume Ac-Ft	2-year Peak cfs	10-year Peak cfs	6 foot deep facility volume to control all runoff
Pre-dev pasture	0.99	1.53	3.56	0.72 ac-ft to match pasture peaks
Pre-dev forest	0.51	0.38	0.98	1.95 ac-ft to match forest peaks
Post-dev total site	2.04	6.41	10.12	1.93 ac-ft to infiltrate all runoff
Post-dev roof	0.48	1.52	2.34	
Post-dev parking	1.40	4.45	6.85	

Results of modeling

The modeling done for this study can be summarized as follows. When conditions are favorable for the use of LID BMPs, all the flow control targets considered can be met using only LID. The favorable conditions include having soil conditions that will allow permeable pavement to infiltrate all rainfall or having soil conditions that will allow all roof runoff and limited parking area runoff from permeable pavement to be managed using bioretention. These soil conditions can be summarized roughly as having a minimum design infiltration rate of about 0.25 inches per hour in regions of low-intensity, moderate-volume rainfall and having a minimum design infiltration rate of about 0.5 inches per hour in regions of high-intensity, high-volume rainfall. These conditions were modeled in KCRTS Cases 3, 5, 7 and 9 through 11, Table C-2. Note that for Cases 4 and 8 roof runoff was modeled for a vegetated roof with runoff characteristics equivalent to 50% grass, 50% impervious surface (an effective impervious factor of 0.5). In these cases, a very small conventional facility was required to meet the targets; to completely eliminate the facility, a more effective vegetated roof would be needed or some bioretention or rainwater harvesting would be needed in addition to the vegetated roof to meet the flow control targets.

Careful determination of infiltration rates is necessary to assess performance of permeable pavement and bioretention systems. Note that the infiltration rate in soils is a function of the wet-season water table, the water/soil temperature and the geometry of the system. As well, performance can be greatly impaired by improper construction techniques and by the long-term migration of fines into the system. Arriving at an accurate prediction of the long-term performance of a large-scale system is difficult, and calls for careful analysis and considerable experience. While a discussion of methods for determining infiltration rates is beyond the scope of this report, it should be noted that small-scale percolation tests tend to greatly overestimate the long-term behavior of large-scale systems.

When the flow control requirement is matching the pre-developed 2 and 10-year peak runoff rates, the requirement can be met using LID BMPs without a conventional end-of-pipe flow-control facility, even if soil conditions are somewhat less favorable than those described above. This was demonstrated in the model with Cases 17 and 20, Table C-2., where runoff from the pervious pavement was modeled as 50% grass, 50% impervious cover, and runoff from the pavement and roof was routed through bioretention.

Sites with very shallow impervious soil/bedrock, very high water tables or steep slopes may not be suitable for permeable pavement and bioretention. In these cases, it may not be possible to use LID BMPs alone to meet required flow control standards. Some benefit can still be realized on these sites through other techniques such as vegetated roofs, rainwater harvesting and reduced impervious coverage. The use of these BMPs in combination with end-of-pipe facilities will help to mitigate some of the runoff volume increase and flashiness of hydrologic response that results from development.

APPENDIX D
Operation & Maintenance of LID BMPs

King County

Department of Natural Resources and Parks
Water and Land Resources Division

Appendix D. Operation & Maintenance of LID BMPs

The following section provides maintenance instructions that include a short description and basic guidelines for the maintenance of different LID BMPs including dispersion, open space, rain garden, permeable pavement, green roofs and rainwater harvesting. This language was borrowed from the 2005 King County Surface Water Design Manual: This manual requires that the maintenance standards be applied through a covenant to properties that contain these BMPs.

Dispersion Systems

Dispersion techniques utilize the natural capacity of vegetated areas to absorb stormwater runoff and filter pollutants from developed surfaces. This BMP has two primary components that must be maintained: (1) the devices that disperse runoff from the developed surfaces and (2) the vegetated area.

Dispersion Devices

The dispersion devices may include the following as indicated on the flow control BMP site plan: splash blocks, rock pads, gravel filled trenches, sheet flow. The size, placement, composition, and downstream flowpaths of these devices as depicted by the flow control BMP site plan and design details must be maintained and may not be changed without written approval from the development permit authority.

Dispersion devices must be inspected annually and after major storm events to identify and repair any physical defects. When native soil is exposed or erosion channels are present, the sources of the erosion or concentrated flow need to be identified and mitigated. Bare spots should be re-vegetated with native vegetation. Concentrated flow can be mitigated by leveling the edge of the pervious area and/or regrading or replenishing the rock in the dispersion device, such as in rock pads and gravel-filled trenches.

Vegetation Retention Area

The vegetated surface required for full dispersion is delineated as a "vegetation retention area" on the flow control BMP site plan. The trees, vegetation, ground cover, and soil conditions in this area may not be disturbed, except as allowed by the following provisions for that portion of the native growth retention area outside of critical areas and critical area buffers:

- Individual trees that have a structural defect due to disease or other defects, and which threaten to damage a structure, road, parking area, utility, or place of employment or public assembly, or block emergency access, may be topped, pruned, or removed as needed to eliminate the threat.
- Dead or fallen trees, tree limbs within ten feet of the ground, and branches overhanging a structure may be removed to reduce the danger of wildfire.
- Noxious weeds and invasive vegetation may be removed.
- Passive recreation uses and related facilities, including pedestrian, equestrian community and bicycle trails, nature viewing areas, fishing and camping areas, and other similar uses that do not require permanent structures, are allowed if clearing and soil compaction associated with these uses and facilities does not exceed eight percent of the vegetation retention area.

Bioretention

Bioretention, also known as "rain gardens " are vegetated closed depressions or ponds that retain and filter stormwater from an area of impervious surface or non-native pervious surface. The soil in the bioretention area has been enhanced to encourage and support vigorous plant growth that serves to filter the water and sustain infiltration capacity. Depending on soil conditions, bioretention areas may have water in them throughout the wet season and may overflow during major storm events.

The size, placement, and design of the bioretention must be maintained and may not be changed without written approval from development permit authority. Plant materials may be changed to suit tastes, but chemical fertilizers and pesticides must not be used. Mulch may be added and additional compost should be worked into the soil over time as needed.

Bioretention must be inspected annually for physical defects. After major storm events, the system should be checked to see that the overflow system is working properly. If erosion channels or bare spots are evident, they should be stabilized with soil, plant material, mulch, or landscape rock. A supplemental watering program may be needed the first year to ensure the long-term survival of the rain garden's vegetation. Vegetation should be maintained as follows: 1) replace all dead vegetation as soon as possible; 2) remove fallen leaves and debris as needed; 3) remove all noxious vegetation when discovered; 4) manually weed without herbicides or pesticides; 5) during drought conditions, use mulch to prevent excess solar damage and water loss.

Permeable Pavement

Permeable pavements reduce the amount of rainfall that becomes runoff by allowing water to seep through the pavement into a free-draining gravel or sand bed, where it can be infiltrated into the ground. Pollutants are trapped and treated in the pavement system.

The type(s) of permeable pavement used may include porous concrete, porous asphaltic concrete, permeable pavers, or modular grid pavement. The area covered by permeable pavement must be maintained as permeable pavement and may not be changed without written approval from the development permit authority.

Permeable pavement must be inspected after one major storm each year to make sure it is working properly. Prolonged ponding or standing water on the pavement surface is a sign that the system is defective and may need to be replaced. If this occurs, contact the pavement installer for further instructions. A typical permeable pavement system has a life expectancy of approximately 25 years. To help extend the useful life of the system, the surface of the permeable pavement should be kept clean and free of leaves, debris, and sediment through regular sweeping or vacuum sweeping. Note that sand, cinders or other similar materials should not be applied to improve traction during the winter, as these materials may clog the permeable pavement. The use of salt or other de-icing chemicals should also be avoided. For grassed modular grid pavement, the grass surface must be regularly mowed and maintained in a good condition. Bare spots must be replanted in the spring or fall.

Rainwater Harvesting

Rainwater harvesting is a means for the collection and storage of roof runoff for domestic or irrigation use. Rainwater harvesting systems include a collection area, a filtering system, a storage device, and an outflow device. The size, components, and configuration of the rainwater system must be maintained and may not be changed without written approval from the development permit authority.

The collection area (e.g., roof) should be routinely inspected for debris and other material that could impede the entrance and/or exit of surface flows. The filtering system should be periodically inspected for effectiveness and replaced or replenished as recommended by the manufacturer. If the system is used only for irrigation, the storage device may need to be drained completely during the dry season in order to provide the needed capacity for an entire wet season. A maintenance log should be kept on site with the aforementioned information and dates of maintenance performance.

Vegetated Roof

Vegetated roofs (also called green roofs) consist of a pervious growing medium, plants, and a moisture barrier. The benefits of this device are a reduction in runoff peaks and volumes due to the storage capabilities of the soil and increased rate of evapotranspiration.

The composition and area of vegetated roof may not be changed without written approval from the development permit authority. Vegetated roofs must not be subject to any use that would significantly compact the soil.

Vegetated roofs must be inspected annually for physical defects and to make sure the vegetation is in good condition. If erosion channels or bare spots are evident, they should be stabilized with additional soil similar to the original material. A supplemental watering program may be needed the first year to ensure the long-term survival of the roof's vegetation. Vegetation should be maintained as follows: (1) replace all dead vegetation as soon as possible, (2) remove fallen leaves and debris, (3) remove all noxious vegetation when discovered, (4) manually weed without herbicides or pesticides and (5) use extreme caution to avoid damage to the waterproof membrane that underlies the vegetation and growing medium.

Open Grid Decking over Pervious Surface

Open grid decking over pervious surface, was installed to minimize or mitigate for the stormwater runoff impacts of some or all of the impervious surfaces on the property. The decking has openings that allow rain water to reach the uncompacted soil below, where it has an opportunity to soak into the ground.

The area and openings of the decking must be maintained and may not be changed without written approval from the development permit agency. In addition, the pervious surface beneath the decking must not be used in a manner that compacts the soil.

Native Growth Retention

Native growth retention is the practice of preserving a portion of a property in a native vegetated condition (e.g., forest) so as to minimize increases in stormwater runoff from clearing and to offset the stormwater runoff impacts caused by impervious surfaces on the property. This native vegetated area on the property was set aside by covenant as "native growth retention area." The trees, vegetation, ground cover, and soil conditions in this area may not be disturbed, except as allowed by the following provisions:

- Individual trees that have a structural defect due to disease or other defects, and which threaten to damage a structure, road, parking area, utility, or place of employment or public assembly, or block emergency access, may be topped, pruned, or removed as needed to eliminate the threat.
- Dead or fallen trees, tree limbs within ten feet of the ground, and branches overhanging a residence may be removed to reduce the danger of wildfire.
- Noxious weeds and invasive vegetation may be removed.
- Passive recreation uses and related facilities, including pedestrian, equestrian community and bicycle trails, nature viewing areas, fishing and camping areas, and other similar uses that do not require permanent structures, are allowed if clearing and soil compaction associated with these uses and facilities does not exceed eight percent of the native growth retention area.

APPENDIX E
Stormwater Pollution Prevention for Big Box Retail Operations

This report was prepared by

King County

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Introduction

Everyone appreciates the value of clean water. Our water resources – our streams and rivers, lakes, wetlands, groundwater and marine waters – provide drinking water and wildlife habitat, as well as recreational activities such as fishing, swimming, and boating. They support tourism, agriculture and industry. Protecting our water resources protects our health, economy, and quality of life.

Even small amounts of commonly used products such as motor oil, soaps, paint waste and pesticides are harmful to aquatic life. Although individual activities often appear insignificant, urban stormwater runoff is now a leading cause of water pollution in our nation's rivers, lakes, and coastal areas.

The goal of this document is to reduce pollution by educating managers, operations personnel and others about how to use stormwater pollution prevention best management practices (BMPs). These BMPs, known as source control BMPs, address business activities for typical big box retail operations that have the potential to pollute stormwater runoff, surface waters and groundwater.

What is Stormwater Runoff?

Pavement and other hard surfaces associated with land development dramatically alter the way rainfall replenishes our surface and ground waters. In natural landscapes, rainfall typically infiltrates slowly into the ground. On hard surfaces such as parking lots and building rooftops rain drains quickly to the storm drainage system and to nearby surface or ground waters. This stormwater runoff picks up pollutants as it drains across the ground. For example, runoff from parking lots becomes polluted with oil and other leaking vehicle fluids, metal and rubber from tire wear, metals and other compounds from vehicle exhaust, and discarded trash and debris. These contaminants are typically washed into the storm drainage system to our lakes, rivers, streams, and marine waters.

Where do Storm Drains Go?

Storm drainage systems are provided to prevent local flooding. Storm drains have grates and openings in streets, curbs, and parking lots that collect the runoff and direct it through pipes or ditches either directly to a nearby surface water or to a downstream stormwater facility that drains to surface water.

Stormwater ponds and other commonly used engineered, "end-of-pipe" facilities are designed to store the large amounts of runoff generated on paved surfaces and then release it slowly to reduce downstream flooding. Low impact development (LID) is a relatively new method of stormwater management that uses on-site physical structures, maintenance procedures, and other management practices to limit surface water runoff and pollutant generation from a development site in order to more closely mimic the flow regime and water quality parameters found on an undisturbed site. While traditional "end-of-pipe" facilities and LID practices improve water quality by removing pollutants, keeping stormwater runoff from becoming contaminated is the best way to protect our groundwater, rivers and streams.

Stormwater Regulations

The federal Clean Water Act (CWA) requires that cities and counties control the quality of stormwater runoff. Under the CWA, the Environmental Protection Agency (EPA) established the National Pollutant Discharge Elimination System (NPDES) stormwater permit program. Phase I of the program, issued in 1990, required permits for large municipalities, certain industrial operations, and large construction sites. Phase II of the program requires smaller communities and construction sites to be permitted. Most states and many cities and counties have developed stormwater programs and regulations to meet the NPDES permit requirements, including requirements to implement source control BMPs.

Best Management Practices and Source Control

Source control BMPs are physical and behavioral activities that eliminate or reduce the amount of pollutants in runoff. Keeping pollutants out of stormwater runoff is more efficient and cost effective than trying to treat contaminated runoff. Examples of source control BMPs include storing drums of liquids on spill pallets and sweeping parking lots regularly to collect pollutants left by vehicles. The BMPs included in this document range from simple changes in "housekeeping" activities to more complex solutions such as constructing a covered storage area. Be aware that even small changes can often make a significant difference in protecting our streams, rivers, and other water resources.

General Best Management Practices (BMPs)

1. Clean and Maintain Your Storm Drainage System

Inspect and clean your storm drainage system by regularly removing sediment and other debris to prevent pollutants from being washed to nearby waterways. The storm drainage system includes all drains, catch basins, pipes, ditches, stormwater ponds, and all other flow control and water quality facilities.

2. Employee Training

Ensure all employees understand that storm drains lead to nearby surface waters and that only clean stormwater should enter storm drains and other stormwater facilities. Incorporate stormwater training into staff and safety meetings.

3. Periodic/Regular Review

Assign an employee to be responsible for performing regular reviews of the site to ensure that BMPs are maintained. This would include checking outside storage areas, dumpster and compactor areas, and other areas where BMPs are needed.

4. Stencil or Mark Your Storm Drains

Stencil or add storm drain markers next to storm drains where appropriate to prevent the improper disposal of pollutants. Storm drains should have messages such as "Dump No Waste, Drains to Stream" next to the catch basin to warn against intentional dumping or the improper disposal of pollutants.

5. Eliminate Illicit Connections to the Storm Drainage System

The discharge of anything other than stormwater to the storm drainage system is prohibited. Internal floor drains or sinks that are connected to the storm drainage system must be disconnected. These discharges must drain to the sanitary sewer system, a holding tank, an approved onsite treatment or recycling system, or a septic system. Contact your appropriate local government agency or sewer utility for more information regarding proper disposal options.

6. Locate Activities as Far as Possible From Surface Drainage Paths

Locating activities far from storm drains, stormwater drainage paths, ditches, gutters, and other stormwater facilities allows more time to recognize spills and to act to prevent water contamination.

7. Avoid the Activity or Reduce its Occurrence

Often an alternate production process or material application process can be used to substitute for another more polluting process. Ideally, a polluting activity can be avoided altogether, or its frequency of occurrence reduced. An example is washing vehicles less often or taking vehicles to commercial car washes or detail shops that discharge to the sanitary sewer or recycle the washwater.

8. Use Less Material

The improper disposal of excess material or the increased application of material simply because excess is available can cause pollution. For example, minimize the use of pesticides and fertilizers to minimize the potential for contaminated runoff. Purchase only the amount of material that will be needed for the foreseeable use. In most cases this leads to cost savings in both purchasing and disposal.

9. Use the Lease Toxic Materials Available

All applications of solid and liquid materials should use the least toxic products and raw materials available, whether in production, cleaning, pesticide applications, or other uses.

10. Create and/or Maintain Vegetated Areas Near Activity Locations

Grass and other types of vegetation can filter out some pollutants in stormwater runoff. Vegetated areas should be maintained around areas where polluting activities occur, especially down slope of activity areas. Routine maintenance will keep vegetated areas healthy and capable of filtering pollutants.

11. Recycle as Much as Possible

Recycling is always preferable to disposal of unwanted materials. Leftover paints, finishes, cleaning and building materials can often be recycled or reused. Contact your local solid waste and recycling agency for more information.

12. Educate Others About Stormwater Pollution Prevention

Educate your contractors, business associates and others about stormwater pollution prevention and encourage them to discuss and find solutions to stormwater pollution problems.

This document addresses best management practices for stormwater pollution prevention. Contact your city or county government for more information regarding specific regulations and requirements in your area. Please note that other regulations may apply. For example, contact your local or state Fire Marshall's office for requirements regarding the storage and handling of flammable materials.

Vehicle and Equipment Parking and Storage

This applies to big box retail store parking lots, driveways, equipment and vehicle rental storage, loading docks, and other similar parking and storage areas. Stormwater runoff from these areas may be contaminated with toxic hydrocarbons and other organic compounds, oil and grease, metals, nutrients and suspended solids.

1. Dry sweep all paved areas as needed to collect dirt, waste, and debris. Never wash down any paved area to the storm drainage system. High efficiency vacuum sweepers are preferred.

2. If wet washing of the parking lot is needed, the wash water must be collected and discharged to a sanitary sewer or other treatment system. There are services that will clean parking lots and collect water for offsite disposal. Never drain washwater to the storm drainage system.

3. A catch basin insert designed for sediment and oil removal may remove some of the pollutants in runoff from vehicles. Catch basin inserts require frequent inspection and replacement to be effective.

4. Clean up oil and antifreeze spills from leaking vehicles with absorbent materials.

5. Encourage customers to use public transit by rewarding valid transit pass holders with discounts. Provide incentives to encourage employees to carpool or use public transit.

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Storage of Liquid Materials in Stationary Tanks

This applies to the storage of liquids such as chemicals, waste oils, solvents, or petroleum products in above ground stationary tanks. Leaking tanks and spills during transfer operations can add toxic organic compounds, oil and grease, metals, harmful pH and nutrients to stormwater runoff.

This best management practice does not address underground storage tanks or facilities that provide for the treatment, storage or disposal of regulated hazardous waste.

1. Store and contain liquids in such a manner that if the tank is ruptured or leaks, the contents will not discharge, flow, or be washed into the storm drainage system, surface waters or groundwater. Typically this means constructing a concrete secondary containment area or using a double-walled tank.

2. If the liquid is oil, gas, or another liquid that floats on water, install a spill control device such as an oil/water separator or down-turned elbow in the catch basins that collect runoff from the storage tank area.

3. Place drip pans or absorbent materials beneath all valves and at all potential drip and spill locations during tank filling and unloading. Any collected liquids or used absorbent materials must be disposed of properly.

4. Store and maintain spill cleanup materials near the tank storage area. Spill cleanup materials should be clearly labeled. Ensure that employees understand proper spill cleanup procedures.

5. Sweep and clean the storage area as needed if it is paved. Never hose down paved areas to a storm drain.

6. Check tanks and any containment areas regularly for leaks and spills. Repair or replace tanks that are leaking, corroded, or otherwise deteriorating. Collect and properly dispose of all spilled liquids.

7. Set up a regular inspection and cleaning program for oil/water separators and other spill control devices.

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Storage of Liquid Materials in Portable Containers

This includes liquids such as waste oil or other petroleum products, solvents or degreasers, detergents, or other chemicals stored outside in portable containers such as drums or five gallon buckets. This typically applies to the storage of vehicle fluids related to automotive maintenance and repair services such as tire shops and lube shops. Liquid cleaning supplies stored outside are another example. Spills and leaks from liquid storage containers may pollute stormwater runoff with toxic compounds, oil and grease, metals, harmful pH and nutrients.

These best management practices do not address hazardous waste regulations or fire code regulations for flammable liquids.

1. Keep tight-fitting lids on all containers.
2. Store the containers under a roof or other covered area, or store the containers in a covered storage locker or shed.
3. Store the containers on a spill containment pallet or similar method that has provisions for spill control. Numerous products are available that provide cover and spill containment for outside liquid storage.
4. Place drip pans or absorbent materials beneath all valves and at all potential drip and spill locations during filling and unloading of containers. Any collected liquids or soiled absorbent materials must be disposed of properly.
5. Store and maintain appropriate spill cleanup materials near the container storage area. Spill cleanup materials should be clearly labeled. Ensure that employees are trained in proper spill cleanup procedures.
6. Sweep and clean paved storage areas as needed. Never hose down the area to the storm drainage system. Properly dispose of any spilled liquids or used absorbent material.
7. Ensure that all containers are properly labeled.
8. Check containers and spill containment regularly for leaks and spills. Replace containers that are leaking, corroded or otherwise deteriorating.
9. Set up a regular inspection and cleaning program for oil/water separators and other spill control devices.

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Storage of Solid Waste and Food Wastes

This includes the outdoor storage of all solid wastes including food waste. This typically refers to garbage dumpsters and compactors, other outdoor waste containers such as restaurant grease barrels, and any stockpiled waste. Stormwater runoff from waste storage areas may become polluted with toxic compounds, oil and grease, nutrients, and suspended solids if waste containers are leaking, uncovered or too small to contain the amount of waste generated.

1. Keep dumpsters and compactors closed except when adding or removing waste. Clean the area around waste containers frequently.

2. Ensure that dumpsters have solid tops to keep out the rain. Dumpsters must be leak proof. If the bottom of the dumpster is corroded or leaking, contact your waste management company to have it replaced.

3. Check compactors regularly for leaking hydraulic fluid. Repair or replace compactors that are leaking. Clean up any spills immediately.

4. Cooking oil or grease must be stored in a covered container to keep out the rain. Locate the container away from storm drains. Never wash down the area to the storm drains.

5. When transferring cooking oil or grease to outside containers from kitchens, use an appropriate container with a sealed lid. Clean up any spills immediately. Ensure that your grease pickup service uses drip pans or other methods so that grease is not spilled on the ground while emptying or removing and replacing the container.

6. Cover any temporary waste pile that is not in a container with a tarp or similar method. Locate the waste pile to prevent stormwater from draining towards the waste pile and picking up contaminants.

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Cleaning or Washing of Tools and Equipment

This applies to the cleaning and washing of all tools and equipment associated with restaurants and other food preparation, auto repair and tire shops, landscaping (e.g. lawnmowers and weed whackers), garden centers and building maintenance activities. Improper outdoor washing can pollute stormwater runoff with toxic hydrocarbons and other organic compounds, oil and grease, nutrients, metals, harmful pH and suspended solids.

1. Never allow wash water from cleaning any tools or equipment to drain to the storm drains. Washwater must discharge to the sanitary sewer, an on-site treatment or recycling system, or be collected for offsite disposal.

2. If washing cannot be done inside in an area that drains to the sanitary sewer, consider constructing a wash pad area for washing floor mats, vent filters, grills, carts, tray racks, and other items that need regular cleaning. Designated wash areas must drain to the sanitary sewer or other approved system. Contact your local government agency or sewer utility for assistance when installing a connection to the sanitary sewer. Also, a temporary or mobile wash pads are commercially available that collect or recycle wash water.

3. Use self-contained parts washers for automotive repair and tire shops as appropriate. Never allow washwater or degreasers from cleaning automotive parts and equipment to discharge to the storm drains.

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Vehicle Washing and Steam Cleaning

This applies to the washing of all vehicles such as company cars, trucks, and forklifts. Commercial car wash operations are also included. Wash water from cleaning activities can pollute stormwater runoff with soaps and detergents, toxic hydrocarbons and other organic compounds, oil and grease, nutrients, metals and suspended solids.

1. Please note that **all** soaps are harmful to aquatic life, including those labeled "biodegradable", "non toxic", or "environmentally friendly".

2. Soapy wash water from cleaning vehicles must never be allowed to drain to the storm drainage system or surface waters. All wash water must drain to the sanitary sewer or to an approved recycling or treatment system.

3. For regular vehicle washing, construct a designated wash area that drains to the sanitary sewer, an on-site septic system, or a recycling system. Contact your local sewer utility for requirements for connecting to the sanitary sewer.

4. Using water only to rinse off the body of a vehicle is acceptable. It is also acceptable to wash only the body of a vehicle using a mild soap (pH neutral) if the washing is done in an area where the water will slowly infiltrate into the ground, such as on grass or loose gravel. These exceptions do not apply to the engine or underside of vehicles or other equipment where rinsing will wash contaminants such as oil or grease onto the ground.

5. Products such as portable wash pads that collect washwater runoff so that it can be drained to the sanitary sewer are readily available. Also available are car wash kits that fit inside storm drains and contain and pump the wash water to an inside sink or other drain that goes to the sanitary sewer.

6. For commercial automatic car wash operations, check to ensure that wash water runoff and overspray does not drain to any nearby storm drains. All wash water must discharge to the sanitary sewer or other approved recycling or treatment facility.

7. Consider taking company vehicles to a commercial car wash operation if one is not available onsite. Wash water from commercial car washes discharges to the sanitary sewer or to a recycling system.

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Fueling Operations

This addresses vehicle refueling including commercial gas stations and fleet maintenance facilities. Stormwater runoff from fueling areas may be contaminated with toxic hydrocarbons, oil and grease, and metals.

1. Cover the fueling area with an overhanging roof structure or canopy so that rain or snow cannot come in contact with the fueling area.

2. Pave the fueling area with concrete and contain the area to prevent clean stormwater from running onto the fueling area and washing spilled fuel to the storm drainage system.

3. Install and maintain a spill control device such an oil/water separator or down-turned elbow in the appropriate storm drains to capture spills from the fueling area.

4. Never hose down the fueling area to the storm drains. Contaminated runoff must be collected for proper disposal.

5. Store and maintain appropriate spill cleanup materials near the fueling area. Spill cleanup materials should be clearly labeled. Ensure that employees are trained in proper spill cleanup procedures.

6. To minimize spills, post signs reminding customers not to top off the fuel tank when filling.

7. Use catch basin inserts, absorbent pillows, or other products designed for oil removal in or around storm drains on the property to filter oily runoff from vehicles. Please note these require frequent monitoring and replacement to be effective.

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Vehicle Repair and Maintenance

This applies to tire shops and automotive maintenance and repair shops. This activity can pollute stormwater runoff with toxic hydrocarbons, other toxic organic compounds, oil and grease, harmful pH and metals.

1. All vehicle repair and maintenance should be done indoors to minimize the chance of spilled liquids reaching the storm drains.

2. If work needs to done outside, use a ground cloth or drip pans beneath the vehicle or equipment to capture all spills and drips. Dispose of all collected spilled material properly.

3. Never wash tires or equipment outside where the water will drain to the storm drains.

4. Ensure employees are trained in the proper handling and disposal of all vehicle fluids.

5. Store and maintain appropriate spill cleanup materials near the container storage area. Spill cleanup materials should be clearly labeled. Ensure that employees are trained in proper spill cleanup procedures.

6. Sweep the area as needed to keep it clean. Clean up drips and spills immediately. Never hose down the area to a storm drain.

7. Use catch basin inserts, absorbent pillows, or other products designed for oil removal in or around nearby storm drains to filter oily runoff. Please note these require frequent monitoring and replacement to be effective.

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Landscaping and Garden Centers

This includes activities related to maintaining the landscaping on the property and also to garden center operations involving plant care. It includes vegetation removal, pesticide and fertilizer application, watering, and other gardening and lawn care practices. Stormwater runoff from areas where pesticides, fertilizers, and other chemicals are used may be polluted with toxic organic compounds, metals, oils, suspended solids, nutrients, and harmful bacteria.

The term pesticide includes insecticides, herbicides, fungicides, rodenticides, etc.

1. Always apply pesticides, fertilizers and other chemicals according to the manufacturer's directions.
2. Ensure pesticide applicators are properly trained and certified. Contact the appropriate local or state government agency for specific requirements and certifications required for your area.
3. Keep pesticide and fertilizer applications at least 100 feet away from surface water such as lakes, ponds, wetlands, and streams.
4. Never apply any pesticides directly to surface waters unless the application has been approved and permitted by the appropriate government agency.
5. Never apply pesticides or fertilizers when it is raining or about to rain. Ensure that runoff from garden center watering does not drain to the storm drainage system. Excessive watering after applying chemicals to plants may cause leaching of pesticides and fertilizers, leading to polluted runoff. Never pour lawn and garden chemicals or rinse water down storm drains.
6. Remove vegetation from ditches and other storm drainage facilities by hand or mechanical means. Use chemicals as a last resort.
7. Dispose of grass clippings, leaves, branches and other collected vegetation by recycling, composting or other appropriate disposal method. Never dispose of collected vegetation into any surface waters or storm drainage facility, including ditches and stormwater ponds.
8. Store pesticides and fertilizers inside or under cover and off the ground to prevent contact with stormwater runoff. Clean up any spills immediately and properly dispose of recovered materials.
9. Consider using the concepts of Integrated Pest Management in landscaping practices, a comprehensive pest control method that minimizes the use of pesticides.

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Building Construction and Maintenance

This applies to painting, pressure washing and other activities associated with building construction and maintenance. Stormwater runoff from these activities can be contaminated with toxic organic compounds, suspended solids, metals, harmful pH, and oil and grease.

These best management practices do not address erosion and sediment control (ESC) at construction sites. Contact your local permitting agency for ESC requirements.

1. Never dump any wash water or any other liquid waste on the pavement, the ground or storm drains.
2. Use ground cloths or another method to capture debris from outdoor scraping and sandblasting. Properly dispose of all collected waste.
3. Clean paint brushes and other tools in inside sinks or in containers that can be drained to the sanitary sewer. If oil-based paints are used, any waste paint and cleaning solvents must be properly collected for recycling or disposed of as hazardous waste.
4. When pressure washing buildings, protect the storm drains by using catch basin inserts or another method to remove any collected dirt and debris from the wash water runoff. If soap or other chemicals are used, the wash water must be collected for proper disposal.
5. Sweep areas as needed to collect waste and debris for proper disposal. Never wash any dirt and debris to a storm drain.
6. Keep spill cleanup materials nearby. Ensure that employees understand proper spill cleanup procedures.

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