LOW IMPACT DEVELOPMENT:
BARRIERS TOWARDS SUSTAINABLE STORMWATER MANAGEMENT PRACTICES IN THE PUGET SOUND REGION

by

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A Thesis: Essay of Distinction
Submitted in partial fulfillment
of the requirements for the degree
Master of Environmental Studies
The Evergreen State College
June 2003

This Thesis for the Master of Environmental Studies Degree

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June 12, 2003
Date

ABSTRACT

Low Impact Development: Barriers Towards Sustainable Stormwater Management Practices in the Puget Sound Region

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As a nonpoint source of pollution, stormwater runoff is a serious threat to water quality and quantity. The trend in stormwater management has been to devise complex designs to address increases in stormwater created by development. Conventional management methods have not adequately addressed either pollution prevention or factors relating to groundwater and surface water impacts.

Low Impact Development is an emerging technology-based approach to managing urban stormwater. The goals of Low Impact Development, known as LID, are maintaining or replicating the predevelopment hydrologic regime of a site and maximizing the use of upland landscape to treat runoff. Through careful site design, stormwater generated from an area within a watershed is more effectively and naturally utilized and managed, avoiding the impacts of development on water resources.

In the Puget Sound region, Low Impact Development has not often been the chosen tool for stormwater management. Parties involved in the development process cite different reasons for this occurrence, ranging from a lack of information and education/training to current economic systems. For the purposes of this paper, these barriers have been placed into two general categories, technical and philosophical. Recognition of these barriers in order to formulate strategies on how to address them will be crucial in making Low Impact Development a more common and attainable stormwater management strategy in this area.

Conclusions regarding the origin of the barriers to Low Impact Development have been made through interviews with development-related professionals and an analysis of the existing data on the promise of Low Impact Development and its implementation. As each of these barriers and their bases are recognized, suggestions and recommendations regarding what are necessary to overcome them follow.

In general, the technical barriers seem to serve as "red herrings" to avoid asking the more difficult questions (represented by the philosophical barriers) regarding society, philosophy, and change.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

A very sincere thank you to all of those contributing to this paper in one way or another. This includes Carolyn Dobbs, Larry Coffman, Derek Booth and Eric Hielema in particular. A huge thank you is also in order for all of my co-workers at the City of Lacey. Each of you has succeeded in helping make this adventure possible. Last but definitely not least, thanks to my family for helping me believe and for helping me remember to have a sense of humor!

Chapter 1

Introduction

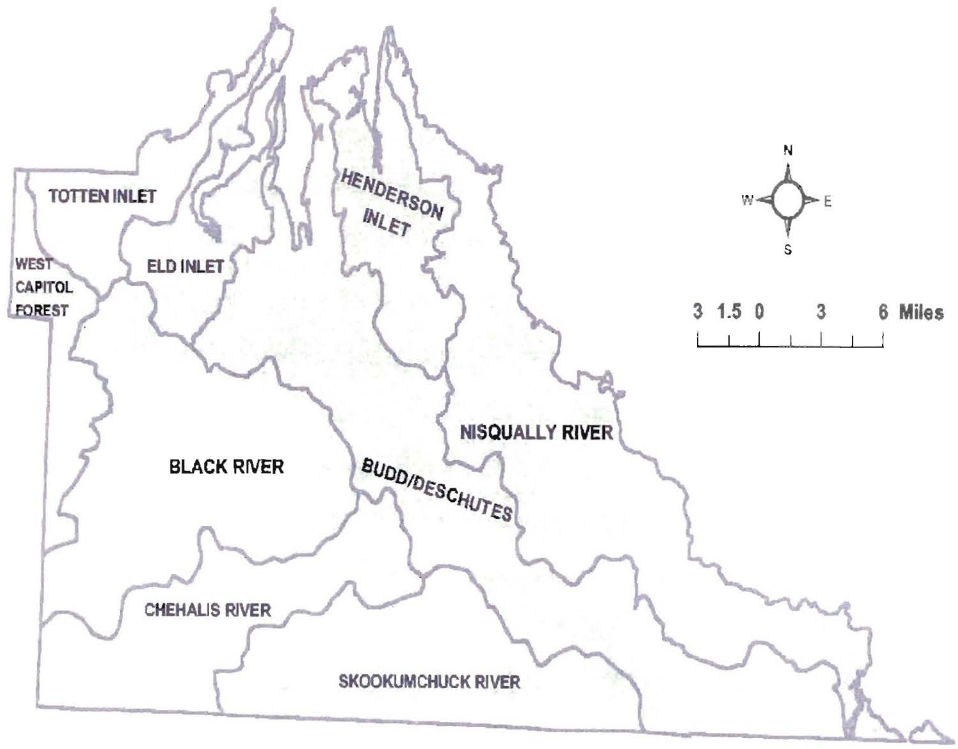
Thurston County has been one of the fastest growing counties in the state of Washington since the 1960's, consistently exceeding the state's overall growth rate. Between 1990 and 2000, 46,000 new residents have been added to the county's population (TRPC II-1). The Central Puget Sound region, made up of King, Pierce, Kitsap and Snohomish counties, is one of the most rapidly growing and urbanizing regions in the United States. Here, the total population has increased by 19.2% since 1990 (over 480,000 new residents), with a 48% increase in incorporated land since 1990 (Alberti 4).

The expansion of cities and increasing urbanization triggers a change in land cover. Previously undeveloped or "natural" areas are converted to urban areas, including such features as roads, buildings, and lawns. In the last 15 years, the large-scale change in land cover detectable from satellite imagery indicates that in Thurston County, approximately 32,000 acres of land were converted from intact forest stands, agricultural lands, or large expanses of shrub vegetation to urban landscapes (TRPC VIII-2).

Watersheds within Thurston County experiencing the greatest percent of urbanization over the last 15 years are Henderson Inlet with 14% and Black River with 10%. Rural basins within Thurston County that have experienced rapid changes in urban land cover in the last 15 years include the Budd/Deschutes Watershed with a 19% increase, Henderson Inlet with a 25% increase, and the Nisqually River Watershed with a 27% increase (Figure 1) (TRPC VIII-2).

One significant land cover change resulting from development and urbanization is an increase in impervious surfaces, which has numerous associated impacts on water systems such as inhibiting precipitation from infiltrating the soil, changing local hydrology, and increasing pollution sources. It is generally believed a watershed's natural hydrology can continue to function without any significant water quality problems until impervious cover reaches 10% to 20% within the drainage basin (NRDC 2; Ballantine, Clarke and Wilding 54; Aponte Clarke et al 130). As a result of an increase in impervious surfaces and soil compaction, rainfall that had previously infiltrated the soil or been stored on site becomes stormwater runoff, which must be collected and disposed of to protect downstream properties from potential flooding increases.

Map1 - Thurston County Watersheds



-Source: Thurston Regional Planning Council, 2002-

The lack of the ability of water to permeate the soil on a developed site inhibits the area's natural hydrological cycle, resulting in less groundwater recharge as well as altered surface water flows. Within highly developed urban areas, the loss of tree canopy and shrubs further degrades the watershed's ability to remove considerable quantities of precipitation through interception and evapotranspiration (Ballantine, Clarke and Wilding 54). Predevelopment, natural surface runoff can range from 10 to 30% of total annual precipitation. Alteration through development can result in increases to over 50% (PGC 3-6).

Stormwater runoff from urbanized areas typically poses two major problems in watershed basins: increased volume and velocity from impervious surfaces, and the concentration of pollutants in the runoff (NRDC 1; Aponte Clarke et al 129). Impervious surfaces and compacted soils prevent rainfall from infiltrating the soil, creating sudden rushes of water in receiving streams during a storm. The increased volume and increased velocity of runoff can cause streambed scouring and erosion in the receiving body, further contributing to water quality and habitat degradation (Ecology, Final Plan 154).

Conventional stormwater management approaches usually involve very efficient site drainage through the use of curbs, gutters, and pipes. The intent of a Best Management Practice (BMP) is to create a drainage system that will prevent on-lot flooding, promote good drainage and quickly convey runoff, commonly to a pond (US EPA, Literature Review 1). BMPs are defined by the Washington State Department of Ecology as "Schedules of activities, prohibition of practices, maintenance procedures, managerial practices, or structural features that prevent or reduce adverse impacts on waters of Washington State" (Manual I-2). These facilities drain excess rainwater from the site providing excellent on-site drainage, but greatly altering the natural hydrologic regime of a site and providing a higher pollutant transport capacity (PGC 3-8).

On an undeveloped site, many of these pollutants are removed from water as it infiltrates through soils and vegetation. When collected in detention structures, stormwater has generally not undergone the levels of treatment inherent in natural systems and can be released into receiving waters with increased and concentrated pollutant quantities.

Objectives

The focus of this paper is primarily on the impacts to water systems resulting from the effects of development through land cover change and it was formulated with two main objectives in mind. The first objective was to provide evidence of the effectiveness of LID and the second was to identify the barriers to its implementation, particularly in the Puget Sound region. The first half of this paper focuses primarily on the first objective, and indicates the promise of Low Impact Development. The primary means of addressing the second objective were an analysis of the existing data regarding Low Impact Development, including projects that have gone forward, interviews with professionals having experience with these types of proposals, and an analysis of stormwater management issues in general.

Importance of Stormwater Related Issues – Problem Statement

Stormwater management is an important issue in Washington State, especially in the Puget Sound region, which is an extensive area of potential receiving waters. As a nonpoint source of pollution, stormwater runoff will continue to be recognized as a serious threat to water quality and quantity. Therefore, efforts must be made to ensure stormwater management techniques adequately address not only pollution prevention, but also factors relating to groundwater and surface water impacts.

Despite significant development regulations, the contribution of stormwater to the degradation of our water resources has continued. The following chapter outlines some of the specific impacts of stormwater on water resources. The trend in stormwater management has been to devise more complex designs to address increases in stormwater created by development, while its ultimate goal has always been to mimic the natural hydrology of a site. BMPs most commonly collect and detain runoff and generally involve discharging it into a receiving body once a certain water level is reached within the detention structure (Ecology, Manual I-5). However, shortfalls inherent in conventional BMPs are beginning to be recognized, which work against their effectiveness in mimicking the natural hydrology of a site.

One emerging stormwater management tool that can be used to more adequately accomplish the goals of pollution prevention and natural hydrological mimicry is Low Impact Development (LID). LID is a practice that some stormwater professionals believe is not only more effective but also can be achieved at lower economic costs as well as being more aesthetically attractive than traditional BMPs. These statements will be further explored in the following chapters.

In general, Low Impact Development is a technology-based best management practice with the goal of maintaining the predevelopment hydrologic functions of a site. This is accomplished through minimizing the disturbance of the site by reducing the use of impervious surfaces and the utilization of natural features to maintain natural drainage patterns and mitigate pollution (Coffman 158). Through site design, the stormwater generated from an area within a watershed is more effectively and naturally utilized and managed, helping avoid the impacts of development on water resources and maximizing the beneficial uses they provide.

LID has not often been the chosen tool for stormwater management in the Puget Sound region. The purpose of this research is to understand why, through an analysis of existing data and literature on LID and communications with various parties involved in the development process. The first objective is to explore and present the potential of LID. The second is to identify the barriers to its implementation. I hope to gain an understanding of these barriers that can then be used to make recommendations regarding information or actions that will required to overcome them. At completion, this paper will be able to serve as a source of information regarding the usefulness of LID and provide some specific examples of where it has been successful and why.

The information included in this paper will also examine the relationship of LID to conventional stormwater management techniques. Presentation of the case studies where LID has been used serves to highlight its effectiveness in terms of cost savings to the developer and avoidance of water quality and quantity impacts. The conclusions and recommendations provide guidance on issues that need to be addressed to overcome the barriers to LID

Chapter 2

Effects of Stormwater Runoff on Groundwater

The protection of Washington's groundwater resources is vital in maintaining instream flows and water quality in the state's streams and lakes during summer months. Groundwater contributes significantly to our surface water bodies; the estimated base flow contribution for streams is 70% (Ecology, Final Plan 18). When land is compacted or paved in urban areas, significant reduction of recharge and of summer streamflow results. Water that flows as storm runoff is not able to recharge the groundwater to supply baseflow during dry weather. Low flows are therefore exacerbated, decreasing water quality during the summer months (Dunne and Leopold 277).

In addition to groundwater recharge and the maintenance of stream flow, groundwater is also a source of drinking water. In Washington, groundwater provides approximately 60% of the drinking water (Ecology, Taking Action 5). If contaminated by runoff, groundwater has the potential to cause significant health problems The Washington State Department of Ecology identifies contamination of groundwater due to nonpoint sources as apparently the most significant widespread threat to groundwater quality in Washington (Final Plan 19). This is of particular concern as the Department of Ecology expects an increased demand on groundwater as the population grows from current levels to an estimated 11 million by the year 2045 (Final Plan 18).

Effects of Stormwater Runoff on Surface Waters

Stormwater affects surface water flows primarily through increased volumes and velocities (peak rates) of runoff (NRDC 1). In particular, when compared to natural systems that infiltrate and slowly release runoff, areas of urban development result in increased peak flows in winter, and reduced base flows in summer (Ecology, Taking Action 3). In most natural, undeveloped watersheds, runoff is slowed at every point along the flow path by a hierarchy of vegetation and soft soils allowing infiltration into the groundwater and then into streams, and swales, creeks, and streams that meander and are covered with vegetation (Sonnenberg 106). This natural slowing attenuates runoff by allowing lower reaches of a watershed to flow into streams and dissipate before runoff from the upper watershed arrives at the lower reaches of the streams.

The variable that describes this process is called the Time of Concentration, or Tc. The time of concentration is defined as the time it takes water from the most distant point in a watershed (hydraulically) to reach the watershed outlet. Tc typically decreases as imperviousness increases (PGC 3-7).

Development can increase velocities along the natural flow path because of the associated compaction and paving, storm drain piping, minimal infiltration, vegetation removal, creek bank lining, and straightening of stream channels. These changes can increase stormwater runoff rates up to three times, allowing the stormwater from the upper watershed to enter the lower stream channel before the lower reaches have a chance to dissipate (Sonnenberg 106). Such changes to a natural regime in a comparatively small area often bring significant and even disastrous effects on the whole river basin downstream of the city (Niemczynowicz 2).

Effects of Stormwater Runoff on Water Quality (Water Pollution)

When discharged into receiving waters, stormwater is classified as a nonpoint source of pollution. The Washington State Legislature has defined nonpoint pollution as: "pollution that enters any water of the state from any dispersed water-based or land-use activities, including, but not limited to, atmospheric deposition, surface water runoff from agricultural lands, urban areas, and forest lands, subsurface or underground sources, and discharges from boats or other marine vessels" (Ecology, Final Plan 13). The U.S. EPA estimates that more than 60% of Washington's water pollution problems are a result of nonpoint sources. Urban areas are the third most significant contributor to nonpoint pollution, despite their relatively small share (2%) of land coverage in Washington (Ecology, Taking Action 10). In combination with specific contaminants, runoff from impervious surfaces delivers nutrients, sediments, fecal contamination, and toxic chemicals to stream systems, affecting stream pH and temperature (Ecology, Final Plan 15).

According to the Department of Ecology, the primary water pollution problems in Washington are high temperature, pathogens, pH, low dissolved oxygen, metals, and nutrients (Final Plan 5). Most of these problems are caused by nonpoint pollution. Urban areas are one category of six major sources of nonpoint pollution, contributing through stormwater, on-site sewage systems, hazardous materials, and construction and maintenance of roads and bridges (Ecology, Final Plan 5). Stormwater runoff in particular contributes to nitrogen pollution, erosion and sedimentation, pH alterations, pesticide contamination, and changes in water temperature (Ecology, Final Plan 7; NRDC 2).

In nearly all cases, urban development is the main source of phosphorus, which ultimately ends up in lakes (Ecology, Final Plan 15). Impacts to estuaries from upland development include excess nutrients and toxics and increases in bacteria counts, which result in shellfish harvesting downgrades and closures and in some extreme cases, complete swimming prohibitions (Ecology, Final Plan 17). Other sources of nonpoint pollution associated with urbanization include misuse of pesticides and fertilizers, household hazardous wastes, landfills, underground storage tanks, waste oil, tires, batteries, etc. (Ecology, Final Plan 181).

Temperature in water quality samples has shown a nearly 2% increase in sample failure rates in the past 20 years. Sample failure rates are the percent of the total number samples that fail to meet standards or limits set forth for their particular occurrence (Ecology, Final Plan 22). Fecal contamination is the only parameter of four: (pH, temperature, fecal contamination, and dissolved Oxygen), that has shown a decline in sample failure rates, nearly 5% (Ecology, Final Plan 24).

Laws and Regulations Pertaining to Stormwater

Recognizing that stormwater runoff from urban areas poses a threat to receiving waters, the following is a brief outline of federal, state, and local regulations that have been formulated to address aspects of its control, and attempts to confront the problems presented above.

Comprehensive stormwater regulation is required under Section 402(p) of the Clean Water Act. Since 1992, certain industries, cities with populations over 100,000, and construction sites over 5 acres have been required to develop and implement stormwater management plans under Phase I of the National Pollutant Discharge Elimination System (NPDES) stormwater regulations. Originally planned for October of 1999 but now for March 2003, new United States Environmental Protection Agency (EPA) rules, outlined in the "Stormwater Phase II Final Rule", will be implemented requiring municipalities with populations fewer than 100,000 located in urbanized areas (defined as those with population densities>1,000 persons per square mile) to develop stormwater plans. This requirement is known as NPDES Phase II.

Various additional regulations exist on the federal level. The planning provisions of Section 6217 of the federal Coastal Zone Act Reauthorization Amendments (CZARA) require states with coastal areas to develop and implement comprehensive nonpoint source programs in those areas. The planning provisions of Section 319 of the federal Clean Water Act (CWA) also require states to develop comprehensive nonpoint source control programs. Section 320 of the CWA created the National Estuary Program, and although not a requirement for creation of state nonpoint source control programs, the EPA subsequently adopted the Puget Sound Plan as a Comprehensive Conservation and Management Plan for the Puget Sound Estuary, which also strives to control nonpoint sources of pollution. Indirectly, the Endangered Species Act (ESA) relates to stormwater as it has the potential to affect salmonids and other species through stream flow and habitat alteration.

On a state level, the 1998 Watershed Planning Act enacted by the Washington State Legislature establishes a framework to identify and rectify problems with water quality, quantity, and aquatic habitat. The Legislature also formulated the Salmon Recovery Act. Both of these planning processes identified nonpoint source pollution as one of the primary causes of impairment of water quality and salmon habitat in Washington State. Revised Code of Washington (RCW) section 90.48 is Washington's Water Pollution Control Act. RCW 90.48 and the CWA designate the Washington State Department of Ecology (DOE) as responsible for water quality.

The Puget Sound Water Quality Action Team, now Puget Sound Action Team (PSAT), is responsible for program planning and overseeing implementation of the Puget Sound Plan, referenced above. RCW 36.70A, the Growth Management Act (GMA), provides legislative direction to local governments, requiring them to develop policies and regulations to ensure the designation and protection of critical areas. The GMA is based on RCW 36.70, the Washington State Planning Enabling Act.

The Shoreline Management Act, RCW 90.58, declares that the interest of all of the people shall be paramount in the management of shorelines of statewide significance. The Department of Ecology, in adopting guidelines for shorelines of statewide significance, and local governments, in developing master programs for shorelines of statewide significance, shall give preference to uses in the following order of preference which: (1) Recognize and protect the statewide interest over local interest; (2) Preserve the natural character of the shoreline; (3) Result in long term over short term benefit; (4) Protect the resources and ecology of the shoreline; (5) Increase public access to publicly owned areas of the shorelines; and (6) Increase recreational opportunities for the public in the shoreline.

Washington Water Quality assessments are done based on data collected by the Department of Ecology and other agencies. These assessments determine if water quality standards are being met, and beneficial uses being protected. The results are reported semi-annually to the EPA in a "305(b)" report, named after section 305(b) of the Clean Water Act.

As a result of the regulations above, various programs have been developed to address surface water, groundwater, and aquatic habitat in Washington, particularly the Puget Sound region. Listed here are those relating to stormwater.

At a state level, under the Watershed Planning Act (90.82 RCW, bill number HB2514), by April 2000 thirty nine of sixty two Water Resource Inventory Areas (WRIA) had begun the Watershed Planning Process, which establishes processes to assess the availability of water, develop base instream flow levels, protect water quality, and restore fish habitat. Under the Salmon Recovery Act, 75.46 RCW, bill number SB5995, forty-one WRIAs are now involved in limiting factor analyses. The intent of this act is to address salmonid habitat restoration in a coordinated manner.

Local governments are working to coordinate the Watershed Planning Act (WPA) and the Salmon Recovery Act (SRA). The data and habitat information gathered during the SRA process can provide baseline information to a WPA planning unit for the instream flow and optional habitat plans. Under the Statewide Strategy to Recover Salmon, required by the SRA above, an "Early Action Plan" was developed that specified activities related to salmon recovery that state agencies would undertake. Many of the early actions were nonpoint source control activities.

Watershed Analysis, adopted into regulation under Washington Administrative Code (WAC) 222-22, includes a biological and physical assessment of a watershed, followed by development of "prescriptions" designed to protect and restore public resources. The Washington State Department of Natural Resources (DNR) approves these prescriptions after public comment through the State Environmental Protection Act (SEPA). The Puget Sound Water Quality Management Plan and Local Watershed Action Plans are promulgated through the planning processes in WAC 400-12. The purpose of these plans is to identify, correct, and prevent nonpoint source pollution, and protect beneficial uses of water. Later plans also deal with habitat restoration and protection. Coordinated Water Systems Plans serve to integrate water utility development with land use planning. They include Source Water Protection Plans, Watershed Control Programs, Wellhead Protection Programs and Conservation Plans. Under NPDES Phase I, development and construction requirements and Best

Management Practices are established by the Washington State Department of Ecology in the September 2001 manual.

Regionally, the Puget Sound Action Team produces the Puget Sound Water Quality Management Plan under RCW 90.71, the Puget Sound Water Quality Protection Act. The purpose of the Action Team is to coordinate the activities of state and local agencies by establishing a biennial work plan. This work plan delineates actions necessary to protect and restore the biological health and diversity of the Puget Sound, and implement the Water Quality Management Plan to the maximum extent possible.

Counties and cities have adopted various ordinances aimed at protecting water resources. With regards to Low Impact Development, in Thurston County the cities of Lacey and Tumwater have each adopted standards relating to zero effective drainage discharge. These standards can be found in Lacey Municipal Code Title 14.31, and Tumwater Municipal Code 13.22. The city of Olympia has adopted Low Impact Development regulations for the Green Cove Basin, and at this time the Thurston County planning department does not have specific regulations pertaining to LID proposals.

CHAPTER 3

Conventional Stormwater Management

Conventional stormwater management centers around the use of BMPs, generally designed to prevent or reduce the impacts of stormwater on the waters of Washington State (Ecology, Manual I-4). Storms of various intensities, recurrence intervals, and resulting volumes of runoff are used to size and design BMPs. Storms with 2- and 10-year return intervals are commonly used for subdivision, industrial, and commercial development design (PGC 3-4). Long term BMPs are subdivided into those that manage the volume and timing of stormwater flows, prevent pollution from potential sources, and treat runoff to remove sediment and other pollutants (Ecology, Manual I-5).

BMPs that prevent pollution or other adverse affects from occurring are called source control BMPs. The Washington State Department of Ecology has called this type "generally more cost effective" than the others (Manual I-5). Treatment-type BMPs include facilities that remove pollutants, and 'facilities' involve the construction of engineered structures. Flow control-type BMPs typically manage flow rate and frequency and flow duration of stormwater surface runoff (Ecology, Manual I-5).

The most commonly used stormwater management practice has been to manage flows through the use of detention ponds, which are intended to capture and detain stormwater runoff from developed areas (Booth 4). The on-site drainage management approach relies on facilities designed to control peak flows primarily for a given storm size and does not control those storm events smaller than the design storm (PGC 3-9). The runoff from storms smaller than the design size bypass the facility and are routed directly to an outlet structure (Ritter pers. comm. 3/5/03). The higher pollutant transport capacity of on site drainage systems is a result both of pollutants collecting in a single centralized facility and of smaller storms bypassing the facility altogether.

The notion of "first flush" can be used to demonstrate a shortcoming of conventional stormwater management systems particularly in relation to pollution. "First flush" alludes to the fact that pollutant concentrations tend to be much higher at the beginning of a storm, compared to the middle or end of an event. This is based on the fact pollutants have accumulated on site since the last storm event. Therefore, a much smaller volume of runoff storage is technically needed to treat and remove urban pollutants than that provided in a BMP, because 90% of the annual pollutant load is found in the first half inch of runoff. This is most pronounced for highly impervious areas. At greater than 50% impervious cover, the rate of pollutant load capture drops off sharply. Only 78% of the annual load is captured at 70% impervious cover, and only 64% is captured at 90% impervious cover (Holland and Schueler 88).

A different type of pollution-related problem with the extensive use of on site sewer systems is that in some areas, distinction between pluvial drainage and household sanitary sewer systems hardly exists. For example, in Santa Catarina, Brazil, 71% of the municipalities are endowed with household sewers connected to storm sewers (Pompeo 157). In situations where these systems are combined, an overflow in the storm sewer system can cause an overflow in the household sanitary sewer system, resulting in human waste overflows into receiving waters, known as combined sewer overflow (CSO).

Since pollution control is designed into some source control and treatment type Best Management Practices, certain BMPs do have the capability to treat stormwater runoff at certain levels. However, one limitation of "end of pipe" (after the fact treatment and flow control-type) BMP installations is that they often cannot account for the cumulative impacts of individual land uses. These individual land uses generate relatively few pollutants by themselves, but collectively can have a significant adverse impact on the water quality of the receiving water bodies in the region (Kunz 39). Although traditional stormwater control measures have been documented to remove pollutants effectively in some situations, the natural hydrology of a site is still affected (US EPA, Literature Review 1).

It has been documented that nearly all water quantity problems stemming from development result from one underlying cause: loss of the water retaining function of the soil in the urban landscape (Booth and Leavitt 314; Booth 3).

"Urban soils" tend to be highly compacted, poor in structure, and low in permeability. Pitt (1993) noted one-third of the disturbed soils he tested had an infiltration rate of zero or near zero, exhibiting the same runoff response as concrete or asphalt (Holland and Schueler 235). Typical runoff calculations often significantly underestimate the amount of rainwater that runs off a site, due to the fact much of the runoff from a constructed site exists because native soils are removed and no amendments are replaced on top of the compacted layers (Kunz 40).

The magnitude of hydrologic change (increases in volume, frequency, and rate of discharge) is amplified as natural storage is lost on a developed site. Typical conventional site design results in developments devoid of natural features that increase travel times and that detain or infiltrate runoff. The amount of impervious surface is increased, the time of concentration is decreased, runoff travel times are decreased, and the degree of hydraulic connection is increased (PGC 1-5). The lack of natural features typically adversely affects the ecosystem, and trying to control or restore these functions using after the fact management techniques is difficult, if not impossible (PGC 2-4).

In addition to the hydrologic changes outlined above, efficient on-site drainage systems result in a significant increase in off-site flooding potential, as well as high downstream environmental impacts associated with increased peak flows and their frequency of occurrence, higher storm flow volumes, and increased delivery of pollutant loads (US EPA, Literature Review 9). Post-development conditions on sites with conventional stormwater BMPs result in hydrographs exhibiting significant increases in the runoff volume and duration of runoff from the predevelopment condition (PGC 3-3).

Taken as a whole, there are several drawbacks to attempting to hold all runoff in a central facility, removed from a developed area. First, construction and maintenance of stormwater facilities are erratic, often with a divergence between design targets and actual performance. Second, there are practical limits to applying drainage regulations to individual small-scale land developments (Booth and Leavitt 315). Jurisdictions usually set a "threshold of concern" for nearly all development activities, above which all regulations apply, below which regulations are minimal or absent. For example, King County between 1987 and 1992 stipulated a minimum 0.50 cubic foot per second (cfs) increase in runoff (which is equal to about 0.5 acres impervious surface) before mitigation was required. However, permit activity between this time indicated about one-quarter of the impervious areas added to the County's watershed was in individual developments below this threshold, and so was constructed without any detention facilities at all (Booth and Leavitt 315).

Finally, even the largest and best-designed stormwater ponds cannot transform precipitation during the wet season into base flow during the subsequently dry season; detention times are simply too brief (Booth and Leavitt 315; Booth 6).

The next section includes a discussion of LID; followed by ways it can address many of the shortcomings of conventional stormwater management techniques outlined in this section.

Low Impact Development

Low Impact Development (LID), pioneered by Prince George's County, Maryland, is a comprehensive, technology-based approach to managing urban stormwater (PGC 1-3). LID has a goal of maintaining or replicating the predevelopment hydrologic regime on a site through the use of design techniques, to create a functionally equivalent hydrologic landscape (US EPA, Literature Review 1). The LID approach attempts to match predevelopment conditions by compensating for runoff through the maintenance of infiltration potential and surface storage, conservation of natural soils, evapotranspiration through the preservation of vegetation, as well as increased travel times to reduce a rapid concentration of excess runoff. A second goal of LID is to maximize the use of upland landscape with its soil/plant/microbe complex to treat runoff (Coffman 165). The combination of these goals is intended to avoid both the water quality and quantity impacts of development on a watershed.

Elements fundamental to understanding LID include impact avoidance versus minimization in an effort to maintain the ecological functions of the receiving waters and determination of appropriate technological tools. It is essential that technologies and tools be appropriately integrated into a site to avoid impacts to terrestrial and aquatic systems, thereby avoiding impacts to or disturbance of the overall ecological functions of receiving waters. Impact avoidance is better for maintaining ecological function in its entirety than impact-minimizing techniques (Coffman, pers. comm. 4/25/03).

LID consists of five major components: Site Planning, Hydrologic Analysis, Integrated Management Practices, Erosion and Sediment Control, and Public Outreach Programs (PGC 1-6). Following is a brief description of three of these components and what they involve.

Site Planning: LID site planning requires that hydrological goals be incorporated into the site planning process as soon as possible (PGC 2-1). This involves defining a development envelope with respect to the site's hydrology and preserving areas that affect it. The purpose is to find the development envelope that will have the least impact on the site while maintaining natural hydrologic features, maximizing undisturbed areas, and preserving environmentally sensitive areas. This involves evaluating layouts to reduce, minimize, and disconnect direct connections of the total impervious area at the site (PGC 2-3). Additional benefits can be derived by designing for water flow from impervious to pervious cover as 'runon', thereby significantly reducing the volume of runoff, and possibly of stormwater pollutants as well (Holland and Schueler 235).

Hydrologic Analysis: The preservation of the predevelopment hydrology is evaluated by comparison of pre and post development hydrologic conditions (PGC 3-10). Four hydrological functions should be analyzed when investigating the effectiveness of LID practices: Runoff curve number (CN), time of concentration (Tc), retention, and detention (US EPA, Literature Review 9). Curve number is an empirical rating of the hydrologic performance of a large number of soils and vegetative covers throughout the United States (Dunne and Leopold 291). Time of concentration was defined in Chapter Two, and refers to the time it takes for runoff from the farthest reaches of a watershed to reach the outlet. Retention and detention of rainfall are the key components of increases in Tc (US EPA, Literature Review 10). Maintaining the predevelopment Tc involves maintaining the predevelopment flow path length by dispersing and redirecting flows (generally through open swales and natural drainage patterns), increasing surface roughness, detaining flows, minimizing disturbance, flattening grades in impacted areas, disconnecting impervious areas, increasing interception, increasing or preserving natural depressions and storage, and connecting pervious and vegetated areas (PGC 3-19).

Integrated Management Practices: Specific LID controls are called Integrated Management Practices (IMPs), which integrate stormwater control throughout a site in many small discrete units (micromanagement) at or near the source of impacts, virtually eliminating the need for a centralized Best Management Practice (PGC 1-3). The goal is to select an appropriate combination of management techniques that simulate the hydrologic functions of the predevelopment condition to maintain the existing CN and corresponding runoff value (Coffman 162). IMPs provide controls to mitigate or restore the unavoidable disturbances at a site using an at-source control approach, in contrast to conventionally used end-of-pipe control methods (PGC 2-1). These controls more closely mimic a natural site than conventional management practices in that they are relatively more evenly distributed throughout a site, as are natural features on an undeveloped site. In addition, they are likely more cost effective if the Department of Ecology's assessment regarding the relative cost effectiveness of source controls is accurate.

Most of these controls are site-specific and are designed to be simplistic and non-structural. Controls include such practices as bioretention, grass swales, vegetative roof covers, and permeable pavements. Other LID strategies include such things as implementation of rain gutter disconnects (redirect rain flow out of gutters and storm sewers into functional landscape devices), shared driveways, rain barrels, cisterns, and attention to the design of residential streets (US EPA, Literature Review 8). Some BMPs, although not the most commonly used, mirror these IMPs. On sites where LID is implemented, the volume of flow in closed channels (pipes) should be minimized to the greatest extent possible (PGC 3-21).

The Erosion and Sediment control component of LID, component four, primarily applies to construction site activities. As the focus of this paper is primarily on the impacts to water systems from the effects of development through land cover change, this component will not be explored in any detail. Additionally the fifth component, the Public Outreach component, will not be explored in detail; however, this should not diminish its importance. In general, public outreach involves encouraging and educating property owners about the use of effective pollution prevention measures and the maintenance of individual controls (Coffman 165; Kunz 39). Details on the Public Outreach Program Prince George's County implemented can be found in Low Impact Development Design Strategies: An Integrated Design Approach.

Specific technical explanations and evaluations of each of these controls are beyond the scope of this paper; however, both Prince George's County and the US EPA have published information on these aspects. Costs and financial considerations of Low Impact Development and conventional stormwater practices will be discussed in more detail at the end of this chapter.

Overall, Low Impact Development is based on the ideal that the most effective stormwater strategies enhance natural processes, recognizing efforts such as buffer zones and sensitive area protection (Aponte Clarke et al 132). It can be thought of as a new philosophical approach to site development, one that will allow the designer to retain the natural hydrologic functions of a particular site and focus on the avoidance of impacts to receiving streams rather than their minimization. LID borrows basic principles from nature, primarily the uniform distribution of micro-management controls. Site design techniques ensure every development feature (green space, landscaping, grading, streetscapes, roads, and parking lots) can be designed to provide some type of beneficial hydrologic function, such as infiltration or maintenance of the time of concentration (Coffman 160).

Low Impact Development Versus Conventional Stormwater Management

As outlined in the previous section, one of the main goals of LID is to preserve the predevelopment hydrologic regime of a site. One of the most significant differences between conventional stormwater management practices and LID is that LID controls runoff from the full range of storm events, including that of storms smaller than the conventional facilities' design storm (PGC 3-1). While still providing for on-site drainage, it strives to avoid hydrological alteration and pollutant transport capacity resulting from development, rather than minimizing them as when traditional management approaches are employed.

Manning's roughness coefficient ("n") represents the boundary resistance to the flow and velocity of a water body based on the makeup of its boundary. For example, a smooth concrete channel would have a lower "n" value than a natural stream, causing less friction than a natural stream and thereby producing less drag or resistance to affect the discharge or velocity of the stream (Dunne and Leopold 593). Using LID techniques to maintain the predevelopment time of concentration effectively shifts postpeak runoff times to that of predevelopment conditions and lowers peak runoff rates. This can be accomplished in a small watershed because LID controls can maintain or raise the Manning's roughness coefficient for the initial overland (sheet) flow at the top of the watershed (PGC 3-20), which can increase flow path length to the most hydraulically distant point in the drainage area.

LID is centered on the premise that using micro-management to control both runoff discharge volume and rate is the key to replicating predevelopment hydrology. Using LID practices also produces runoff frequencies that are much closer to predevelopment conditions than can be achieved through the application of conventional BMPs. Hydrograph analysis showed using *just* LID site planning techniques (no IMPs) resulted in a significant reduction in both postdevelopment peak rate and volume in postdevelopment hydrographs (PGC 3-18). This is an illustration of implementing compensation or restoration of hydrologic functions as close as possible to the point or source where the impact is generated

With reference to particular LID controls, vegetative rooftops have been used extensively in Germany for more than 25 years. Results show up to a 50% reduction in annual runoff (volume) in temperate climates (US EPA, Literature Review 8). A biodetention system (essentially a filter with native grasses and a rock berm), disperses concentrated flow to sheet flow, in an effort to maintain the time of concentration, decrease peak runoff volumes and rates, and increase infiltration to predevelopment levels (Murfee, Scaief and Whelan 47).

In a 2000 review of literature regarding Low Impact Development, the US EPA presented an analysis of fourteen LID practices for effectiveness using the four components of LID hydrologic analysis (Literature Review 9). As a recap, these four components are a lower postdevelopment CN (curve number), an increase in the time of concentration, retention functions, and detention functions. Of the fourteen practices, eight resulted in lower postdevelopment CN, twelve increased the time of concentration, seven effectively functioned as retention, and three as detention. Through these various comparisons, six of the fourteen practices were classified as "good", meaning they functioned effectively under at least three of the four hydrologic analysis components. These six practices were vegetative filter strips, rain barrels, rooftop storage, bioretention, revegetation, and vegetation preservation (9).

In addition to runoff volumes and velocities, one of the major drawbacks to conventional stormwater management illustrated in the first section of this chapter is water quality protection. One example outlined the notion of "first flush", referring to the relatively high pollutant concentrations found in the first half inch of runoff from a developed site. In terms of pollutant removal measures, LID provides a higher level of water quality treatment controls due to runoff volume controls of the first flush as opposed to conventional systems (US EPA, Literature Review 10). This is because conventional Best Management Practice facilities are designed to allow runoff from storms smaller than the design storm to bypass the system, which is not the case with LID micro controls. In general, by increasing the time of concentration and decreasing the flow velocity, LID practices result in a reduction in pollutant transport capacity and overall pollutant loading (US EPA, Literature Review 10). The Department of Ecology's Final Washington Nonpoint Source Management Plan recognizes, "Future development using today's BMPs will continue to exacerbate the situation" (15).

The majority of the available data on LID controls and pollution have centered on bioretention systems. Generally, the experimental data show a fairly consistent removal rate for all of the tested bioretention systems for heavy metals and most nutrients (US EPA, Literature Review 31). In a study conducted in Ontario, Canada, a loading comparison revealed that the system released significantly fewer pollutants than conventional systems (US EPA, Literature Review 32). Additionally, as a result of the increased vegetation used in bioretention, sediment trapping is increased (Murfee, Scaief and Whelan 47).

LID has additional benefits not specifically related to runoff velocities, volumes, or pollutants. For example, a major technical advantage of LID micromanagement techniques is that one or more of the systems can fail without undermining the overall integrity of the site control strategy (PGC 2-5). Failure of a conventional pond or other single facility would not have the same result. In addition, LID provides a much greater range of control practices that can be adapted to specific site conditions. It can provide functions such as volume control and the maintenance of predevelopment groundwater recharge, thereby compensating for significant alterations of infiltration capacity while adding aesthetic value (PGC 2-1).

LID provides many opportunities to retrofit existing highly urbanized areas with pollution controls, as well as to address environmental issues in newly developed areas (US EPA, Literature Review 3). In urbanizing watersheds, less and less land is available for mitigation and implementation of regional management alternatives (SPAC 4). In existing highly urbanized areas, permeable pavements and vegetative rooftops are two ways to reduce impervious surfaces (US EPA, Literature Review 3). In addition, developers can implement LID in retrofits by disconnecting impervious surfaces from conventional drainage infrastructure and installing LID integrated management practices to capture and treat runoff (NRDC 2).

As noted previously in this chapter, LID urban landscape or infrastructure features can be designed to be multi-functional. For example, in a bioretention cell, the tree canopy provides interception and hydrological and habitat functions, the 6 inch storage depth provides for the detention of runoff, soils, organic litter and mulch provide pollutant removal and water storage, planting bed soils provide infiltration, pollutant removal, and groundwater recharge, and evapotranspiration is provided by plant materials (PGC 2-5).

While providing a more environmentally benign alternative for stormwater management, there are potential constraints to LID that must be acknowledged. For example, not all sites are suitable for LID. Considerations such as soil permeability, the depth of the water table, and slope must be considered, in addition to other factors (US EPA, Literature Review 3). A designer must carefully consider how best to make use of the hydrologic soil groups and site topography to help reduce and control runoff (Coffman 160). Further, the use of LID may not completely replace the need for conventional stormwater controls, depending on specific site limitations (US EPA, Literature Review i). The use of LID may necessitate the use of structural BMPs in conjunction with LID techniques in order to achieve watershed objectives (US EPA, Literature Review 3).

In addition, LID maintenance issues can be more complicated than for conventional stormwater controls because the LID measures reside on private property (US EPA, Literature Review i). However, it is also more likely for a homeowner to monitor and maintain these controls than traditional stormwater ponds, because of their location on one's property and the fact that it contributes to or takes away from the total value of the property (Coffman, pers. comm. 4/25/03).

Costs and Financial Considerations

In general, LID measures are more cost effective and lower in maintenance than conventional, structural stormwater controls (US EPA, Literature Review i). This is based on construction and maintenance costs, representing both short and long term costs. LID can significantly reduce development costs through site design by reducing impervious surfaces (roadways, curbs, and gutters), decreasing the use of storm drain piping and inlet structures, and eliminating or decreasing the size of large stormwater ponds (PGC 1-3). This is because control or treatment structure costs can increase with distance from the source (PGC 2-4).

The US EPA's 2000 LID review produced the following general cost information:

- The Center for Watershed Protection (1998) reports the cost for traditional structural conveyance systems ranged from $40 to $50 per running foot. This is two to three times more expensive than an engineered grass swale (7).
- Vegetative roof covers are especially effective in older urban areas with chronic combined sewer overflow (CSO) problems. They also add a variety of benefits such as extending the life of roofs, reducing energy costs, and conserving valuable lands that otherwise would be required for stormwater runoff control (7).
- The Center for Watershed Protection (1998) reports the cost for pervious paving may range from $2 to $4 per block/stone, whereas asphalt costs $0.50 to $1 to cover the same area (7).

Permeable pavements are more expensive to construct than traditional asphalt pavements; however, costs of these systems may be offset by the reduction of traditional curb and gutter systems to convey stormwater (US EPA, Literature Review ii). LID practices offer an additional benefit in that they can be integrated into the infrastructure and are more aesthetically pleasing than traditional structural stormwater conveyance systems (US EPA, Literature Review 1).

More specific information and findings related to cost are presented in the case studies in Chapter Five.

Chapter 4

Barriers to the Implementation of Low Impact Development

Low Impact Development has not often been the chosen tool for stormwater management in the Puget Sound Region. To gain an understanding of the barriers and insight on how to overcome them, it was necessary to extend the area of inquiry outside this region to areas where it has been practiced relatively more often. Although it definitely is still not a common approach in any region, there are areas of the country where it has been more widely used and experts to share their experiences.

The results of interviews and analysis of existing data reveal barriers that can essentially be broken down into two categories, technical and philosophical. Although these categories are not mutually exclusive nor are each of the barriers within them, they represent a general break between the levels of complexity determined to exist during examination of their aspects.

Technical Barriers

Technical barriers can be thought of as specific issues needing resolution in order for LID to be an option that development parties will use. They are not as broad as philosophical barriers and concern particular questions with relatively tangible answers. Technical barriers tend to center around questions of technology and process. During the analysis and interviews a few barriers of this sort seemed to surface consistently. Following is a description of the most common.

On a general level, there has been a slow accumulation and lack of dissemination of information regarding Low Impact Development (Booth, pers. comm. 4/16/03). This finding relates to the lack of many different types of information and can be in the form of specific details or more general and broad-based communication. Technical assistance and uncertainty among stakeholders as to whether stormwater programs even work were two common themes the Washington State Stormwater Policy Advisory Committee (SPAC) identified as high priority and needing further attention (7). Along with this lack of information being circulating is the lack of information regarding successful LID projects, including such information as effectiveness and financial considerations.

Funding shortages compound the ability of government agencies in particular to generate and disseminate information. The 1999 local government infrastructure study conducted by the Washington State Department of Community, Trade and Economic Development found significant funding gaps for stormwater projects. This funding gap was the largest of any of the study's infrastructure categories, including roads, bridges, domestic water, and sanitary sewer (SPAC 17).

On a more technical level, there are genuine engineering questions surrounding LID. Specific issues in this region are soils (Booth, pers. comm. 4/16/03). Soils in this region are spotty, meaning the soil matrix in one location has been found to be completely different than that in an area less than one-half mile away (Ritter, pers. comm. 5/14/2003). In addition, there is a proliferation of hardpan underlying much of the soils in this region. There is uncertainty surrounding the construction and effectiveness of certain Integrated Management Practices with reference to this fact. The public questions how something smaller (considered "less") will be capable of accomplishing what the existing larger ("more") storm ponds have not necessarily been able to, referring to effective infiltration (Ritter, pers. comm. 5/14/2003).

Specifically in terms of maintenance, questions exist surrounding what is involved, how often what types of maintenance must be done, and what will happen if the practices are not maintained (Tosomeen, pers. comm. 3/25/03). Difficulty also exists in the determination of responsibilities for maintenance of LID practices. The wisdom of conferring maintenance for what are thought to be complex facilities to lot owners associations or individual lot owners with no knowledge or understanding of the systems has been questioned (Coffman pers. comm. 4/25/03).

A specific barrier to LID from the viewpoint of construction associations has been agencies' use of prescriptive standards in their implementation ordinances (Booth, pers. comm. 4/16/2003; DeForest pers. comm. 5/21/03). They feel that with many questions surrounding the success and effectiveness of various LID technologies, construction standards and requirements are too rigid. High levels of stormwater mitigation requirements are applied in blanket fashion (SPAC 13), and agencies do not typically give full credit for the anticipated capabilities of these systems as an incentive (Booth and Leavitt 317). Hulsmann (as quoted in Corvin) believes this is unacceptable for what developers feel is a potentially risky and expensive undertaking (C 1).

Construction challenges were cited as a technological barrier to the acceptance of LID from an agency perspective (Tosomeen, pers. comm. 3/25/03). Generally these challenges related to the specifications for construction or fabrication of certain LID elements, such as bioinfiltration swales and pervious pavements. Structures of these types require specific inputs or specific assembly methods, which if not precisely followed can render them entirely ineffective. An example is porous pavement, which requires a specific mix of aggregate to properly function. Agencies responsible for public safety are extremely wary of the possibility of failures relating to these challenges.

Philosophical Barriers

Occurring on a broader level than technical barriers, philosophical barriers involve traditional models and ways of thinking that do not lend themselves to discernable solutions as simply as technical barriers. Philosophical barriers are also founded in a larger temporal scale than technical barriers and anything aimed at overcoming them must address the notion of change and all it encompasses.

One of the most common reasons for the avoidance of LID is its portrayal as 'something new' (Coffman, pers. comm. 4/25/03). It is true that LID involves a different thought process and paradigm than conventional stormwater management, but the premise behind it is certainly not new. The same goals and ideals behind LID can be found when examining the ways in which a natural, undeveloped site manages stormwater. Coffman believes this barrier exists beneath many of the technical barriers, which in effect serve as 'red herrings' to avoid the acceptance that LID is not something new, radical, or worthy of being afraid of (pers. comm. 4/25/03).

Another barrier to LID is a result of its confusion in development circles with the use or success of other 'ecological' or 'environmentally friendly' development tools (Coffman, pers. comm. 4/25/03). Other approaches, such as 'conservation design' or 'smart growth', do not focus primarily on avoiding watershed impacts but rather on minimizing them. This difference is key to understanding Low Impact Development, and this is not to say that the other approaches are without merit. As previously indicated it may be necessary to use elements of them all to achieve watershed objectives or depending on site constraints.

LID requires a multidisciplinary approach involving multiple agencies, professionals, and consultants with different backgrounds and also the public. This situation is often marred by communication problems. Often the involved parties have different goals, different or even conflicting missions and responsibilities, and individuals have different educational and professional backgrounds. The result is ineffective communication and 'spinning wheels', which require pointed efforts to overcome (Coffman, pers. comm. 4/25/03).

One of the most significant barriers can be characterized as multi-layered and can be summarized with the words "regulatory structure". This barrier results from the conflicting goals, policies, and philosophies of the multiple agencies and interests involved in the development process (Coffman, pers. comm. 4/25/03). An illustration can be found in the numerous regulations and programs having to do with stormwater presented in chapter 2. Because of the unfamiliarity and uncertainty surrounding LID, agencies and individuals are relatively more cautious than they would be with more common proposals. Each party has constituents, which are often the public, whose interest they are charged with protecting. This barrier is also related to responsibility and assurance (risk avoidance).

A final broad-scale barrier to LID is that it is contrary to the current economic model of managing stormwater, referred to throughout this paper as the "end of pipe" approach. When regulations were passed requiring the treatment and mitigation of stormwater in the 1970's, conventional approaches were modeled on existing sanitary sewer engineering techniques. Conventional approaches have come to involve centralized thinking, techniques, and technologies from which there is little variance. Over time, the companies and individuals specializing in these management techniques have captured a comfortable market share (Coffman, pers. comm. 4/25/03).

Although the barriers discussed above do not represent the only obstructions to the acceptance or use of Low Impact Development, they encompass the most commonly encountered issues in the literature and correspond to experiences related by professionals with LID experience. Based on an understanding of the possibilities LID holds for avoiding the impacts of development on water resources and an understanding of some of the common barriers to its use, especially in this region, conclusions and recommendations for overcoming these barriers can be formulated. Chapter six involves more detailed discussions of some of the barriers presented above.

CHAPTER 5

Case Studies

The purpose of this chapter is to highlight the results from a number of projects utilizing Low Impact Development that provide evidence of its effectiveness. Following are excerpts from reports documenting these results, mostly centered on the concepts of effectiveness in terms of pre- and post development hydrological considerations and pollutant removal capacities. According to Prince George's County (3-1), "The preservation of the predevelopment hydrologic regime of the site can be evaluated through consideration of the runoff volume, peak runoff rates, storm frequency and size, and water quality management". The other major focus of these case studies is cost and financial consideration. An effort has been made to communicate which LID strategies or controls were implemented in each situation, when available.

The following excerpts of results, which primarily focus on the function and effectiveness of different LID strategies, are from the US EPA's 2000 Low Impact Development Literature Review. According to the US EPA these case studies were the best examples of projects that use LID concepts and both hydrologic and pollutant removal effectiveness were investigated (11).

Bioretention Facility – Beltway Plaza Mall Parking lot, Greenbelt, Maryland

- Removal rates of heavy metals by the bioretention system were 97% for copper, and more than 95% for lead and zinc. The removal for ammonia was over 95%, nitrate concentrations were below input levels with a removal of about 17%, phosphorous removal was observed at approximately 65%, and Total Kjeldahl Nitrogen (TKN) removal was about 50% (12).

Permeable pavements and swales – Florida Aquarium Parking Lot, Tampa, Florida

- Four different scenarios were tested: Asphalt paving with no swale, asphalt paving with a swale, cement paving with a swale, and permeable pavement with a swale.
- For rainfall events less than 2 cm, the basins with swales and permeable pavements resulted in 80-90% less runoff than basins without swales, and 60-80% less runoff than basins with the other pavement types and swales. Larger rainfall amounts show fewer differences in runoff amounts between the different pavement types, but overall basins with swales have approximately 40% less runoff then the basins without swales.
- Metal removals for the permeable pavement with swale treatment were copper at 81%, iron 92%, lead 85%, manganese 92% and zinc 75%. The removals for the cement with swale treatment were somewhat lower, with the asphalt with swale treatment showing the poorest performance of the three treatments with swales (18).

Vegetative roof covers – Green Rooftop, Philadelphia, Pennsylvania

- Green roofs are comprised of three components: subsurface drainage, growth media, and vegetation.
- During a nine-month period, 44 inches of rainfall was recorded at the pilot scale test station, with only 15.5 inches of runoff generated. Attenuation was approximately 40%.
- Benefits of the project included extended life of the underlying roof materials, reduction of energy costs by improving the effectiveness of insulation, and restoration of ecological aesthetic value of open space in densely populated areas (23).

In addition, the Ontario, Canada, study referenced previously concluded that no evidence existed to show that nutrient or metal concentrations in soils increased with age in grass swales, as concentrations varied regardless of age. Also, the study determined no degradation in vegetative quality resulted from continuous exposure to stormwater runoff (32).

In addition to effective pollutant removal and hydrologic controls, the use of LID measures result in cost savings as a result of less impervious surfaces and other types of infrastructure compared to conventional developments. Infrastructure (roads, sidewalks, storm sewers, utilities, and street trees, for example) normally constitutes over half the cost of total subdivision development (Holland and Schueler 472). As such, the minimization of infrastructure can provide considerable savings. In subdivisions, savings occur at the rate of approximately $150 for each linear foot a road is shortened, including pavement, curb and gutter, and storm sewer. Savings of $25 to $50 are found for each liner foot of roadway that is narrowed, and $10 for each linear foot of sidewalk that is eliminated (Holland and Schueler 473). See Table 1, below.

Commercially, reductions in impervious cover leading to savings include $1100 for each parking space eliminated in a commercial parking lot. When future maintenance is considered, lifetime savings in the range of $5000 to $7000 per space occur (Holland and Schueler 473).

Table 1: The Unit Cost of Subdivision Development

(Source: SMBIA 1987 and others, as published in Schueler 1995 – pg 475)

Subdivision Improvement	Unit Costs
Roads, grading	$22.00 per linear foot
Roads, paving (26' width)	$71.50 per linear foot
Roads, curb and gutter	$12.50 per linear foot
Sidewalks (4 feet wide)	$10.00 per linear foot
Storm Sewer (24 inch)	$23.50 per linear foot
Clearing (forest)	$4,000 per acre
Driveway aprons	$500 per apron
Sediment Control	$800 per acre
Stormwater Management	$300 per acre (variable)
Water/Sewer	$5,000 per lot (variable)
Well/Septic	$5,000 per lot (variable)
Street Lights	$2.00 per linear foot
Street Trees	$2.50 per linear foot

One method of reducing infrastructure is using the LID tool of site planning. Cluster development has been identified as one design concept that can reduce the capital cost of subdivision development by 10 to 33%. This is primarily by reducing the length of infrastructure needed to serve the development (Holland and Schueler 472). Cluster site design can reduce impervious cover 10 to 50%, thereby lowering costs for both stormwater conveyance and treatment. Cost savings resulting from this reduction can be considerable, as the cost to treat the quality and quantity of stormwater from a single impervious acre can range from $2000 to $50,000 (Holland and Schueler 472). An example of estimated development costs associated with two different development scenarios (conventional and cluster) for the Remlik Hill Farm subdivision in Maryland are presented in Table 2 below.

Table 2: Remlik Hill Farm Example: Costs, Land Cover, and Pollution Associated with Two Plans (Land Ethics, Inc.) (pg 473)

Development Costs	**Scenario A Conventional Plan**	**Scenario B Cluster Plan**
1. Engineering Costs (boundary survey, topo, road design, plans, monumentation)	$79,600	$39,800
2. Road Construction Costs	20,250 linear feet $1,012,500	9,750 linear feet $487,500
3. Sewage and Water (permit fees and design only)	Individual septic and wells $25,200	$13,200
4. Contingencies	$111,730	$54,050
GRAND TOTAL	$1,229,030	$594,550

Table 2 continued

Land Cover and Stormwater Pollution Estimates

Total Site Area = 490.15 acres

	Scenario A	Scenario B
Total Developed Land	287.41 acres (58.6%)	69.41 acres (14.2%)
Roads and Driveways	19.72 acres	11.75 acres
Turf	261.09 acres	54.04 acres
Buildings	6.60 acres	3.92 acres
Total Undeveloped Land	202.74 acres	420.64 acres
Forest	117.55 acres	133.01 acres
Wetlands	11.46 acres	11.46 acres
Total Impervious Cover	5.4%	3.7%
Total Nitrogen (*lbs. per year*)	2,534 lbs./year	1482 lbs./year
Phosphorus (*lbs. per year*)	329 lbs./year	192 lbs./year

The three following case studies are excerpts from the book Green Development: Integrating Ecology and Real Estate, published by John Wiley and Sons in 1998 (Rocky Mountain Institute). From the findings set forth in their publication, the authors of this book claim "the financial rewards of green development are now bringing mainstream developers into the fold at an increasing pace".

1. Land development and infrastructure costs for Dewees Island (Charleston, SC), which used a LID approach, were 60% below average. This was because impervious roadway surfaces and conventional landscaping were not used. Porous sand roads and low maintenance native vegetation for landscaping were instead utilized. However, it is important to note this island is car-free, which may contribute to the ease with which impervious roadways were avoided.

2. In Davis, California, developer Michael Corbett saved $800 per lot in the two hundred forty unit Village Homes subdivision, by using natural swales for stormwater infiltration in place of a storm sewer system. As a result of a better looking product, homes here command $10 to $25 more per square foot than those of surrounding developments, and homes sell more quickly when they come onto the market.

3. Prairie Crossings near Chicago, Illinois, is a 667-acre residential development. By designing infrastructure to reduce environmental impacts, the developers saved $1.4 million total, and $4400 per lot. This was accomplished by designing streets that are eight to twelve feet narrower than normal, minimizing impervious concrete sidewalks, and using vegetated swales and detention basins for infiltration rather than conventional storm sewer systems. In the Davis and Chicago examples above, savings were spent to enhance common open space and other project amenities.

Pembroke, a half-acre plot residential subdivision in Frederick County, Maryland was the first Low Impact Development subdivision permitted in this county, and one of few comprehensive LID subdivisions in the country. The use of LID practices throughout the development enabled the developers to eliminate the use of two stormwater management ponds they had envisioned in an earlier site conception (NRDC 5). This elimination represented a reduction in infrastructure costs of roughly $200,000. It also permitted them to preserve a 2.5-acre wetland and surrounding area in an undisturbed state, which resulted in considerable savings for wetland impact mitigation. The use of LID site planning allowed the preservation of approximately 50% of the site in an undisturbed wooded condition. Site footprinting allowed developers to gain two additional lots by using LID design, increasing the overall forty three-acre yield from sixty eight to seventy lots. This added roughly $100,000 of additional value to the project (NRDC 6).

Within Pembroke, the developers also converted approximately 3000 linear feet of road from "urban" to "rural" standards, by replacing curbs and gutters with vegetative swales and reducing the paving width of the road from thirty six to thirty feet. The use of swales saved the developers $60,000 in infrastructure construction, and the reduced road width lowered paving cots by 17%, while reducing overall imperviousness (NRDC 6).

Another comprehensive Low Impact Development is the one hundred thirty-acre residential site of Gap Creek, in Sherwood, Arkansas. The developer originally envisioned a site planned and developed in accordance with conventional methods. When preliminary engineering and cost estimates revealed unusually high costs for such an ordinary development, the developer (Terry Paff, President of Metropolitan Realty and Development in Sherwood), decided to take a new direction. He abandoned the plan and opted instead for a 'sustainable' site plan (Tyne 28). Table 3 below presents a comparison of the two different land plans

TABLE 3

LOW IMPACT DEVELOPMENT

A Comparison of Two Different Land Plans

PROJECTED RESULTS FROM TOTAL DEVELOPMENT

Total Site	**Conventional Plan**	**Sustainable Plan**
Lot Yield	358	375
Linear Feet Street	21,770	21,125
Linear Feet Collector Street	7,360	0
Linear Feet Drainage Pipe	10,098	6,733
Drainage Structures: Inlets/Boxes/Headwalls	103	79
Estimated Total Cost	$4,620,600	$3,942,100
Estimated Cost Per Lot	$12,907	$10,512

TABLE 3 CONTINUED

ACTUAL RESULTS FROM PHASE I

Phase I	**Conventional Plan** *(Engineer's Estimated Figures)*	**Sustainable Plan** *(Actual Figures)*
Lot Yield	63	72
Total Cost	$1,028,544	$828,523
Total Cost Per Lot	$16,326	$11,507

ECONOMIC AND OTHER BENEFITS FROM LOW IMPACT DEVELOPMENT

Higher Lot Yield	17 additional lots
Higher Lot Value	$3,000 more per lot over competition
Lower Cost Per Lot	$4,800 less cost per lot
Enhanced Marketability	80% of lots were sold in first year
Added Amenities	23.5 acres of green space/parks
Recognition	National, State, and Professional Groups
Total Economic Benefit	More than $2,200,000 added to profit

Tyne & Associates, North Little Rock, Arkansas (pg 28)

The numerous benefits of this design are documented in the article "*Bridging the Gap: Developers Can See Green – Economic Benefits of Sustainable Site Design and Low Impact Development*", written by Ron Tyne, the project consultant. While the entire report documents the project benefits, the following excerpts reference some specific economic benefits:

The LID design was projected to achieve a per lot savings of nearly \$2400. After completing Phase I, cost savings were almost \$4800 per lot. When completed, the LID plan also added 17 lots. So far, Terry Paff has been able to sell his lots for \$3000 more per lot than larger lots in competing areas. Upon completion of the total project, Paff expects the added economic benefit resulting from a 'green approach' will exceed \$2 million over the projected profits (30).

With respect to cost savings for control mechanisms, the benefits of LID are not only for construction, but also for long-term maintenance and life cycle cost considerations. The LID design also resulted in a reduction of landscape and maintenance costs, by emphasizing the use of native trees, natural vegetation, and low maintenance prairie grasses (30).

In 1999 the City of Olympia installed 1,500 linear feet of five and one half foot-wide porous pavement sidewalk along North Street. The average bid for regular concrete was \$20/yard^2, and \$25/yard^2 for porous pavement. Estimates during this time period were lower than the usual \$30/yard^2 for concrete and \$40 to \$45/yard^2 for porous pavement. While using porous pavement increased the total project cost approximately \$10,000 over that estimated using regular concrete, the total project savings was approximately \$100,000 taking into consideration the cost to obtain land for and construct a stormwater pond (Tosomeen, pers. comm. 3/25/2003).

While cost savings and water quality and quantity benefits have been documented in projects utilizing LID, land use plans that retain open space, a rural landscape, and recreational opportunities also can contribute to the quality of life of a community or region. A 1992 National Park survey of Chief Executive Officers ranked quality of life as the third most important factor in locating a new business. This should be of interest to regions and communities because as regional economies become even more competitive, a high quality of life ranking can provide a critical edge in attracting new businesses (Holland and Schueler 470).

As previously indicated, local conditions will dictate under what circumstances Low Impact Development is most likely to be effective. The US EPA states, "Detailed comparison of pre- and post development conditions and an analysis of adjacent areas using traditional stormwater controls and LID practices side by side would provide the best possible assessment of LID effectiveness" (Literature Review 33). In an attempt to illustrate where this has been done with a regional representation, an evaluation of the 2nd Avenue NW Street Edge Alternative (SEA) Streets Millennium Project in Seattle is presented below, from Burges, Horner, and Lim's Hydrologic Monitoring of the Seattle Ultra-Urban Stormwater Management Projects, 2002.

Evaluation of the SEA Streets project (an "ultra-urban" stormwater management project) was undertaken jointly by the University of Washington's Center for Urban Water Resources Management and Seattle Public Utilities through a memorandum of understanding in the summer of 1999. The project was deigned to reduce stormwater quantities discharged to Pipers Creek.

The SEA Streets project represents a full street right of way design, on 2nd Ave NW between NW 117th and NW 120th streets. The roadway length of six hundred sixty feet was reduced from a width of twenty-five feet to fourteen feet, parking spaces were provided at angles to the street, and sidewalks were added. The remainder of the sixty-foot right of way was devoted to runoff detention ponds planted with native vegetation. The original right of way covered approximately .91 acres, about .38 acres of asphalt and the remainder in vegetation on the edges. The redesign reduced hard surfaces to approximately .31 acres, with the remainder given to ponds. The catchment area draining to the 2nd Ave NW pond system totals approximately 2.3 acres.

Results evaluated are from the period beginning just after the completion of construction (approximately January 20, 2001) and concluding on April 30, 2002. The evaluation found that with the new street design, there was no dry-season (April 1, 2001 through September 30, 2001) runoff release, even during a large August storm. Over the entire study period, 98.2% attenuation was achieved. The mean average flow volume decrease was 99.5%. Two specific rainfall events (January 6 and January 9, 2002) yielded only 4.9% and 3.2% runoff volume of the precipitation volumes falling on the catchment, respectively.

The SEA Streets design thoroughly outstripped the prediction made during the initial study period that it would reduce total discharge from the pre-existing street for equivalent conditions by only 42%. A project benefit ratio comparison, determined using the overall retained volume of runoff per month under each system, resulted with SEA Streets having a benefit ratio of 3.7 times that of the original street at this location. The benefit ratio was equal to a factor by which runoff discharged to Pipers Creek in wet months was reduced. In comparison to a conventional street designed to the City of Seattle's current standards, SEA Streets compared with a 4.7 times higher benefit ratio.

Overall, during monitoring the 2nd Ave SEA Streets project has prevented discharge of all dry season flow, and 98% of the wet season runoff. Whereas all events in the baseline monitoring period created a discharge, only about 10% have since the project's construction. The SEA Streets design can fully attenuate 2300 ft^3 of runoff, which represents the volume produced by approximately 0.75 inch of rain on its catchment. For context, the mean storm quantity at Sea-Tac International Airport is 0.48 inch. Figures 2 and 3 on the following pages, courtesy of Seattle Public Utilities, are photos of the SEA Streets project.

FIGURE 2

SEA STREETS CROSS SECTIONS

BEFORE AND AFTER

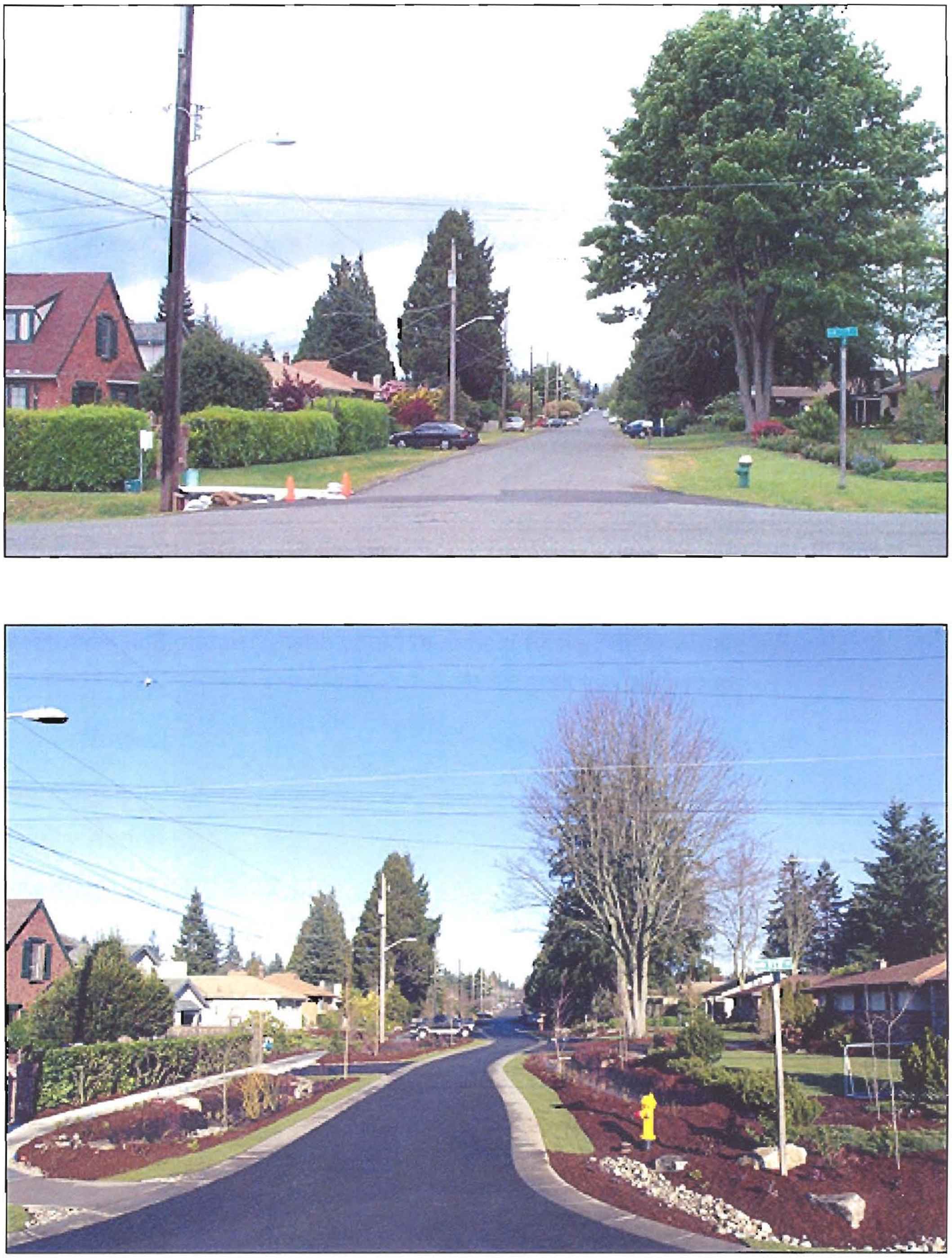


FIGURE 3
SEA STREETS AERIALS
BEFORE AND AFTER

Chapter 6

Discussion and Conclusions

The first sections of this paper address the potential of LID as an alternative tool for stormwater management in the Puget Sound region. While it is evident that technical and process-related questions exist, research and data support the notion that Low Impact Development holds promise as an effective technique, in terms of both the cost to implement it and the benefits it projects. As indicated previously there are questions among stakeholders about the effectiveness of stormwater management programs. It would make sense when investing time or money into answering these questions to extend the inquiry to address Low Impact Development.

One of the barriers to more common use of LID was identified as a lack of available information. My research has indicated this is not a lack of available information on the subject as a whole, but more a lack of a 'regional clearinghouse' for the information that does exist and a lack of projects in this region to relate to local conditions. The lack of information is circular in that it also ties in with a lack of education and training for many engineers, consultants, developers and planners, who could then help further disseminate information (Coffman, pers. comm. 4/25/03).

However, efforts are currently underway to address this lack of information in this region, due primarily to the efforts of the Puget Sound Water Quality Action Team (PSAT). The Action Team has accumulated information regarding LID practices used in this region and published a manual entitled Natural Approaches to Stormwater Management: Low Impact Development in Puget Sound. The Action Team has also developed an assortment of educational materials on the subject, and educated people at LID conferences and regional workshops throughout Puget Sound (PSAT 2). This agency is in the process of establishing itself as a potential clearinghouse for LID information and actively engaging many communities in discussions regarding LID.

In terms of the more technical questions regarding design and technology, consulting and engineering firms within the region have begun to use the "lack of information" to their benefit. These firms, such as SCA in Lacey and AHBL in Tacoma, have put forth the effort to educate themselves in LID strategies and technologies and are creating a market niche for themselves as interest in LID spreads. As LID catches on and becomes more competitive and people become more comfortable with it, these firms will be able to capitalize on their expertise (Coffman, pers. comm. 4/25/03). Business consultant Michael Porter, of the Harvard Business School, cautioned in the Harvard Business Review:

> We are now in a transitional phase of industrial history in which companies are still inexperienced in handling environmental issues creatively...The early movers – the companies that can see the opportunity first and embrace innovation-based solutions, will reap major competitive advantages, just as the German and Japanese car makers did [with fuel-efficient cars in the early 1970's] (Browning et al 7).

In addition, governments and establishments in the region, such as the City of Bellingham, City of Olympia and The Evergreen State College, have begun to experiment with using LID technologies in their agency projects. Examples include the City of Olympia's porous pavement sidewalk along North Street and the Evergreen State College's implementation of recommendations from its Zero Impact Feasibility Study. These include a garden roof on the new Seminar 2 building currently under construction and rebuilding portions of its parking lot using pervious pavement systems (PSAT 28).

The City of Olympia's porous pavement project on North Street provides a good working example of a barrier resulting from maintenance issues. Due to the nature of porous pavement and the ability for the pores to become clogged and inhibit infiltration, regular maintenance is required. However, as is fairly common knowledge, Washington State agencies and local municipalities are facing severe budget constraints at this time. The likelihood of the City installing any further porous pavement as a part of City projects in the near future will be limited due the funding issues regarding requirements for its maintenance (Tosomeen, pers. comm. 3/25/03).

The same maintenance issues exist in private developments and maintenance responsibilities are often assigned to lot owners associations, or to a single lot owner if the control is entirely placed within their lot. With association maintained facilities and the lack of direct single-party responsibility, the possibility exists that the maintenance will never actually be done, presenting the same problem as the maintenance of conventional stormwater ponds at the present time. However, in the experience of Larry Coffman there are multiple ways to address the question of maintenance issues within a private development.

First, it has been his experience that individual controls placed on private lots are better maintained than community or association maintained facilities. This appears to be the case because the appearance and function of the control have a direct effect on the value of the private property. To help educate the private lot owners and associations, creation and designation of an ecological committee is required as part of the lot owners' associations when they are created. Coffman stated that on a large scale, however, he does not feel these concerns are necessary. This is because in most cases the proper use of site design techniques can minimize or do away with individual controls and, therefore, the necessity for their active maintenance (Coffman, pers. comm. 4/25/03).

To illustrate construction challenges, porous pavement can again be used as a good example. The mix designs for these types of systems are aggregate specific, and testing of the mix is required each time it is done, resulting in higher engineering costs. The concern is that this mix balance can be difficult to maintain and tricky to specify. Education of the suppliers and installers is necessary, requiring additional time and money of developers and their construction teams (Tosomeen, pers. comm. 3/25/03). However, as maintenance issues are resolved, education increased, and example projects more prolific, a market niche is likely to open up for those with experience in LID and expertise in implementing its management practices. Investing in this education now may prove to be of immense benefit for developers and firms in the future (DeForest pers. comm. 5/21/03; Coffman, pers. comm. 4/25/03).

As indicated in the previous chapter, the process-related technical barriers such as those discussed above seem to act as a diversion for avoiding larger questions and barriers to LID. The larger questions exist on a broader scale and are more philosophical in nature. It has been my experience as a professional involved in the development process that the efforts required to address details such as these consistently arise during project design and are inherent in the life of almost any project. Questions such as these, while important to address, are not the real barriers that are going to stop LID development projects with a dedicated and prepared group of applicants. Essentially, technical barriers are not necessarily specific to LID projects and are not necessarily the barriers that need to be addressed to facilitate its acceptance and use. The primary barriers exist in getting to the point where dedicated and prepared applicants and staff exist, and are capable of and committed to working with one another towards a common goal.

Recommendations

The first step in making LID more feasible will be a common understanding of its true definition and a commitment to the goals it strives to achieve. In essence, LID strives to maintain the predevelopment hydrology of a site and treat stormwater runoff using the natural features of the site. The key to understanding this goal is the fact that LID does not involve mitigating or lessening the impacts of development on a receiving stream, but rather alleviating them all together (Coffman, pers. comm. 4/25/03). Therefore, it is critical to separate LID from other development techniques with goals of impact minimization. Confusion or blurring of the lines among these techniques will serve as a barrier to the implementation of LID because techniques involving minimization do not command the same level of commitment as avoiding the impacts of development on receiving waters.

Larry Coffman, creator and pioneer of LID, is adamant about separating LID and organizations affiliated with its promotion from other strategies like Conservation Design, the Center for Watershed Protection's Better Site Design, and the EPA's "smart growth" endorsements (pers. comm. 4/25/03). It is not that these strategies completely lack merit, but Coffman believes their focus on the minimization of impacts will not require or lead people to recognize the fact that as we change the terrestrial ecosystem we also alter the aquatic ecosystem, a chain which he believes begins with soils (pers. comm. 4/25/03). Other strategies often consist only of relatively easy actions such as the minimization of paved surfaces that do not require a paradigm shift or focus on the consequences of human actions.

Another issue resulting from the widespread use of conventional mitigation practices is the question of cumulative impacts. Because conventional techniques focus only on lessening development impacts, there is still the potential for influence on receiving waters. There is concern this may fundamentally alter a watershed's hydrological regime and water quality, adversely affecting receiving waters and the integrity of their ecosystems (Coffman 195). This issue has been recognized as an important one, as the Stormwater Policy Advisory Committee illustrates in their Report to the Legislature. They outline an example of a coordination and implementation issue that stakeholders identified as needing identification and prioritization as, "How the GMA planning framework or other stormwater management mechanism takes into account cumulative effects of development" (11).

Coffman questions whether strategies like those listed above even realistically benefit receiving waters. Objects like paved surfaces possess characters that result in effects on streams, but are not themselves the direct effect. An example can be made using polluted runoff. While paved surfaces contribute pollutants to the runoff resulting from precipitation, minimization or removal of only this paved surface under typical development scenarios would not alleviate polluted runoff. The compaction of soils results in an impervious-like surface that acts almost exactly like a paved surface. On a site with extensive grading and compaction the lack of pavement will not result in benefits to receiving waters. It is key that correlation be separated from cause (Coffman, pers. comm. 4/25/03). In addition, these strategies often are not effective in infill or retrofit projects. Again consider the polluted runoff scenario and compacted soils remaining even after pavement has been removed. It is essential to remember that streams run through these areas as well.

Related to the necessary paradigm shift for a true understanding of LID, Coffman points to the way in which many rules and regulations address water quality as a significant roadblock. Repeated mention of the "beneficial uses" of waters has been made and can be found in the section of this paper relating to stormwater laws and programs. However, specifically the EPA has traditionally interpreted beneficial uses and the Clean Water Act to deal only with water quality. The customary interpretation of these laws and regulations has not been extended to include the ecological integrity or physical or biological aspects of the receiving waters (pers. comm. 4/25/03), while the spirit of these laws is intended to address these functions. When they are considered, the shortfall of many traditional management techniques and mitigation measures are even more glaring.

In terms of regulatory structure, much has been written on the critical need for agencies and groups to work together if success is to be possible. Washington's Water Quality Management Plan to Control Nonpoint Sources of Pollution states, "Relationships between agencies, tribes, and key local counterparts need considerable strengthening if water quality is to improve" (Ecology 10). Aponte Clarke et al echo a statement to this effect in the "Water in the Public Realm" conference proceedings. They have identified through over 100 case studies that there are nine critical elements of effective stormwater programs, two of which are strong leadership and effective administration (133). The NRDC has carried this finding one step further, and promotes these nine critical elements as recommendations for local action in the executive summary of their Stormwater Strategies publication (5).

Elements like education and familiarity with Low Impact Development projects and their results will be critical to the success of LID on a regulatory level. As referenced in the previous section, the Puget Sound Action Team has been active in taking on this role at a regional level and is striving to educate stakeholders and broaden the base of available information. However, as information and advocacy continue to gain momentum, the time is approaching when an agency must step forward and enrich the information movement with something concrete. This step most likely needs to be a pilot project that can provide monitoring data and act as a case study from which to gather results (Booth, pers. comm. 4/16/03; Ecology, Final Plan 160). The SEA streets project represents a step in this direction. An agency is also more likely to be successful at catalyzing interest in a LID project, because as Doug DeForest states, "Most builders and developers are not innovators. They do not generally look down the road, and their operations are focused on building on the land that is [readily available] now" (personal communication 5/21/03).

With the funding issues being experienced in the State of Washington and undoubtedly in other areas, the question will be which agency should entirely undertake or enter into a partnership to undertake an LID pilot project. Different individuals and agencies all have different suggestions. In Washington the Department of Ecology has been given the responsibility for water quality by the EPA under the Clean Water Act. The Puget Sound Action Team is responsible for program planning and overseeing implementation of the Puget Sound Plan, which has been adopted as a Comprehensive Conservation and Management Plan for the Puget Sound Estuary and strives to control nonpoint sources of pollution. However, the EPA has stated their analysis of water quality issues in Washington State indicate nonpoint source control is largely a local land use issue with the exception of forest practices (Ecology, Final Plan 10).

In the interim report to the Washington State Legislature, the Stormwater Policy Advisory Committee issued a policy statement maintaining, "Washington needs to clarify a collaborative stormwater leadership structure", referenced as the "Coordination Team" (9). They recommend, "an effective convener for such a structure is the Governor's Office, based on the opportunity for this team to then examine broad problems and give legitimacy to solutions and players" (9). They state that vesting leadership in (The Department of) Ecology is an option, as it would provide "the benefit of close integration with direct stormwater regulatory authority and strengthening program legitimacy". However, they also state the importance of the perspective of the Coordination Team remaining broad, without particular allegiance to any agency, program, or regulation (9).

The formulation of a Coordination Team under leadership of the Department of Ecology working to clarify stormwater related issues would be well vested to extend its area of inquiry to include specific analysis of Low Impact Development. This is a logical suggestion for the reasons outlined above regarding DOE's responsibilities for the promulgation of stormwater regulations. Should this committee be able to represent a broad perspective as the SPAC advised, local governments, developers, tribes, other offices of the Governor, and numerous agencies would have the responsibility and opportunity to participate.

I find the issue of collaboration of multiple agencies, and particularly local agencies, of great importance when examining the Department of Ecology's (DOE) Water Quality Management Plan to Control Nonpoint Sources of Pollution. In it DOE states, "six groups had a key role in developing this plan" (313) followed by an outline of the composition of each of those groups. While making statements throughout the document like, "A locally managed watershed plan is one of the best approaches to implementing a Nonpoint Source Total Maximum Daily Load "NPS TMDL (336)", "Enforcement by local governments...plays an important role in nonpoint source programs" (339), and legitimizing statements, such as the EPA's regarding nonpoint source control being largely a local land use issue, not one single local government representative is listed as a member of any of these six key groups (313).

In accordance with formulating a coordination group or solidifying a regulatory structure where stormwater issues can be identified and analyzed, problem definition is another key barrier to overcome regarding the acceptance of stormwater regulations and management techniques. This barrier also relates to the barrier of inaccurate definition recognized by Larry Coffman.

In terms of problem definition, the Stormwater Policy Advisory Committee acknowledges a perceived lack of demonstrated benefit from stormwater mitigation and control methods (13), or as identified previously in this paper, the fact stakeholders question whether BMPs and IMPs are or can be truly effective. They explain this perceived lack of demonstrated benefit is compounded by inadequate problem and goal definition and that "it is difficult to determine the best solution when the problem and its causes are complex and not well defined" (13). I would argue this relates to Coffman's definition barrier with regards to the ability (or lack of) strategies other than LID to force people to recognize that their actions have an effect on receiving waters.

It will be essential for any Coordination Team to begin with the task of illustrating this fact, adequately and accurately defining "problems", and publicizing demonstrable benefits in the suggested solutions. In order to be able to be to demonstrate benefits, a baseline from which to begin must be established. As of April 2000, approximately half of Washington State's surface waters and a vast majority of ground waters had not been monitored and needed baseline data (Ecology, Final Plan 21). Consistent enforcement measures must also be formulated to provide a sense of equity and establish accountability (NRDC 4; Ecology, Taking Action 21). As it is recommended this route be taken for all stormwater management and regulations at this point, it seems very logical to integrate LID into this process, as this would provide much of the data and contribute to the comfort level it is believed will be necessary for LID to be more commonly implemented.

Regional planning processes and management coordination will be required to add clarity to the process of stormwater management as a whole, and to simplify the process of negotiating a predictable path through the regulations (SPAC 8). In turn, if LID can be recognized as fulfilling the potential it has demonstrated in this region, incentives and benefits must exist for developers and interested parties to 'get on board'. The opportunities for consultants and contractors to break into this market have already been discussed. In addition to the information presented in this paper, developers must be able to depend with almost absolute certainty on the fact their investment will provide returns. In addition, permitting and approval processes cannot be so confusing, burdensome, or unpredictable as to discourage an applicant from being interested in this route. Additionally, permitting agencies and water quality authorities must be convinced there is no risk involved in permitting projects such as these, and that the provided controls will serve to protect the public health, safety, and welfare.

In terms of risk associated with these types of projects, I would recommend exploration of a tool comparable to "stopgap" insurance. Stopgap insurance typically functions as a protection to cover costs above and beyond those estimated for a specific type of project. An example is costs associated with environmental cleanup or decontamination of brownfields prior to redevelopment. Stopgap insurance can be purchased in some cases and is being further explored to cover unexpected costs resulting from pollution or contamination that is far worse and costlier to address than originally expected and budgeted for. This sort of insurance mechanism for LID projects could serve to address the fears of possible failure or performance below an expected level.

On a similar note, the US EPA in conjunction with several states, is currently exploring funding mechanisms and grant and loan programs for brownfields redevelopment. I would recommend similar programs, primarily to fund pilot projects by public agencies, be explored for Low Impact Development.

After projects have been constructed, monitoring must be carried out and the results made widely available to both the public and the development community (Booth, pers. comm. 4/16/03). At the present stage, I would suggest monitoring schemes such as those required for wetland mitigation projects. These typically require a 5-year monitoring plan be implemented at completion of the project, with specific requirements regarding the content of the plans and specific goals for which results will be gathered.

Generally a developer does not want to be tied to a project after its completion and will not want to be bound by this requirement. A solution might be a requirement that the developer bond for this monitoring, allowing the permitting agency to hire a consultant at the specified time to determine whether the project was indeed "successful" in meeting its established goals. Unfortunately, it is also unlikely most developers will agree to be bound by conditions of this sort, which do not appear to be incentives. In the long run, this illustrates why it will likely be necessary for state, regional and local agencies to "get the ball rolling" by participating in pilot projects and gathering pertinent information from their results.

In terms of education, as indicated previously, the Puget Sound Action Team has begun the general education process in this area. Independent contractors and consultants are following, recognizing the need to educate themselves in their respective fields to break into this market. Training for agencies and the general dissemination of information, results, and success stories is also beginning to take place. Universities are recognizing the necessity for urban water resources and management programs, and the University of North Carolina, University of Virginia and Boise State have all implemented college-level programs covering LID methods (Coffman, pers. comm. 4/25/03).

One potential barrier to Low Impact Development that this paper does not address is the financing of projects of this sort. In order for LID to be a truly attractive and advantageous option, the securing of loans or credit for their development must be as straightforward as that for any parallel project. It is likely this will not be entirely possible until their effectiveness has been established and successes have been recognized and can be counted on repeatedly.

Beyond these suggestions to facilitate generally better stormwater management and Low Impact Development in particular, a final philosophical and social issue relating to water protection must be recognized. This issue has been referenced in numerous sections of this paper with regards to people's reactions to something "new", our openness to change, and the necessity for recognition of the fact that our habits and lifestyles have an impact on water quality and quantity. The NRDC recognizes, "LID is much more than the management of stormwater – it is rethinking the way we plan, design, implement and maintain projects. Comprehensive [LID] programs usually compliment LID practices with broader issues such as: considering where growth disturbance should occur, increasing awareness of the cumulative impacts of development, involving the community and raising watershed awareness…" (3).

With regards to questions relating to the preservation of water, the avoidance of the impacts of development on a watershed or receiving waters is unquestionably beneficial. However, the question of the effects of human habits and lifestyles outside of development must also be addressed if water protection efforts are to be successful. These include such issues as stream buffers, pesticide and herbicide application, and combined sewer overflows (Booth, pers. comm. 4/16/03).

Water protection will not be successful if development is the only facet of human habits and lifestyles we acknowledge and address, and therefore LID cannot do it alone. The Center for Watershed Protection notes, "While many advances have been made recently in innovative stormwater practice designs, their ability to maintain resource quality in the absence of the other watershed protection tools (e.g. aquatic buffers and non-storm discharge) is limited" (Holland and Schueler 132).

An example of a human habit that must be acknowledged is our proliferating population, which has been identified by many as a factor in environmental problems worldwide, including stormwater. In their article *Stormwater Management: Shifting the Present Paradigm*, Ballantine, Clarke and Wilding recognize, "It appears as environmental efforts take one stride forward today to improve the water quality of a watershed, the water quality in the future will be taking two or more steps backwards with the addition of more people, more impervious area, and more runoff being managed by poorly maintained ponds" (55). In Washington in particular, the Department of Ecology maintains, "Population growth has had a disturbing impact on water availability that in turn impacts the quality of the water in streams and rivers" (Final Plan 15).

Closing thoughts

Throughout the ten years that Larry Coffman has been involved in the creation and growth of Low Impact Development, he relates he has consistently experienced a single initial reaction. This reaction is ridicule. His advice? WORK THROUGH IT. Larry relates that time and again, this initial reaction is followed by a process of consideration, in which new information begins to accumulate and people become more comfortable with a different style. He states that what then follows is a recognition that "it works", which is then followed by a gain in its acceptance and its engagement into convention. LID is not a technique that will be accepted overnight, and the acceptance process is a slow one. Derek Booth relates he believes its common acceptance in this region will take five to ten years, unless there is a significant shift in the approach of all involved parties, and we begin to seek the information we say we need rather than waiting for it to come to us.

Two quotes from Albert Einstein are in hindsight eerily applicable to this situation and to almost any situation relating current environmental problems and technology. The first quote reads, "Any intelligent fool can make things bigger and more complex...It takes a touch of genius -- and a lot of courage -- to move in the opposite direction." The second states, "The significant problems we face can not be solved at the same level of thinking we were at when we created them." It is evident that the wisdom of these statements has not changed, and recognition of this fact can be found in Ecology's Stormwater Management Manual for Western Washington:

> The engineered stormwater conveyance, treatment, and detention systems advocated by this and other stormwater manuals can reduce the impacts of development to water quality and hydrology. But they cannot replicate the natural hydrologic functions of the natural watershed that existed before development, nor can they remove sufficient pollutants to replicate the water quality of pre-development conditions. Ecology understands that despite the application of appropriate practices and technologies identified in this manual, some degradation of urban and suburban receiving waters will continue, and some beneficial uses will continue to be lost due to new development. This is because land development, as practiced today, is incompatible with the achievement of sustainable ecosystems. Unless development methods are adopted that cause significantly less disruption of the hydrologic cycle, the cycle of new development followed by beneficial use impairments will continue. (1-21).

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