RAIN GARDENS IN SUBURBIA:

LOW-IMPACT DEVELOPMENT RETROFITTING IN GEORGIA

by

ESTRELLA VELAZQUEZ SANTIAGO

(Under the Direction of Ronald B. Sawhill)

ABSTRACT

This thesis investigates the retrofitting of existing large lot residential neighborhoods with low-impact development water quality controls as a necessity for the long-term success of a regional stormwater management plan. The research involves looking back at the history of stormwater management, establishing the environmental benefits of stormwater retrofitting for water quality and identifying key legislation, funding and public support issues. Case studies of urban water quality stormwater retrofits are analyzed. A project application is used to determine the possibilities and limitations of a low-impact development water quality retrofit of a suburban residential neighborhood in the Georgia Piedmont region, using bioretention areas as the water quality control. In order to provide a quantifiable value for this project, a cost estimate was generated using extrapolated numbers from an existing retrofit project.

INDEX WORDS: retrofit, stormwater, low-impact development, LID, bioretention, subdivision, water quality management

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ESTRELLA VELAZQUEZ SANTIAGO

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ESTRELLA VELAZQUEZ SANTIAGO

Major Professor:	Ronald B. Sawhill
Committee:	Bruce K. Ferguson Todd C. Rasmussen Michael W. Breedlove

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
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DEDICATION

This work is dedicated to my parents Roberto Velazquez and Silvia Santiago, who have supported me always. It is also dedicated to my husband, Adam Mitchell Wosotowsky, who cared for me day and night while this work was progressing.

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CHAPTER 1

INTRODUCTION

The field of stormwater management has changed substantially over the last two decades. An increased awareness of water pollution and its harmful effects on both humans and the surrounding environment has caused a field-wide reform of the ways in which designers, builders and legislators plan for and treat stormwater management. A growing consciousness of human intervention in natural systems is promoting the development of new, less damaging and even restorative technology. These advances are constantly advertised and promoted in such field publications as Landscape Architecture and Stormwater Magazine.

Professionals are taking a cue from natural systems, attempting to incorporate these into better site design. Low-Impact Development (LID) is one such technological advancement. Using our knowledge of the way the land manages and utilizes stormwater to its benefit we have developed a growing set of technological and design guidelines to help our land development projects mimic natural processes. New developments all over the world are being designed with more stringent water quality regulations that promote the use of these “natural” technologies to manage stormwater quality while still providing the necessary flood protection that has been required for decades. Even re-development projects are receiving attention in the way of water quality management. However, there is a deficiency in stormwater water quality management that is not currently being adequately addressed. While new development and re-development runoff is being managed the runoff from existing developments, primarily those located in aging suburban areas, is still being allowed to flow untreated into our rivers, streams and bodies of water.

Ten years ago, many of these stormwater quality controls were untested hypothetical solutions. While still based on natural systems, their ability to remove non-point source pollution from stormwater runoff was untested. Today, these tried-and-true methods should be employed in as many applications as possible in order to achieve healthy watersheds. It is now past time for the field of stormwater to begin tackling the looming problem of existing suburban development. Much of the runoff generated by this built environment is quickly conveyed to flood prevention structures or out to streams and rivers. Existing suburban neighborhoods may be one of the largest sources of non-point source pollution that remains essentially unchecked under water quality regulations.

The problem of suburban non-point source pollution does not have a simple solution. There are many factors to be considered on the way to developing a viable method of stormwater retrofitting for these artificially created sub-watersheds. First, reviewing the history of the development of stormwater management can help identify the reasons why stormwater quality management is of such importance today. Understanding the environmental benefits of water quality management can also provide a strong support for stormwater retrofit applications. Also, familiarity with stormwater legislation and regulation is crucial to the implementation of an unconventional stormwater quality control plan. Proposing a new stormwater quality agenda will require a keen understanding of existing stormwater legislation. Understanding the funding of government managed stormwater projects is also necessary in order to maintain the ability to continue environmental initiatives. The process of garnering public support is a key part of any government program, and stormwater management is no exception. Much of the funding for stormwater projects is generated from the public forum. Studying and understanding what has been tried in the field will begin to define what is working as well as what may need more thought and development. Finally, project applications performed in suburban regions, particularly residential areas, would allow for further testing of these technologies in a new environment. Public exposure of better site design would also be increased, which further spreads the knowledge about stormwater quality control.

This thesis endeavors to study the retrofitting of existing large lot residential neighborhoods with LID-based on-site stormwater quality management controls. It is one of the premises of this volume that this type of stormwater application should be addressed in order to achieve a successful regional stormwater management plan. The following is an expansion of the various points mentioned above. A project application is included for the purposes of determining the possibilities and limitations of retrofitting a suburban residential neighborhood in the Piedmont region of Georgia with LID-based stormwater management controls.

CHAPTER 2

DEVELOPMENT OF STORMWATER MANAGEMENT REGULATION IN THE UNITED STATES

This chapter seeks to provide a brief historical account of the development of stormwater management practices in the United States. In order to understand how we got where we are today it is crucial that we study the major influences behind past development. We must learn from the past in order to plan for a better future.

2.1 The Beginning of Stormwater Management

The Federal Register defines stormwater management as the mechanism for controlling stormwater runoff for the purposes of reducing downstream erosion, water quality degradation, flooding, and mitigating the adverse effects of changes in land use on the aquatic environment.[1] It is the single largest influence on all aspects of every construction site, and is in return influenced itself by the site.[2]

The development of stormwater management practices in the United States is intrinsically tied to soil conservation practices. Water quality did not become a primary reason for conservation until the 1970s, but soil conservation has been a critical issue for the agriculture industry since the early part of the 20th century. The increase in dust storm activity in the Great Plains region during the mid 1930s caused by decades of land

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[1] *Federal Register* 65, no.47 (2000) 12,898.
[2] Bruce K. Fergusson. *Introduction to Stormwater: Concept, Purpose and Design*. New York: John Wiley & Sons, Inc. (1998) 13.

misuse, overgrazing and the natural drought patterns of the region[3] began to affect the quality of life for the entire country; agricultural productivity was severely impacted due to the depletion of nutrients in the soil.

Galvanized by public and industry outcry, the U.S. Department of Agriculture (USDA) conducted initial research and experiments on soil erosion control. Out of this research emerged the Soil Conservation and Domestic Allotment Act of 1935. This act recognized that "soil erosion is a menace to the national welfare and that [it is] hereby declared to be a policy of Congress to provide permanently for the control and prevention of soil erosion."[4] As a result the act created the Soil Conservation Service (SCS) as a division within the USDA in order to develop programs of soil and water conservation.[5]

The initial concept behind creation of the SCS worked well on paper, but implementing far reaching erosion control tactics required local and grass roots support. Key state legislation was necessary, and in 1937 the Soil Conservation District Law empowered local farmers and landowners to designate conservation districts specifically for soil and water conservation. District boundaries tended to follow either county lines or, more commonly, watershed boundaries. This was the kind of local support the SCS needed in order to be more effective in its mission. The conservation district concept has evolved since its inception and is still used today, with close to 3,000 designated districts in the whole country.[6]

As mentioned, the primary concern for the SCS at the time of its inception was soil erosion on agricultural lands. These soil conservation practices contributed to

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[3] Natural Resource Conservation Service-Idaho (*http://www.id.nrcs.usda.gov/about/history.html*)
[4] Pub. L. No. 74-46, 49 Stat. 163, 16 U.S.C. 590(a)-(f).
[5] Soil and Water Resources Conservation Act: 1980 Appraisal Part II, Soil, Water and Related Resources in the United States: Analysis of Resources Trends, USDA. (August 1981) 209.
[6] National Association of Conservation Districts (*http://www.nacdnet.org/about/districts/index.phtml*)

improved water quality, although typically in an indirect manner.[7] During the 1940s and 50s the SCS worked with farmers and ranchers to implement conservation measures specifically meant to increase infiltration, reduce runoff and prevent sediments from moving into streams. The SCS took a holistic view of conservation, working with the entire watershed to reduce erosion. It was their policy not to involve themselves in any in-stream or floodplain projects without stabilizing the situation farther up on the watershed that had caused the problem to begin with. This position became of great importance when the USDA became involved with flood control in the mid 1950s. The Watershed Protection and Flood Prevention Act of 1954 authorized the USDA's Small Watershed Program and linked the importance of holistic treatment of the watershed with federally funded flood prevention measures.

The 1960s brought awareness of the eutrophic effects of agricultural sources of nitrogen and phosphorus, as well as the detrimental effects of synthetic pesticides on wildlife. One of the most prominent outcries for environmental revolution was the book *Silent Spring* by Rachel Carson, first published in 1962. Within its pages, Carson presented a dismal view of the ecological situation at the time, and called for immediate public and private action to change the disastrous course of our future.[8] Industrial sources of pollution also received attention during this time. As a result of this new research and public interest in a cleaner environment, the SCS suggested amendments to the Small Watershed Program to legitimize water quality as a project purpose. In 1972 these amendments were finally realized, including water quality management as a viable

[7] Helms, Douglas. "Water Quality in the Natural Resources Conservation Service: An Historical Overview." *Agricultural History* 76, no.2 (2002) 291.

[8] Milne, Lorus & Margery. "There's Poison All Around Us Now." *The New York Times*; September 23 (1962) 303.

purpose for small watershed projects. Previously these projects could only be implemented through the necessity of soil conservation techniques or to implement flood prevention measures. Projects considered for funding included recharging groundwater, trapping sediment, reducing salinity in irrigation projects and providing deep cold water for trout streams, among others.

It was also during the 1960s that the focus of water quality concerns shifted from agriculture to the sedimentation and erosion caused by suburban development. Due to inadequate or nonexistent erosion control measures, land development was causing both on-site and off-site problems. These ranged from on-site ponding, structural settling and the cracking of basement walls to off-site sedimentation, fish kills and severe stream bank erosion. Consequently the SCS was encouraged to become more actively involved in the increasing amount of urban-rural fringe development, a significant expansion of responsibility for the SCS.

Much of the base information in urban erosion control was adopted from earlier agricultural research, resulting in the remodeling and retrofitting of agronomic erosion control solutions for use in urban development. This information was used to create handbooks and guidelines for developers, including construction criteria for silt fences, diversions, dikes, sediment basins, rock dams, sediment traps and inlet protection of storm drains.[9] Plant material scientists were developing vegetative methods of curbing erosion on construction sites as well.

With the SCS's more prominent position and expertise in soil and water conservation practices, they became the primary mediator between conservation districts

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[9] Helms, Douglas. "Water Quality in the Natural Resources Conservation Service: An Historical Overview." *Agricultural History* 76, no.2 (2002) 295.

and developers in matters relating to the adherence of construction to county and state ordinances. The SCS was technical advisor for both groups, helping developers comply with site erosion control requirements and also advising the conservation districts on the level of compliance of projects submitted for approval. There was some opposition to the new regulations and ordinances, primarily from officials seen as allies of developers who wanted no rules. Fortunately the majority of the construction industry saw the severity of the situation and the ordinances were upheld and followed.

Further legislation passed in the 1960s emphasized the need to perform soil surveys in urbanizing areas in response to the growing need for water quality protection. These surveys aided in properly designating suitable areas for land development dependent on the soil quality. This decade also proved to be a period of multidisciplinary discussion and attentiveness with regard to soil and water conservation. In 1967 the conference on Soil, Water and Suburbia, hosted by the USDA and the Department of Housing and Urban Development, brought together professionals from various sections within the construction field, as well as government officials and residents, to discuss the future course of suburban land development in relation to soil and water conservation.

2.2 The Environmental Protection Agency and the Clean Water Act

The next decade brought the introduction of a new term in the conservation movement. Non-point source pollution was brought to public attention through water quality studies performed in various bodies of water across the United States. Results indicated there was no single end pipe, or point source, for much of the pollution found in streams and lakes. There were both rural and urban sources identified as non-point source pollution. In response to growing public demand for cleaner water, air and land, the federal government established the Environmental Protection Agency in 1970. Two years later the agency was given teeth with the Federal Water Pollution Control Act Amendments of 1972, commonly known as the Clean Water Act. Since then, further amendments to the legislation have only increased the EPA's ability to protect water quality.

The Clean Water Act was the first federal acknowledgement of the causes and effects of non-point source pollution. It promoted the development of guidelines to help control and mitigate the problem, commonly known today as Best Management Practices (BMPs), as well as proposing regional planning strategies in the tradition of the SCS. Guidance documents were created through the combined efforts of stormwater contractors and the SCS for wide range dispersal. From this point on the EPA and the SCS shared a plethora of common interests, solidifying a relationship that continues today. In 1994, the Soil Conservation Service was reorganized into the Natural Resources Conservation Service (NRCS) in order to encompass the many different responsibilities they hold beyond soil conservation.[10]

2.3 National Pollutant Discharge Elimination System

Another result of the 1972 Clean Water Act was the creation of the National Pollutant Discharge Elimination System (NPDES) by the EPA. This is a permit program originally created to control the wastewater discharges from various industries and wastewater treatment plants, known as point sources. Enforcement authority for these permits was given to the EPA, while permit granting was handled at the state level in 45

[10] Natural Resource Conservation Service - *http://www.nrcs.usda.gov/about/agency.html*

of the 50 states. This is the type of regional planning the SCS had been practicing since its conception. In 1987 the Clean Water Act was amended with the Water Quality Act, expanding the NPDES permit program to address “non-point” source pollution. In response to this amendment the EPA developed Phase I of the NPDES Stormwater Program.[11] The purpose of NPDES Phase I was to permit all Municipal Separate Storm Sewer Systems (MS4s) of large or medium sized populations (250,000 and 100,000 to 250,000, respectively).[12] Phase I also regulated any companies falling within one of the eleven categories of industrial activity presented, as well as any construction activity disturbing five or more acres of land. Any company, municipality or construction activity falling within this rule was required to acquire an NPDES permit as well as develop a stormwater management plan (SWMP) designed to prevent harmful pollutants from reaching open bodies of water either through stormwater runoff or the MS4 itself.[13]

Phase II of the NPDES stormwater program was enacted in December of 1999, with the expectation of full implementation by December of 2002, and built upon the foundation set by the Phase I program. It increased regulation by requiring designated small MS4s (communities with populations under 100,000 located within an identified urbanized area), as well as construction activities disturbing 1 to 5 acres of land, to request water discharge permits under NPDES. In addition to a permit, small MS4s have to develop a stormwater management program which incorporates the six minimum control measures required by the Phase II rules. Measurable goals have to be set within

[11] Phase I NPDES Stormwater Permit Requirements - http://www.stormwaterauthority.org/regulatory_data/phase_1.aspx
[12] *Georgia Stormwater Management Manual, vol. 1*. Georgia: Atlanta Regional Commission. (2001) 2-3.
[13] Phase I NPDES Stormwater Permit Requirements - http://www.stormwaterauthority.org/regulatory_data/phase_1.aspx

the program, using appropriate stormwater controls or BMPs, and an evaluation of the program's effectiveness must be performed after implementation.

2.4 Observations

The Clean Water Act and its Water Quality Act amendment created and inspired many other guidelines and regulations for the protection of water quality, most of which are handled at the state or district level. The NPDES program is the largest determinant to the level of stormwater management implemented in most new construction projects today. This standard by which we measure our future development should be much more than the minimum requirement. Even so, that is exactly what is stated in much of the NPDES literature – minimum requirement. This raises the question: "Is the minimal sufficient?" Little to no incentive exists for construction and design professionals to go the extra mile and provide more than what is minimally required to secure a permit.

Water conservation, and by association stormwater management, have come a long way since the agricultural and environmental disaster of the Dust Bowl. Today in the 21st century non-point source pollution is one of our primary environmental concerns. Our long standing agencies in resource conservation along with many scholars and professionals around the country are working to develop methods of stormwater management that will help mitigate non-point source pollution and stream bank erosion as well as recharge our groundwater supplies, mostly through on-site stormwater infiltration techniques. The future health and welfare of our natural habitats depends on our ability to allow natural systems to function properly even after our manipulations of the land.

CHAPTER 3

LOW-IMPACT DEVELOPMENT AND ITS ENVIRONMENTAL BENEFITS

The term on-site stormwater management refers to a variety of methods used to handle both water quantity and quality at the site level. While municipalities have been regulating water quantity for flood control purposes since about 1970[1], water quality control is a relatively new concept in stormwater management. Most suburban residential neighborhoods built after this time use some form of large (collective) on-site stormwater structure in order to manage the increased runoff from impervious surfaces. It is difficult and expensive, however, to provide both quantity and quality control using a single stormwater management structure. Today the majority of these existing neighborhoods still do not provide adequate water quality control.

As stated in chapter 2, it was not until the implementation of NPDES Phase II regulations around 2000 that new developments were required to include any sort of stormwater quality control. Prior to the 1970's few subdivisions employed any sort of stormwater management system, collective or otherwise. Between 1970 and 2000 suburban developments included primarily water quantity controls as required for flood protection purposes. Most of these older neighborhoods still lack any sort of stormwater quality management controls.

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[1] Ferguson, Bruce K.; Debo, Thomas N. *On-Site Stormwater Management Applications for Landscape and Engineering*. New York, New York: Van Nostrand Reinhold. 1990 (15).

Retrofitting existing neighborhoods with on-site stormwater management controls at the lot level is a viable solution to this problem. These types of stormwater runoff quality controls are also known as low-impact development (LID) stormwater techniques, meant to manage rainfall at the source using uniformly distributed decentralized micro-scale controls.[2] Rather than sending the untreated runoff from an entire development downstream to combine with the polluted runoff from other sub-watersheds it can be caught and treated at the source, there by reducing the pollutant load on streams, open bodies of water, and water treatment plants. Often these small, lot-oriented stormwater controls use native vegetation as their primary filter; native plants can be used to create habitats for local fauna, increasing both plant and animal diversity in typically homogenous residential neighborhoods. These environmental benefits will be discussed in this chapter with a specific focus on retrofit applications.

3.1 Low-Impact Development

The types of on-site stormwater quality management controls described above were first recognized as low-impact development principles during the mid-1980's in Prince George's County, Maryland. Before they were labeled LID these techniques were being developed and tested by scholars in the field of stormwater management. The introduction of LID principles as a way to address the growing environmental and economic limitations of conventional stormwater management practices allows for greater development potential with less environmental impact.[3] Stormwater management has for too long been seen as stormwater disposal. LID technology makes it

[2] LID Urban Design Tools – Background (*http://www.lid-stormwater.net/background.htm*)
[3] See *supra* note 2.

possible for people to redefine their relationship with stormwater in a way that is beneficial to both the community and the environment.

There are many different stormwater quality techniques that are considered low-impact development. The EPA recognizes five low-impact development techniques: bioretention areas, cisterns, green roofs, permeable and porous pavement and grass swales.[4] Soil amendments are an extra LID technique included by the Low-Impact Development Urban Design Tools website. Application of the appropriate technique for a specific water quality issue is critical in order to achieve maximum water quality control.

3.1.1 Bioretention Areas

Bioretention areas are shallow stormwater basins or landscaped areas that utilize engineered soils and vegetation to capture and treat runoff.[5] They function as soil and plant-based filtration devices that remove pollutants through a variety of physical, biological, and chemical processes.[6] Not surprisingly, bioretention areas have specific design requirements. Two of these requirements actually make this technique more appropriate than other LID techniques for use in existing stormwater systems in low density neighborhoods: donor area size and connection type.

The donor area is essentially the area of the site that will be contributing runoff to the bioretention area. This is not necessarily equal to the lot size, as only the area uphill

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[4] EPA – Stormwater Menu of BMPs (*http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=124*)

[5] *Georgia Stormwater Management Manual, vol.2* Georgia: Atlanta Regional Commission. (2001) 3.2-43.

[6] LID Urban Design Tools – Bioretention (*http://www.lid-stormwater.net/bio_benefits.htm*)

and directed into the bioretention cell would be contributing runoff. This makes the donor area extremely site specific. The size of the donor area is important when designing the bioretention cell. The Georgia Stormwater Management Manual specifies a maximum of five acres for any single bioretention area, with a maximum efficiency area of one-half to two acres. This size requirement makes bioretention basins ideal for use in low density residential neighborhoods where the average lot size is between three-quarters and two acres. For most lots one basin would be enough to treat the runoff from the majority of storms.

The type of connection between the donor area and the bioretention area is crucial to the effectiveness of the structure. There are two types of connections that can be made between a bioretention area and the donor area: on-line and off-line. On-line connections allow the entire runoff volume of every storm to pass through a bioretention area. This does not mean that the bioretention area is sized to treat the water quality volume of every storm. Rather the bioretention area must be capable of either safely detaining large storm volumes (typically those produced by 25-year, 24-hour storms) or safely conveying storm volumes greater than its capacity back into the existing conveyance system so that the runoff may continue to the site's quantity control structure.

On-line structures are typically less effective at pollutant removal than the alternative off-line structure. The off-line structure is designed to treat a specified amount of runoff (In Georgia, typically the water quality volume for the 85th percentile storm). Once the bioretention area's water capacity has been reached, a flow diverter prevents runoff from entering the cell. In this manner, off-line bioretention cells can be more effective at removing pollutants. Both on-line and off-line structures work well with existing curb and gutter systems. If the basin were to fill to capacity excess runoff would be diverted to the conveyance system through the exit curb cut. This would ensure that the basin never holds more water than it is designed to treat.

3.1.2 Cisterns and Rain Barrels

Rain barrels and cisterns can be used to catch rain from roofs as it travels down gutters, reducing the overall runoff volume exiting a property. They provide a source of essentially free water that can be readily utilized for outdoor purposes, such as landscape watering and car washing. They are considered an "on-lot treatment" of stormwater runoff, meaning that they manage runoff from individual residential lots.[7] While rain barrels and cisterns do manage a portion of the runoff leaving a property, it is a small percentage of the total volume as the majority of the runoff generated on a site originates on parking areas and other paved surfaces. Rain barrels and cisterns could be part of a larger LID-based stormwater quality management strategy that incorporates bioretention areas, grassed swales and permeable pavements to treat the majority of the runoff.

3.1.3 Green Roofs

Green roofs are roof-tops partially or completely covered with plants. This technique has been used in Europe for centuries to mitigate urban "heat island" effects as well as reduce peak stormwater flows. The reduction of peak storm flows, however, is only possible through wide-spread regional applications of this technology. Green roofs are viable stormwater quality management solutions for new development and re-

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[7] EPA – Stormwater Menu of BMPs (*http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=81*)

development. Their use in retrofit applications is more limited due to the weight of the roof structure, planting medium, plants and eventual water weight. Most typical roof structures are not designed to carry these loads, and so would require extensive structural reinforcement to support the green roof.

3.1.4 Permeable and Porous Pavement

Permeable and porous pavement can be used to replace much of the impervious surface area on a site such as driveways, walkways, and terraces. Medium traffic areas are the ideal application for this LID as heavy loads may damage the structure. These pavements can act as a treatment filter, removing pollutants such as oils and heavy metals. Once the runoff begins to filter through the pavement it can either be stored within the voids in the pavement itself for filtration into the sub-grade, or it can be directed to another stormwater quality or quantity structure such as a bioretention area or a detention pond.

3.1.5 Grass Swales

Grass swales are vegetated open channels used to slow runoff and facilitate sediment removal. They are typically sized for a specific storm event; where they are the primary form of stormwater conveyance they are typically sized to carry up to a 25-year, 24-hour storm event. Because grassed swales are in essence improvements on the traditional drainage ditch or culvert, they are not necessarily meant to remove a high percentage of pollutants. Relatively flat slopes are preferable, as this will aid in slowing the runoff and reducing the cost of installation by avoiding the need for check dams.

When using with other LID techniques grass swales can act as pretreatment areas, allowing larger sediment to settle out of the runoff before entering a more intensive water quality control structure such as a bioretention cell.

3.1.6 Applicability of LID Techniques

Low density residential neighborhoods are perfectly qualified for implementation of LID principles. One LID technique out of the ones described above is particularly applicable for use in these existing suburban residential areas due to the relatively large ratio of pervious to impervious surface in these neighborhoods. Bioretention areas could be used along the roadway to treat pavement runoff; they could also be used within individual lots to treat roof runoff, perhaps in combination with cisterns or rain barrels.

This thesis focuses on the use of bioretention technology to create hybrid stormwater systems in existing residential developments. It is impractical to devise a new system for an existing neighborhood that would handle both the quality and quantity of all the runoff generated by the largest storm. This is an expensive, extremely environmentally invasive and unnecessary undertaking if a neighborhood already employs conveyance and flood control structures that perform this task well. A hybrid stormwater system is one that combines both the existing conveyance/quantity control system and the newly integrated water quality treatment facilities. Hybrid systems are flexible and have the potential to work well for many types of developments if designed appropriately.

Low-impact development techniques and processes are virtually indispensable to stormwater retrofit applications. These principles could allow an already developed area to contribute to regional water quality and environment health through low-impact and low cost stormwater management alternatives. With the help of local government legislation, funding and public awareness these advanced methods of stormwater management have the potential to become the rule instead of the exception.

3.2 Downstream Environmental Effects

The non-point source pollution in our open bodies of water comes from many donors upstream. Every particle that makes up the entirety of the pollution in a lake, for example, started out as quite a small amount of dust, oil, fertilizer, etc. that was carried away by stormwater runoff. By themselves these particles pose little threat to the environment, but when the runoff from a large residential development, carrying millions of these deceptively harmless particles, combines with that of two or three developments of equal or greater size, the pollutant load is concentrated into an ecological hazard with many harmful consequences.

Concentrations of non-point source pollution in surface waters affect every living creature that uses them. Turbidity due to suspended soil particles from erosion blocks sunlight and promotes higher levels of harmful bacteria. It can also abrade fish gills and cover the bottom habitats of streams and lakes.[8] Increased levels of phosphorus and nitrogen from fertilizers promote harmful algal blooms,[9] as well as causing abnormal hormonal levels and miscarriages in humans.[10] Oils and other organic compounds

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[8] Ferguson, Bruce K. *Introduction to Stormwater Management – Concept, Purpose, Design*. New York, New York: John Wiley & Sons, Inc. 1998.

[9] National Research Council. *Clean Coastal Waters: Understanding and Reducing the Effects of Nutrient Pollution.* Washington, DC: National Academy Press; 2000.

[10] Gaffield, Stephen J.; Goo, Robert L.; Richards, Lynn A.; Jackson, Richard J. "Public Health Effects of Inadequately Managed Stormwater Runoff." *American Journal of Public Health* 93, no.9 (2003) 1527-1533.

decompose in water and deprive fish, crustaceans, and aquatic plants of adequate oxygen content.[11] The list of pollutants is almost endless.

LID-based on-site stormwater quality controls are one effective method of preventing non-point source pollutants from banding together. Using these methods reduces the pollutant load downstream by capturing and filtering out as much as possible at the site. Studies show that bioretention basins are effective at removing 80% of total suspended solids (TSS) in stormwater runoff. Phosphorus, nitrogen, and heavy metals are also reduced by 60%, 50%, and 80% respectively.[12] Filtration of the runoff reduces the total volume leaving the site, preventing serious downstream erosion and further sedimentation.

The creation of safe, potable water also benefits from on-site stormwater quality controls. The treatment of water for human consumption can be made less complex, less expensive, and ultimately less harmful if more pollutants are removed at the source. Water treatment for drinkability uses a slew of chemicals to detoxify, disinfect and remove odors from surface waters. Decades of increasing non-point source pollution have added levels of complexity to the processes that make water treatment a costly endeavor.[13] These treatments also carry their own hazards, typically in the way of potentially carcinogenic compounds that are never the less necessary to make water drinkable.[14] If more is done to prevent pollution from entering open bodies of water,

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[11] See *supra* note 6.

[12] *Georgia Stormwater Management Manual, vol.2* Georgia: Atlanta Regional Commission. (2001) 3.1-7.

[13] Awwa Research Foundation. *Impacts of Major Point and Non-Point Sources on Raw Water Treatability [Project #2616]*. Awwa Research Foundation. 2002-2008. (*http://www.awwarf.org/research/topicsandprojects/execSum/2616.aspx*)

[14] See *supra* note 8.

treatment processes will be simpler, less dangerous and less costly. Bioretention basins installed at the source of stormwater runoff can reduce the pollutant load significantly.

The environmental benefits of on-site stormwater LID controls go far beyond the lot on which the bioretention basin is located. With a widespread use of these techniques in neighborhood retrofit applications, new development and re-development, non-point source pollution could be reduced to a fraction of what it is. Recreation in open bodies of water would not be guided by whether or not the levels of pollution are too high; instead it would be a simple decision of whether or not it is a nice day to go swimming. Eating fish caught in a local stream would not mean taking your life into your hands. Instead, we would be able to enjoy our environmental resources the way they were meant to be enjoyed – without reservation.

3.3 Localized Environmental Benefits

Low-impact development stormwater controls can benefit the local environment in many ways. Bioretention basins can be designed to imitate a natural area, or as "naturescapes". Landscape plans should include at least three different species each of trees, shrubs and herbaceous plants, in order to create a truly well rounded habitat. This level of biodiversity can have a revitalizing effect on a suburban residential neighborhood where landscapes tend to suffer from a drab homogeneity.

Bioretention cells are also typically landscaped with native plant species.[15] Due to their adaptation to a local environment, native plants tend to be hardier than non-native

[15] *Georgia Stormwater Management Manual, vol.2* Georgia: Atlanta Regional Commission. (2001) 3.2-50.

species.[16] It is important that the plants chosen for the cell can withstand periods of extreme wet and dry, both of which can occur in a bioretention basin. The creation of well rounded plant habitats can also help support plant health by avoiding monoculture landscapes that can encourage the spread of disease. If appropriate, a plant could even be chosen for its soil fixing properties to support other plant in the basin. A native plant bioretention area can also provide a habitat for native birds and insects.[17] If desired, a basin can be designed with multiple purposes, such as to support butterfly or dragonfly populations or to provide birds with nesting opportunities.

The promotion of native habitats in bioretention cells also helps to preserve a sense of place and the local ecology. The replacement of native flora with non-native species in residential landscapes has been a prevalent trend for a long time. This can lead to an ecological instability in the local environment which often requires the introduction of another non-native species to re-balance it. Eventually, this self-perpetuating cycle can lead to the loss of entire native ecosystems. The use of native plants in bioretention basins can help avoid this fate.

The general addition of more planted spaces to an area can have other effects as well. Perennial and herbaceous plantings can help cool the entire neighborhood through evaporation and evapotranspiration of the runoff caught in the basins and on plants. With a neighborhood-wide retrofit installation, the ambient temperature reduction could be significant. Finally, landscaped bioretention basins can help beautify an entire neighborhood, providing aesthetic enjoyment for the public. These sensory benefits, along with the added knowledge of the seemingly simple work these rain gardens are

[16] Greenacres: Landscaping with Native Plants (http://www.epa.gov/greenacres/index.html)
[17] Native Plants for Conservation, Restoration, and Landscaping (http://www.dcr.virginia.gov/natural_heritage/nativeplants.shtml)

doing to remove pollutants from our eventual drinking water, may help to increase public feelings of stewardship for the land and responsibility for environment health.

3.4 Observations

This chapter looked at the environmental benefits of retrofitting an existing development with lot-oriented on-site stormwater management structures. These low-impact development strategies can contribute to environment health in many different ways. The effects of a water quality systems composed of multiple LID techniques can be far-reaching. The effects of such a system implemented at a regional scale could significantly restore an urbanized area's natural, pre-development ability to treat for water quality.

Bioretention basins can combine with existing stormwater systems to create hybrid stormwater management systems that are effective at both runoff quality and quantity control. This can be achieved in a minimally invasive manner with maximum environmental rewards. Combined with other methods of pollution and volume control, existing conveyance/quantity stormwater management systems can be transformed into hybrid systems that can comply with water quality requirements currently only enforced for new and re-development.

Neighborhoods can reap significant benefits from a hybrid stormwater management system. Using native plants in bioretention basins increases plant biodiversity and reduces neighborhood landscape homogeneity. Natives also support the local ecology and wildlife, providing food and nesting for local birds and insects. The greater occurrence of leafy planted areas as opposed to large expanses of lawn can also have a cooling effect on the locale. Eventually the overwhelming benefits of bioretention basins for local residents can foster feelings of environmental stewardship and responsibility along with knowledge of natural processes, making the neighborhood as a whole more environmentally aware.

CHAPTER 4

SOCIO-POLITICAL CONSIDERATIONS FOR STORMWATER RETROFITTING

Making the retrofitting of on-site stormwater management a common practice is no small task. Three factors are of most importance on the road to this goal: legislation, funding and public support. This chapter studies the obstacles each of these holds for this thesis, as well as possible solutions for each.

4.1 Stormwater Legislation in Georgia

Legislation is the backbone of the stormwater management reform movement. It is through legislation that new and innovative ideas can be widely incorporated into the regular planning and implementation of stormwater management systems. Legislation also provides enforcement of these policies and ordinances. However, this does not mean that current legislation is by any means complete. At the state level, NPDES regulations fail to provide incentives for the use of stormwater runoff pollution removal systems that are more effective than the most common, low budget alternative. In addition, there is no legislatively supported vehicle in place to trigger existing development stormwater retrofitting at the local level. Significant stormwater improvements are currently only required for new land development and redevelopment projects.

4.1.1 National Pollutant Discharge Elimination System (NPDES)

NPDES regulations provide a broadly defined minimum set of guidelines for regulated Municipal Storm Sewer Systems (MS4's). Urbanized areas of specific population sizes fall under one of two categories: medium and large MS4's with populations of 100,000 or more are regulated through Phase I requirements; small MS4's of populations from 50,000 to 100,000 are regulated through Phase II requirements. Phase I requires medium and large MS4's to implement "controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and system, design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants."[1] Stormwater management programs required by Phase I regulation must include measures to:

- Identify major outfalls and pollutant loadings,
- Detect and eliminate non-stormwater discharges to the system,
- Reduce pollutants in runoff from industrial, commercial and residential areas, and
- Control stormwater discharges from new development and redevelopment areas.[2]

The specifics, however, are left undefined with the intention that each regulated municipality or local jurisdiction is responsible for its own stormwater management plan.

Phase II requirements for small MS4 operators located in urbanized areas have a greater number of guidelines, but still leave the actual design and implementation of the stormwater management plan up to the municipality in question. "The operator must design its stormwater management program to satisfy applicable CWA [Clean Water

[1] Clean Water Act, Section 402: National Pollutant Discharge Elimination System (p)(3)(B)(iii)
[2] EPA – Permit Application Requirements for Medium and Large MS4's
(*http://cfpub.epa.gov/npdes/stormwater/lgpermit.cfm*)

Act] water quality requirements and technology standards. The program must include the development and implementation of best management practices (BMP's) and measurable goals for the following six minimum measures, and include evaluation and reporting efforts:

- Public education and outreach,
- Public participation/involvement,
- Illicit discharge detection and elimination,
- Construction site runoff control,
- Post-construction runoff control, and
- Pollution prevention/good housekeeping for municipal operations."[3]

Within the ten combined requirements of Phases I and II, only one relates specifically to the reduction in residential stormwater runoff. Also, while the use of BMP's is promoted in Phase II, the method of implementation is left wide open for interpretation. This amount of freedom in policy can be a double edged sword, depending on the municipality in question, as states Joel P. Thrash, M.En., CPESC-IT, in the following excerpt from his article "Ecologically Functional Stormwater Basin Retrofits":

> For some municipalities and their elected officials, Phase II regulation is viewed as an opportunity to update local ordinances or enforcement measures and to invest in surface-water resources previously ignored at the local government level. For others, even within the same watershed, Phase II stormwater requirements are a necessary evil packaged and presented to citizens as six *de minimus* control measures mandated to them

[3] EPA – Storm Water Phase II Compliance Assistance Guide (http://www.stormwaterauthority.org/assets/SW_PhaseII_Compliance_Guide.pdf)

by the federal government. From both perspectives, short- and long-term economic growth associated with urban development is understandably of greater importance than the NPDES program and its potential ecological significance.[4]

Current legislation in Georgia does not strongly promote one method of stormwater management over another, perhaps less effective method. So while smaller, low-impact development (LID) on-site stormwater management device chains may be more effective than large dry detention ponds at pollutant removal from smaller storm events, it is entirely up to the municipality whether or not they include or promote these in their stormwater management plan.

4.1.2 Local Legislation and Existing Development

The second legislative issue exists at the local level and draws closer to the heart of the problem. Currently local policy does not provide a vehicle for improvement of stormwater systems in existing developments unless the system fails and requires repair. The result is that existing developments do not enter the stormwater improvement system, funds are not allocated and plans are generally not made.

This would appear to be a real-life application of the old saying, "if it ain't broke, don't fix it." However, when dealing with large stormwater systems and their aging infrastructure, a better management tactic may be to provide a legislatively established method by which these existing developments can begin

[4] Thrash, Joel P.. "Ecologically Functional Stormwater Basin Retrofits." *Stormwater*. May 2007. (http://www.stormh2o.com)

the process of planning, fund-gathering and phased implementation of new, LID-based on-site stormwater management systems, before their existing systems break. It is, after all, inevitable that our infrastructure will require replacement.

One method of addressing this issue as a proactive approach to infrastructure replacement would be for local governments to create a division, group or organization specifically geared towards the replacement and redesign of aging stormwater infrastructure. Once created, this division would be in charge of producing local area information on material types, age and expected date of replacement for existing municipal stormwater infrastructure. This information would allow for the creation of a schedule of replacement, hopefully well in advance of the need for replacement. Finally, the local jurisdiction would require that a specified amount of LID on-site stormwater management structures and BMP's be incorporated into the replaced/redesigned system.

As with most stormwater management plans, the one described above would work best if implemented at a watershed scale. This would mean that local governments in a given region would need to coordinate their efforts and help each other through research and information exchanges. The next section discusses regional planning districts as a method of achieving this goal.

4.1.3 Regional Water Planning Districts

The two legislative problems discussed above can be addressed through the creation of regional water planning districts. A multi-municipal planning organization can promote the adoption of environmentally sound concepts, such as LID and on-site stormwater management retrofitting, into local government policy at a regional scale. As well, model ordinances can be proposed to implement a system of identifying, funding and planning for the replacement of existing, aging stormwater infrastructure with more effective on-site stormwater runoff pollutant removal solutions.

The Metropolitan North Georgia Water Planning District (MNGWPD) is the first of this type of organization in the state of Georgia. Created in 2001 by the Georgia General Assembly, the MNGWPD exists to establish policy, create plans and promote intergovernmental coordination of all water issues in the District from a regional perspective.[5] It encompasses 16 counties within the metropolitan Atlanta area, where nearly half of the state's entire population resides. This organization has already proposed a Watershed Management Plan, as well as six Model Stormwater Management Ordinances to be adopted by all District members.

The MNGWPD also promotes use of the Georgia Stormwater Management Manual (GSMM), commonly referred to as the Blue Book. Released in 2001 by the Atlanta Regional Commission (ARC) not long before the MNGWPD was made official, the GSMM was developed as a three volume guide for local governments, land developers, businesses and citizens. It covers basic stormwater principles, legislation, minimum standards for new development and redevelopment, better site design practices, maintenance information and pollution prevention practices. This being said, it is important to realize that the

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[5] Metropolitan North Georgia Water District (*http://www.northgeorgiawater.com/html/aboutus.htm*)

GSMM is not in fact a state document. It has jurisdiction only in those municipalities that adopt it, and its adoption is entirely voluntary. The GSMM also lacks specific information for regions other than those within the ARC jurisdiction, such as the coastal plain. Future supplements to the GSMM will likely begin addressing these omissions but the document is still far from becoming a state sanctioned manual.

The GSMM has been adopted by many municipalities in Georgia as the definitive guide to stormwater management design, implementation and regulation, but many of them have yet to see a single project incorporate a significant amount of what the GSMM calls structural stormwater controls.[6] In addition, existing development retrofit projects are not even referenced. Obviously, more support for these types of systems is necessary. The solution could be the creation of more regional water planning districts, like the MNGWPD, over the rest of the state. This would make the spreading of information and support of future retrofit concepts and policy possible state-wide.

4.2 Stormwater Retrofit Program Funding

The next question is of course, where would the money come from? Funding is what makes stormwater management plans, municipal or otherwise, possible. Without allocated funds any new stormwater systems or improvements to older systems would not be possible. The acquisition of appropriate funds can be achieved in many different ways at all levels of government.

[6] *Georgia Stormwater Management Manual, vol.2* Georgia: Atlanta Regional Commission. (2001) 3.1-1.

Once a stormwater retrofit program has been established in a jurisdiction the stormwater utility in charge must secure the necessary funds for the program. There are many different ways of acquiring funding for government programs. This thesis will focus on those that would seem to be the most amenable to a public stormwater retrofit program; these are: general revenue appropriations, SPLOST funding, utility user service fees, federal 319(h) grants, Community Development Block Grants (CDBG), and private funding sources.

4.2.1 General Revenue Appropriations

General revenue appropriations are traditionally the most common source of funding for stormwater projects, as well as operations and maintenance costs. The money comes "from taxes (e.g., property, sales, and income), exactions (e.g. franchise fees on utilities), and federal/state revenue sharing, and are simply appropriated for specific purposes … through the normal budget process."[7] Because this is the general city or county tax fund, stormwater has to compete for funds with all other governmental departments. This means that it is unlikely that general revenue appropriations alone could fund a growing stormwater program. Extra funds must be acquired from a different location.

4.2.2 SPLOST Funding

The Special Purpose Local Options Sales Tax (SPLOST) is typically a one percent sales tax that is voted on by residents of a county. The revenue created can pay

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[7] National Association of Flood and Stormwater Management Agencies. *Guidance for Municipal Stormwater Funding*. (January 2006) 2-10.

for specified capital improvement projects within the area of tax collection. In order for a project to receive these funds, the residents of the local area must first vote for the project's approval. A SPLOST program is typically voted on for renewal every four to five years, depending on the county.

The key to acquiring SPLOST program funds allocated towards a stormwater retrofit program is public awareness, education and involvement. Since it is the taxpayer who decides whether or not to even allow a SPLOST program, the stormwater utility should work to educate the public about the necessity for existing stormwater system retrofitting well in advance of a SPLOST vote. A plan of action spanning the length of the SPLOST collection period would boost public confidence in the stormwater utility's ability to complete any proposed retrofits in time and with the funds generated.

One drawback to the SPLOST is its time frame. Because revenue is collected as a sales tax, funds would not be immediately available for use. One way most municipalities deal with the lag time is through the use of bonds that can be established in anticipation of future revenue.

An example of the use of SPLOST funding to implement a stormwater retrofit project occurred between 2005 and 2007 in Athens, Georgia. Excessive flooding of Lumpkin Street, an arterial that connects the University of Georgia (UGA) to downtown Athens, promoted collaboration between the Unified Government of Athens-Clarke County and UGA to devise a solution. The final design involved the installation of several bioretention areas along the roadway designed to filter and treat polluted runoff from Lumpkin Street. Project funding was primarily provided by the city-county government through SPLOST, in return for use of UGA land to install the bioretention areas. UGA also agreed to regularly maintain the bioretention areas. To date, the project has been successful at completely eradicating flooding on Lumpkin Street.[8]

4.2.3 Fee-Based Funding

This is one of the most popular methods of funding the operations and maintenance of a government run stormwater utility. In general, fee-based funding requires the creation of a stormwater user service fee, to be paid to the local stormwater utility. In the past the demand a property placed on a system had been measured in terms of the peak flow of stormwater runoff generated by the property; the greater the flow, the greater the use and thus the greater the user fee. However, new stormwater user fees are typically calculated using two other major components: volume of runoff and pollution. At the end of 2007 it was estimated that over 600 local stormwater utilities existed in the United States, with many more in the planning stages.[9]

Utility user fees have proven themselves reliable and stable forms of revenue. As well, equitability of charges and revenue sufficiency to support a growing stormwater program make it a popular choice for local governments that have recently fallen under NPDES Phase II regulation. An example of this method's success is the city of Griffin, Georgia:

> In 1992 the City of Griffin was faced the challenges of undersized infrastructure, the lack of storm drainage systems, and the condition of the system was in bad repair. Furthermore, Griffin had been identified as a

[8] Sniff, Daniel E., Johnson, Ralph F., Kirsche, Kevin M., Adams, P. Dexter. *Testing the Waters: Lessons Learned through Innovative Town-Gown Partnerships*. Athens, Georgia: Athens-Clarke County. 2005.

[9] Reese, Andrew J.. "Stormwater Utility User Fee Credits." *Stormwater*. November-December 2007. (http://www.stormh2o.com)

> NPDES Phase II candidate and the City was identified as a contributing source to a listed stream segment under EPA 303 (d). Griffin began to investigate their options for funding of the non-point source program. After [due] diligence and several years of program review, the City of Griffin concluded that the best way to establish a permanent program was to create an enterprise fund and establish a Utility in 1998, Georgia's first.
>
> The Stormwater Utility has paved the way for GIS Inventory and mapping, Hydrologic and Hydraulic modeling, Watershed Assessments and Capital Improvement Planning, not to mention the daily operation and maintenance of the storm sewer system. This proactive approach to dedicated funding has enabled Griffin to pursue other support funding sources and revenues.
>
> The Utility produces a revenue stream of 1.3 million dollars annually. Its user fee is set at $2.95/ERU and the Equivalent Residential Unit is 2200 square feet. The system has around 35,000 ERU's. The Utility has no exemptions and also has a credit mechanism for detention, education and soon to be water quality.[10]

It is this funding method's ability to support a developing stormwater program what makes it an obvious choice to fund special stormwater projects, such as on-site retrofits in existing developments. One drawback is that growing a stormwater program would likely require increasing the user service fee since some sort of stormwater fee is already in effect in many places. Extra funds could perhaps come from a fee imposed on the

[10] Keller, Brad D. *Funding of Non-Point Source Program's "Stormwater Utilities" – The Griffin Experience*. 2001. (http://www.griffinstorm.com)

amount of turf area on a property; as it has been shown that turf care in the form of fertilizers and pesticides make up a large part of non-point source pollution, a turf maintenance fee could be well supported from a stormwater runoff pollution standpoint. Of course, any added fees would have to be combined with an educational campaign explaining the necessity of funds to help prevent non-point source pollution. The fee along with the knowledge could galvanize the public into action to help mitigate the problem through the replacement of turf area with native plantings that require less chemical care, and perhaps reduce or remove the fee as a form of compliance credit.

Fee-based funding can be a very flexible system depending on the governing authority. It can be tailored to virtually any stormwater program and it is a keenly noticeable way for the general public to become aware that there is a stormwater runoff pollution problem, as well as what is required to begin the mitigation process.

4.2.4 Federal 319(h) Grant Funding

When the Clean Water Act was amended in 1987, one of the new provisions was section 319, the Non-point Source Management Program. This program provides grant money to the states to implement non-point source projects and programs. The grant funds are then distributed across the state. An example of the use of 319(h) funds in Georgia was carried out by the city of Griffin. In their efforts to mitigate the pollution in urban stormwater runoff, they used 319(h) funding to create a constructed wetlands that would receive and treat runoff from 180 acres of urbanized land.[11]

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[11] Keller, Brad D. *Funding of Non-Point Source Program's "Stormwater Utilities" – The Griffin Experience*. 2001. (http://www.griffinstorm.com)

319(h) grant funding would be helpful in supporting the implementation of larger stormwater related projects, such as a regional stormwater retrofit initiative, rather than working at the local level on specific retrofit projects. This type of funding would support example stormwater management applications, such as the one in Griffin, GA. A regional water planning district would be essential in securing this type of federal fund, as the area benefiting from the funding would be greater.

4.2.5 Community Development Block Grant Program (CDBG)

The CDBG program is a flexible program that provides communities with resources to address a wide range of unique community development needs.[12] Many of our older suburban communities in need of significant infrastructure repair and restoration can benefit from the different types of programs provided through CDBG. The retrofitting of stormwater systems in these areas can be part of a larger renewal initiative which combines road work with other public works projects that are also eligible for funding through CDBG. This would help further the region's goal of reducing non-point source pollution in residential areas, as required by NPDES Phase II regulation.

Including an on-site stormwater retrofit installation in a community development project can also help create public interest in environmental endeavors. When properly designed these on-site, low-impact stormwater management structures can also act as landscape improvements that are

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[12] Community Development Block Grant (CDBG) Programs – CPD – HUD (*http://www.hud.gov/offices/cpd/communitydevelopment/programs/*)

aesthetically appreciated by the entire community. If a stormwater utility fee is in effect, a stormwater retrofit provided through CDBG could be the source of a neighborhood-wide stormwater credit, further supporting community development through financial incentives.

As with other funding sources, Community Development Block Grants are rarely by themselves enough to fund large multi-faceted projects. It would be especially difficult if one CDBG were being used to complete several large renewal and restoration projects at once since the fund amount is finite. A combination of funding sources is generally the best way to ensure a project is properly carried out and finished on time.

4.2.6 Private Funding

The world of private funding is also a viable source of income for a fledgling stormwater retrofit program. There are myriad organizations willing and able to provide money in the form of grants, loans and trusts for the furthering of environmental endeavors. Some examples are:

- America's Charities
- Philip Morris Companies Inc. – one of the largest supporters of environmental protection and conservation causes.
- Turner Foundation – specific focus on water environmental goals.[13]

This type of funding may be more appropriate as primary donation for a single large stormwater retrofit project and more than likely would need to be combined with one of the other funding methods described above. Conversely, private

[13] Program/Project Funding: Polluted Runoff (*http://www.epa.gov/nps/capacity/funding.htm*)

company fund drives could provide money for smaller retrofitting or restoration projects.

The six different methods of funding studied and described above are by no means a definitive list of funding possibilities. Regardless of what single funding source or combination of funding sources a municipality chooses to fund their stormwater retrofit program, there should always be a funding strategy in place to guide the acquisition and distribution of funds. A stormwater program should always define whether the funding program will be expensed ("pay-as-you-go") or debt based. Linkages and dependencies between funding sources and projects also need to be identified to ensure that the proper funds are being utilized accordingly. Funding resources must also be dedicated and stable in order to avoid over-budget situations. Above all else, the municipality must take into account community expectations and public support. Most funding methods are at least partially dependent on public education and support.

4.3 Public Support and Stormwater Retrofits

Public support, involvement and education are the keys to the overall success, longevity and financial robustness of any stormwater management plan. Without strong public support, funding for all parts of the stormwater management plan would suffer. The public must be educated and integrated into any stormwater plan so that they can be the entity that creates impulse for future stormwater management paradigm shifts.

4.3.1 Educating the Public

Involving the public in watershed protection efforts is crucial because it promotes broader public support, helps create an ethic of stewardship and community service, and enables the public to make informed choices about resource management.[14] Since both Phases I and II NPDES stormwater regulations require communities to develop and implement public education and outreach programs, most regulated local governments have already established environmental public education initiatives. Programs such as the Clean Water Campaign, Atlanta Stream Clean-Up, Pollution Prevention Assistance Division (P^2AD), and others make sure that the public has accurate information about the dangers of non-point source pollution, as well as teaching about watershed health and how individuals can help mitigate non-point source water pollution.

Since the educational vehicle exists, any new programs or initiatives – such as promoting a new stormwater retrofit division – should work with existing programs to include information about the stormwater retrofit program. This would help cut initial start-up costs, provide an already created list of recipients and promote cooperation between different environmental groups, perhaps creating a much stronger united front. A coordinated voice also helps reduce the incidence of confusion due to multiple sources of information.

4.3.2 Voluntarism and Community Service

Local governments and environmental organizations should work to promote a higher incidence of voluntarism and community service within stormwater management.

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[14] CH2MHILL. *District-Wide Watershed Management Plan – Final Report.* Atlanta, Georgia: Metropolitan North Georgia Water Planning District. (September 2003) 7-2.

This is a good way to bridge the gap between the education provided and the reality of stormwater non-point source pollution. Events such as storm drain tagging/stamping and neighborhood-oriented street and gutter clean-ups add to the awareness created through stormwater education initiatives, further developing a sense of stewardship and responsibility for the land. Local or neighborhood-based volunteer efforts can make the residents of an area more aware of their own natural resources, such as streams and flood plains. Volunteers also help to spread information about the importance of preventing non-point source pollution by word of mouth.[15] This "grass-roots" informational chain can be more effective than traditional educational methods, as people have a tendency to listen to their family and friends more intently than impersonal pamphlets and television commercials.

A stormwater retrofit volunteer organization would be greatly beneficial to the stormwater utility. In the beginning of the retrofit program these volunteers could be trained to locate and identify stormwater systems across the entire municipality, gathering the necessary data to create the initial replacement and retrofit schedule. Once the projects begin, these volunteers could help by spreading the word about stormwater retrofitting by speaking at schools and civic association meetings. Volunteers could help finish out retrofit projects by helping to plant any prepared bioinfiltration basins, saving the stormwater utility on labor costs and helping the neighborhood attain its service fee credit.

Monitoring and maintenance of newly installed stormwater retrofit facilities may also benefit from help of volunteers. Once trained in the proper way to maintain the

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[15] Rafter, Dan. "The Importance of Volunteers." *Stormwater*. May 2007. (http://www.stormh2o.com)

BMPs, volunteers can go out and help residents learn to maintain them themselves. For BMPs that remain under the control of the stormwater utility the volunteers could visually inspect and/or provide maintenance on a scheduled basis, ensuring that the water quality control structure retains its maximum capacity to reduce non-point source pollution. Volunteers can be a valuable commodity for a stormwater utility as well as the entire watershed.

4.3.3 User Fee Credit

Public support for stormwater retrofit projects can also be encouraged through various incentive programs. Citizens tend to respond favorably to financial incentives. Mentioned several times throughout this chapter and one of the most commonly implemented forms of financial incentive, is the user service fee credit which will now be explained. These credits are one of the few methods stormwater utilities have to encourage sound development using a "carrot" instead of a "stick."[16] A user service fee credit is presented as a method for a property owner to reduce the fee they would otherwise pay. The application of these credits can be based on any number of reasons from property location to type of property; some are purely political. This can bring up questions of fairness with regard to who receives a credit, so if a stormwater utility is considering the use of a fee credit, the rules regarding its application should be clear and concise, with a solid methodology and rigid enforcement. In essence: credits should be earned, not given.

[16] Reese, Andrew J.. "Stormwater Utility User Fee Credits." *Stormwater*. November-December 2007. (http://www.stormh2o.com)

Utility user fee credits are already offered as real incentive for the personal installation of on-site stormwater BMP's. The key to a successful credit program is the amount of credit offered. Many utilities limit the amount of credit that a residential client can receive from BMP installations to around 10% of the fee. This may not be enough to truly reward a property owner. According to studies gathered by the EPA, the estimated cost of installing a bioinfiltration basin with the capacity to treat 100 cubic feet of runoff is approximately $700.[17] Now consider the following example:

> A residential lot with a total area of 39,147sf, or 0.898 acres, contains 4,069sf of impervious cover, approximately 10.39% of the site. Using the formula provided by the GSMM to calculate the Water Quality Volume[18] use to size a BMP, we arrive at 0.129acft, or 561cuft of treatable water. Now, if we calculate the cost of construction, design and permitting using the formula provided by the EPA, we arrive at an estimated cost of $3,844.11.
>
> If the stormwater fee is calculated to be $0.77 per 100sf of impervious surface, the property owner would owe $40.69 in fees. A 10% credit would save him $4.07 per year, if the fee base remained static.

The cost of designing, permitting and constructing the BMP is a significant amount for the property owner to incur, and does not include future maintenance costs. A larger credit, more appropriate to the amount spent, would allow the property owner to feel vindicated for his actions. He may then be compelled to speak about his experience in a positive and constructive way that might convince other people to follow in his footsteps.

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[17] EPA – Stormwater Menu of BMP's (http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=min_measure&min_measure_id=5)

[18] *Georgia Stormwater Management Manual, vol.1* Georgia: Atlanta Regional Commission. (2001) 4-13.

An appropriate financial reward is a critical issue that must be clearly addressed if fee credits are to play a significant part as incentives for stormwater retrofitting. The main reason for implementing user fee credits is to get more stormwater quality management controls into the ground.

4.3.4 Neighborhood Retrofit Credit

The same idea of a user fee credit described above could be applied at the neighborhood or small community level. A neighborhood retrofit credit could be offered as an incentive for entire communities to participate in the stormwater retrofit initiative, either under the utility or on their own. An appropriate credit amount combined with informational and educational initiatives could work to motivate the neighborhood to gather enough funding for a planning effort towards the implementation of on-site stormwater management structures over the entire area. These would act as a treatment train (a connected group of stormwater quality controls) for the neighborhood watershed. The goal would be to treat runoff from the maximum amount of impervious surface and reduce the amount of non-point source pollution as much as possible. Neighborhoods that undertake this challenge could later be used as demonstration projects by the utility and/or as an educational tool to promote further support of the program.

4.4 Observations

The three topics studied above are almost impossible to study independently of each other. Each exerts influence and pressure on the others in a multitude of ways. Legislation can give or take away funding sources for the development of a stormwater utility and its various programs. Unless there is a legislatively defined vehicle for stormwater retrofit projects under the utility, money cannot be allotted to that end. Public support can mean the success or failure of a stormwater retrofit division. With enough public involvement funding can be secured for a special or demonstration project. There are many ways in which these three aspects can interact and affect each other. A proper stormwater retrofit initiative takes into account all of these factors and uses them to its advantage:

- Promote legislation that facilitates stormwater retrofitting in residential areas;
- Gather funding sources that will provide the necessary capital to support the program; set up reliable and equitable resources; seek grant funding;
- Work with existing stormwater support and education organizations to provide private property owners, civic associations and Home Owners Associations with information about residential stormwater retrofitting possibilities; offer appropriately rewarding incentives.

There are communities around the country that have already taken the steps and implemented stormwater retrofit projects. The next chapter presents three case studies of successful stormwater retrofits.

CHAPTER 5

CASE STUDIES IN URBAN STORMWATER RETROFITTING

As seen in Chapter 3, many obstacles still exist on the way to wide-spread effective stormwater retrofit programs. While many municipalities have begun requiring the use of stormwater best management practices (BMPs) in new construction in order to address water quality issues, as well as to encourage groundwater recharge and subsurface outflow, few places have government sponsored programs in place promoting the use of on-site stormwater quality management structures in existing developments. Few incentives exist to motivate municipalities or private land owners to do something about water quality in their areas beyond the minimal. Most of the stormwater management systems built prior to water quality regulations were intended to efficiently move water out and away from a site as quickly as possible, with minimal concern to non-point source pollution. So while new development is being strongly encouraged to do as much as possible to clean up and filter its runoff, existing development still catches, collects and conveys its runoff – pollutants and all – through impervious pipes and out into overland streams and rivers.

While few, the number of communities addressing the problem of existing development runoff is steadily growing due to an ever expanding knowledge base and increased sense of environmental responsability. This chapter looks at a few examples of proactive locales across the United States with well-developed stormwater management initiatives with a primary focus on existing stormwater retrofits.

5.1 Portland, Oregon – Green Streets Program

The Green Streets program in Portland, Oregon, is an excellent example of a municipal government taking the lead in promoting and incorporating the use of sustainable stormwater strategies primarily in urban public and private development. A little over ten years ago, at about the time NPDES Phase I was implemented, the city began looking for ways to manage stormwater runoff in order to reduce combined sewer overflows (CSO) into the Willamette River. Typical solutions such as detention vaults and stormwater ponds were not feasible due to a lack of large open space in the metropolitan center. Since then, the city has creatively converted a growing number of locations using a variety of BMP's, under the guidance of the Green Streets program.

This program falls under the Portland Bureau of Environmental Services, a local government agency that combines water quality protection, economic development and stormwater and sewage collection. The official program was developed in 2005 and 2006 by a coalition of city staff members from all public works departments. The charge came down from the city Commissioner, Sam Adams, and the task was to create a "programmatic approach to implementing green streets elements as a component of street projects wherever feasible, and to increase feasibility by identifying solutions to current implementation issues and challenges."[1] This task would have two phases: Phase I was to identify opportunities and challenges, and to recommend solutions for key issues; Phase 2 looked at potential options for moving forward with implementing a broader

[1] City of Portland, Oregon. *Green Streets Cross-Bureau Team Report Phase I*. (March 2006) 1.

green streets program, and scoping what a green program could look like over the next 5 to 10 years.

This multi-departmental group effort yielded the structure for the Green Streets program. The program resolution, report and policy were approved by the Portland City Council in April 2007. Construction regulations and specifications, a stormwater management manual, educational initiatives and funding strategies were devised, giving the program a good head start. Today "Portland prides itself on being a leader in using strategies that manage stormwater runoff, enhance community and neighborhood livability, and strengthen the local economy."[2]

A significant characteristic of the Green Streets program is that one of its potential focus areas of implementation was retrofit applications. Portland is a densely built city which means retrofits play a large part in their stormwater management strategy. This means many of the demonstrative installations around the city are retrofits of existing systems that capture runoff and infiltrate it at the site. In order to comply with Green Streets aesthetic standards these retrofits often take the shape of bioinfiltration basins, or rain gardens. Monitoring of these structures has generally shown that proper design, installation and maintenance often yield better than expected results in infiltration capacity and volume reduction capacity. Currently few of these facilities receive water quality sampling due to the cost of monitoring.

The Green Streets program presents an excellent example for other municipalities interested in implementing a progressive stormwater management department. Appendix A of this thesis provides project reports for two of the oldest Green Streets projects as

[2] Green Streets (*http://www.portlandonline.com/bes/index.cfm?c=44407*)

typical examples: NE Siskiyou Green Street Project and SW 12th Avenue Green Street Project.

5.2 Kansas City, Missouri – 10,000 Rain Gardens

The Kansas City 10,000 Rain Gardens program emerged as part of a response to aging stormwater and wastewater infrastructure. Some parts of the municipal stormwater and wastewater system have been in place for 100 years. Kansas City's Wet Weather Program assessed the infrastructure situation and developed KC-ONE, a comprehensive plan for stormwater management throughout the city and its suburbs. This plan's mission is to create "one Plan, one People, and one Voice for the management of stormwater in Kansas City."[3]

In April 2005 this initiative succeeded in getting voters to approve a $500 million bond issue that will fund new and improved water infrastructure for Kansas City.[4] Even with this vote, the planned infrastructure changes will take years to implement. The idea for 10,000 Rain Gardens was hatched at a Stormwater Coordination Meeting in May 2005, and was proposed as a method of taking care of stormwater during the lengthy process of infrastructure changes. The project was launched six months later at a regional rally by former mayor Kay Barnes, Jackson County Executive Katheryn Shields and Johnson County Commission Chairman Annabeth Surbaugh.

Today, 10,000 Rain Gardens is a regional effort dedicated to educating citizens about water quality and what they can do to prevent non-point source pollution in

[3] KC-ONE – Stormwater Management Plan (*http://www.kcmo.org/water.nsf/web/kconehome?opendocument*)
[4] Buranen, Margaret. "Rain Gardens Rule." *Stormwater*. May 2008. (*http://www.stormh2o.com/may-2008/rain-gardens-management.aspx*)

stormwater runoff. The program provides detailed information about the design and installation of residential rain gardens in the region for the use of residential land owners. Rain barrels are also heavily promoted as methods of reducing both municipal water usage and stormwater runoff. By 2010, the program hopes to reach its target goal of 10,000 rain gardens in the city and surrounding suburbs. As of early 2008, officials believed there to be at least 1,000 rain gardens in place.

The 10,000 Rain Gardens program is an excellent example of a successful aggressive education and public support campaign for on-site stormwater retrofitting. Although it was started by city officials, it has turned into a grassroots initiative and is now heavily supported by the citizens of the entire community. All types of properties are encouraged to participate, from public parks managed by the city to private business lots and especially private residential lots where individual owners can decide to support the program. The initial success and continued growth of the program shows how a well-defined educational initiative combined with a strong support web can change the way an entire region thinks about stormwater management. Future additions to the program include a rain garden registration incentive and specifications and tools for professionals in the field of stormwater management design.

5.3 Burnsville, Minnesota – Rainwater Gardens

The water quality pilot project performed in Burnsville, MN, during 2002 and 2003 was largely a study to measure the effectiveness of rain gardens in reducing the pollution in and volume of stormwater runoff into nearby Crystal Lake from surrounding suburban areas. This project was a group effort by the Metropolitan Council, the City of Burnsville, BARR Engineering, and the residents of the selected project site.

In studying this project it is important to understand who all the players are. The Metropolitan Council is the regional planning agency for the seven-county metropolitan area of Minneapolis and St. Paul. It provides a variety of essential services to the area and is engaged in an on-going program of research and study concerning the control and prevention of water pollution.[5] The City of Burnsville is a suburb of the Twin Cities, and is one of 30 chosen by the Minnesota Pollution Control Agency (MPCA) to participate in a Non-degradation Report for the metropolitan area. This report required Burnsville to perform an in-depth study of the changes in pollution and volume of water contained in stormwater runoff resulting from development in the city since 1988. This Non-degradation Report also listed past, present and future practices necessary to either return pollutant loads to 1988 modeled levels or to minimize the impact of stormwater discharges on the receiving waters.[6]

Urged on by the necessity to deal with the increasing levels of phosphorus and nitrogen as well as other pollutants found in local bodies of water, and specifically in Crystal Lake, the Metro Council and the City of Burnsville co-funded a prototypic rainwater garden system to infiltrate street runoff. They hired BARR Engineering, a local firm with expertise in implementing ecologically sound stormwater management techniques, to perform the rain garden study in order to demonstrate its effectiveness in reducing stormwater runoff in a suburban neighborhood.

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[5] Metropolitan Council – About the Council (*http://www.metrocouncil.org/about/about.htm*)
[6] Burnsville, MN – Official Website – Nondegradation Report
(*http://www.ci.burnsville.mn.us/index.asp?nid=659*)

The first order of business was to secure the funds for the project. Leslie Yetka, a water resource specialist for the city, secured $30,000 from the city's general fund and a $117,000 grant from the Metropolitan Council. The total $147,000 budget limited the project's options somewhat. Also, as in the Green Streets project studied above, large tracts of open land were not available for the installation of stormwater ponds or detention vaults. The solution was to treat runoff at its source by using on-site stormwater management structures, so Yetka's approach focused on installing a rain garden at every home.

Initial technical research and support on possible stormwater-treatment practices at the residential-lot level was conducted by the Dakota County Soil and Water Conservation District. With this information, Leslie hired BARR Engineering to help identify a treatment technique within the scope of funding would result in the greatest reduction of runoff.[7] Together they decided that rainwater gardens offered the most promising solution. BARR agreed to design the rainwater gardens, select landscape plantings, and work with Leslie in educating the homeowners and overseeing the construction process.

Selecting the project neighborhood involved a significant education and awareness effort by the City in the form of community meetings, informational flyers and pamphlets discussing the project and its necessity in order to mitigate pollution in runoff. Soil testing and analyses were also conducted to determine geographic suitability of neighborhoods around Crystal Lake. Out of the three potential sites identified by the geographic analysis, one street was chosen based on an estimated 85% volunteer

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[7] "Burnsville Rainwater Gardens." *Land and Water*. v. 48 no. 5. (http://www.landandwater.com/features/vol48no5/vol48no5_2.php)

participation of street residents. The rain garden plan called for 17 gardens in 14 lots; four of those gardens would be in back yards. Another street was chosen as the control site for the experiment.

In order to produce accurate performance results, the next step was to gather two seasons worth of stormwater data for both the project site and the control site. Gages were installed to measure runoff volume and would be used again after installation to determine how successful the gardens were at reducing runoff. The gardens were then engineered for appropriate water reception using curb cuts, safety and aesthetic considerations. They were sized appropriately to treat the water quality volume, or first flush, of smaller 85th-percentile storms. City easements and utility right-of-ways provided the space for garden installation and soil amendments were used where necessary to aid infiltration and drainage.

The plantings and resulting landscapes used in the gardens were a result of extensive communications between the landscape architect and the home owners. Earlier in the process it had been agreed upon by all parties that the long-term maintenance of the gardens would be the home owner’s responsibility. This decision resulted in the majority of the gardens being planted with less labor-intensive perennials and shrubs. The actual construction work was bid out and won by a local landscape business, Mike’s Lawn and Landscape. They completed the work for less than the $50,000 budget. Gardens were planted in September 2003 by the community, city employees and some volunteers from BARR. After the plantings were established, curb cuts were made to allow water from the street to enter the rainwater gardens. Study results show immediate runoff volume entering Crystal Lake dropped by 90%.[8]

This project is a textbook example of a successful stormwater retrofit collaboration. State, regional, city, private consultant and resident were intimately involved in the design and implementation of this pilot study in the effectiveness of bioinfiltration basins, or rain gardens, to reduce the runoff volume of a suburban residential neighborhood while treating for stormwater pollution at the same time. The results are encouraging for other municipalities looking for ways to effectively reduce stormwater volume and pollution through more natural and cost-effective methods. Appendix B of this thesis contains more information on the process, implementation, cost and resultant data from this study.

5.4 Observations

The three examples studied above provide three very different but effective methods of municipal stormwater management through the use of on-site stormwater management. While every place is different and warrants individual research and in-depth study before undertaking any stormwater management program, these three examples provide valuable insight and information. The third example is especially pertinent to this thesis. The methods used in the Burnsville pilot study provide a solid base on which to base the following application of the ideas presented in the preceding chapters.

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[8] BARR Engineering Company. *Burnsville Stormwater Retrofit Study*. Burnsville, MN: City of Burnsville. June 2006.

CHAPTER 6

STORMWATER RETROFIT PROJECT APPLICATION: WOODS OF HABERSHAM SUBDIVISION, ATHENS, GA

The purpose of this project is to determine the possibilities of retrofitting a suburban residential neighborhood in the Piedmont region of Georgia with LID-based stormwater management controls. Project costs will be estimated in order to provide a basis of comparison to other stormwater projects. Two project studies will be established in which the difference will be the amount of impervious area being treated. The first study will treat only roadway and driveway pavement through the use of bioretention cells in the right-of-way. This study assumes houses in the neighborhood have disconnected roof drainage that is expelled onto pervious surfaces. The second study will calculate the water quality volume of all impervious surfaces on the site. Bioretention cells placed strategically in both front and back yards to catch roof runoff, as well as in the right-of-way to treat pavement runoff, will be used in design examples.

6.1 Regional Analysis

The Woods of Habersham residential subdivision is located in Clarke County, Georgia, approximately five miles southeast of Athens, the county seat (Figure 6.1.1). Established in 1996, the subdivision was built in three phases and was not completed until late 2001. Prior to development, the area was heavily forested with some dirt pathways traversing its area. Houses are built of varying materials including brick, stucco and wood siding with real estate prices ranging between $150,000 and $200,000.

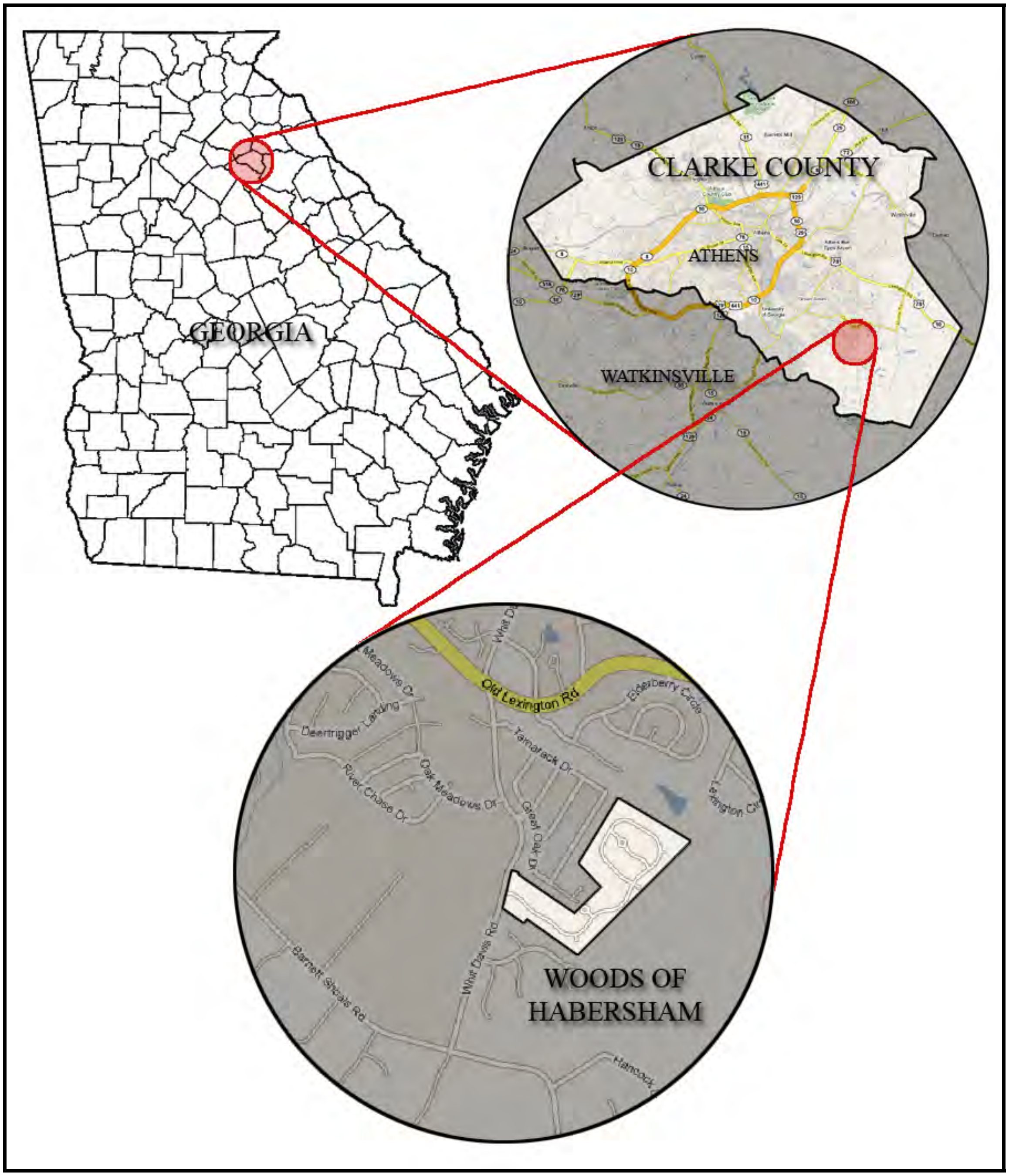

Figure 6.1.1 – Vicinity Map for the Woods of Habersham Subdivision, Athens, GA[1]

[1] Portions of this map were acquired from Google Maps (*http://maps.google.com/maps?hl=en&tab=wl*)

This subdivision was chosen primarily because of its density. It is zoned Single-Family Residential with a minimum lot size of 25,000sf[2] (RS-25). With a total area of 3,809,625.15sf (87.46ac) subdivided into 106 lots the neighborhood density comes to one residence for every 35,940sf (.83ac). This density should provide enough land for the installation of bioinfiltration cells. More importantly, the minimum allowed street frontage per lot is 85ft. This should provide sufficient areas of continuous right-of-way for placement of roadside bioretention basins. Other factors of importance were the site's pre-development conditions and remaining vegetation, its existing stormwater drainage and detention system, topography and site soils. These and other site characteristics are further discussed in Section 6.2.

6.1.1 Soils

Determining the soil at a site is crucial to the design of a water quality control system. Knowing the type of soil at the site allows the designer to determine infiltration capability and plan for soil amendments. Athens is located in the Piedmont region of Georgia. Cecil series soils are dominant in much of this area, with associated series found nearby.[3] Soils in this area are characterized by an O-horizon of organic materials of varying degrees, an A-horizon made up of 6-9 inches of mineral rich soils and a B-horizon of two to three feet of blocky red clay over a significantly thick layer of saprolite (weathered bedrock) stretching down to bedrock.[4] The organic layer is most prevalent in forested areas with significant leaf cover. The A-horizon has been eroded over much of

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[2] Code of Ordinances – County of Athens-Clarke, Georgia (http://www.municode.com/RESOURCES/gateway.asp?pid=12400&sid=10)

[3] Robertson, Stanley M. *Soil Survey: Clarke and Oconee Counties, Georgia*. Washington, D.C.: Soil Conservation Service. 1968.

[4] Soil horizon – Wikipedia (http://en.wikipedia.org/wiki/Soil_profile)

the Georgia Piedmont, due primarily to unsustainable farming practices. These practices were curbed in the 1930's through the efforts of the Soil Conservation Service. Today, increasing urbanization poses as much of a threat to the highly erodible soils of the Piedmont as those outdated and irresponsible farming practices.

6.1.2 Precipitation

Rainfall for the region is important in determining the suitability of a water quality control structure. A measurable amount of rain falls on about 120 days each year, producing between 50 and 55 inches.[5] Figure 6.1.2 is a graphical interpretation of average annual precipitation in Georgia. Clarke County is located in the 50 to 54 inch region.

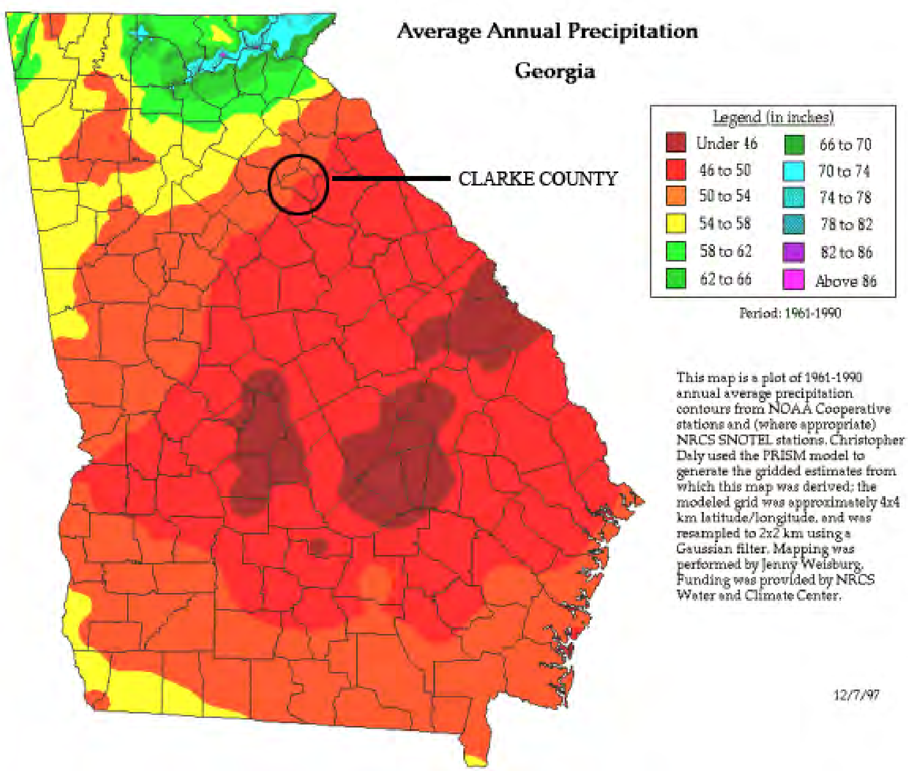

Figure 6.1.2 – Average Annual Precipitation: Georgia. National Weather Service Forecast Office

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[5] What's Typical in North and Central Georgia (*http://www.srh.noaa.gov/ffc/html/clisumlst.shtml#sec2*)

While this map provides regional averages of rainfall, it is important to use more exact quantities when analyzing a site for stormwater management. Table 6.1 provides precipitation averages for individual months in the city of Athens. The averages have been calculated using 58 years of rainfall information.

Table 6.1.1 – Average Monthly Rainfall, Athens, Georgia[6]

Athens WSO Airport, Georgia - Monthly Total Precipitation (inches)													
MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
AVG.	4.47	4.39	5.14	3.66	3.95	4.2	4.96	3.59	3.67	3.04	3.66	3.84	48.36
MAX.	9.47	9.24	10.9	10.92	11.34	13.25	10.53	7.43	11.84	7.75	14.98	8.42	71.39
MIN.	0.64	0.75	1.05	0.69	0.41	0.87	1.36	0.09	0.17	0	0.33	0.81	28.61
NO. YRS.	58	58	58	58	58	58	59	59	59	59	59	59	58

At the time of the writing of this thesis, Georgia is experiencing one of the worst droughts on record. It is important to consider this information when choosing plants to use in bioretention basins or other water quality control structures. However, it is also important to note that droughts are part of the natural cycle of rainfall in any region, and stormwater structures should not be designed using solely drought year precipitation information.

6.2 Site Analysis

The following physical site characteristics were documented and analyzed: general area calculations, soils and topography, vegetation, drainage, utilities, and impervious cover. This inventory and analysis provided the necessary information with which to perform the two studies described above. Here in follows an analysis of the facts.

[6] Monthly Precipitation, Athens WSO Airport, Georgia – (http://cirrus.dnr.state.sc.us/cgi-bin/sercc/cliMONtpre.pl?ga0435)

6.2.1 General Information

General site information is included in Table 6.2.1. Figure 6.2.2 illustrates the site area. Woods of Habersham encompasses a total of 87.46 acres. The site is subdivided into 106 lots averaging 0.73 acres per lot. This average lot size lends itself well to the use of bioretention basins for water quality control, as it falls well within the prescribed one-half to two acre limit.[7] Compared to surrounding subdivisions, this one encompasses the smallest area and has the smallest number of lots.

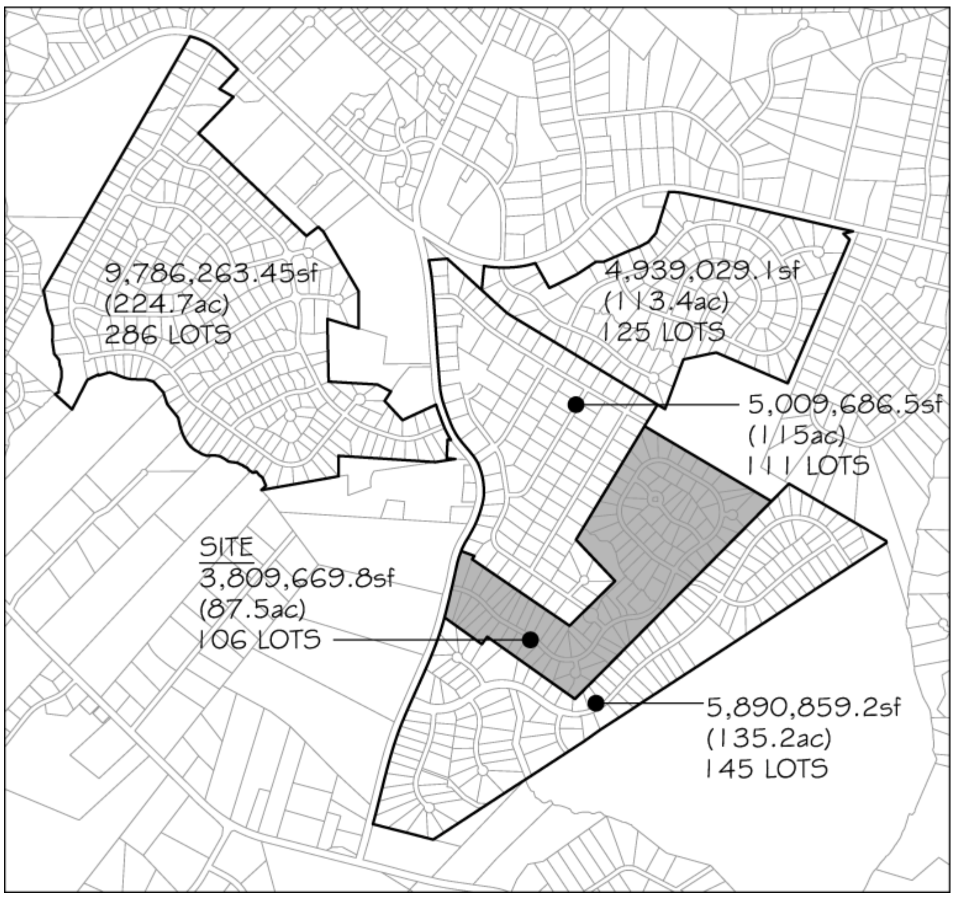


Figure 6.2.1 – Comparison of Subdivision Sizes in the Surrounding Area

Even so, a stormwater quality retrofit of the whole site would likely present funding and project coordination issues.

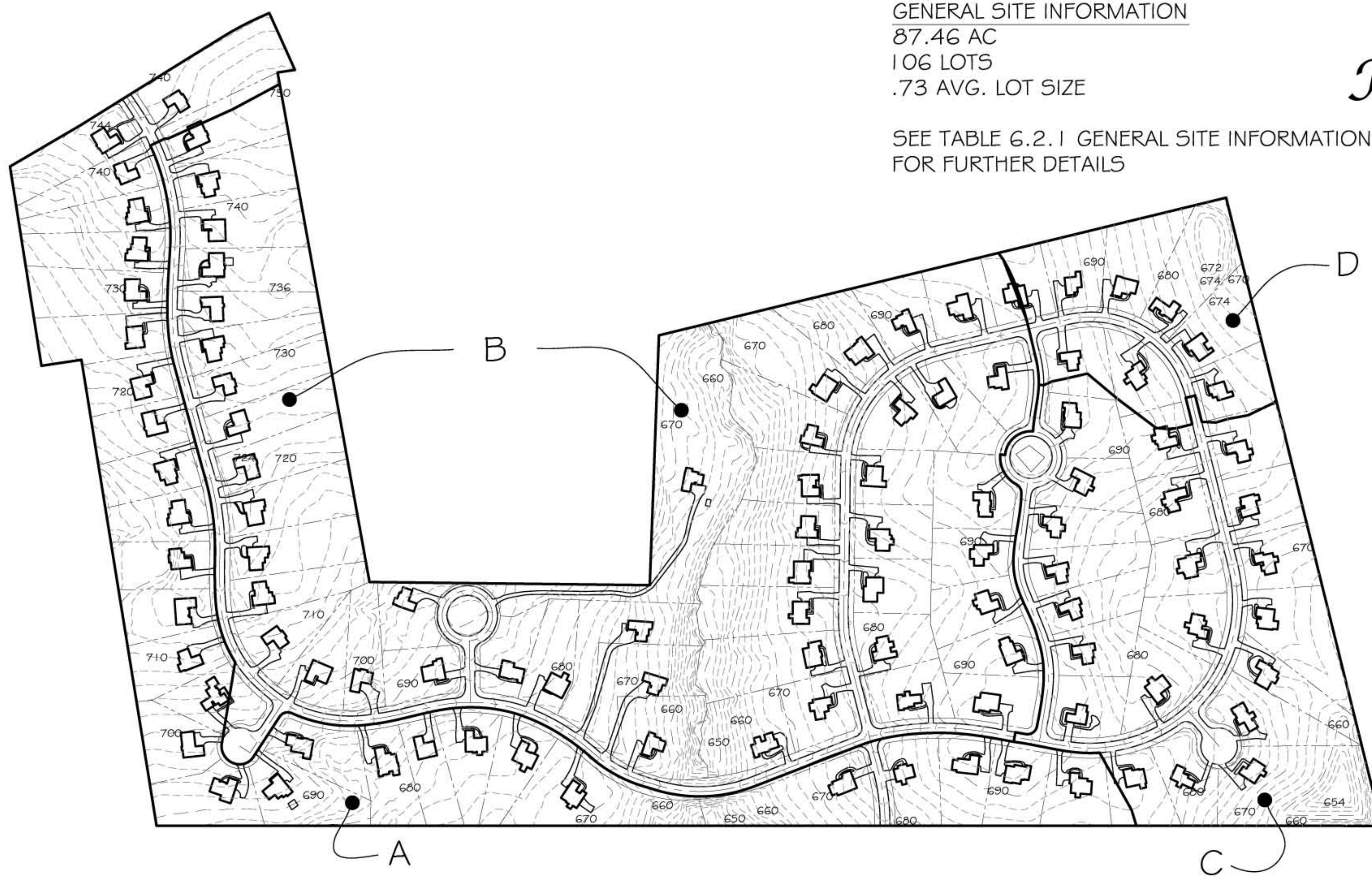
[7] *Georgia Stormwater Management Manual, vol.2* Georgia: Atlanta Regional Commission. (2001) 3.2-47.

GENERAL SITE INFORMATION

SCALE: 1"=300'

GENERAL SITE INFORMATION
87.46 AC
106 LOTS
.73 AVG. LOT SIZE

SEE TABLE 6.2.1 GENERAL SITE INFORMATION FOR FURTHER DETAILS



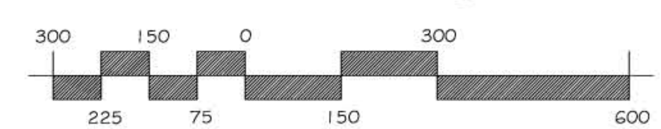


Figure 6.2.2 - General Site Information

Table 6.2.1 - Woods of Habersham - General Site Information

Woods of Habersham - General Site Information															
BASINS	SITE AREA		2-WAY ROAD LENGTH	TOTAL AREA ROADWAY PAVING		TOTAL AREA DRIVEWAY PAVING		# LOTS	TOTAL LOT AREA		AVERAGE RESIDENCE FOOTPRINT		TOTAL RESIDENCE FOOTPRINT		
	SF	AC	LF	SF	AC	SF	AC	QT.	SF	AC	SF	AC	SF	AC	
A	962,606.55	22.10	629.56	7,425.01	0.17	46,914	1.08	29	892,772.42	20.50	2,360	0.05	68,452	1.57	
B	1,856,904.09	42.63	5,755.35	136,767.54	3.14	91,059	2.09	48	1,602,059.72	36.78	2,247	0.05	107,867	2.48	
C	734,639.32	16.86	1,901.42	63,581.70	1.46	34,031	0.78	21	623,352.59	14.31	2,087	0.05	43,831	1.01	
D	255,475.19	5.86	488.59	13,588.36	0.31	13,159	0.30	8	237,902.70	5.46	2,035	0.05	16,276	0.37	
TOTAL	3,809,625.15	87.46	8,774.92	221,362.61	5.08	185,163	4.25	106	3,356,087.43	77.05	2,182.33	0.05	236,426	5.43	
BASINS	AVG. LOT SIZE		AVG. IMPERVIOUS PER LOT		TOTAL IMPERVIOUS PER LOT		TOTAL IMPERVIOUS		% IMP.	TOTAL R/W AREA		PAVED R/W AREA			
	SF	AC	SF	AC	SF	AC	SF	AC		SF	AC	SF	AC		
A	30,785.26	0.71	3,978.14	0.09	115,366	2.65	122,791.01	2.82	12.76	57,335.22	1.32	5,971.99	0.14		
B	33,376.24	0.77	4,059.71	0.09	198,926	4.57	335,693.54	7.71	18.08	111,929.00	2.57	9,955.73	0.23		
C	29,683.46	0.68	3,707.71	0.09	77,862	1.79	141,443.70	3.25	19.25	48,450.99	1.11	3,930.45	0.09		
D	29,737.84	0.68	4,205.00	0.10	29,435	0.68	43,023.36	0.99	16.84	14,958.57	0.34	1,348.03	0.03		
TOTAL	31,661.20	0.73	3,987.64	0.09	421,589	9.68	642,951.61	14.76	16.88	232,673.78	5.34	21,206.20	0.49		
BASINS	UNPAVED R/W AREA		VEGETATION		TREE CANOPY		TURF & LANDSCAPE								
A	SF	AC	SF	AC	SF	AC	SF	AC							
B	51,363.24	1.18	839,815.54	19.28	294,907.26	6.77	544,908.28	12.51							
C	101,973.27	2.34	1,521,210.55	34.92	695,457.77	15.97	825,752.78	18.96							
D	44,520.53	1.02	593,195.62	13.62	61,164.17	1.40	532,031.45	12.21							
	13,610.54	0.31	212,451.83	4.88	173,333.85	3.98	39,117.98	0.90							
TOTAL	211,467.57	4.85	3,166,673.54	72.70	1,224,863.06	28.12	1,941,810.49	44.58							

[8]

[8] The information for this table was gathered by the author using AutoCAD and GIS files as part of the site analysis for this project.

6.2.2 Soils and Topography

Figure 6.2.3 depicts the various soil groups present at the site, while Table 6.2.2 further defines these soils. All soils on the site fall within Hydrologic Soil Group B, indicating that they are adequate but not optimal for infiltration purposes. Soil amendments would be recommended in the planting area of the bioretention basins. The largest soil group, Cecil Sandy Loam at two to six percent slopes provides an excellent base for bioretention basins.

Figure 6.2.4 Approximately 41 percent of the development has terrain of six percent slopes or more, making them unsuitable for bioretention basins. These areas are also mostly wooded and undeveloped. The steepest roadway grades were studied, revealing less than six percent slopes along the entire roadway. Roadside bioretention basins are not hindered by the slope.

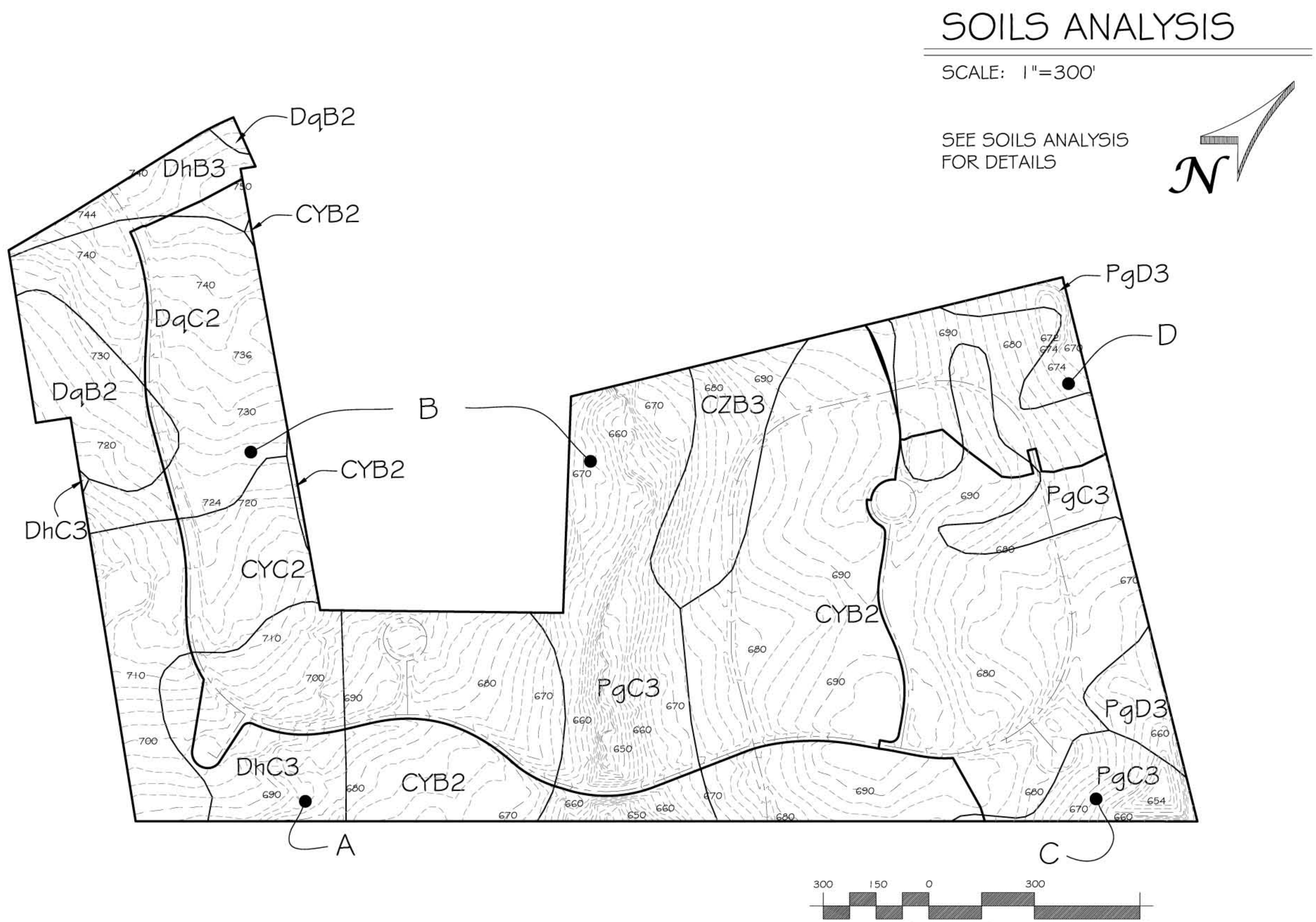


Figure 6.2.3 - Soils Analysis

Table 6.2.2 – Woods of Habersham Soils Analysis[9]

Woods of Habersham Soils Analysis					
Soil Type	**Description**	**Area (sf)**	**Percent of Site**	**Saturated Hydraulic Conductivity (Ksat) (in/hr)**	**Hydrologic Soil Group**
CYB2	Cecil sandy loam, 2 to 6 percent slopes, eroded	1,591,737.57	41.78%	1.98-5.95 - First 7 in. 0.57-1.98 - 7 to 75 in.	B
CYC2	Cecil sandy loam, 6 to 10 percent slopes, eroded	311,314.09	8.17%	1.98-5.95 - First 7 in. 0.57-1.98 - 7 to 75 in.	B
CZB3	Cecil sandy clay loam, 2 to 6 percent slopes, severely eroded	156,165.16	4.10%	0.57-1.98 - 0 to 70 in.	B
DhB3	Davidson clay loam, 2 to 6 percent slopes, severely eroded	87,556.22	2.30%	0.57-1.98 - 0 to 70 in.	B
DhC3	Davidson clay loam, 6 to 10 percent slopes, severely eroded	803.64	0.02%	0.57-1.98 - 0 to 70 in.	B
DqB2	Davidson sandy loam, 2 to 6 percent slopes, eroded	149,364.88	3.92%	0.57-1.98 - 0 to 70 in.	B
DqC2	Davidson sandy loam, 6 to 10 percent slopes, eroded	388,294.80	10.19%	0.57-1.98 - 0 to 70 in.	B
PgC3	Pacolet sandy clay loam, 6 to 10 percent slopes, severely eroded	763,216.48	20.03%	0.57-1.98 - 0 to 70 in.	B
PgD3	Pacolet sandy clay loam, 10 to 15 percent slopes, severely eroded	106,737.89	2.80%	0.57-1.98 - 0 to 70 in.	B

Hydrologic Group Descriptions (From NRCS Web Soil Survey)

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately dee p or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

[9] The information for this table was gathered from: Robertson, Stanley M. *Soil Survey: Clarke and Oconee Counties, Georgia*. Washington, D.C.: Soil Conservation Service. 1968.

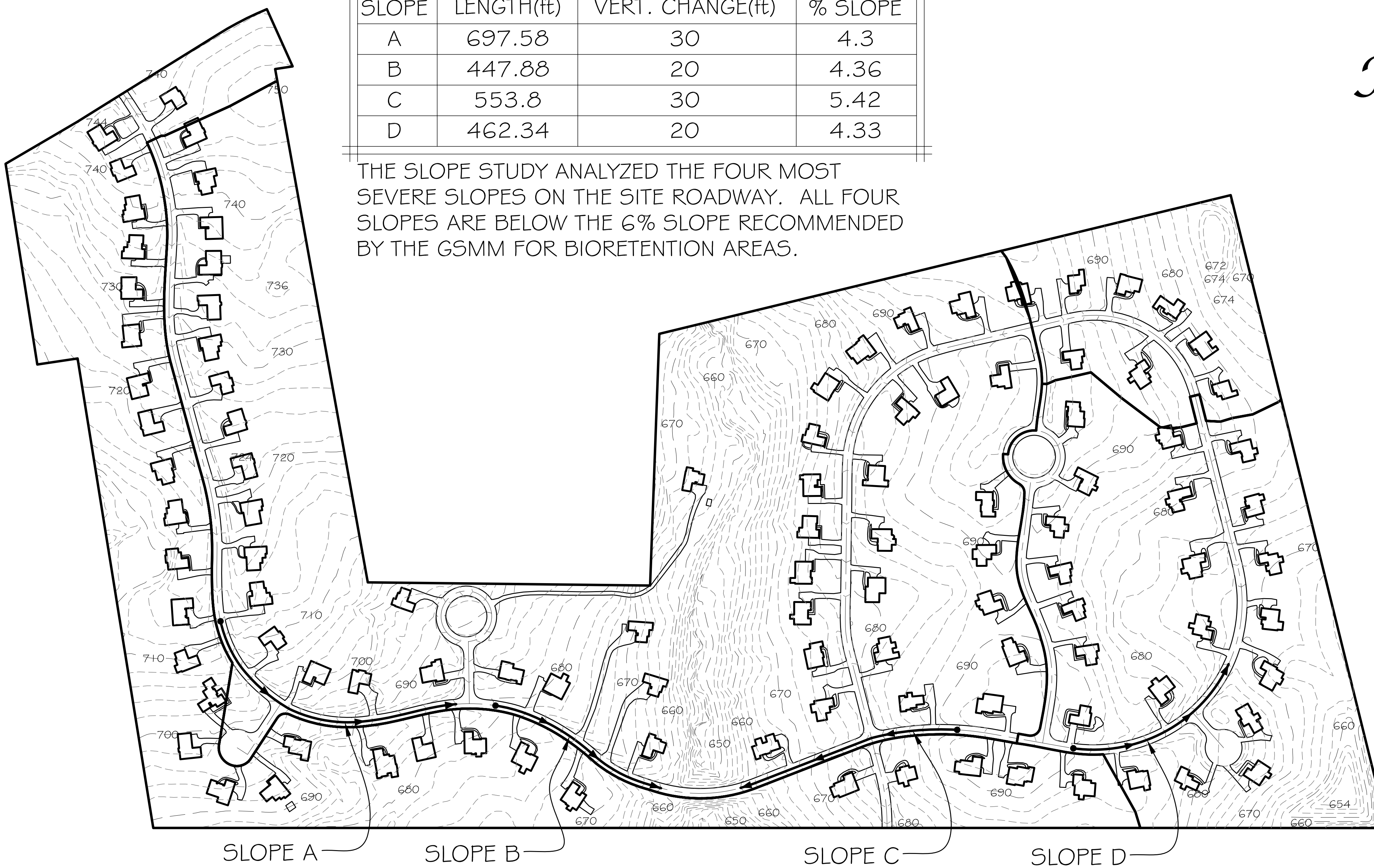
SITE TOPOGRAPHY

SCALE: 1"=300'

N

ROADWAY SLOPE STUDY			
SLOPE	LENGTH(ft)	VERT. CHANGE(ft)	% SLOPE
A	697.58	30	4.3
B	447.88	20	4.36
C	553.8	30	5.42
D	462.34	20	4.33

THE SLOPE STUDY ANALYZED THE FOUR MOST SEVERE SLOPES ON THE SITE ROADWAY. ALL FOUR SLOPES ARE BELOW THE 6% SLOPE RECOMMENDED BY THE GSMM FOR BIORETENTION AREAS.



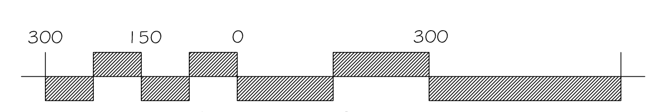


Figure 6.2.4 - Site Topography

6.2.3 Drainage

The neighborhood employs a curb and gutter system to convey runoff. Eight sub-watershed basins were identified by the development's hydrology study, three of which are studied together in this thesis as basin A. Basins B, C, and D use dry detention ponds to control all but the 50 and 100 year peak rates of flow. Due to the small amounts of roadway paving in basin area A, these do not require detention of runoff in order to comply with pre-development limits and are allowed to drain off site. While water quality controls do not generally relate to water quantity issues, the addition of bioretention basins to the development will reduce the overall volume of runoff for all storm frequencies by a small percent, and may completely control runoff for those storms with an 85^{th}-percent chance or greater of occurring.

The curb and gutter system in the subdivision is constructed in such a way as to guide runoff into the existing pipe system without diversion. Driveway curb cuts do not impede the system's function by diverting runoff out of the gutter.

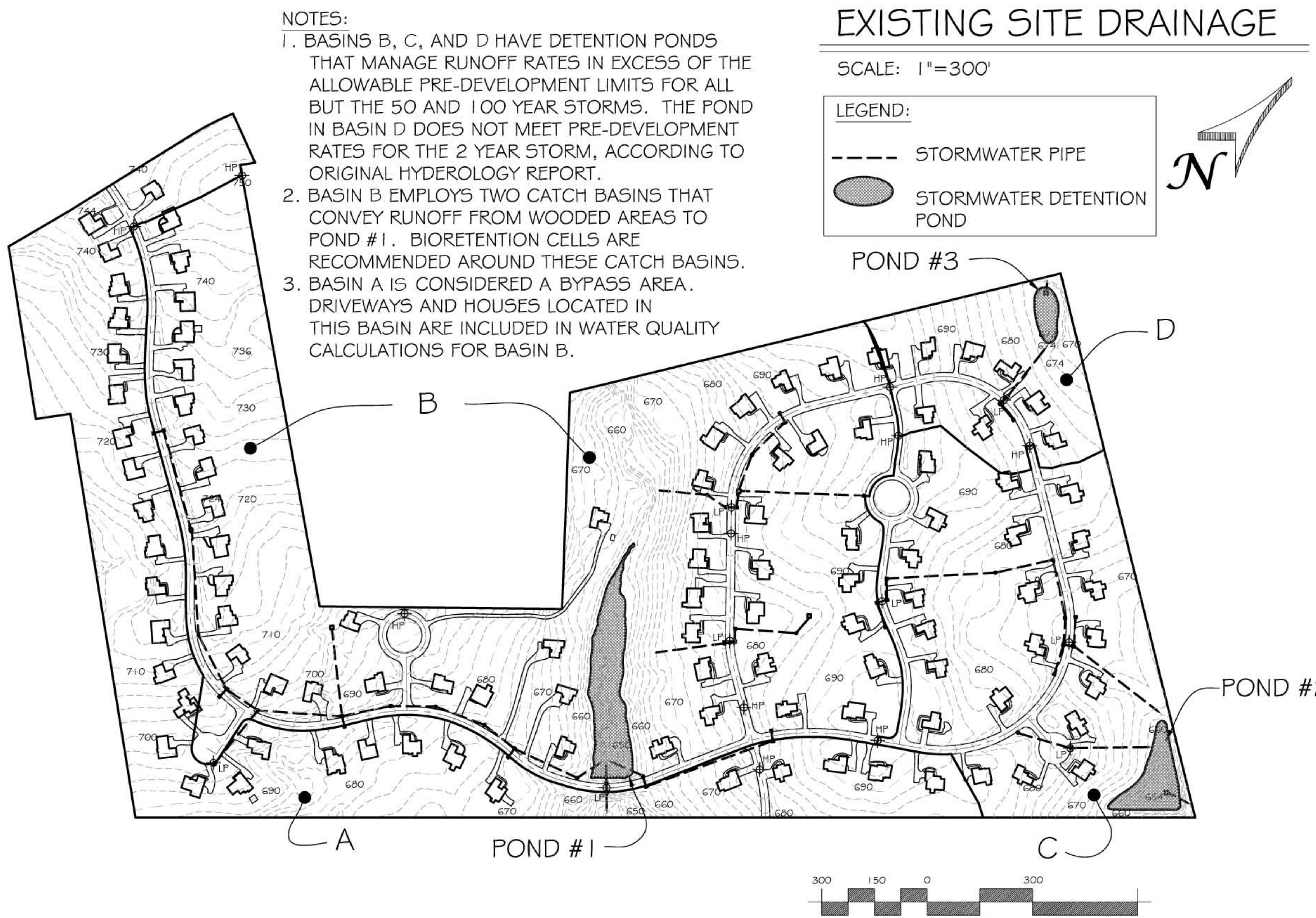


Figure 6.2.5 - Existing Site Drainage

6.2.4 Vegetation

Figure 6.2.6 illustrates the site vegetation, with the shaded region representing tree cover. Vegetation on the site ranges from undeveloped forested areas to manicured landscapes. One area of special interest is the detention pond used by basin B. Prior to development this area was a natural forested ravine. The first phase of construction for the site utilized this area by building a dam where the roadway intersects the ravine. It was unnecessary to disturb the ravine further, leaving a wide swath of forested area in the center of the site. This ravine is part of the 28.12 percent tree cover on the site, most of it in existence since before construction judging from the size of some of the trees. The remainder of pervious site, approximately 45 percent, is turf or landscape which provides plenty of land for bioretention basins to be installed.

SITE VEGETATION

SCALE: 1"=300'

SITE VEGETATION AREA CALCULATIONS					
BASIN	AREA(ac)	CANOPY(ac)	TURF(ac)	TOTAL VEG.(ac)	% AREA
A	22.54	6.77	12.35	19.12	84.83%
B	42.19	15.97	18.79	34.76	82.39%
C	16.86	1.40	12.51	13.92	82.56%
D	5.86	3.98	0.94	4.92	83.96%
TOTAL	87.46	28.12	44.59	72.71	83.14%

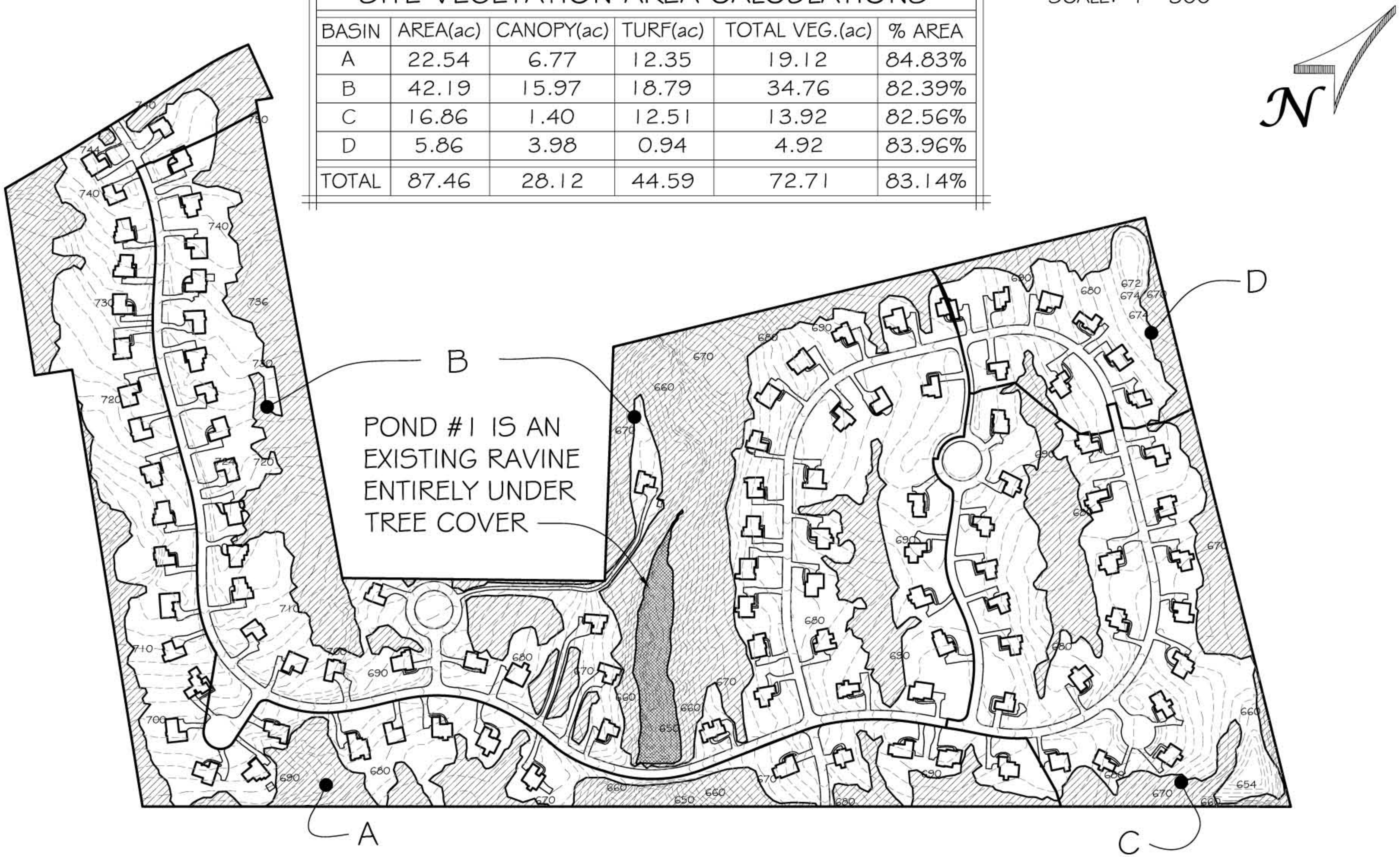


Figure 6.2.6 - Site Vegetation

6.2.5 Utilities

All of the utilities at Woods of Habersham are buried. Water pipes were located using information provided by the Department of Public Utilities in Athens. These along with hydrant locations are illustrated in Figure 6.2.7 below. Water pipes are buried at a minimum depth of 4 ft. It was not possible to gain access to power, gas, and other buried utility information. Markers at the site indicated the presence of buried electrical lines, fiber optic cable, and gas pipes along both sides of the roadway.

Buried utilities are typically located in the road right-of-way and this subdivision is no exception. The existence of these utilities presents a challenge to the placement of roadside bioretention cells. Precedent exists for the allowance of utilities within bioretention areas,[10] however proper precautions should be observed during installation. With respect to the utility grid within individual lots, it will be important to locate these and avoid them during construction as well. Each lot must be individually inspected for utility location to avoid service disruptions.

The treatment of wastewater in this subdivision also presents challenges to the placement and effectiveness of bioretention areas. Houses in this neighborhood use septic systems to handle wastewater. This limits the location of bioretention areas, as these cannot be placed within the drain field of a septic system. While often septic systems are located in the back yard of a property, this is not always the case. It will be important to locate the septic tank and field for each property individually in order to avoid problems.

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[10] Winogradoff, Derek A. *The Bioretention Manual*. Prince George's County, Maryland: Programs and Panning Division: Department of Environmental Resources. November 2001.

EXISTING SITE UTILITIES

SCALE: 1"=300'

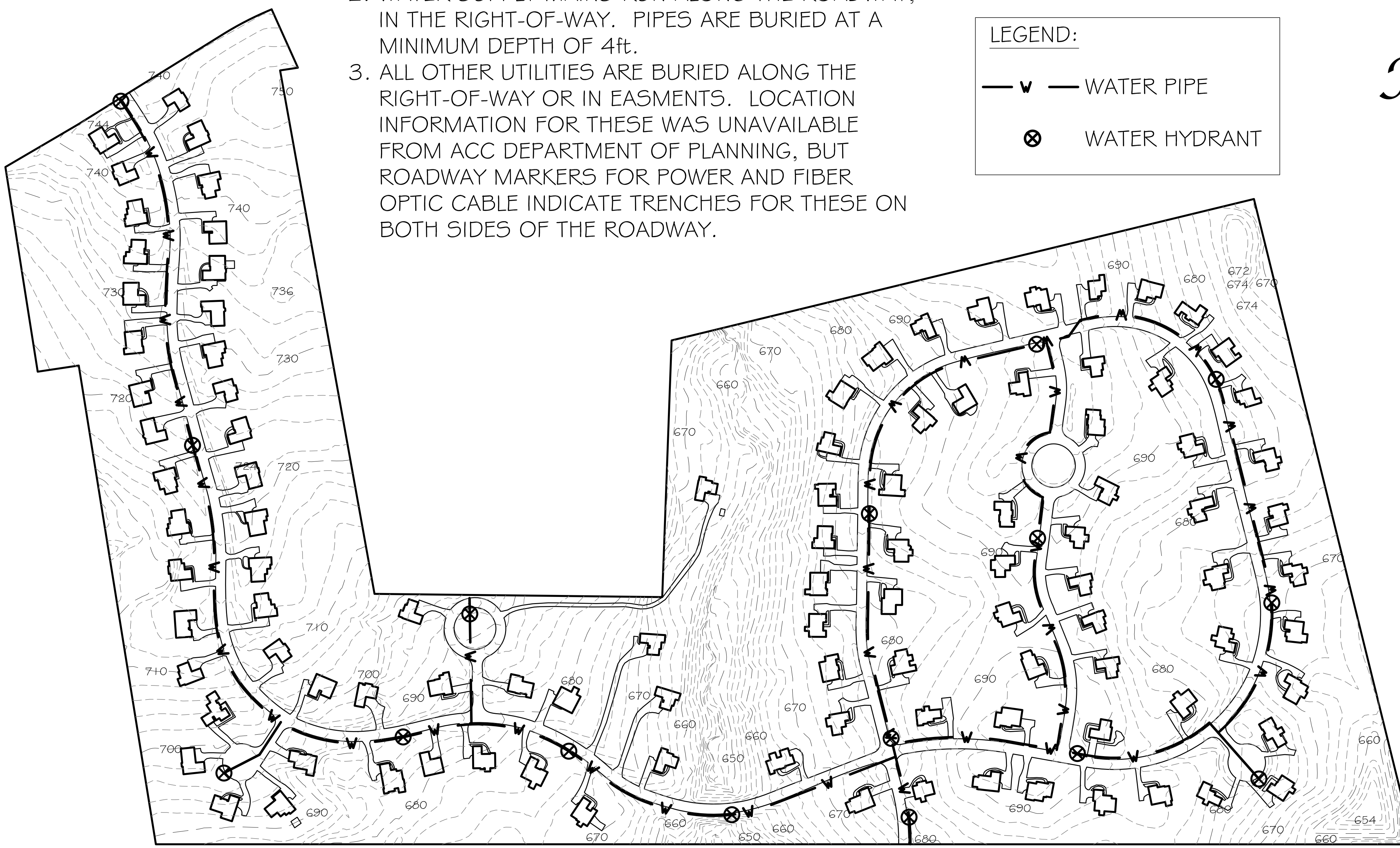
NOTES:
1. WASTEWATER IS HANDLED THROUGH INDIVIDUAL LOT SEPTIC SYSTEMS.
2. WATER SUPPLY MAINS RUN ALONG THE ROADWAY, IN THE RIGHT-OF-WAY. PIPES ARE BURIED AT A MINIMUM DEPTH OF 4ft.
3. ALL OTHER UTILITIES ARE BURIED ALONG THE RIGHT-OF-WAY OR IN EASMENTS. LOCATION INFORMATION FOR THESE WAS UNAVAILABLE FROM ACC DEPARTMENT OF PLANNING, BUT ROADWAY MARKERS FOR POWER AND FIBER OPTIC CABLE INDICATE TRENCHES FOR THESE ON BOTH SIDES OF THE ROADWAY.

LEGEND:

— W — WATER PIPE

⊗ WATER HYDRANT

N



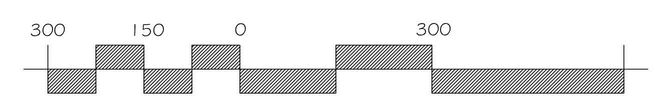


Figure 6.2.7 - Existing Site Utilities

6.2.6 Impervious Cover

Percent impervious cover on the entire development was found to be 16.86 percent, while the amount of impervious cover for the average 0.73 acre lot was approximately 0.10 acres. Of the eight sub-watershed basins established in section 6.2.3, basin B had the highest percent impervious cover, while the combined sub-watershed basin A had the smallest percent impervious cover. If phasing of the retrofit project is required it would be prudent to divide the work by sub-watershed. This would ensure that the water quality volume for an entire sub-watershed is being managed and would prevent the overloading of certain bioretention basins due to inadequate or incomplete sub-watershed design.

Water quality volume calculations are directly linked to the amount of impervious surface on a lot. The necessary bioretention area was determined using the quantities of impervious cover listed in Table 6.2.1.

6.3 Study #1: Water Quality Control for Roadway and Driveways

The first study proposes the installation of bioretention cells in the right-of-way for the water quality control of the common roadway and driveways only. The inclusion of driveways occurs because most of the driveways in the subdivision contribute runoff to the common roadway. This study assumes that all houses have disconnected downspouts that drain onto the landscape. Were this not the case, roadside bioretention basins would be hard pressed to properly treat the prescribed Water Quality Volume. While the amount of unpaved right-of-way is nearly three times as much as is necessary for water quality control, the right-of-way is not always available where it is needed. It is interspersed with curb cuts for driveways, breaking the continuity and increasing the project costs significantly through the installation of smaller, less effective cells.

6.3.1 Water Quality Volume Site Calculations

Water quality volume was calculated for each basin individually, with the exception of combined sub-watershed areas in basin A. To calculate the water quality volume contributed by the impervious surfaces only, the study used a drainage area equal to the paved impervious cover, provided originally in Table 6.2.1. This resulted in an impervious cover of 100 percent. Table 6.3.1 provides water quality calculations for each basin and will be referenced throughout the study explanation.

The formulas used to calculate water quality volume and ponding/filter area are referenced from the Georgia Stormwater Management Manual (GSMM) Volume 2, Section 3.2.3. The water quality volume formula was modified to calculate only the paved impervious surface water quality volume, as described above. The ponding/filter area formula is not modified beyond the definition of its variables, as stated in Table 6.3.1. The formula uses a two day (48 hour) ponding time at a 6 inch ponding depth, and takes into account the 0.5 feet/day (0.25 in/hr) hydraulic conductivity of a silt-loam planting medium. The resultant bioretention cell has a smaller area with an available ponding depth of one foot. Using these formulas and assumptions, the study calculates a bioretention area of about 110sf per 100 linear feet of roadway. Due to the central crown along the roadway, this area would need to be divided into two areas of about 55sf each, one on either side of the road. To this area must be added the necessary amount of bioretention for any driveways that may be contributing runoff.

If this were a new development, the resultant ponding/filter area necessary for water quality volume treatment in each basin provided in Table 6.3.1 could be designed into one or two large water quality treatment control structures per basin. Because it is a retrofit application, roadside bioretention cells are a reasonable alternative.

Table 6.3.1 - Pavement - Overall Basin Water Quality Calculations

Pavement - Overall Basin Water Quality Calculations								
Total Area (ac)	Bypass Area (ac)	Drainage Area **(A)** (ac)	Roads & Driveways (ac)	Percent Impervious Cover **(I)**	Volumetric Runoff Coefficient **(Rv)**=0.05+0.009(I)	Water Quality Volume (85% Storm) **(WQv)**=1.2(Rv)(A)/12 (af)	(cu.ft.)	Ponding/Filter Area **(Af)**=(WQv)(df)/[(k)(hf+df)(tf)] df=4ft k=0.5 hf=0.25ft tf=2days (sf)
Basin A								
22.1	21.85	0.25	0.25	100.00	0.950	0.023	1,023.009	962.832
Basin B								
42.63	36.60	6.03	6.03	100.00	0.950	0.573	24,971.938	23,503.000
Basin C								
16.86	14.42	2.44	2.44	100.00	0.950	0.231	10,078.003	9,485.179
Basin D								
5.86	5.25	0.61	0.61	100.00	0.950	0.058	2,541.000	2,391.529

Total Water Quality Volume Treated	**38,613.95 cu.ft.**
Total Necessary Treatment Area	**36,342.541 cu.ft.**

Where:

A = Site Area (Drainage Area)

I = Percent Impervious Cover (100% in this case)

Rv = 0.05+0.009(I) where I is **percent** impervious cover

WQv = water quality volume (provided in both acre-feet and cubic feet)

df = filter bed depth (4ft minimum)

k = coefficient of permeability of filter media (ft/day) (use 0.5 ft/day for silt-loam)

hf = average height of water above filter bed (ft) (typically 3in, which is half of the 6in ponding depth)

tf = design filter bed drain time (days) (2.0 days or 48 hours is recommended maximum)

Units:

ac = acres

af = acre-feet

cu.ft. = cubic feet

sf = square feet

The formulas used in these calculations are referenced from the Georgia Stormwater Management Manual, Volume 2.

6.3.2 Basin A

The three combined sub-watershed areas in basin A were treated together here in deference to the original hydrology report for the development. Combined, these basins contain a total of 1.25 acres of paved impervious cover (Table 6.2.1). However, Figure 6.3.1 illustrates that 0.96 acres of this paved area are assumed to drain into the roadway located in basin B and .04 acres are assumed to drain into basin C. This leaves only 0.25 acres of calculated paved impervious cover. Using this total paved impervious area, the water quality calculations in Table 6.3.1 result in a total water quality volume of approximately 0.02 acre-feet (1,023.0cu.ft.). The ponding/filter area formula provided in the Georgia Stormwater Management Manual Volume 2 allows the calculation of a necessary bioretention area of 962.8sf (Table 6.3.1).

The right-of-way space within basin A is 1.23 acres (51,363.2sf) as listed in Table 6.2.1, but the majority of this area will be utilized by bioretention cells treating the runoff from those pavement surfaces draining from basin A to basin B. By subtracting the right-of-way area located in basin A adjacent to the roadway in basin B (45,306.1sf) it is possible to calculate the actual unpaved right-of-way area available for bioretention use in basin A, at 6,057.1sf. This should be more than enough to accommodate the calculated necessary bioretention area of 962.8sf.

PAVEMENT AREA: BASIN A

SCALE: 1"=300'

PAVED IMPERVIOUS COVER		
TOTAL PAVEMENT	54,339.01sf	1.25ac
DRAINS TO BASIN B	41,896.38sf	0.96ac
DRAINS TO BASIN C	1,674.14sf	0.04ac
TOTAL CALCULATED PAVEMENT	10,768.50sf	0.25ac

LEGEND:
CALCULATED PAVEMENT
EXCLUDED PAVEMENT

SEE TABLE 6.3.1 FOR WATER QUALITY CALCULATIONS.

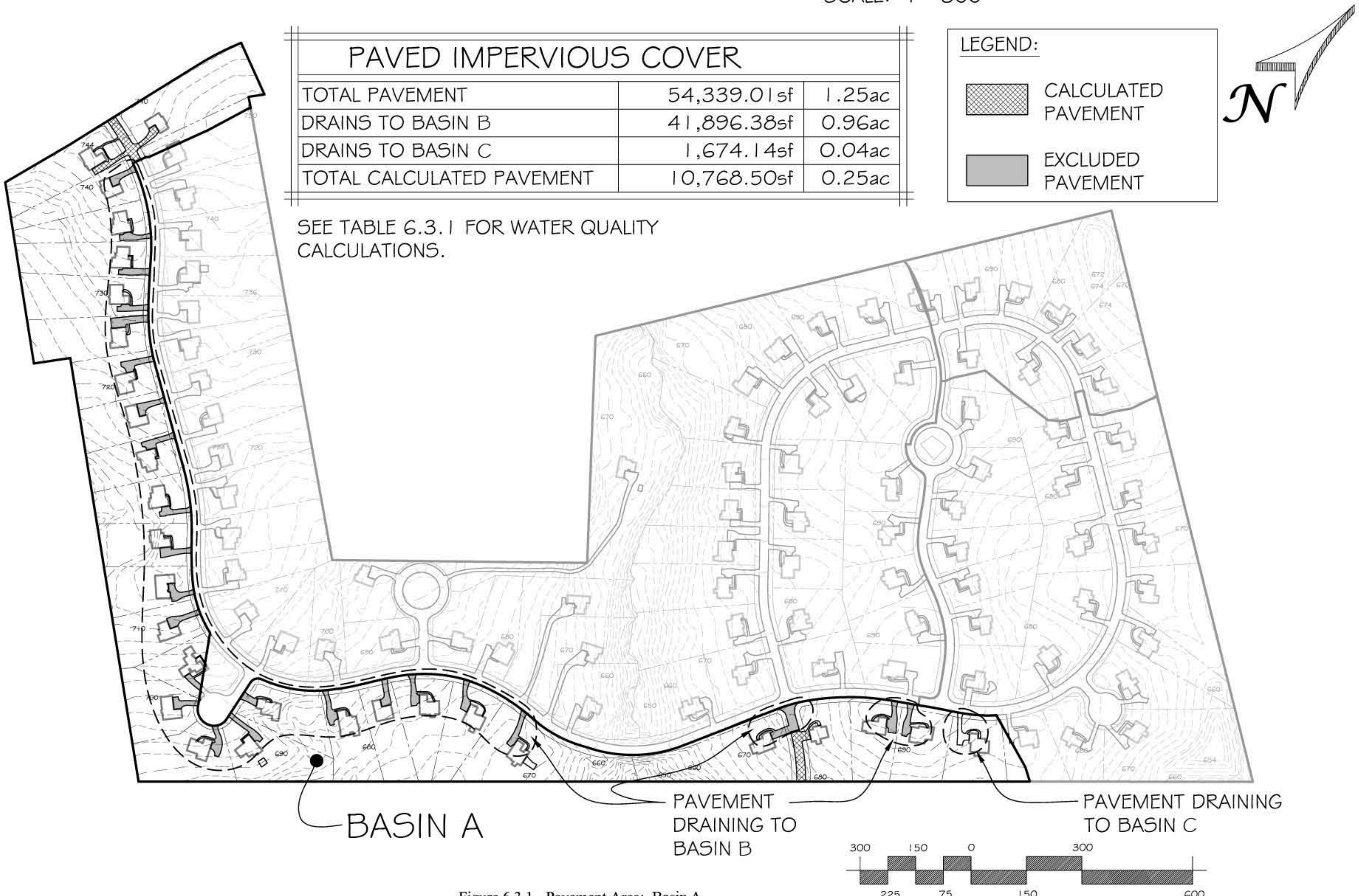


Figure 6.3.1 - Pavement Area: Basin A

6.3.3 Basin B

Basin B has 5.23 acres of paved impervious cover (Table 6.2.1). Figure 6.3.2 locates four driveways with a combined area of 0.16 acres within basin B which drain into basin C. This reduces the paved area in basin B to 5.07 acres. Added to this are the driveways draining into basin B from basin A (0.96 acres), to total 6.03 acres of paved impervious cover. Resultant water quality calculations provided in Table 6.3.1 yielded a water quality volume contribution of approximately 0.57 acre-feet (24,971.9cu.ft.) which is treatable in 23,504.0sf of right-of-way space during a two-day period according to ponding/filter area calculations in Table 6.3.1.

The available unpaved right-of-way area in basin B is 2.34 acres (101,973.3sf). To this number is added the right-of-way area in basin A adjacent to roadway, provided in section 6.3.2 (45,306.1sf); the right-of-way adjacent to the four driveways draining to basin C (8,453.0sf) is subtracted, as this area will be used to treat the water quality volume from these driveways. This yields 138,826.4sf, or 3.19 acres of usable right-of-way area, more than five times the necessary right-of-way area needed.

PAVEMENT AREA: BASIN B

SCALE: 1"=300'

PAVED IMPERVIOUS COVER		
TOTAL PAVEMENT	227,826.54sf	5.23ac
DRAINS TO BASIN C	6,860.41sf	0.16ac
DRAINS FROM BASIN A	41,896.38sf	0.96ac
TOTAL CALCULATED PAVEMENT	262,862.50sf	6.03ac

SEE TABLE 6.3.1 FOR WATER QUALITY CALCULATIONS.

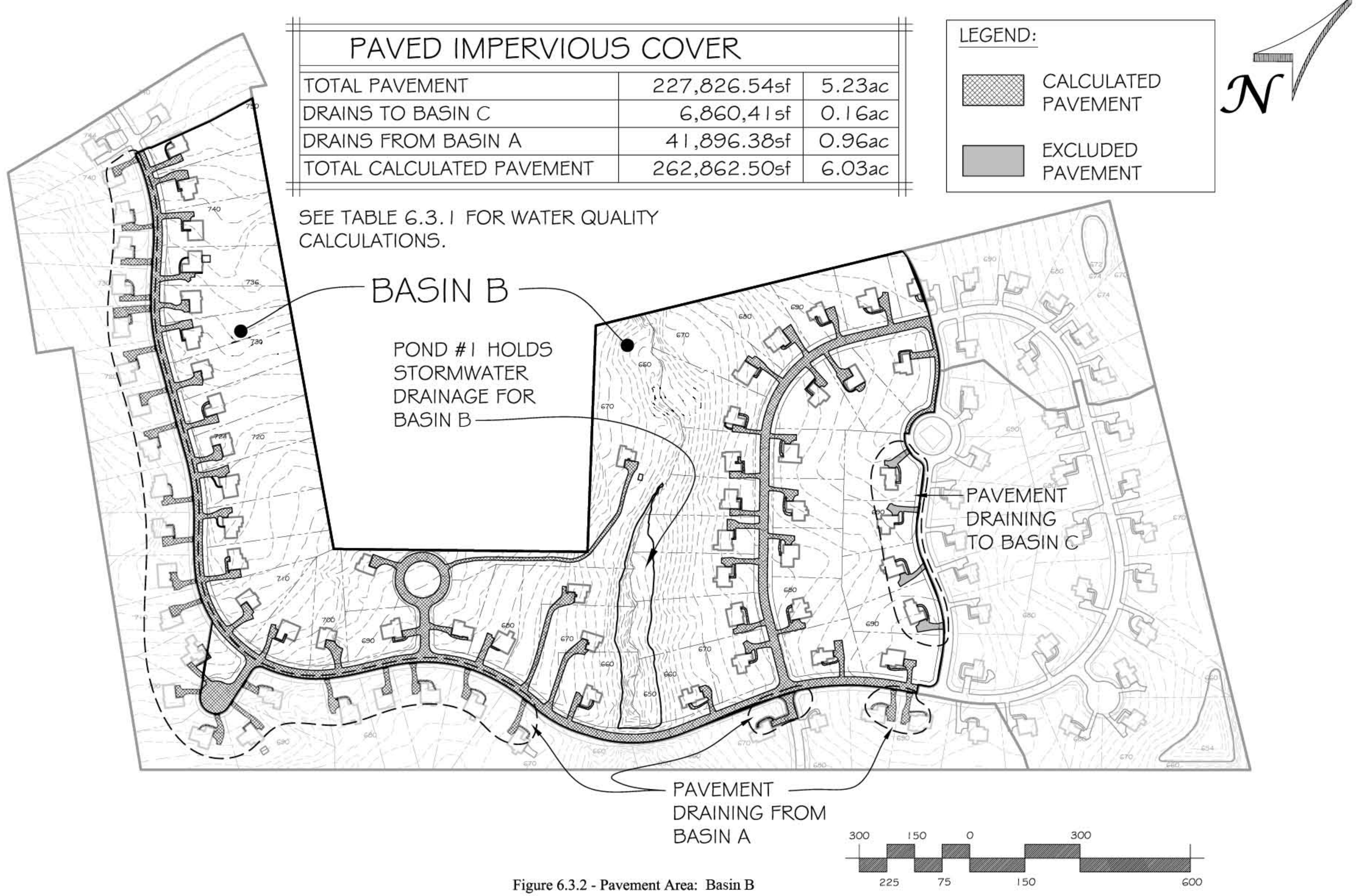


Figure 6.3.2 - Pavement Area: Basin B

6.3.4 Basin C

Basin C contains 2.24 acres of paved impervious cover. To this is added the four driveways from basin B (0.18 acres) as well as the single driveway from basin A (0.04 acres), resulting in a total of 2.44 acres of paved impervious cover (Figure 6.3.3). Water quality calculations in Table 6.3.1 yield a water quality volume of 0.23 acre-feet, or 10,078.0cu.ft. Ponding and filter area calculations in the same table conclude a necessary treatment area of 9,485.2sf. The available unpaved right-of-way area in basin C is 44,520.5sf, plus 8,453.0sf from the right-of-way area adjacent to the four driveways draining from basin B. This totals 52,973.5sf of available right-of-way.

PAVEMENT AREA: BASIN C

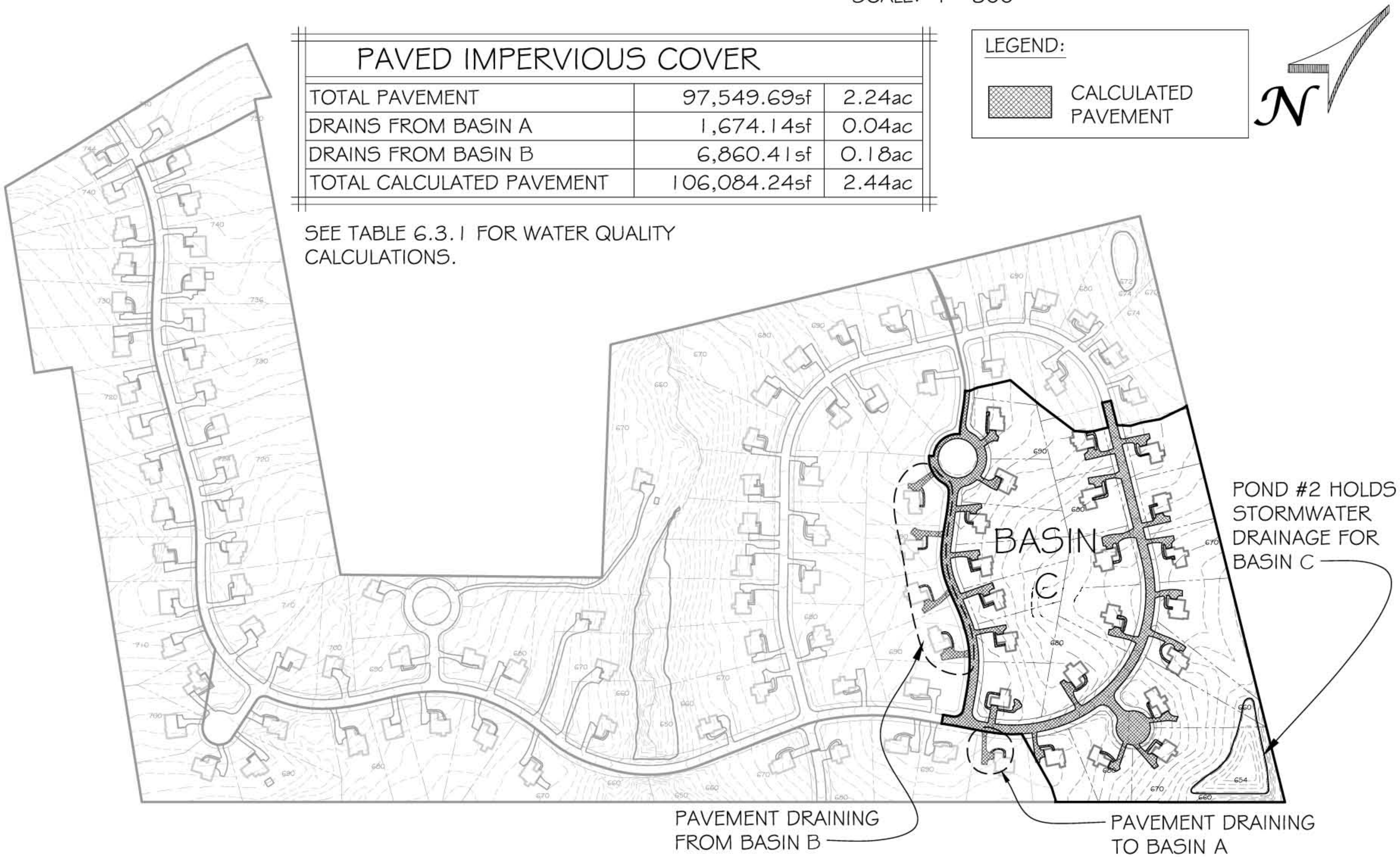
SCALE: 1"=300'

PAVED IMPERVIOUS COVER		
TOTAL PAVEMENT	97,549.69sf	2.24ac
DRAINS FROM BASIN A	1,674.14sf	0.04ac
DRAINS FROM BASIN B	6,860.41sf	0.18ac
TOTAL CALCULATED PAVEMENT	106,084.24sf	2.44ac

SEE TABLE 6.3.1 FOR WATER QUALITY CALCULATIONS.

LEGEND:

CALCULATED PAVEMENT



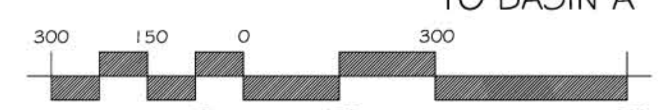


Figure 6.3.3 - Pavement Area: Basin C

6.3.5 Basin D

Basin D has 0.61 acres of paved impervious cover, as identified in Figure 6.3.4. Calculations in Table 6.3.1 yield a water quality volume of approximately 0.06 acre-feet (2,541.0cu.ft.) for this area. Necessary treatment area is calculated at 2,391.5sf, an area easily accommodated by the 13,610.5sf of available right-of-way space.

PAVEMENT AREA: BASIN D

SCALE: 1"=300'

PAVED IMPERVIOUS COVER		
TOTAL CALCULATED PAVEMENT	26,747.36sf	0.61ac

SEE TABLE 6.3.1 FOR WATER QUALITY CALCULATIONS.

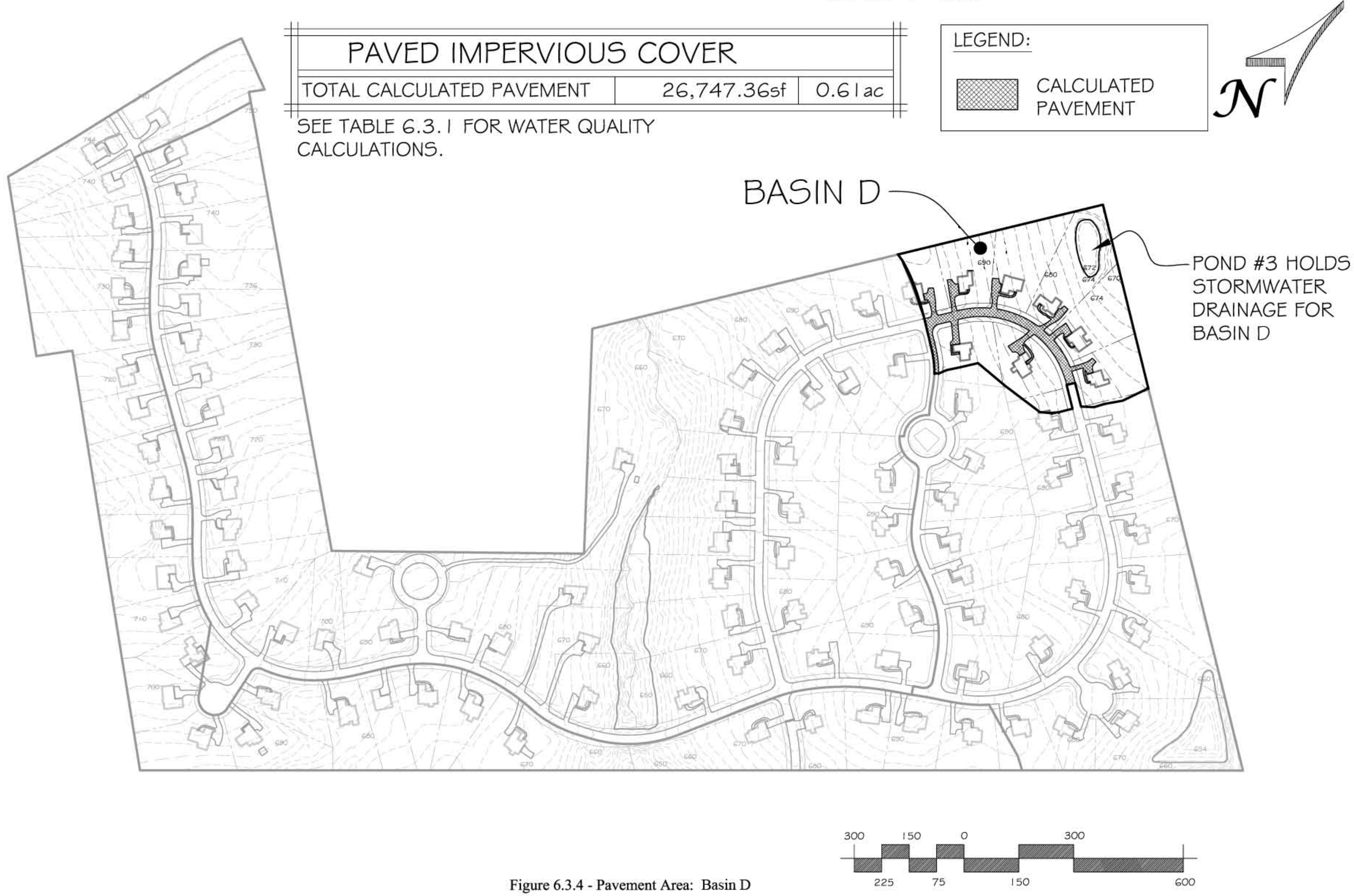


Figure 6.3.4 - Pavement Area: Basin D

6.3.6 Roadside Bioretention Cell Design Example

The roadside bioretention cells are intended to fit into the right-of-way immediately to the side of the roadway. These structures are designed as on-line cells, meaning that while their treatment capacity is that of the water quality volume for the 85^{th}-percentile storm event, they can also safely allow the passage of storm flows from larger storms if necessary. Figures 6.3.5 and 6.3.6 along with Table 6.3.2 illustrate the design of a roadside bioinfiltration cell within the calculated area of basin B.

In order to remain within the prescribed 1:2 bioretention area size ratio recommended by the GSMM, this large cell has been subdivided into four smaller cells through the use of check dams with weirs. During a rainstorm, runoff enters the cell through the curb cut at the high end of the cell where it traverses a pre-treatment grassed swale. Within the cell itself, water is allowed to accumulate to a level of one foot before spilling over the weir in the check dam into the next cell. During a storm that exceeds the cell's water capacity, runoff would fill all the cells to their one foot maximum depth and then exit through the grassed swale at the low end of the cell, reentering the existing conveyance system and continuing on to the basin's detention structure.

Due to the configuration of driveways and limited right of way area this cell was designed by defining the available bioretention area first, then calculating the amount of runoff it could effectively treat. The result is a drainage area of 0.072 acres, or 3,136sf (Table 6.3.2). Used in tandem these cells can treat nearly all the water quality volume produced by the pavement on the site, excepting rare cases in which an inlet to the existing stormwater conveyance system prohibits the treatment of a driveway immediately uphill from the inlet.

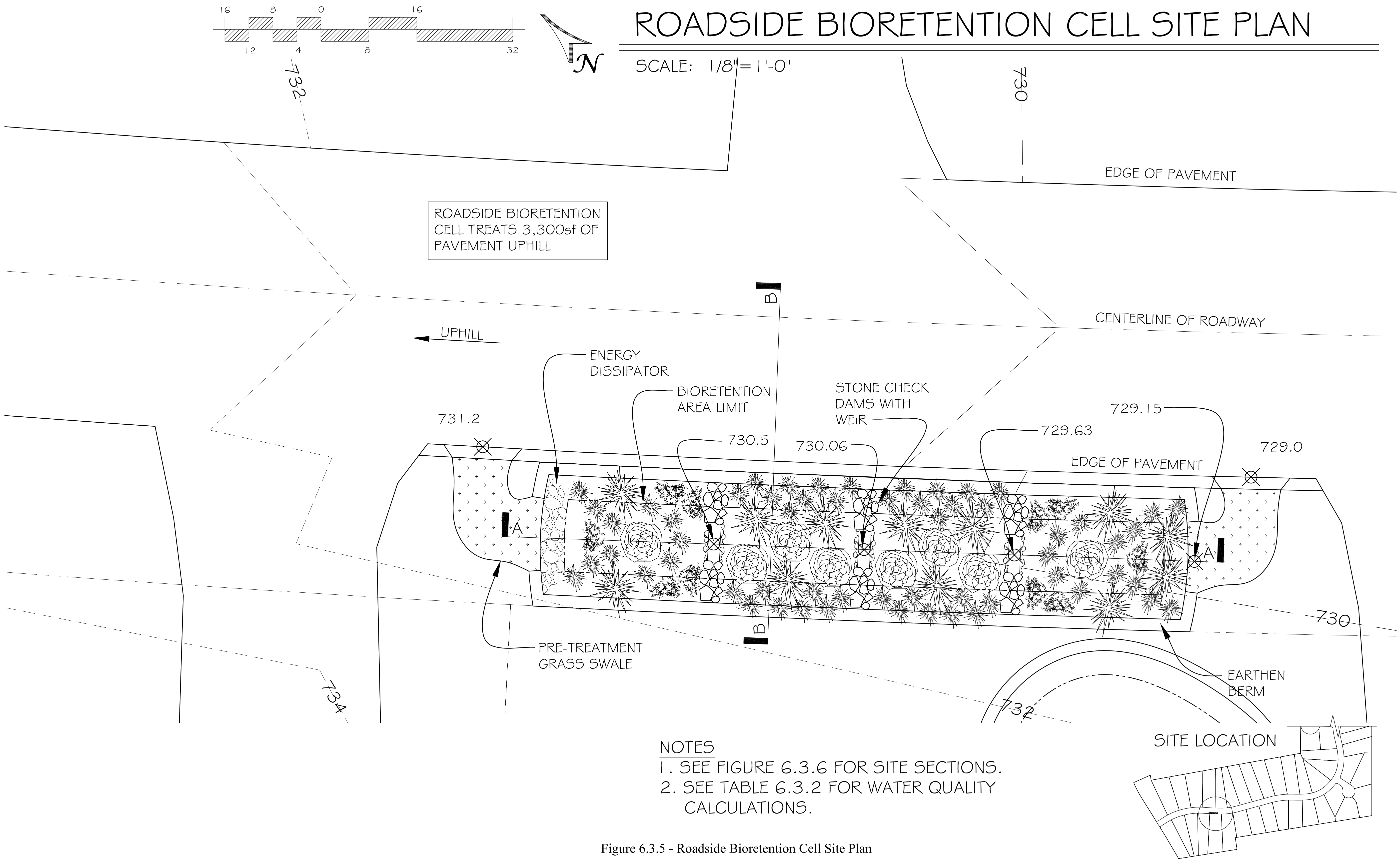


Figure 6.3.5 - Roadside Bioretention Cell Site Plan

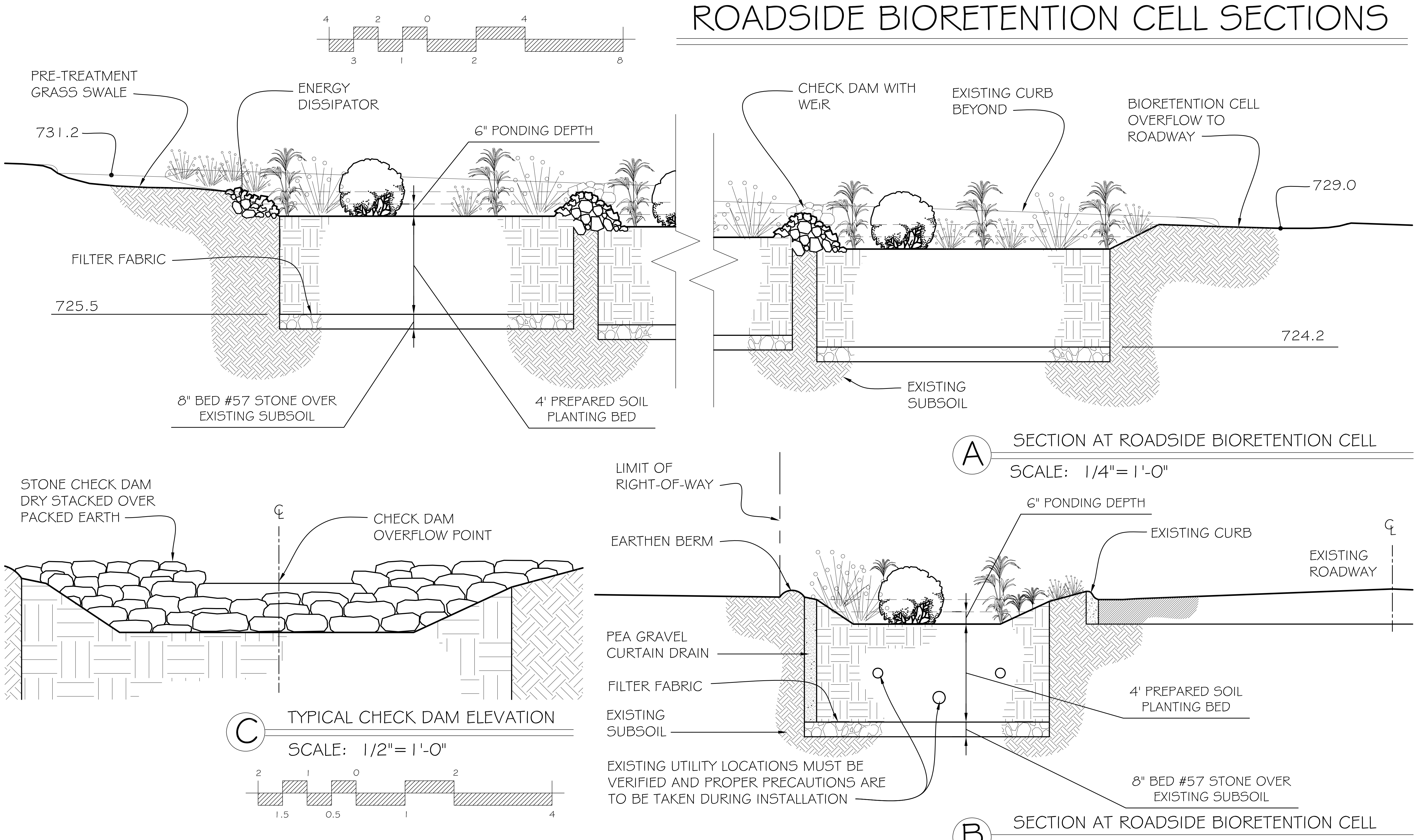


Figure 6.3.6 - Roadside Bioretention Cell Sections

Table 6.3.2 - Roadside Bioretention Area Water Quality Calculations

Roadside Bioretention Area Water Quality Calculations								
Total Area (ac)	Bypass Area (ac)	Drainage Area **(A)** (ac)	Impervious Cover (ac)	Percent Impervious Cover **(I)**	Volumetric Runoff Coefficient **(Rv)**=0.05+0.009(I)	Water Quality Volume (85% Storm) **(WQv)**=1.2(Rv)(A)/12 (af)	(cu.ft.)	Ponding/Filter Area **(Af)**=(WQv)(df)/[(k)(hf+df)(tf)] df=4ft k=0.5 hf=0.25ft tf=1day (sf)
0.072	0.00	0.072	0.072	100.00	0.950	0.0068	297.50	280.00

Where:

A = Site Area (Drainage Area)

I = Percent Impervious Cover (100% in this case)

Rv = 0.05+0.009(I) where I is **percent** impervious cover

WQv = water quality volume (provided in both acre-feet and cubic feet)

df = filter bed depth (4ft minimum)

k = coefficient of permeability of filter media (ft/day) (use 0.5 ft/day for silt-loam)

hf = average height of water above filter bed (ft) (typically 3in, which is half of the 6in ponding depth)

tf = design filter bed drain time (days) (2.0 days or 48 hours is recommended maximum)

Units:

ac = acres

af = acre-feet

cu.ft. = cubic feet

sf = square feet

The formulas used in these calculations are referenced from the Georgia Stormwater Management Manual, Volume 2.

6.3.7 Limitations

In a perfect world, runoff from roof gutters would be directed into the landscape, where it would be evenly distributed between runoff, evaporation, and groundwater. In reality, much of the runoff from rooftops is directed onto paved surfaces such as driveways and allowed to enter the conveyance system without water quality treatment. A design which only treats the water quality volume of paved impervious surfaces on a site is flawed in that it does not take into account the possibility of added roof runoff. This can be further explained by comparing paved impervious cover to rooftop impervious cover. Table 6.2.1 lists paved impervious cover on the entire site as 9.33 acres while rooftop impervious cover is 5.41 acres. This amount of untreated impervious rooftop cover is equivalent to more than 50 percent of the treated paved impervious cover, and a significant portion of the entire site's water quality volume. If left untreated, it is likely that the roadside bioretention cells designed to treat only paved impervious runoff would become overloaded and would be unable to function at their peak performance levels. The next section will calculate the bioretention area necessary to treat stormwater runoff from all rooftop impervious cover.

6.4 Study #2: Water Quality Control for Residences

This study addresses 100% of the rooftop impervious cover in the entire development for water quality treatment. The resultant rooftop water quality volume for each basin can be directly added to the pavement water quality volume calculated in Study #1. Table 6.4.1 provides the water quality calculations for this segment. Following the table is a summary of the calculations per basin area.

As in Study #1, the formulas used to calculate water quality volume and ponding/filter area are referenced from the Georgia Stormwater Management Manual Volume 2. Unlike Study #1 there is no need to modify the water quality volume formula, as this study uses the entire basin areas as the drainage areas. This may result in a small amount of runoff being included which originates on pervious surfaces. However, the 85^{th}-percentile design storm is unlikely to cause concentrated overland flow from pervious surfaces unless the landscape is severely sloped, eroded or both.

Once again, the necessary bioretention area is calculated using a two day (48 hour) ponding time, in order to achieve the smallest bioretention area possible. While this is perfectly adequate, reducing the ponding time to one day and the maximum bioretention cell depth to 6 inches would ensure that the bioretention area will be ready for another water quality sized storm the next day. In order to decrease the ponding time, the bioretention areas calculated in Table 6.4.1 would have to be multiplied by two. With these larger bioretention areas, it may be more appropriate to split the total bioretention area. The design example featured in Figure 6.4.1 and Figure 6.4.2 was created using a one day (24 hour) ponding time.

Table 6.4.1 - Rooftop Impervious Cover - Overall Basin Water Quality Calculations

Rooftop Impervious Cover - Overall Basin Water Quality Calculations								
Total Area (ac)	Bypass Area (ac)	Drainage Area **(A)** (ac)	Impervious Cover (ac)	Percent Impervious Cover **(I)**	Volumetric Runoff Coefficient **(Rv)**=0.05+0.009(I)	Water Quality Volume (85% Storm) **(WQv)**=1.2(Rv)(A)/12 (af)	(cu.ft.)	Ponding/Filter Area **(Af)**=(WQv)(df)/[(k)(hf+df)(tf)] df=4ft k=0.5 hf=0.25ft tf=2days (sf)
Basin A								
22.1	0.25	21.85	1.57	7.19	0.115	0.251	10,920.217	10,277.852
Basin B								
42.63	6.03	36.60	2.48	6.77	0.111	0.406	17,678.531	16,638.618
Basin C								
16.86	2.44	14.42	1.01	6.98	0.113	0.163	7,086.477	6,669.625
Basin D								
5.86	0.61	5.25	0.37	7.12	0.114	0.060	2,607.411	2,454.034

Total Water Quality Volume From Houses	**38,292.637 cu.ft.**
Total Necessary Treatment Area	**36,040.129 cu.ft.**

Where:

A = Site Area (Drainage Area)

I = Percent Impervious Cover (100% in this case)

Rv = 0.05+0.009(I) where I is **percent** impervious cover

WQv = water quality volume (provided in both acre-feet and cubic feet)

df = filter bed depth (4ft minimum)

k = coefficient of permeability of filter media (ft/day) (use 0.5 ft/day for silt-loam)

hf = average height of water above filter bed (ft) (typically 3in, which is half of the 6in ponding depth)

tf = design filter bed drain time (days) (2.0 days or 48 hours is recommended maximum)

Units:

ac = acres

af = acre-feet

cu.ft. = cubic feet

sf = square feet

The formulas used in these calculations are referenced from the Georgia Stormwater Management Manual, Volume 2.

6.4.1 Basin A

Basin A includes a total drainage area of 22.1 acres (Table 6.2.1). This area is subdivided into 29 lots with a combined rooftop impervious cover of 1.57 acres (Table 6.4.1). The rooftop impervious cover water quality volume for these basins is 0.251 acre-feet (10,920.2cu.ft.). Ponding/filter area calculations yield a necessary treatment area of 10,277.9sf. Dividing the treatment area by the number of lots in the combined basins yields an average bioretention area of 354.4sf per lot. Adhering to the 2:1 bioretention area ratio, an area approximately 13ft x 27ft with a maximum depth of 1ft would be appropriate. If a one day ponding time is desired, two bioretention cells of these dimensions with a maximum six inch ponding depth can be used. Alternatively, one bioretention cell measuring 18ft x 39ft would suffice.

6.4.2 Basin B

Basin B covers a total of 42.63 acres (Table 6.2.1), subdivided into 48 lots. The rooftop impervious cover for the basin is 2.48 acres (Table 6.4.1). Water quality volume calculations result in approximately 0.41 acre-feet (17,678.5cu.ft.). The necessary bioretention area is calculated at 16,638.6sf (Table 6.4.1). An average bioretention area of 346.6sf can be calculated by dividing the total basin bioretention area by the number of lots. This average bioretention area is only slightly smaller than the one calculated for basin A. Areas similar in dimension to the ones calculated for those basins can be used in both two day and one day ponding scenarios for basin B.

6.4.3 Basin C

Basin C is composed of 16.86 acres (Table 6.2.1) subdivided into 21 lots. Of this total area, 1.01 acres are rooftop impervious cover (Table 6.4.1). Water quality volume is 0.16 acre-feet (7,086.5cu.ft.), needing 6,669.6sf of bioretention space (Table 6.4.1). Divided by 21 lots, the average bioretention cell space per lot is 317.6sf. A bioretention area of this size at a ratio of 1:2 is approximately 12ft x 25ft. Two areas of this size would serve to treat the site runoff in one day.

6.4.4 Basin D

Basin D is only eight lots encompassing 5.86 acres and containing 0.37 acres of total rooftop impervious cover. The water quality volume produced by this area is 0.06 acre-feet, or 2,607.4cu.ft. (Table 6.4.1) The necessary bioretention area is approximately 2,454.0sf. Each lot needs an average bioretention area of 306.75sf. Again, this area is only slightly smaller than the area provided for basin C. Bioretention area dimensions similar to those calculated above can be used in basin D as well.

6.4.5 Rooftop Impervious Cover Comparisons

One trend is prevalent in the above calculations. Basin A and basin B exhibit fairly similar average bioretention basin sizes for their respective lots. The average residence sizes in these areas are 2,360sf and 2,240sf, respectively (Table 6.2.1). Basins C and D exhibit smaller average bioretention areas per lot as well as smaller average residence sizes (2,087sf and 2,035sf respectively). This difference in residence footprints is likely due to the odd shape of the development as a whole. The majority of the lots area not regularly shaped, and many are well beyond the minimum 25,000sf specified by the area zoning. Basins C and D contain the majority of the regularly sized lots, as well as those that are closest to the 25,000sf limit. The same zoning regulation imposes a maximum impervious cover of 25 percent. These smaller lots must also leave enough unbuilt land to accommodate septic systems. The result is that smaller lots have smaller houses built on them.

6.4.6 Lot Bioretention Cell Design Example

The following example is provided to illustrate the way bioretention basins would be used on an individual site. In this example, the driveway is assumed to drain to the street and is not included in the water quality calculations. See Table 6.4.2 for calculations.

Figure 6.4.1 show the site and its location in the development. The limits of the drainage area are identified, allowing the design to exclude non-contributing land from the water quality volume calculation. The basins on the site and the bioretention cell in the right-of-way were sized using calculations in Table 6.4.2. Due to the shape of the roof, the bioretention area was divided into two areas.

Of concern is the rear yard bioretention area, as it must be positioned to avoid the lot's septic system. In analyzing the site, it was determined that the septic tank would most likely be placed at the south side of the house for service access through the driveway and the drain field would extend into the back yard in a parallel orientation to the site contours. This required placement of the rear bioretention area on the western corner of the house. While this location is not optimal to the location of rear downspouts it does allow for the integration of a longer pre-treatment swale to aid in further pollutant removal. Both bioretention areas are designed to treat the volume specified in Table 6.4.2 in a one day period. Figure 6.4.2 shows section details through bioretention area 1. This is a standard cross-section depicting typical construction methods.

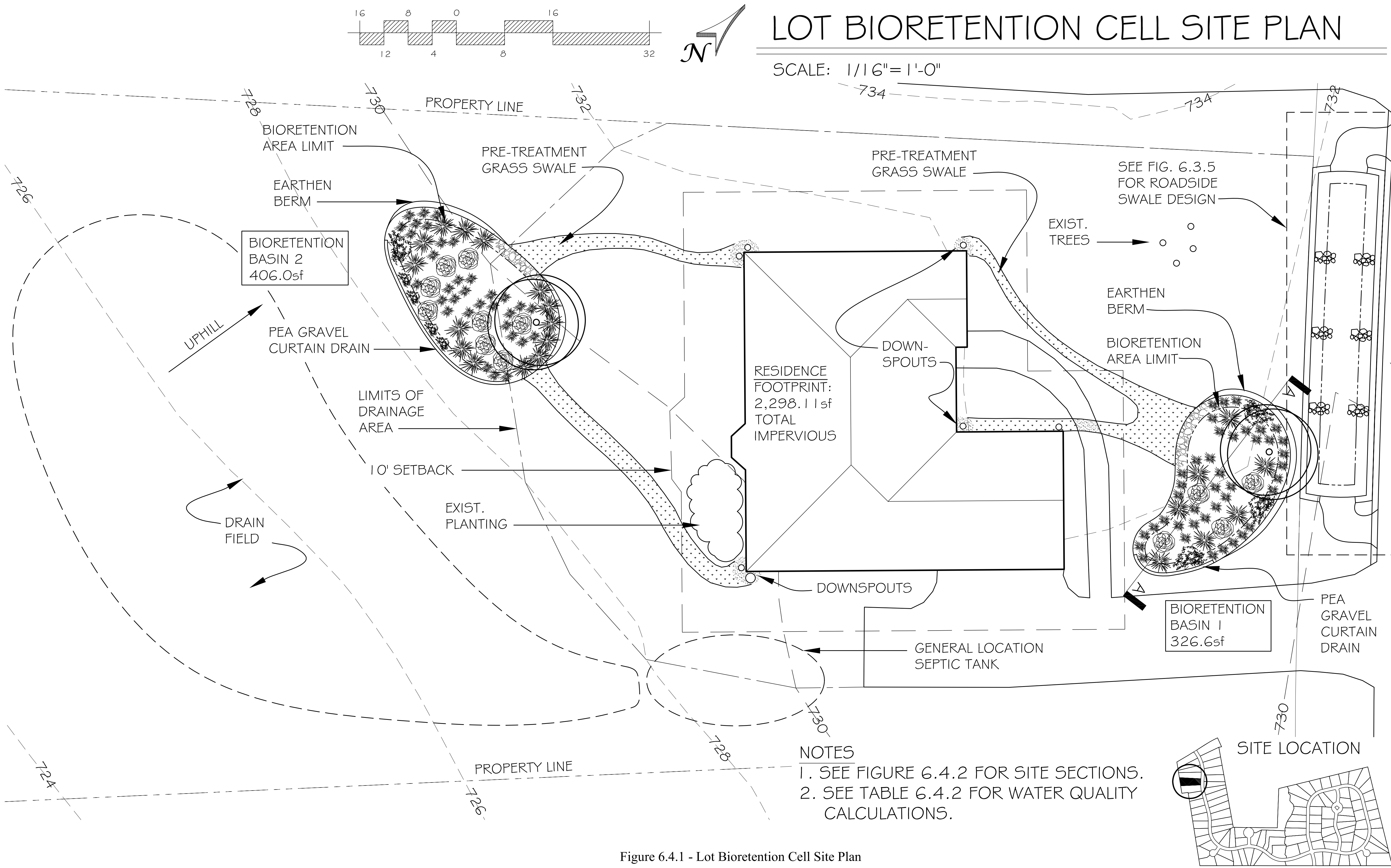


Figure 6.4.1 - Lot Bioretention Cell Site Plan

LOT BIORETENTION CELL SECTION

SCALE: 1/4"= 1'-0"

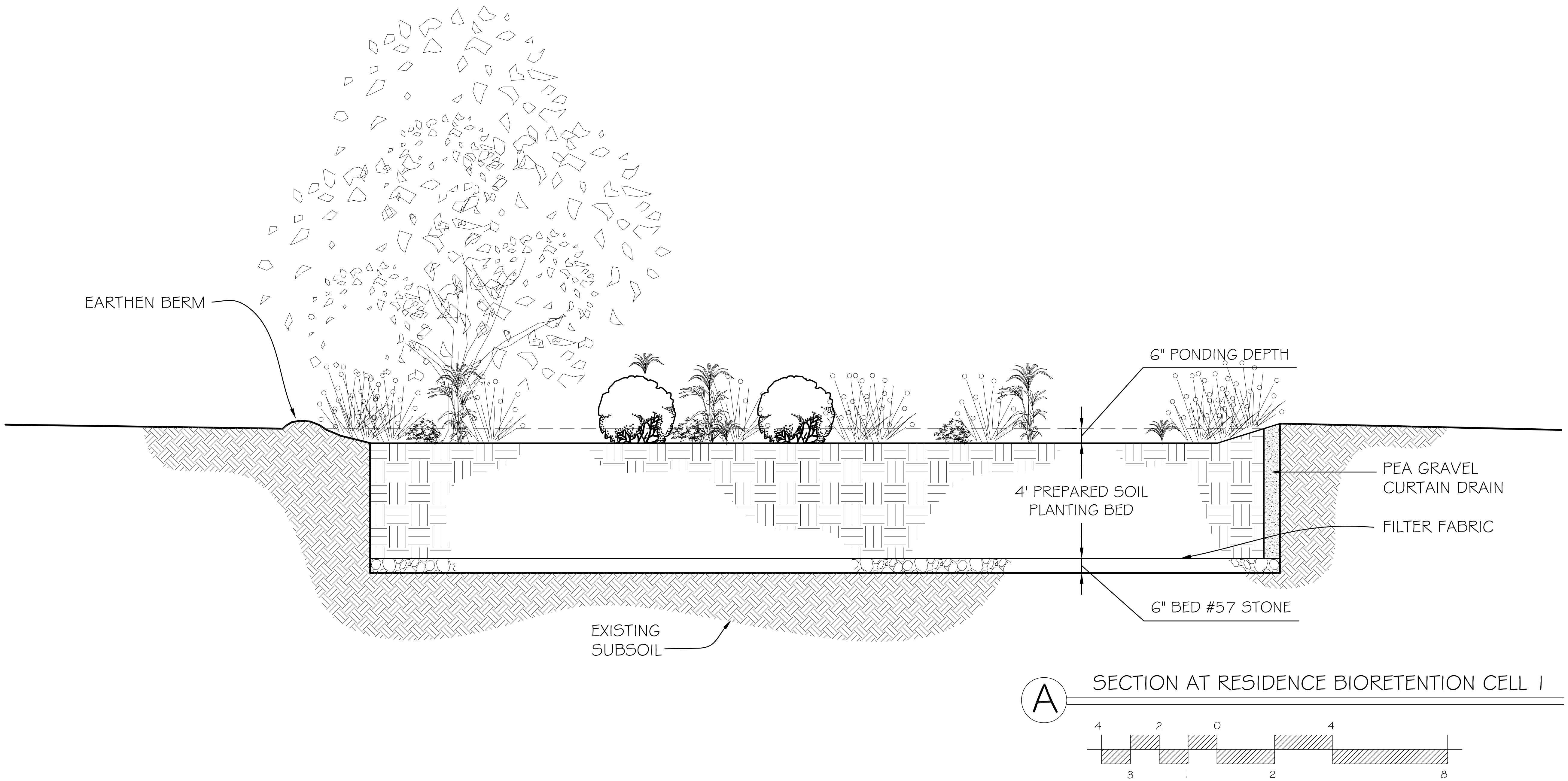


Figure 6.4.2 - Lot Bioretention Cell Section

Table 6.4.2 - Lot Bioretention Area Water Quality Calculations

Lot Bioretention Area Water Quality Calculations								
Total Area (ac)	Bypass Area (ac)	Drainage Area **(A)** (ac)	Impervious Cover (ac)	Percent Impervious Cover **(I)**	Volumetric Runoff Coefficient **(Rv)**=0.05+0.009(I)	Water Quality Volume (85% Storm) **(WQv)**=1.2(Rv)(A)/12 (af)	(cu.ft.)	Ponding/Filter Area **(Af)**=(WQv)(df)/[(k)(hf+df)(tf)] df=4ft k=0.5 hf=0.25ft tf=1day (sf)
0.85	0.62	0.23	0.0251	10.81	0.147	0.003	148.796	280.087
0.85	0.62	0.23	0.0277	11.94	0.157	0.004	159.039	299.367
Total Water Quality Volume Treated				**307.84 cu.ft.**				

Where:

A = Site Area (Drainage Area)

I = Percent Impervious Cover (100% in this case)

Rv = 0.05+0.009(I) where I is **percent** impervious cover

WQv = water quality volume (provided in both acre-feet and cubic feet)

df = filter bed depth (4ft minimum)

k = coefficient of permeability of filter media (ft/day) (use 0.5 ft/day for silt-loam)

hf = average height of water above filter bed (ft) (typically 3in, which is half of the 6in ponding depth)

tf = design filter bed drain time (days) (2.0 days or 48 hours is recommended maximum)

Units:

ac = acres

af = acre-feet

cu.ft. = cubic feet

sf = square feet

The formulas used in these calculations are referenced from the Georgia Stormwater Management Manual, Volume 2.

6.4.7 Cost Estimate

The cost estimate for both studies combined (Figure 6.4.3) is extrapolated using cost information from the existing bioretention retrofit installation in Burnsville, MN, included in Appendix B of this volume. The costs for specific items, such as retaining walls and imported planting soil, were calculated by taking the original cost provided in the Burnsville cost estimate and dividing by 17, the number of gardens constructed in that project. While not all gardens needed curb cuts or retaining walls, this exercise was meant to provide an approximation of cost. Labor costs for planting and mulching the gardens were not part of the Burnsville estimate, as this job was performed by residents of the Burnsville project area. The cost estimate for this project provides a separate line item for labor in this capacity in order to cover the possibility that residents may not want to participate in planting the roadside bioretention areas.

If the reader will note, maintenance costs are not included in this cost estimate. It is assumed that for a project of this magnitude to pass approval and actually be implemented it would require support from a decisive majority of the neighborhood residents themselves. A large part of this support would be the regular maintenance of bioinfiltration areas located within the lots. It is likely that a home owners association or civic group would be created to govern this regular maintenance, as well as to manage funding and upkeep of roadside bioretention areas, possibly through the implementation of a neighborhood specific stormwater structure maintenance fee. Conversely, the local stormwater utility could retain maintenance costs and operations for the roadside cells by creating a fund pool dedicated specifically to the maintenance of retrofit application roadside bioretention cells.

Construction Costs

Excavation & Sod Stripping	$724.12
Retaining Walls	$291.71
Imported Planting Soil	$652.82
Edging	$397.29
Sod	$116.47
Mulch	$125.29
Plants	$562.29
Curb Cuts	$382.35
Average Cost Per Bioretention Cell	$3,252.35
Planting Labor Cost (+33%)	$265.34

Homeowner Education Costs

Home Owner Education	$129.36
Meetings With Home Owners	$359.24
Total Per Home Owner	$488.60

Design Costs

Per Bioretention Cell (Based on Const. Cost)	$1,626.18

Construction Administration Costs

Per Bioretention Cell (Based on Design Cost)	$813.09
Total Per Bioretention Cell (no labor)	$6,180.22
Total Per Bioretention Cell (labor)	$6,445.56
Total for Subdivision (no labor)	$1,310,206.14
Total for Subdivision (labor) (106 Lots @ 2 Bioretention Cell Per Lot)	$1,366,458.10
Avg. Cost per sq.ft. (no labor)	$37.30
Avg. Cost per sq.ft. (labor)	$38.90
Total for Roadway Treatment (Includes Labor)	$1,502,269.01
Total for Development (no labor)	$2,812,475.15
Total for Development (labor)	$2,868,727.11

Figure 6.4.3 – Project Cost Estimate

6.5 Observations

This project was a large undertaking with many variables and possible outcomes. The results indicate that much more research would be required to appropriately design a water quality management system for this size of development. Water quality calculations are extremely lot-specific. It is difficult to precisely determine what is required of a treatment area when the water quality volumes range in the tens of thousands of cubic feet and available land for water quality control installation is so disconnected. The best interpretation of water quality volume was the individual lot design, which provided a tangible comparison between the impervious surface and the bioretention area necessary for treatment. The bioretention area turned out to be smaller than expected, and the two bioretention cell solution was more appropriate to water flow. The reverse engineered roadside bioretention cell provided accuracy in predicting the amount of area that a specific size of cell can realistically treat.

A thorough site analysis was crucial to the outcome of this retrofit application study, as site specific soils and slopes could severely limit the amount of land appropriate for bioretention area. While the site chosen for this study had adequate soils, it was still necessary to supply the bioinfiltration planting medium in order to ensure the proper water infiltration rates. This added significant cost to the overall project. Sites with more appropriate soils would be better candidates for stormwater retrofit applications.

Topography was not an issue on this site, as the majority of the steep slopes had been left wooded and undeveloped. These occur mainly in the deep ravine that bisects basin B and creates the depression for detention pond #1. Steeply sloped developments would not be adequate for this type of stormwater retrofit. There are many other stormwater quality management controls that could be used in steeply sloped areas. Further study of these methods would be required in order to provide retrofit possibilities for these developments.

The cost estimate brought a sobering reality to the entirety of the project. Considering that a retrofit installation of this size could conceivably cost nearly $3 million supports the necessity for a retrofit program to be instituted under the stormwater utility, so that said program can acquire the funds it needs for projects of this size. Homeowners should incur a part of the overall cost; primarily that which pertains to bioretention cells on their properties. As discussed in section 6.4.6, homeowners should also be responsible for part of the maintenance cost of the bioretention cells.

Overall, the project succeeded in determining that while the retrofitting of existing developments with water quality controls can be applied to a large suburban residential area with the proper site requirements in the Georgia Piedmont, design limitations related to available area as well as the large cost of implementation could significantly hinder or even prohibit the installation of the water quality controls.

CHAPTER 7

CONCLUSION

The premise of this thesis has been to study the retrofitting of existing large lot residential neighborhoods with low impact development on-site stormwater quality management structures, ultimately as a tool for the long-term success of a regional stormwater management plan. The research took the shape of four specific areas: history, low-impact development, socio-political influences and case studies. A project application was performed using the information gathered.

The history of the development of stormwater regulation in the U.S. identified key events that helped define current stormwater regulation. Due to its very nature, though, history is never complete. Every year, new legislation is proposed to further define and change our treatment of stormwater quality management. The issue of minimal sufficiency brought up at the end of Chapter 2 may yet be addressed in future regulation modifications. We as a community must continue to move toward a more sustainable relationship with nature, perhaps one guided by the natural systems that we continually disrupt.

Low-impact development (LID) was researched as one solution to the problems caused by non-point source pollution originating in residential areas. The techniques defined can be used to mitigate this large problem in almost any type of development. Bioretention was identified as one of the more appropriate LID techniques for use in retrofit applications due in part to other benefits besides stormwater quality management. Bioretention areas can provide plant biodiversity, habitats for local wildlife and aesthetic benefits to a residential area. They also provide an accessible, hands-on way for residents to learn more about their environment through the regular maintenance and monitoring of bioretention areas, in this way helping to foster feelings of responsibility and stewardship for the land.

The three socio-political factors studied in Chapter 4 (legislation, funding and public support) were found to be entirely intertwined; one was unable to be truly studied without the others. It was found that a successful stormwater retrofit program would need to consider all three factors carefully and determine how to use them to the best advantage. There are a multitude of combinations that would yield good results and every municipality needs to be treated in an individual manner.

Several communities in this country have begun the process of stormwater retrofitting. Three were included as case studies in Chapter 5. Each was found to be achieving success in stormwater retrofitting endeavors through different combinations of the three socio-cultural factors mentioned above. Of the three, the most pertinent to this thesis was the Rainwater Gardens Pilot Project in Burnsville, Minnesota. Their retrofit of a suburban street with bioretention areas provided much of the inspiration for the project application performed for this thesis.

The project application in Chapter 6 strived to determine the possibilities of retrofitting a suburban residential neighborhood in the Piedmont region of Georgia with LID-based stormwater management controls. An extensive two-part study of the Woods of Habersham subdivision in Athens, GA, resulted in the conclusion that while the retrofitting of existing developments with water quality controls can be applied to a large suburban residential area with the proper site requirements in the Georgia Piedmont, design limitations related to available area as well as the large cost of implementation could significantly hinder or even prohibit the installation of the water quality controls.

The project design was based entirely on guidelines set forth by the Georgia Stormwater Management Manual (GSMM) and this has brought up some pertinent questions. While technically correct, the design of the bioretention basins proved excessive in several ways. First, the excavation and complete replacement of the native soils in order to achieve the prescribed filtration rate was unnecessary, as the native soils would have provided a filtration rate that more than satisfied the requirement by the GSMM. This design requirement caused a significant and unnecessary increase in the cost of implementation due to the need to purchase and transport the replacement soil. Second, it may not be necessary to excavate quite so deeply in order to achieve proper function of the bioretention cells. This would also reduce the overall cost of the project. Individual site soil samples would have to be studied in order to determine the necessary depth of excavation. These issues lead one to question the rules in the GSMM: perhaps they do not in fact apply to all locations in Georgia. This project has shown above all else that every site is unique in its hydrology and must be treated individually when designing stormwater quality management controls.

Another outcome of this project is an understanding of the supreme importance of cost and funding in a stormwater retrofit application. It would be difficult to justify the almost $3 million price tag of this project in an area that does not necessarily exhibit any visible need. The cost calculated is equivalent to the cost of capital improvement projects that would benefit an entire community where as the retrofit project would only benefit a single neighborhood. The changes discussed in the previous paragraph may work to reduce the cost to an acceptable amount. Other ways to reduce cost are to involve residents in planting and mulching the roadway bioretention basins instead of hired labor, or reduce the number of roadway bioretention cells by combining them into larger areas. A competitive bid process when selecting an engineering firm and a construction company to do the work may also yield lower design and project management fees. Seeking materials donations by local landscape suppliers may also help reduce costs. Lowering the cost will be crucial in a successful implementation of the project.

The research presented here suggests that the concept of retrofitting existing residential areas with stormwater quality management controls has been considered by others in the past, but is still far from becoming a reality in any municipality. Of the three socio-cultural factors that would influence the implementation of a retrofitting program within a stormwater utility, cost is perhaps the most daunting.   It is also unfortunately difficult to compare the price of a retrofit with the benefits that type of project would have on something as amorphous as "the environment."   Ultimately the benefits of water quality management must be weighed carefully against the heavy burden of cost it would entail.

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APPENDIX A

PORTLAND GREEN STREETS EXAMPLE PROJECTS

- SW 12th Avenue Green Street Project – Project report provided by the Portland Bureau of Environmental Services, City of Portland, Oregon. (*http://www.portlandonline.com/bes/index.cfm?c=44463&*)
- NE Siskiyou Green Street Project – Project report provided by the Portland Bureau of Environmental Services, City of Portland, Oregon. (*http://www.portlandonline.com/bes/index.cfm?c=44463&*)

SW 12th Avenue Green Street Project
SW 12th Avenue between SW Montgomery and SW Mill
Portland, Oregon

PROJECT SUMMARY

Project Type:	Stormwater retrofit of an existing downtown street – demonstration project
Technology:	A treatment train of four consecutive street stormwater planters
Major Benefits:	• The planters capture runoff from approximately 7,500 square feet of paved surfaces. They treat and infiltrate most of the runoff they receive, providing volume and flow control and water quality benefits. • Runoff is managed onsite, instead of entering the storm drain system that feeds directly into the Willamette River. • The planters improve the existing urban streetscape by adding attractive greenspace. • The planters are designed to safely accommodate pedestrians, on-street parking, and vehicle access.
Cost:	The total project construction cost, including project management (but not design), w $38,850. Of this, construction of the stormwater planters cost $34,850, or $4.65 per square foot of impervious area managed. The remaining $4,000 was required for ancillary street and sidewalk repairs and landscaping adjacent to the planters; these costs may not be needed for other similar projects.
Constructed:	May-June 2005
Maintenance	The City of Portland will maintain the facilities.

Features

- This was Portland's first Green Street project to transform existing landscape to street stormwater planters that manage street runoff and safely maintain on-street parking.

- The design provides water quality treatment and maximizes infiltration of the runoff. Each facility can pond about 7 inches of stormwater runoff and retain it for infiltration.

- The award-winning design successfully integrates stormwater management into an urban environment.

Stormwater Street Planters at SW 12th and Montgomery
Portland, Oregon

BACKGROUND

This Green Street project converted a previously underused landscape area between the sidewalk and street curb into a series of landscaped stormwater planters designed to capture, slow, cleanse, and infiltrate street runoff. Built in the summer of 2005, the project demonstrates how both new and existing streets in downtown or highly urbanized areas can be designed to provide direct environmental benefits and be aesthetically integrated into the urban streetscape. Although the project has a strong functional component, it is the integration of the landscaped stormwater planters into the urban environment that has gained the interest of the design community, developers, policy makers, and local citizens in the City of Portland's commitment to promote natural systems to manage urban stormwater runoff.

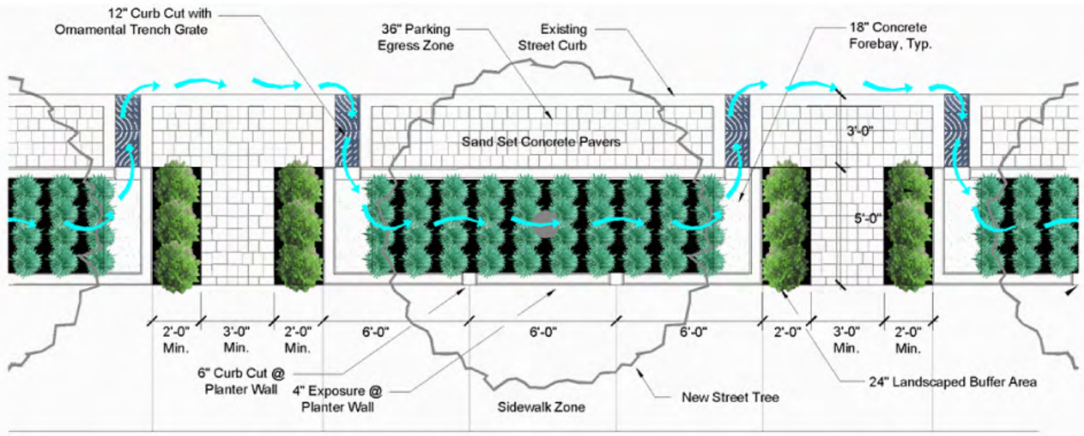
How do the Street Stormwater Planters Work?

- Stormwater runoff from the street flows downhill along the existing curb until it reaches the first of four consecutive stormwater planters.

- A 12-inch-wide trench drain channels the street runoff into the first stormwater planter. The trench drain moves the water under the vehicle step-out area and into the facility. The runoff is directed over a concrete pad, where sediment and debris are deposited for easy removal.

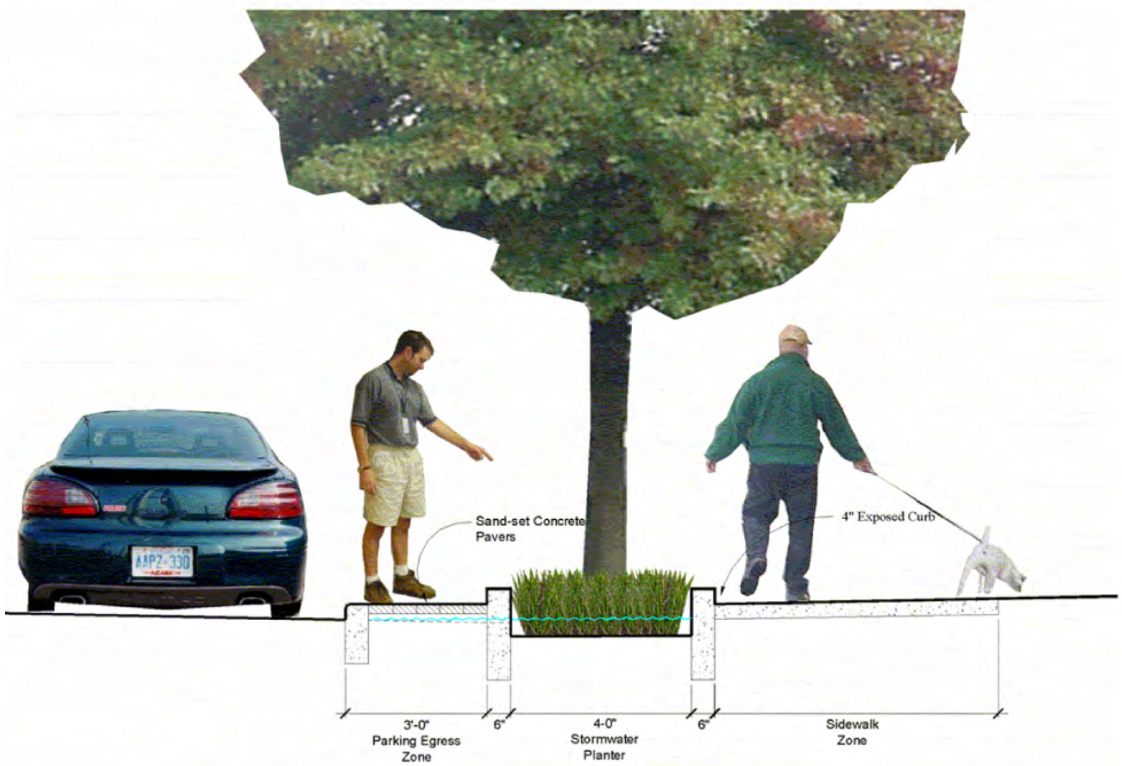
- Stormwater is allowed to pond to a depth of 7 inches before infiltrating through the soil at a rate of approximately 4 inches per hour. During large storm events, water may enter the planter at a rate faster than the soil can infiltrate, resulting in a ponding depth greater than 7 inches. In that case, the runoff exits a second curb cut, flows back into the street, and enters the second (downhill) planter. This process continues for the third and fourth planters. If the fourth planter ponds to capacity, it overflows to the existing storm system.

- The adjacent sidewalk slopes toward the planters, and sidewalk runoff enters the planters through curb cuts.



SW 12th Avenue Stormwater Planter ~ Enlarged Plan

N.T.S.



SW 12th Avenue Stormwater Planter ~ Typical Cross Section

N.T.S.

SITE SELECTION CRITERIA

- **Traffic Impacts**: The project was not expected to have any traffic impacts.

- **Stormwater Catchment Area:** The size of the catchment area, approximately 7,500 square feet, was considered fairly representative of conditions in the surrounding area.

- **Utility Conflicts:** An existing gas service line to the adjacent building was the only subsurface utility that intersected any of the stormwater planters (the third one). The existing shut-off valve was located and preserved with a plastic standpipe for easy access. The existing street lighting remained in place.

- **Loss of Parking Spaces:** The project did not affect existing on-street parking.

- **Street Slope:** The moderate street slope (2 percent) was suitable for the project.

- **Suitability for Monitoring:** The configuration of the local combined sewer allowed for placement of a flow monitor. There is also a rain gage near the project to measure rainfall events.

- **Soil Infiltration Rates:** Specialized infiltration tests were not required at the site. (See "Geotechnical Evaluation," below.)

- **Available Space:** The existing underused landscape area was 8 feet wide from face of curb to sidewalk edge. This allowed for 3 feet of flat area for parking egress and 5 feet for the stormwater planter, including 6-inch-wide perimeter curbing around the planters.

STORMWATER CAPACITY AND SYSTEM CONFIGURATION

Stormwater Management Goals

The stormwater management goal was to maximize the capture, treatment, and infiltration of street runoff, while providing a visual amenity for the neighborhood.

Geotechnical Evaluation

An infiltration test was not required before construction because adequate documentation already existed concerning the well-draining characteristics of the local soils. The Natural Resources Conservation Service soil survey for Multnomah County classifies the soils as 51C-Urban Land and well-drained Multnomah soils. The surface horizon typically is dark brown loam about 16 inches thick. Soil below this depth is gravelly sand to a depth of approximately 60 inches or more.

Inlet to Stormwater Street Planter

System Configuration

Catchment Area (street, driveway, sidewalk):
- 7,500 square feet

Planter Details (applies to each of the four facilities):
- Dimensions:
  - Length: 18 feet
  - Width: 4 feet (not including 6-inch-wide perimeter curb)
  - Depth: Approximately 13 inches from sidewalk grade to finish grade of planter
- Maximum ponding depth: Approximately 7 inches
- 6-inch-wide perimeter curb around each planter: 4 inches high
- Total landscape area: 72 square feet
- A 3-foot-wide parking egress zone made of sand-set concrete pavers provides for vehicle access.
- A 2-foot-wide landscape buffer at each end of the planters directs people safely around the facilities.

Overflow:
- Overflow from each planter exits through a second curb cut back into the street. Final overflow exits through a curb cut in the last planter and enters the existing storm inlet in the street.

Additional Information:
- A design modification placed asphalt berms (1 inch high) on the downhill side of each curb cut to help runoff make the 90-degree turn into the planter.
- No rock sub-base was used underneath the planters.
- An 18-inch-wide concrete pad at each planter's uphill curb cut dissipates flow and collects sediment and debris.

Landscaping

The facilities were excavated throughout to 24 inches below grade and backfilled in 6- to 9-inch lifts with a three-way mix of sand, topsoil, and compost. The mix was tilled into the native soil and spread to create a flat cross section. (See illustration on page 3.)

Each facility was densely planted with *Juncus patens* and a *Nyssa sylvatica* tree. Both types of vegetation appear tolerant of the wet and dry soil conditions. The stiff structure of the *J. patens* helps slow the passage of water, and the root structure helps infiltrate water into and through the soil. The evergreen characteristic of the *J. patens* also helps minimize weed growth. A row of *J. patens* was planted next to the concrete pad in each facility to hold back sediment and debris and keep it from entering the facility.

Planting internal and external to the facilities

The plants were installed at a density greater than required by the City's Stormwater Management Manual. This was done to reduce maintenance requirements (weeding, watering, etc.) and to create an aesthetically appealing landscape quickly.

The types of vegetation external and adjacent to the facilities were selected for their drought tolerance, low maintenance, evergreen foliage, and short stature; the typical mature height of the plants is approximately 24 inches. Plants included *Nandina domestica* 'Moon bay'; *Liriope muscari* 'lilac beauty'; and *Polystichum munitum* (under the existing trees).

PROJECT COSTS

Street planter construction and landscaping costs for the project totaled $38,850, including project and construction management and ancillary construction costs (but not including design).

Stormwater Street Planters under construction: Grading (far left); Formed concrete walls (center); Forming the concrete trench and sediment collection pad (far right)

- **Curb Extension Construction**
  The core construction activities cost $29,950, or approximately 77 percent of the total project cost. This included sawcutting and removing existing landscaping and hardscape, excavation, concrete curb installation, sand-set concrete unit pavers installation, curb cuts and ornamental grate installation, soil import and preparation, and final grading.
- **Landscape Construction**
  The landscape construction activities cost $4,900, or approximately 13 percent of the total project cost. This included fine grading, plant procurement, plant material, and pea gravel mulch installation.

- **Ancillary Construction Activities**
  Miscellaneous street and sidewalk repair work cost $4,000, or approximately 10 percent of the total project cost. This included re-landscaping of a small area just south of the facilities, under existing trees, for visual continuity. These ancillary construction and landscaping tasks contributed to higher project costs.

As Green Street projects become an accepted practice, it is likely that design and project management costs will decline.

MAINTENANCE AND MONITORING

Maintenance


Sediment collecting behind the juncus on the concrete pad

Maintenance of the facilities includes hand weeding (no chemicals are allowed), plant trimming, plant replacement, and debris and sediment removal.

Portland Parks and Recreation staff maintained and hand-watered the planters and adjacent landscaping during the 2-year plant establishment period. There is no permanent irrigation system.

City staff removed sediment from the planters four or five times during the first 2 years. A landslide upland of the facilities in winter 2006 and debris from adjacent fruiting trees contributed to heavier-than-average sediment loading during that time.

The maintenance frequency for these types of facilities depends on the site. City staff will monitor long-term maintenance needs. Maintenance visits will occur at least four times a year; additional visits will occur if needed because of sediment accumulation.

Monitoring

The City will monitor the facilities for hydraulic performance, maintenance requirements, metal- and petroleum-based constituents, and the success of the vegetation. Because of the difficulty of collecting stormwater samples, water quality monitoring will not occur.

SUCCESSES AND LESSONS LEARNED

- Where communities struggle with ever-increasing impervious areas and degraded water quality, these simple landscape approaches can have a measurable positive impact.

- A flow test at this site indicated that the stormwater planters are effective in reducing the peak flow of a 25-year storm event by at least 70 percent. (This value is site dependent and may not be the same at a different location.)

- The final project design resulted from several discussions among design and engineering staff from various bureaus (Transportation, Maintenance, and Environmental Services). All bureaus agreed that the design would not pose safety issues for pedestrians or for people getting in and out of vehicles.

- In the first 2 years of operation, the first two planters filled often with sediment and debris (to a depth of 1-3 inches). City staff removed the sediment by hand with a shovel and rake. The facilities appear to manage much more than the drainage area that was assumed during design. The inlet just upstream of the facility and another inlet at the base of an overpass frequently clog with leaves and other debris, resulting in significant additional flow and resultant higher levels of sediment.

- It is difficult to force curb runoff to turn 90 degrees into curb openings during heavy storm flows. The momentum of the runoff becomes more problematic as the slope of the street increases. Small asphalt berms have been installed to encourage flow to enter the facilities and appear to be working well. Other options can include angled entries, gutter depressions, or other methods to ease the transition of flow from the curb into the facility.


Asphalt berm at facility inlet to help direct stormwater flow into the stormwater planter

NE Siskiyou Green Street Project

NE Siskiyou Street between NE 35th Pl. and NE 36th Ave., Portland, Oregon

Project Summary

Project Type:	Stormwater retrofit to an existing residential street – demonstration project
Technology:	A pair of stormwater curb extensions
Major Benefits:	• The extensions capture runoff from approximately 9,300 sq. ft. of paved surfaces, treating and infiltrating a large proportion of the runoff (see Flow Test Report[1]). • The curb extensions converted about 590 square feet of pavement to landscape. • They are attractive additions to the neighborhood, improve the urban environment, and increase pedestrian safety at the intersection.
Cost:	The total project cost, including management, design, and construction was $20,000 of which $3,000 is attributed to ancillary street and sidewalk repairs costs that may not be needed for other similar projects. Total cost for the stormwater curb extensions only was $17,000 or $1.83 per square foot of impervious area managed.
Constructed:	City crews constructed the extensions in two weeks in October 2003.
Maintenance	Portland Parks and Recreation will maintain the facilities during the two-year establishment period (until October 2005); the source of long-term maintenance services is to be determined.

Features

- This was Portland's first Green Street project to use landscaped stormwater curb extensions to manage street runoff.
- The design provides water quality treatment but also maximizes infiltration of the runoff. Each facility has four compartments separated by check dams to promote infiltration.
- The project demonstrates one of the simplest types of Green Street retrofits. The existing street curb was left intact and no modifications were made to the stormwater collection system.
- The design integrates well with its surroundings. The low evergreen plantings blend with landscape areas on the adjacent residential properties.
- The adjacent neighbors have played a major role in maintaining the two facilities, providing seasonal watering and weeding.

March 2005

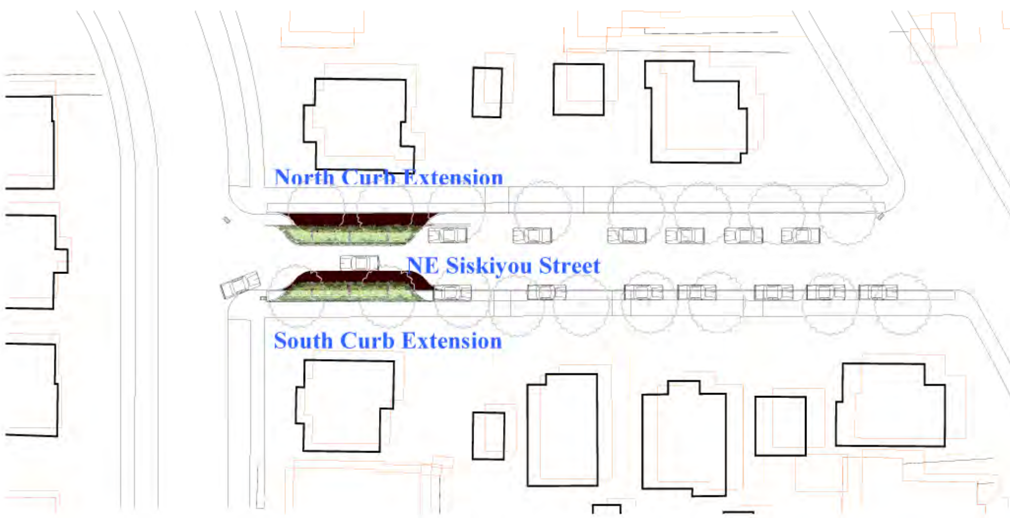
[1] Flow Test Report for the Siskiyou Curb Extension, October 2004; BES

Background

The Environmental Services Sustainable Management Team undertook the project in 2003 as part of an on-going evaluation of techniques for managing runoff from streets. Urban stormwater runoff pollutes rivers and streams and contributes to combined sewer overflows (CSOs) to the Willamette River. It can also cause localized backups of the combined sewer during large storms.

Stormwater curb extensions hold particular promise as a sustainable practice for managing runoff from existing streets. These natural systems capture and filter runoff and allow it to infiltrate into the ground. They are an alternative to traditional stormwater sumps for managing street runoff. In addition to treating and disposing of runoff, they integrate well with existing neighborhood vegetation and generally improve the urban environment. Portland has constructed many curb extensions over the years to improve pedestrian safety; this new version of the curb extension provides many additional benefits.

The project on Siskiyou was the first retrofit to an existing street in Portland. Environmental Services built a second set of curb extensions on Ankeny Street (at SE 56th) in 2004, and by 2005 both the City and private developers were implementing a number of similar projects. These types of facilities can be constructed in a variety of configurations, as retrofits or as part of new development, and are referred to alternatively as bump-out swales, pocket swales, or street stormwater planters.



NE Siskiyou Green Street Plan View

Site Selection Criteria

- **Traffic Impacts:** City traffic engineers considered the low-traffic residential setting ideal for a demonstration project. The street is 28 feet wide. The addition of two 7-foot wide curb extensions created an acceptable queuing configuration.
- **Stormwater Catchment Areas:** The size of the catchment, a little over 9,000 sq. ft., was considered fairly representative of conditions in the surrounding neighborhood.
- **Utility Conflicts:** Water lines were the only subsurface utilities within the project area and did not present obstacles. See a detailed discussion under "System Configuration."
- **Loss of Parking Spaces:** The project did not eliminate on-street parking. Adjacent property owners can park in front of their houses on SE 35th Place.
- **Street Slope:** The moderate street slope (2%) was suitable for a first test of the technology.
- **Suitability For Monitoring:** The configuration of the local combined sewer allowed for placement of a flow monitor. There is also a rain gage near the project.
- **Soil Infiltration Rates:** Specialized infiltration tests were not required at the site. See "Stormwater Capacity and System Configuration" for details.
- **Space Available for the Facilities:** The space available for the curb extensions – length of curb unbroken by driveways or near a fire hydrant – is considered representative of conditions in other areas.

Stormwater Capacity and System Configuration

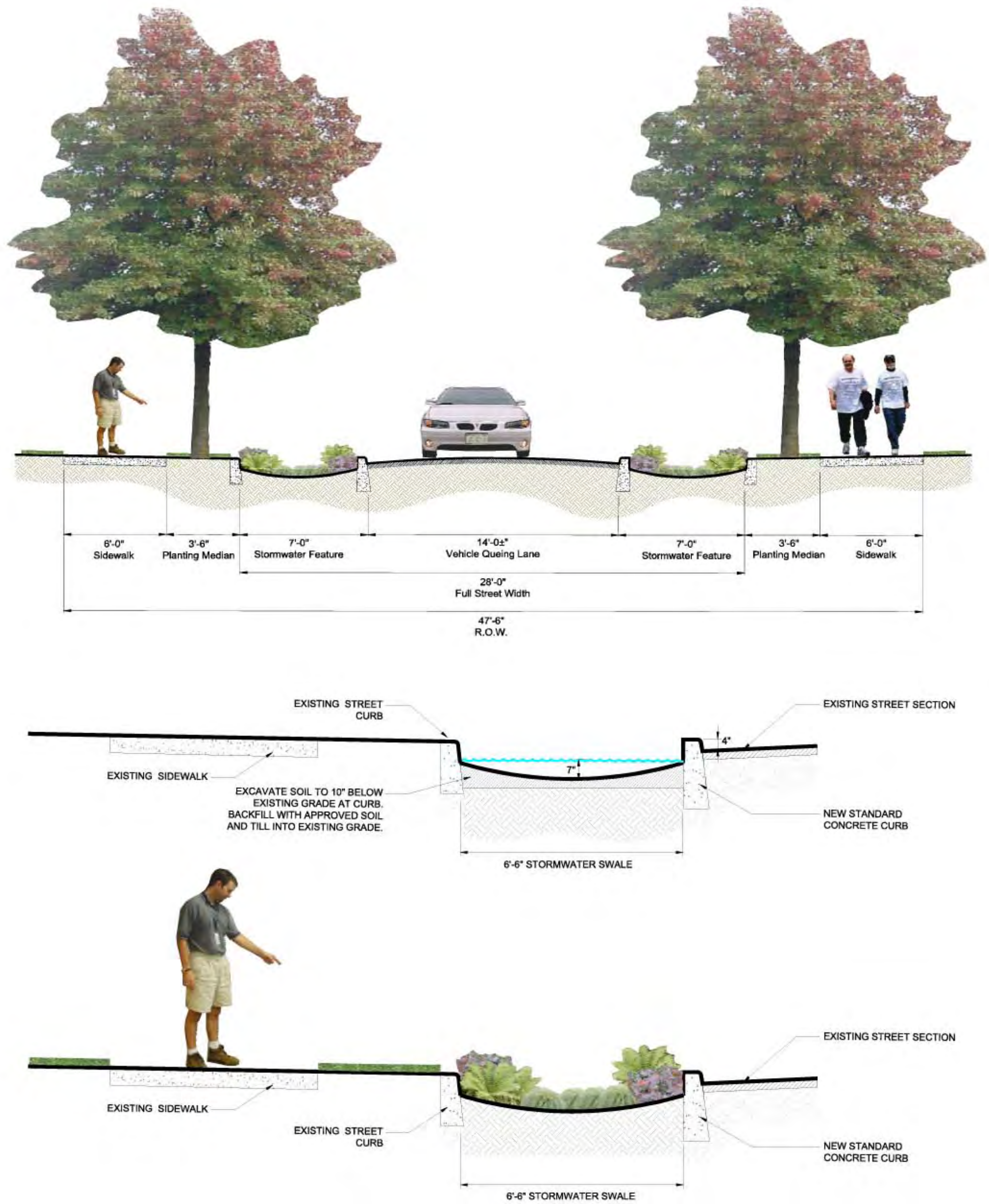
Stormwater Management Goals

The objective was to maximize the capture, treatment, and infiltration of street runoff while providing a visual amenity for the neighborhood and improved pedestrian safety.

Geotechnical Evaluation

An infiltration test was not required before construction. Adequate documentation of characteristics of the local soils already existed. The Natural Resources Conservation Service (NRCS) soil survey for Multnomah County classifies the soils as 51A-Urban Land and well-drained Multnomah soils. The surface horizon typically is dark brown silt loam about 25" thick. Soil below this depth is gravelly silt loam and gravelly sand to a depth of approximately 60".

March 2005



NE Siskiyou Green Street (Cross Section)

System Configuration

With few exceptions, the two curb extensions are identical in configuration.

Catchment Areas (pavement, driveways):
- North curb extension: 3,000 square feet
- South curb extension: 6,300 square feet

Street Slope: Approximately 2%

Facility Dimensions (applies to each facility):
- Length: 60 feet; width: 7 feet
- Total area: 275 square feet
- Depth at curb: 6 inches
- Depth at center: 12 inches
- Maximum ponding depth: 7 inches at center

Internal Storage Volume: 120 cubic feet

Overflow: Overflow exits through a curb cut at the west end of the facility, draining to the combined sewer via the street gutter and the existing street inlet. No modifications were made to the inlet.

Check Dams: Each curb extension has three checkdams, with four separate compartments for ponding runoff and slowing its passage through the facility.

Additional Information:

- The asphalt crown on Siskiyou Street is north of the center of the street, a large factor in the difference in catchment sizes.
- The gravel subgrade under the asphalt on Siskiyou Street is about 4 inches thick.
- The two extensions were excavated to a depth of 14 inches below grade. The native soil was tilled prior to importing 8 inches of soil mix and then the material was tilled a second time. There is not a gravel trench underlying the facility (a common feature of some designs).
- Excavation in the north extension intersected the top of a gravel-filled trench containing a water utility line. The trench runs the length of the middle of the facility, about 3 feet from the pre-existing curb. Excavation of the southern extension did not intersect the adjacent water utility trench, which runs underneath the new curb (about seven feet off the pre-existing curb).
- The check dams were constructed of compacted clay and covered with pea gravel and river rock to minimize erosion. See "Success and Lessons Learned" for details.
- The first compartment (forebay) in each curb extension has the same configuration and planting regime as the other compartments.

Landscaping

The facilities were excavated throughout to 14 inches below grade and backfilled with a 3-way mix of sand, topsoil, and compost. The mix was tilled into the native soil and spread to create a shallow parabolic cross section (see illustration).

The plants were selected for their drought tolerance, evergreen foliage, and short stature. The typical mature height of the plants is less than two feet. These characteristics were a priority in order to minimize maintenance and address safety concerns. The most common plants, including sedges, rushes, ferns, and broadleaf evergreen shrubs, are native species. The planting plan also included some non-native plants, primarily to provide seasonal color accents. Rushes are the dominant plant in the lowest portions of the two facilities. Their stiff structure helps slow the passage of water and they thrive in the variable moisture conditions. There is no permanent irrigation system in the curb extensions.

The plants were installed at a density greater than required by the Environmental Services Stormwater Management Manual in order to reduce weeding and other maintenance requirements and to quickly create an aesthetically appealing landscape.

Curb cuts: inflow point (top), side inlet (bottom)

	BOTANICAL NAME	COMMON NAME	PNW Native
SHRUBS			
	Euonymus japonica "Microphylla"	Boxleaf Euonymus	no
	Mahonia repens	Creeping Oregon Grape	yes
	Polyshtichum munitum	Swordfern	yes
PERENNIALS			
	Helictotrichon sempervirens	Blue Oat Grass	no
	Deschamsia caespitosa "Northern Lights"	Variegated Tufted Hair Grass	native cultivar
	Iris spp.	Iris Bulbs	no
	Narcissus spp.	Daffodil bulbs	no
BASIN PLANTINGS			
	Carex testacea	New Zealand Orange Sedge	no
	Juncus patens	California Grey Rush	yes

NE Siskiyou Green Street Plant List

Project Costs

The final project cost was $20,000 for design, management, construction activities, and ancillary sidewalk repairs.

I. Budget Elements

1. Construction Management and Overhead
Project and construction management cost $4,500 or 23% of the total.

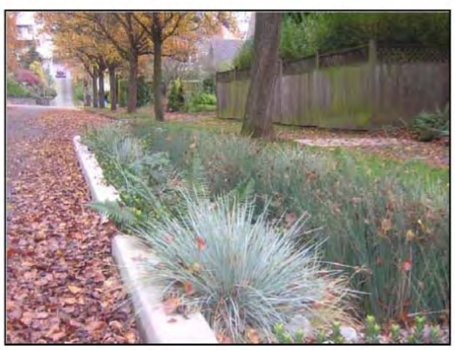
2. Construction Activities (Curb Extensions Only)
Curb extension construction and landscaping cost $12,500 or 62% of the total budget.

- **Curb Extension Construction**
  The core construction activities cost $8,250 or 41% of the total project cost. This included sawcutting and removing existing asphalt, excavation, concrete curb installation, soil import and preparation, grading, and safety painting and reflectors on the curbs.

- **Landscape Construction**
  Landscape construction cost $4,250 or 21% of the total project costs. This included check dam construction, fine grading, plant procurement, plant material, and mulch installation.

3. Ancillary Construction Activities
Miscellaneous street and sidewalk repair work cost $3,000 or 15% of the total.

II. Budget Discussion
It's likely that design and project management costs will decline for curb extension projects as they become more routine. The project included one-time costs such as the development of outreach materials and standard drawings. Ancillary construction tasks – repair to the adjacent pavement as well as the sidewalk – may have also made this project more expensive than subsequent projects.



The south planter; fall 2004

South curb extension. Spring 2004

Maintenance and Monitoring

Maintenance
Adjacent property owners have voluntarily modified their home irrigation systems to help water the curb extensions. In the long term, the City is responsible for providing any irrigation required. Given the shady location of the curb extensions, irrigation after the 2-year startup period should be minimal.

Portland Parks and Recreation will maintain the curb extensions for two years after construction, ending October 2005. Maintenance includes hand weeding (non-chemical applications), trimming plants, plant replacement, and major leaf and debris removal as needed. Environmental Services will re-evaluate maintenance requirements in December 2005 and make arrangements for long-term maintenance services.

Monitoring
Environmental Services will monitor hydraulic performance, maintenance requirements, the success of the planting regime, and comments from neighborhood residents. Environmental Services conducted a first flow test in summer 2004. See *Flow Test Report: Siskiyou Curb Extensions, August 4th, 2004* online at www.portlandonline.com/shared/cfm/image.cfm?id=63097.

Successes and Lessons Learned

- The data suggest that the curb extensions on Siskiyou are capturing and infiltrating a large proportion of the runoff that drains to them.
- The plants grew vigorously during the first year and little weeding was required.
- In the first year the vegetated forebays filled twice with sediment and debris (to a depth of 4-6 inches). City staff removed the sediment by hand with a shovel and rakes. The cleanings typically required about 30 minutes per forebay.
- The earthen checkdams are susceptible to erosion during large storms, as observed during the hose test in August 2004. A more substantial structural design should be employed in the future.

APPENDIX B

BURNSVILLE STORMWATER RETROFIT CASE STUDY

- Burnsville Stormwater Retrofit Study – Project report by BARR Engineering, created for the City of Burnsville, MN.
- "I. Burnsville Rain Gardens Case Study: Retrofitting for Water Quality" from 2005 Minnesota Stormwater Management Manual, version 1.0. – Created by the Minnesota Stormwater Steering Committee for the Minnesota Pollution Control Agency.
- Burnsville, MN Costs Handout – Created and provided by BARR Engineering. November 2003.

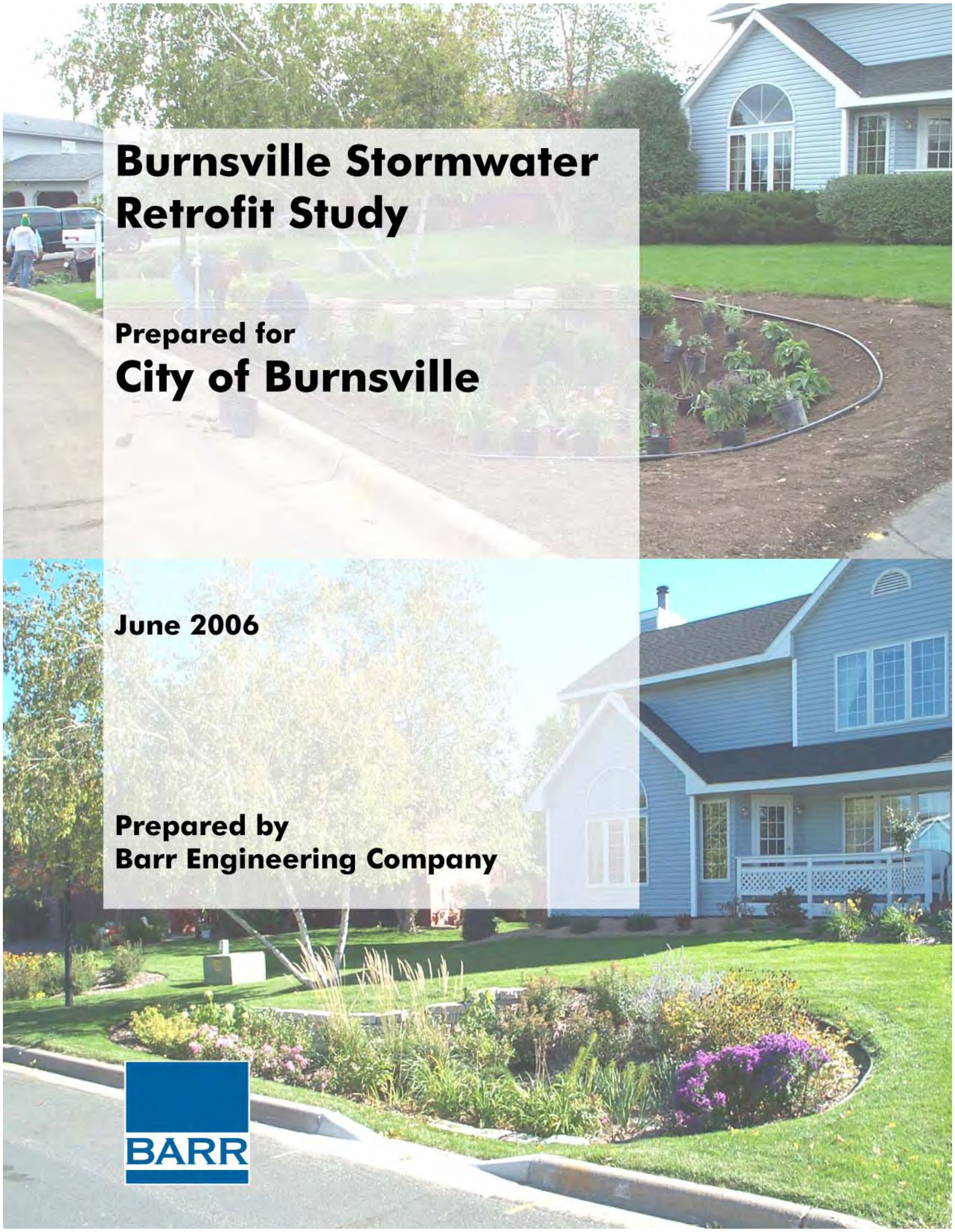
Burnsville Stormwater Retrofit Study

Prepared for

City of Burnsville

June 2006

Prepared by
Barr Engineering Company



Burnsville Stormwater Retrofit Study

Prepared for
City of Burnsville

June 2006

BARR

4700 West 77th Street
Minneapolis, MN 55435-4803
Phone: (952) 832-2600
Fax: (952) 832-2601

Burnsville Stormwater Retrofit Study

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1.0 Introduction

In an ongoing effort to protect Crystal Lake from excess phosphorus and large volumes of stormwater runoff from surrounding hard surfaces, the Metropolitan Council, along with the City of Burnsville, Minnesota and the Dakota County Soil and Water Conservation District funded a prototypic rainwater garden system to infiltrate street runoff. While the City had been interested for some time in constructing rainwater gardens, questions about their effectiveness remained. To better document the effect of rainwater garden implementation, this project involved the completion of a "paired watershed" study, in which two very similar residential areas are monitored —one was the study's control site and the other treatment watershed employs 17 new rainwater gardens within a 25-lot, 5.3-acre neighborhood with traditional curb and gutter (see Figure 1). The project, a retrofit of a 1980s neighborhood, involved individual designs for each resident-participant's property and close attention to homeowner education and easy maintenance. The gardens were primarily designed to capture street runoff through the installation of curb cuts at each garden. The depressions feature gradual side slopes, limestone retaining walls, and colorful plantings. They were carefully sized to, at a minimum, accept the first 0.9 inches of rainfall runoff from the impervious surfaces in the subwatershed for each storm event.

Existing soils and utilities were surveyed in 2002 to identify potential garden sites. Seventeen sites were identified in the treatment watershed; thirteen along Rushmore Drive and four in a backyard swale that drains to Rushmore Drive (see Figure 2). Each garden along the street was designed to have a curb cut to capture street runoff. Individual homeowners were involved in creating final planting designs for each basin. Gardens were constructed in September 2003. Curb cuts were installed in May 2004. The contractor cut the sod, excavated below grade, backfilled with topsoil/compost mix, and installed edging and retaining walls. Homeowners planted plants in September 2003. After planting, the contractor placed shredded wood mulch and sod to finish gardens.

Both the control and treatment watersheds were monitored before and after rainwater garden construction to facilitate the statistical evaluation of the paired watershed data.

Figure 1 Paired Watershed Study Area

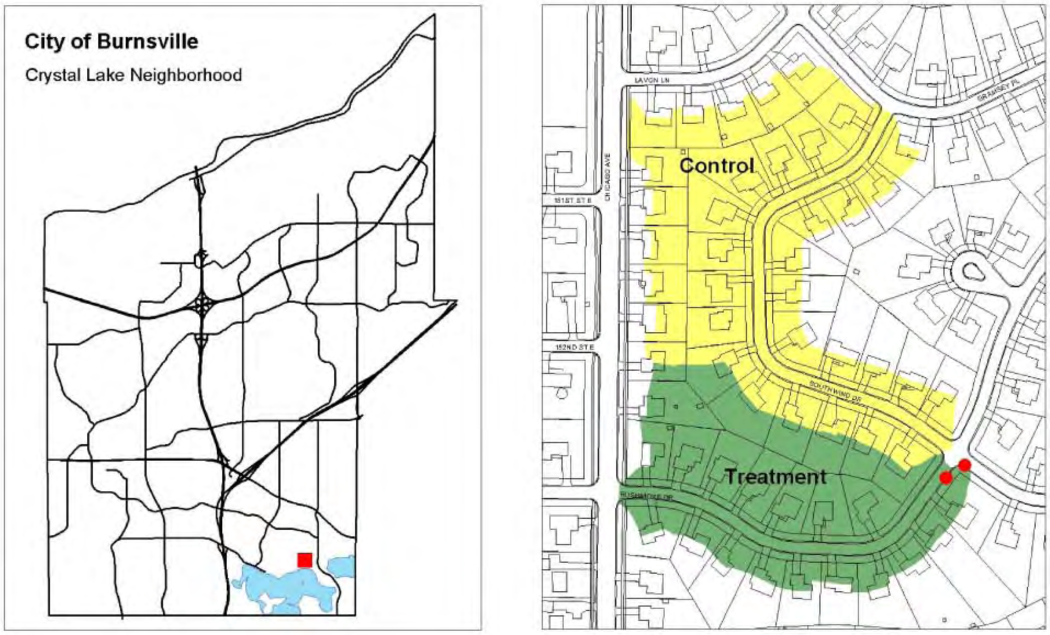


Figure 2 Treatment Watershed Rainwater Garden Layout

2.0 Study Methodology

2.1 Paired Watershed Approach

Clausen and Spooner (1993) describe the paired watershed approach for conducting nonpoint source water quality studies. The basic approach requires a minimum of two watersheds – control and treatment – and two periods of study – calibration and treatment. The control watershed accounts for year-to-year or seasonal climate variations, and the management practices remain the same during the study. The treatment watershed has a change in management or implementation of a Best Management Practice (BMP) during the study. During the calibration period, the two watersheds are treated identically and paired data are collected. During the treatment period, the treatment watershed undergoes the implementation of a BMP while the control watershed remains the same as during the calibration period (see Table 1).

Table 1 Typical Paired Watershed Schedule of BMP Implementation (Clausen and Spooner, 1993)

Period	Watershed	
	Control	Treatment
Calibration	No BMP	No BMP
Treatment	No BMP	BMP

This "paired watershed" study was conducted by selecting two similar and adjacent subwatersheds in the Crystal Lake watershed—one to serve as the study control and the other to be the site of 17 rainwater gardens (Figure 1). Stormwater runoff was monitored both prior to and after installation of the gardens. As per Clausen and Spooner (1993), a linear regression and analysis of variance was conducted on the paired data from the calibration period to evaluate the significance of the relationship. At the end of the treatment period the significance of the effect of the rainwater gardens was determined by completing an analysis of variance on the treatment regression equation and comparing the difference between the slopes, and confidence levels of the calibration and treatment regressions.

2.2 Stormwater and Rainfall Monitoring

For the calibration period, stormwater and rainfall monitoring began in 2002 and continued through the spring of 2004 to fully establish the relationship between the control and treatment watersheds. The treatment period occurred between the summer of 2004 and the fall of 2005 to determine the treatment efficiency of the gardens. Runoff rates and volumes were collected using area-velocity flow meters in the storm sewer pipe at the outlet of each watershed (see Figure 1). Automatic samplers were also set up to collect water quality samples at each of the watershed monitoring locations. Due to several instances of equipment malfunction during the calibration period and low runoff rates from the treatment watershed during the treatment period, there was not enough paired data from the study to conduct meaningful statistical analyses on the water quality treatment associated with the rainwater gardens. A tipping bucket rain gauge, which recorded the data electronically, was set up within the study area for the entire period of record.

The monitoring data from the flow meters and rain gauge were downloaded on a regular basis and used to determine the flow and rainfall volumes associated with each of the runoff events at each monitoring location. The paired flow volume data that was available from both watershed monitoring locations was compiled in a spreadsheet, along with the rainfall data associated with each runoff event. In each case the runoff volume was also expressed as runoff, in inches, and as a runoff coefficient by dividing the flow volumes by the watershed area, and then by the rainfall amount from each runoff event.

3.0 Results and Discussion

3.1 Stormwater Monitoring Results

The stormwater monitoring data, collected during the calibration and treatment periods, were compared in two separate ways: 1) an overall comparison of the rainfall/runoff results from the treatment and control watersheds; and 2) a statistical analysis of the rainfall/runoff relationships between the two watersheds both before and after rainwater garden implementation.

Appendix A provides a summary of each of the rainfall/runoff events during the calibration and treatment periods. Figure 3 shows the linear regression that was conducted on the paired runoff volume data from the calibration period (shown in Appendix A) to evaluate the significance of the relationship. The graph shows that there was very good agreement between the runoff volumes collected at each site during the calibration period, since the regression coefficient of determination is high ($R^2 = 0.89$) and the y-intercept is low (0.05). Figure 3 also shows the 95 percent confidence levels around the slope of the linear regression. Since the confidence level was within 15 percent of the slope of the regression line, it indicated that there was enough data available from the calibration period to justify the construction of the rainwater gardens and transition to the treatment period.

The rainwater gardens were constructed in the fall of 2003 and brought on-line with curb cuts later in the spring of 2004. The treatment period monitoring began at the end of May, 2004 (see Appendix A). Figures 4 and 5 shows how the runoff hydrographs and volumes varied at each monitoring site during the calibration and treatment periods for moderate and larger rainfall events. Both figures show that, for similar rainfall events, the runoff rate and volume from the treatment watershed (with the rainwater gardens) was greatly reduced relative to the data from the control watershed. The variability of the runoff volumes from the control watershed for similar rainfall events, as shown in Figures 4 and 5, also underscore the importance of using a paired watershed approach to accurately evaluate the changes due to BMP implementation.

Figure 3 Linear Regression of Runoff Volume Data for Calibration Period

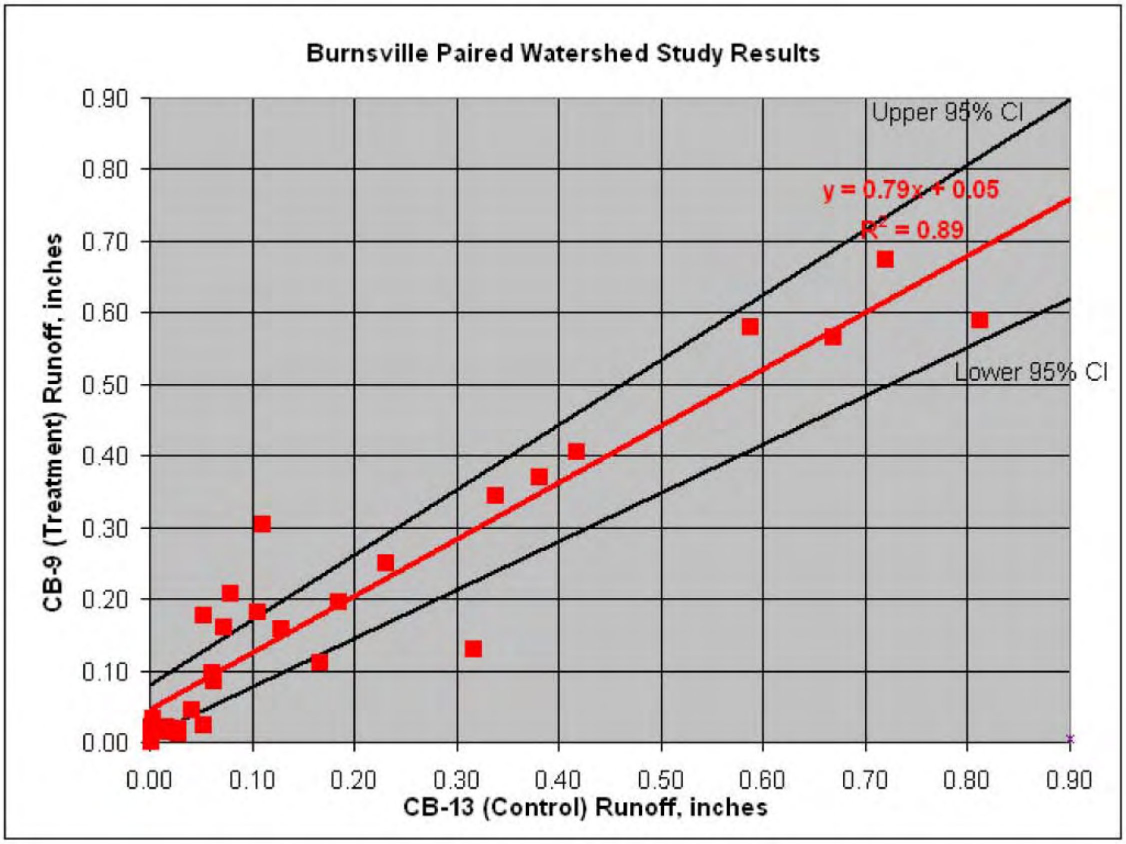
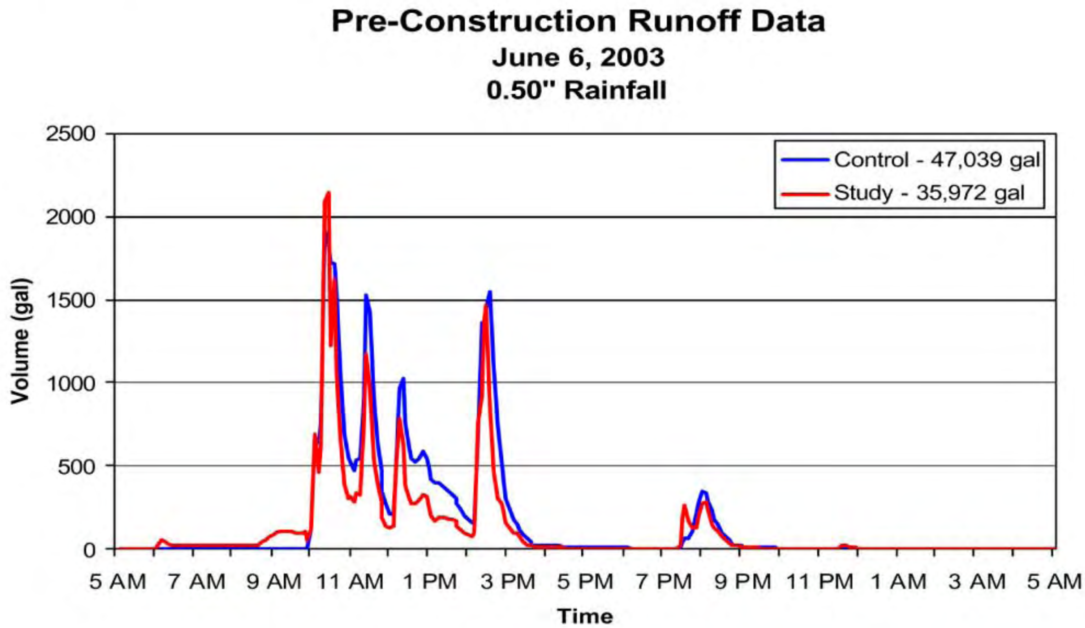


Figure 4 Calibration and Treatment Period Runoff Hydrographs from Moderate Rainfalls



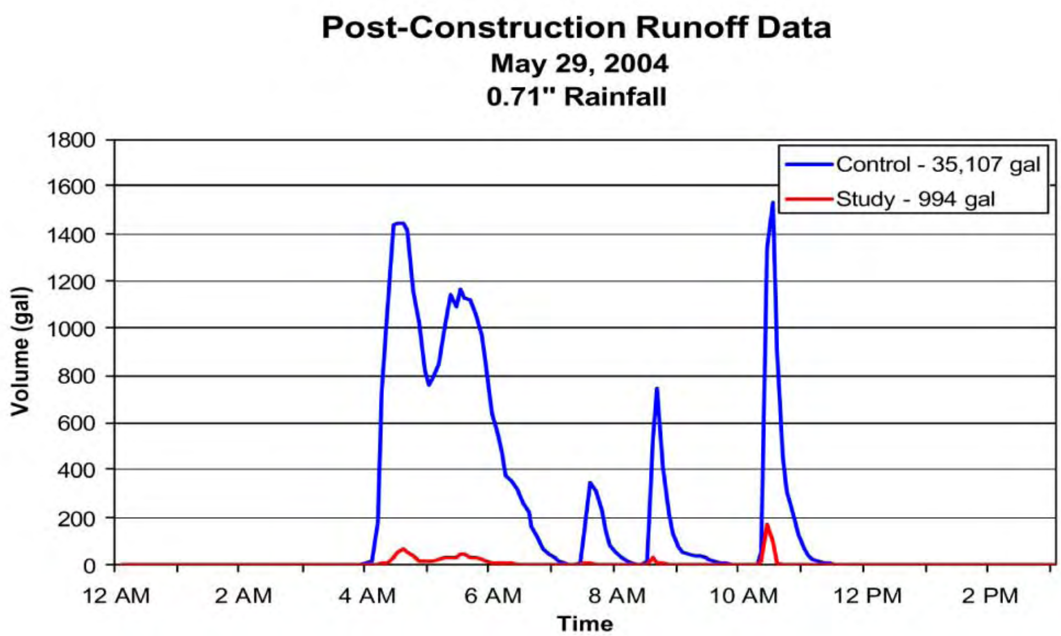
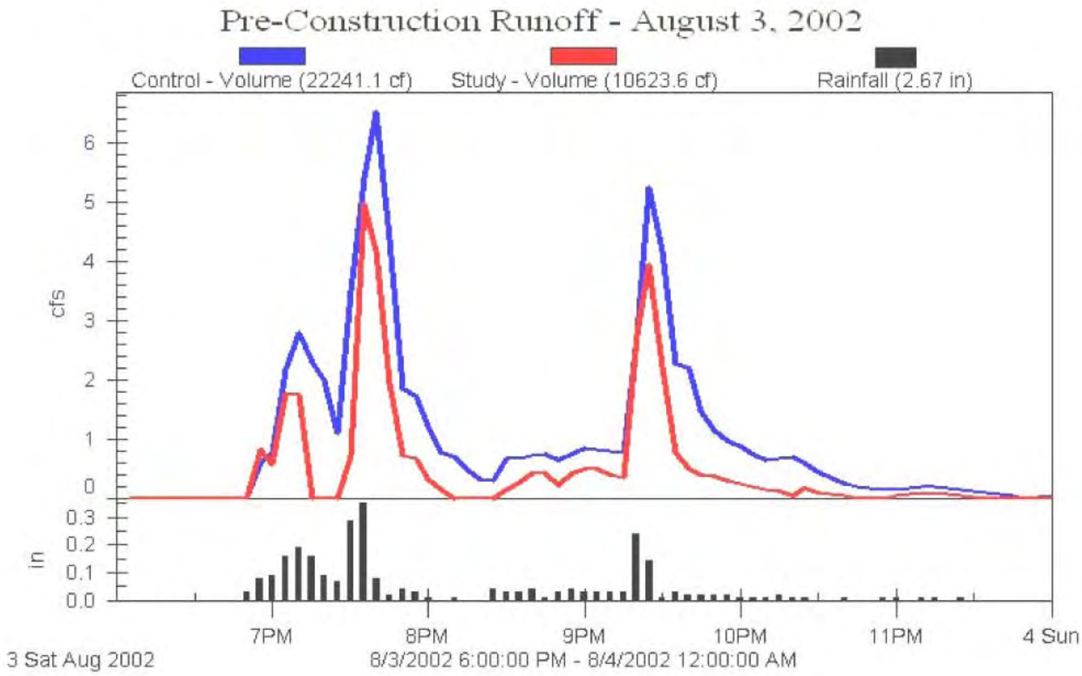


Figure 5 Calibration and Treatment Period Runoff Hydrographs from Larger Rainfalls



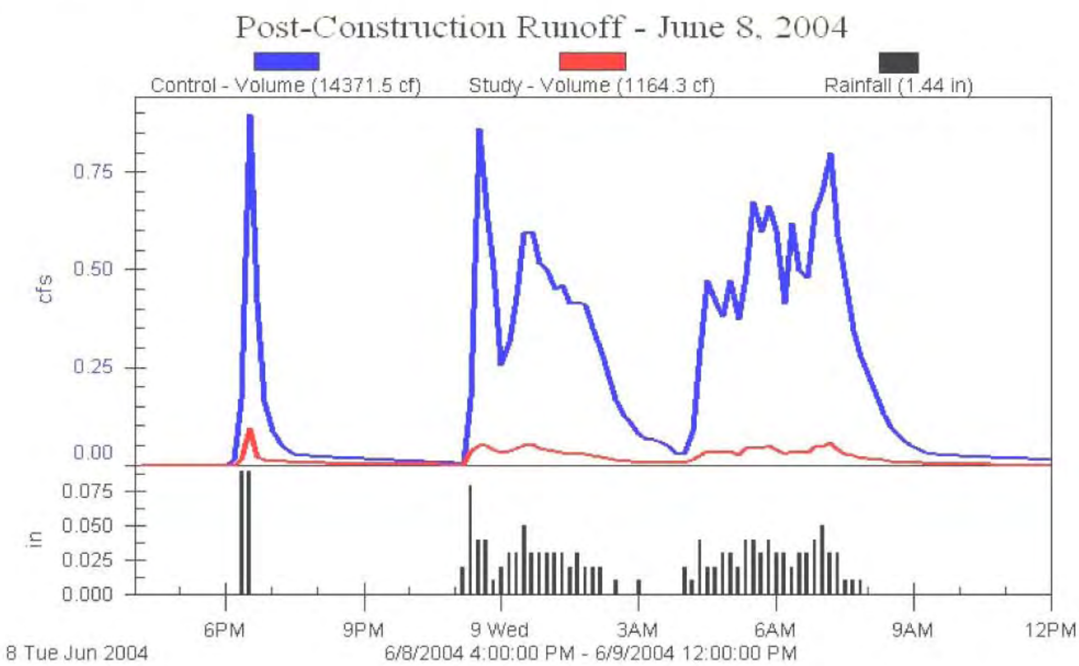
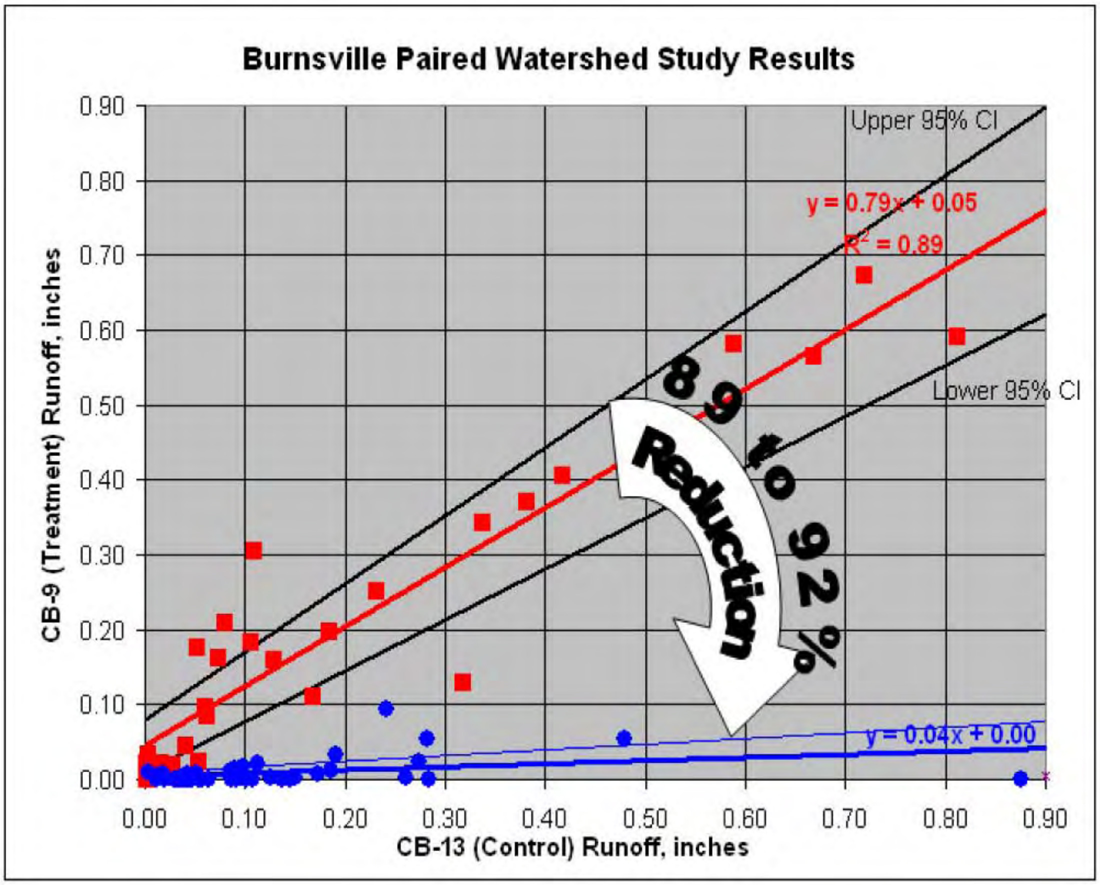


Figure 6 provides a comparison between the confidence levels associated with the slopes of the calibration and treatment period regressions. The results show that there is an 89 to 92 percent reduction in the runoff volumes from the treatment watershed associated with the rainwater gardens, and the difference in the slope of the linear regressions is statistically significant at greater than the 95 percent confidence level.

Figure 6 Linear Regressions of Runoff Volume Data for Calibration and Treatment Periods



The following summary of the runoff event data from Appendix A and Figure 7 show that there is a 93 percent reduction in the overall runoff volume from the treatment watershed since the rainwater gardens were installed:

Pre-construction (2002-2004)

28 rainfall events = 23.77 inches total

Control Watershed (7.5 acres) = 153,313 cu. ft. runoff (5.69")

Treatment Watershed (5.5 acres) = 111,120 cu. ft. runoff (5.78")

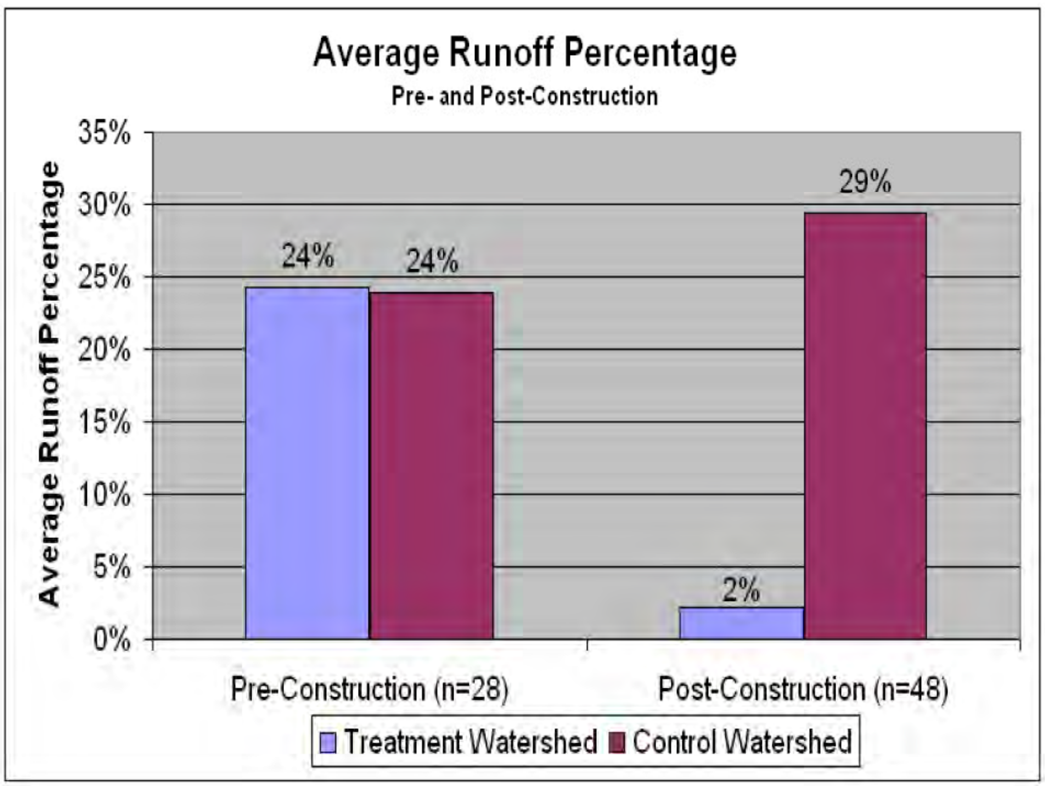
Post-construction (2004-2005)

48 rainfall events = 18.97 inches total

Control Watershed (7.5 acres) = 151,897 cu. ft. runoff (5.58")

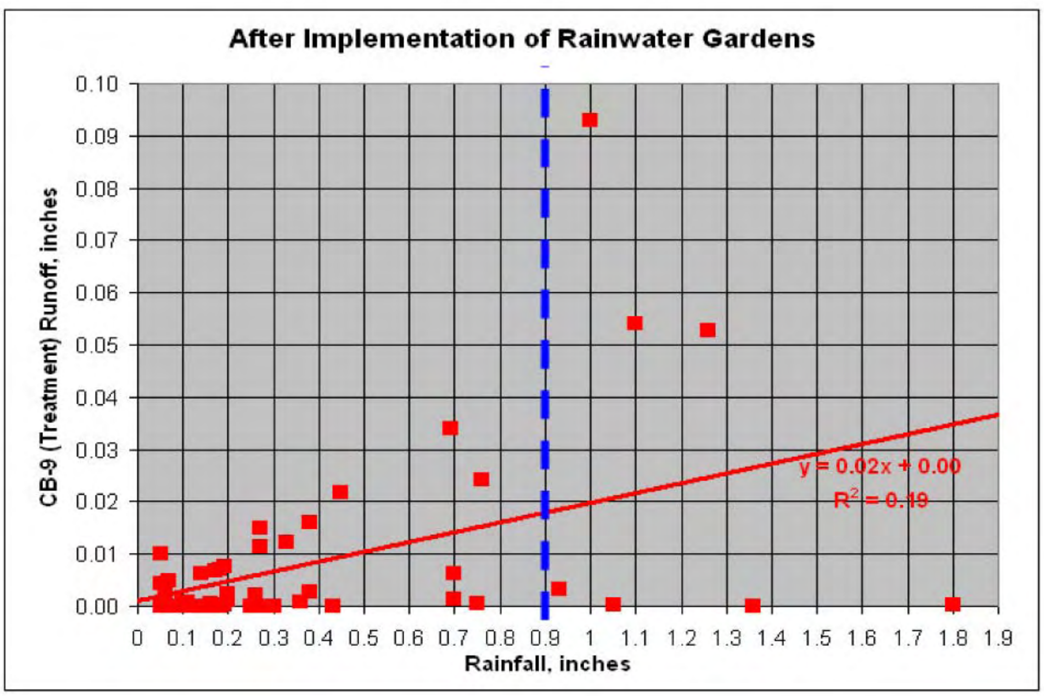
Treatment Watershed (5.5 acres) = 7,861 cu. ft. runoff (0.41")

Figure 7 Runoff Volume Reduction Associated with Rainwater Gardens



As discussed in Section 1.0, the rainwater gardens were sized to, at a minimum, accept the first 0.9 inches of rainfall runoff from the impervious surfaces in the treatment watershed for each storm event. Figure 8 was developed to show whether the rainwater gardens were removing the runoff volume for which they had been designed. The data for some of the largest rainfall events indicates that the infiltration rate of the rainwater gardens was able to keep up with and treat all of the runoff, or at the very least, treat more than 0.9 inches of rainfall runoff from the watershed in nearly all cases. Figure 8 and Appendix A show that there were seven events during the treatment period where the rainfall amount exceeded 0.9 inches, three of which resulted in more measurable runoff volumes from rainfalls between 1.0 and 1.3 inches. The other four rainfall events, with precipitation amounts between 0.9 and 1.8 inches, did not produce measurable runoff volumes because they represented lower rainfall intensity events. The regression shown in Figure 8 indicates that, with the limited number of larger rainfall events from the treatment period, there currently is a limited ability to show a strong relationship between rainfall and runoff volumes from the treatment watershed. Future monitoring efforts that capture larger, more intense rainfall events will enable the same data shown in Figure 8 to be used to estimate the actual treatment volume associated with the rainwater gardens.

Figure 8 Observed Rainfall/Runoff Relationships Associated with Rainwater Gardens



3.2 Conclusions and Recommendations for Further Study

This paired watershed study has determined, with greater than 95 percent confidence, that the rainwater gardens designed to capture 0.9 inches of rainfall over the tributary impervious area have reduced the runoff volumes by approximately 90 percent. This project confirms that existing residential neighborhoods with sandy soils, gradual slopes and 15-foot rights-of-way (from the back of curb) can be successfully retrofitted with rainwater gardens and provide very high levels of runoff reduction and stormwater quality improvement. In addition, the greater than 80 percent rainwater garden participation rate by the homeowners in the treatment watershed, and that they are well maintained, indicates that this BMP can be viewed as an amenity to property owners.

While the results of the monitoring from this study provided statistically significant conclusions, it is recommended that the City repeat the exact same monitoring program again every three to five years to document the long-term functionality of rainwater gardens in a residential setting.

References

Clausen, J.C., and J. Spooner. 1993. Paired Watershed Study Design. Prepared for U.S. Environmental Protection Agency. Office of Water. Washington, D.C. 841-F-93-009.

Appendix A

Rainfall/Runoff Events Summary for Calibration and Treatment Periods

Rainfall/Runoff Events Summary--Calibration Period

		Time period	CB-9 (Treatment)			CB-13 (Control)		
Event #	Rainfall(in.)		Total flow(ft.^3)	Runoff(in.)	Runoff Coeff.	Total flow(ft.^3)	Runoff(in.)	Runoff Coeff.
1	2.68	8/3/2002 6:50:00 PM-8/4/2002 12:05:00 AM	11350	0.59	0.22	22111	0.81	0.30
2	2.11	8/16/2002 7:35:00 PM-8/17/2002 1:55:00 AM	7812	0.41	0.19	11379	0.42	0.20
3	2.16	8/20/2002 3:45:00 PM-8/21/2002 1:40:00 PM	10876	0.57	0.26	18208	0.67	0.31
4	0.39	9/1/2002 6:10:00 PM-9/1/2002 8:15:00 PM	870	0.05	0.12	1122	0.04	0.11
5	1.97	9/5/2002 4:40:00 PM-9/6/2002 8:05:00 AM	12949	0.67	0.34	19592	0.72	0.37
6	0.05	9/10/2002 4:35:00 AM-9/10/2002 5:50:00 AM	17	0.00	0.02	25	0.00	0.02
7	0.1	9/14/2002 1:10:00 AM-9/14/2002 2:25:00 AM	410	0.02	0.21	66	0.00	0.02
8	0.16	9/14/2002 6:50:00 AM-9/14/2002 9:30:00 AM	641	0.03	0.21	73	0.00	0.02
9	0.76	9/25/2002 9:40:00 AM-9/25/2002 5:00:00 PM	3512	0.18	0.24	2876	0.11	0.14
10	0.16	9/25/2002 10:20:00 PM-9/26/2002 1:10:00 AM	393	0.02	0.13	435	0.02	0.10
11	0.24	9/26/2002 6:50:00 AM-9/26/2002 9:50:00 AM	208	0.01	0.05	777	0.03	0.12
12	1.72	10/4/2002 2:35:00 AM-10/4/2002 3:10:00 PM	2477	0.13	0.07	8649	0.32	0.18
13	0.95	10/5/2002 8:55:00 PM-10/6/2002 5:45:00 AM	2140	0.11	0.12	4562	0.17	0.18
14	0.48	10/10/2002 12:00:00 AM-10/10/2002 3:45:00 AM	1859	0.10	0.20	1643	0.06	0.13
15	0.13	10/18/2002 2:10:00 AM-10/18/2002 6:05:00 AM	273	0.01	0.11	370	0.01	0.10
16	2.41	4/15/2003 5:05:00 PM-4/16/2003 9:35:00 PM	7117	0.37	0.15	10385	0.38	0.16
17	0.46	4/18/2003 6:10:00 PM-4/20/2003 5:35:00 AM	3773	0.20	0.43	3551	0.18	0.40
18	2.31	5/10/2003 4:50:00 PM-5/11/2003 2:30:00 PM	11170	0.58	0.25	16013	0.59	0.25
19	0.64	5/14/2003 12:10:00 AM-5/14/2003 1:35:00 PM	3104	0.16	0.25	1995	0.07	0.11
20	0.54	5/19/2003 9:35:00 AM-5/19/2003 11:00:00 PM	3049	0.16	0.29	3502	0.13	0.24
21	0.07	5/22/2003 9:05:00 AM-5/22/2003 5:55:00 PM	1627	0.08	1.21	1695	0.06	0.89
22	0.23	5/30/2003 1:50:00 AM-5/22/2003 8:15:00 PM	468	0.02	0.11	1459	0.05	0.23
23	0.56	6/6/2003 6:05:00 AM-6/7/2003 1:30:00 AM	4809	0.25	0.45	6283	0.23	0.41
24	0.3	6/24/2003 2:35:00 AM-6/25/2003 8:00:00 PM	6597	0.34	1.14	9207	0.34	1.13
25	0.31	7/21/2003 11:55:00 PM-7/22/2003 5:30:00 AM	378	0.02	0.06	747	0.03	0.09
26	0.74	4/18/2004 8:05:00 PM-4/19/2004 6:30:00 AM	5841	0.30	0.41	2991	0.11	0.15
27	0.71	4/20/2004 2:50:00 PM-4/21/2004 12:45:00 PM	4009	0.21	0.29	2155	0.08	0.11
28	0.43	4/24/2004 7:05:00 PM-4/25/2004 7:00:00 AM	3387	0.18	0.41	1441	0.05	0.12
Totals	23.77		111,120	5.78	0.24	153,313	5.69	0.24
Avg Rainfall	0.85							

Rainfall/Runoff Events Summary--Treatment Period

		Time period	CB-9 (Treatment)			CB-13 (Control)		
Event #	Rainfall(in.)		Total flow(ft.^3)	Runoff(in.)	Runoff Coeff.	Total flow(ft.^3)	Runoff(in.)	Runoff Coeff.
1	0.7	5/29/2004 3:05:00 AM-5/29/2004 11:30:00 AM	122	0.01	0.01	4707	0.17	0.25
2	0.38	5/30/2004 1:50:00 AM-5/30/2004 5:40:00 AM	309	0.02	0.04	2661	0.10	0.26
3	0.19	5/30/2004 7:50:00 AM-5/30/2004 10:45:00 AM	148	0.01	0.04	1424	0.05	0.28
4	0.14	5/30/2004 7:00:00 PM-5/30/2004 9:30:00 PM	119	0.01	0.04	1132	0.04	0.30
5	0.27	6/1/2004 2:10:00 AM-6/1/2004 8:55:00 PM	217	0.01	0.04	2342	0.09	0.32
6	0.45	6/5/2004 8:05:00 PM-6/6/2004 1:15:00 AM	417	0.02	0.05	3076	0.11	0.25
7	0.18	6/8/2004 6:15:00 PM-6/8/2004 10:05:00 PM	135	0.01	0.04	1383	0.05	0.28
8	1.26	6/8/2004 11:10:00 PM-6/9/2004 10:45:00 AM	1017	0.05	0.04	13061	0.48	0.38
9	0.27	6/11/2004 6:20:00 AM-6/11/2004 12:25:00 PM	287	0.01	0.06	2456	0.09	0.33
10	0.76	6/11/2004 6:10:00 PM-6/11/2004 8:15:00 PM	463	0.02	0.03	7455	0.27	0.36
11	0.38	7/3/2004 2:40:00 PM-7/3/2004 10:05:00 PM	52	0.00	0.01	4075	0.15	0.39
12	0.33	7/6/2004 11:25:00 AM-7/7/2004 2:25:00 AM	233	0.01	0.04	5068	0.19	0.56
13	0.2	7/21/2004 6:25:00 AM-7/21/2004 10:55:00 AM	47	0.00	0.01	977	0.04	0.18
14	0.07	08/01/2004 10:45:00 AM-08/01/2004 05:00:00 PM	95	0.00	0.07	366	0.01	0.19
15	0.06	08/03/2004 03:30:00 PM-08/03/2004 08:15:00 PM	69	0.00	0.06	376	0.01	0.23
16	0.16	08/07/2004 04:35:00 AM-08/07/2004 06:50:00 AM	9	0.00	0.00	1280	0.05	0.29
17	0.13	08/07/2004 12:25:00 PM-08/07/2004 01:30:00 PM	1	0.00	0.00	801	0.03	0.23
18	0.69	08/15/2004 11:00:00 PM-08/16/2004 11:15:00 AM	652	0.03	0.05	5188	0.19	0.28
19	0.06	08/22/2004 04:25:00 AM-08/22/2004 06:15:00 AM	15	0.00	0.01	294	0.01	0.18
20	0.05	09/05/2004 06:10:00 AM-09/05/2004 10:45:00 AM	82	0.00	0.09	459	0.02	0.34
21	1	09/05/2004 04:15:00 PM-09/05/2004 11:40:00 PM	1789	0.09	0.09	6586	0.24	0.24
22	1.1	09/13/2004 11:45:00 PM-09/14/2004 08:25:00 AM	1040	0.05	0.05	7657	0.28	0.26
23	0.05	09/14/2004 11:55:00 AM-09/14/2004 05:10:00 PM	195	0.01	0.20	74	0.00	0.05
24	0.17	09/23/2004 01:40:00 PM-09/23/2004 07:50:00 PM	131	0.01	0.04	490	0.02	0.11
25	0.19	4/15/2005 11:14:00 PM-4/16/2005 4:18:00 AM	4	0.00	0.00	1235	0.05	0.24
26	0.7	4/16/2005 9:54:00 AM-4/16/2005 9:32:00 PM	26	0.00	0.00	7111	0.26	0.37
27	0.36	4/19/2005 7:36:00 AM-4/19/2005 7:00:00 PM	17	0.00	0.00	3743	0.14	0.38
28	0.11	4/26/2005 12:14:00 AM-4/26/2005 3:34:00 AM	0	0.00	0.00	849	0.03	0.28
29	1.8	5/10/2005 5:48:00 PM-5/13/2005 11:42:00 PM	4	0.00	0.00	23842	0.88	0.49
30	0.1	5/14/2005 9:00:00 AM-5/14/2005 6:40:00 PM	0	0.00	0.00	2741	0.10	1.01
31	0.06	5/21/2005 8:58:00 AM-5/21/2005 9:26:00 PM	1	0.00	0.00	1151	0.04	0.70
32	0.2	5/25/2005 3:32:00 PM-5/25/2005 7:16:00 PM	19	0.00	0.01	2332	0.09	0.43
33	0.11	5/26/2005 5:22:00 PM-5/26/2005 9:06:00 PM	16	0.00	0.01	2338	0.09	0.78
34	0.1	5/27/2005 12:04:00 PM-5/27/2005 3:18:00 PM	14	0.00	0.01	1745	0.06	0.64
35	0.05	5/27/2005 9:06:00 PM-5/27/2005 10:00:00 PM	0	0.00	0.00	816	0.03	0.60
36	0.26	6/4/2005 10:22:00 AM-6/4/2005 4:30:00 PM	41	0.00	0.01	2518	0.09	0.36
37	1.05	6/8/2005 12:02:00 AM-6/8/2005 9:14:00 AM	6	0.00	0.00	3938	0.14	0.14
38	0.93	8/3/2005 11:44:00 PM-8/4/2005 1:38:00 AM	60	0.00	0.00	3407	0.13	0.13
39	0.18	8/8/2005 6:12:00 AM-8/8/2005 9:42:00 AM	0	0.00	0.00	536	0.02	0.11
40	0.75	8/9/2005 3:16:00 PM-8/9/2005 4:28:00 PM	8	0.00	0.00	2494	0.09	0.12
41	0.13	8/11/2005 12:18:00 PM-8/11/2005 6:30:00 PM	0	0.00	0.00	898	0.03	0.25
42	0.43	8/18/2005 6:50:00 AM-8/18/2005 2:36:00 PM	0	0.00	0.00	2950	0.11	0.25
43	0.25	9/3/2005 5:14:00 PM-9/3/2005 7:16:00 PM	0	0.00	0.00	1096	0.04	0.16
44	0.15	9/19/2005 4:36:00 AM-9/19/2005 7:28:00 AM	0	0.00	0.00	978	0.04	0.24
45	0.27	9/21/2005 9:28:00 PM-9/22/2005 1:50:00 AM	0	0.00	0.00	1542	0.06	0.21
46	1.36	9/24/2005 8:28:00 PM-9/25/2005 10:36:00 AM	0	0.00	0.00	7703	0.28	0.21
47	0.08	9/25/2005 6:14:00 PM-9/25/2005 11:32:00 PM	0	0.00	0.00	1062	0.04	0.49
48	0.3	9/28/2005 7:18:00 AM-9/28/2005 12:18:00 PM	0	0.00	0.00	1480	0.05	0.18
Totals	18.97		7,861	0.41	0.02	151,897	5.58	0.29
Avg Rainfall	0.40							

Fall2002-September2005 Overall Summary.xls 5/22/2006

I. Burnsville Rain Gardens Case Study: Retrofitting for Water Quality

Location: Burnsville
Landscape Setting: Suburban residential
Drainage area: 5.3 acres, 25 houses (17 with rain gardens)
Project timeline: 2001 – 2006
Project cost: $147,000
More information: Kurt Leuthold
Barr Engineering Company
(952) 832-2859
E-mail: kleuthold@barr.com

Issue

Over the past decades, Burnsville's Crystal Lake had seen a marked decrease in water clarity, due in part to algae bloom resulting from increased phosphorus entering the lake. Water quality typically decreased from spring to late summer, which impacted recreational use of the lake.

Background

Recognizing that incoming stormwater from surrounding residential neighborhoods was an important factor in lake health, the City of Burnsville sought an alternative treatment method to reduce that runoff. However, curb and gutter was already in place in the 20-year-old neighborhoods near the lake, and there was insufficient room for traditional stormwater ponds.

Rain gardens—shallow, vegetated depressions that capture runoff and allow it to soak into the ground—emerged as the best solution. In addition to suiting the space and budget constraints in this fully built residential area, rain gardens offer visual amenity that tend to increase residents' commitment to help implement and maintain them.

With the help of two grants—$30,000 from the city and $117,000 from the Metropolitan Council—Burnsville was not only able to design and build the gardens, but to implement a study to gauge their effectiveness. A paired watershed study—monitoring one 5.3 acre neighborhood

Figure 14.1 Burnsville Rain Garden

Figure 14.2 Control and Treatment Watersheds

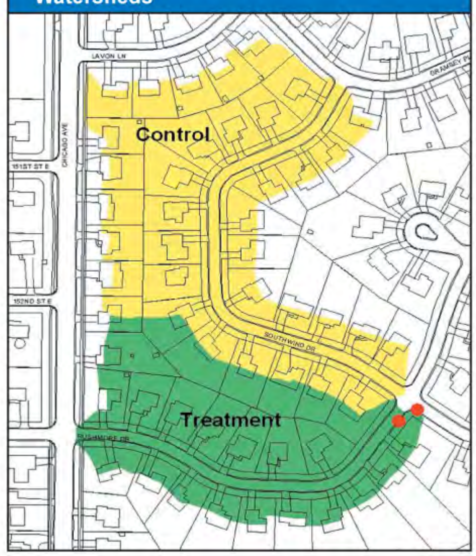


Figure 14.3 (a) Home Before Installation of Rain Garden and (b) Home After Installation of Rain Garden

with 17 rain gardens and a similar, no-rain-garden neighborhood nearby—allowed the city and its partners to see how the BMPs performed during actual storm events.

Implementation

To get baseline data, gauges were installed in each neighborhood to measure runoff for two summers prior to rain garden installation.

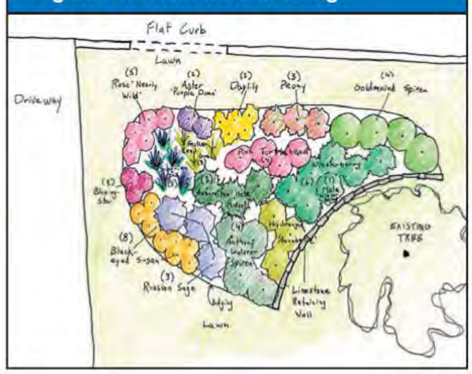
Since the greatest concentration of pollutants is washed off impervious surfaces during the first inch of precipitation, rain gardens are designed to accommodate that "first flush" from a given watershed. The Burnsville gardens were designed to accommodate 0.9" and drain rapidly, within 24 to 48 hours. Rain gardens can be planted with many types of vegetation, including native perennials and shrubs or cultivated varieties. The Burnsville participants were given the choice of three basic garden styles: native wildflower, cultivated perennials and/or shrubs.

Following evaluations of soil and topography, city staff and consultants sought to educate area residents about efforts to improve Crystal Lake water clarity and how rain gardens fit into the picture. The Rushmore Drive neighborhood, characterized by gentle topography and sandy soils, was selected, with hopes of getting at least 30 percent of the 25 residents to participate. As it happened, 85 percent of households signed on, resulting in 17 gardens—13 in front yards, 4 in back. All but one selected a scheme using low-maintenance cultivated perennials and shrubs, which tend to look neater than an all-native garden.

Grading plans, created by engineer Kurt Leuthold, in consultation with landscape architect Fred Rozumalski, incorporated stone retaining walls and gradual slopes from street to basin. During the design phase, Gopher One marked underground utilities so they could be accurately surveyed. The project engineer stresses the importance of this step to help minimize pre-construction surprises and changes.

The landscape architect met with homeowners and drew up planting plans that considered individual resident preferences. Each garden is separated from the street and curb cut by a mow strip, which serves two purposes: to lend a neat, intentional edge to the garden and to trap sediment traveling with the rainwater. The planting designs emphasize showy groupings of tidy-looking plants, which enhance the appearance of the front yards. Construction began in fall 2003. In order to avoid hitting utilities and to ensure proper flow, precise

Figure 14.4 Rain Garden Design



grading of the gardens was critical, as was close adherence to soil specifications and avoiding compaction. Native sandy topsoil was stockpiled and mixed with compost, then installed at a depth of 12 inches following grading. To ensure quality, the city relied on the engineering consultant to do extensive construction observation, and Gopher One marked utilities two additional times—before sod stripping and soil removal and also prior to grading.

Small construction companies were more responsive to the request for bids on this relatively small project (the grading budget was $50,000); city staff indicated that in the future they would not solicit bids from large companies for a project of this scale.

Instead of having planting completed by the contractor, the Burnsville project utilized resident-volunteers to plant their own gardens, with the help of the landscape architect and city staff. This not only helped keep the budget down, but gave homeowners a hands-on investment in their gardens, and familiarized them with the plants.

In order to let plants become established before being inundated, curb cuts were not made until spring 2004. It is important to design curb cuts sufficiently wide so stormwater actually reaches the gardens; a too-narrow cut can allow water to wash on by. At Burnsville, the typical curb opening was 6 feet, with 2 feet tapering sections on each side.

Costs

Cost per garden was approximately $7500, with about $500 of this going toward plants.

Results

Resident reviews have been favorable (an important factor in ongoing success of the gardens), and the monitoring data indicates excellent results.

2004 monitoring data showed that the rain gardens achieved an 80 percent reduction in runoff volume in 49 rain events. Most basins drained dry within 3 to 4 hours. During winter, some ice build-up was evident, but as the melt infiltrated, ice collapsed and disappeared with no adverse effects.

Future Actions

The Dakota County Soil and Water Conservation District conducted runoff audits on each lot in the study neighborhood to provide homeowners with additional suggestions on reducing runoff from their properties, such as redirecting downspouts, installing rain barrels to capture roof runoff and aerating lawns to enhance infiltration.

Another effort to benefit Crystal Lake, a single infiltration basin in West Buck Hill Park, was installed in fall 2004. It accepts runoff from a 25-acre subwatershed.

The Burnsville rain garden project area and control neighborhood are being monitored through 2005. While the success of the project recommends installing more rain gardens elsewhere in the city, the project coordinator has departed, so it is unclear whether additional gardens will be built in the near future.

Figure 14.5 Street Scene

Burnsville Retrofit Rainwater Garden Costs

Barr Engineering Company
Nov-03

Construction Costs

	Retrofit		If New Construction	
Excavation & sod stripping	$12,310		$2,000	
Retaining walls	$4,959		$4,959	
Imported planting soil	$11,098		$11,098	
Edging	$6,754		$6,754	
Sod	$1,980		$0	
Mulch	$2,130		$2,130	
Plants	$9,559		$9,558	
Curb cuts	$6,500		$1,000	
Total	$55,290	($7.21/Sq.Ft.)	$37,500	($4.89/Sq.Ft.)

Home Owner Education Costs

	Retrofit	If New Construction
Home owner education	$3,234	$0
Meetings with home owners	$8,981	$0
	$12,215	$0

Design Costs	**Retrofit**	**If New Construction**
	$34,663	$20,000

Construction Administration Costs	**Retrofit**	**If New Construction**
	$23,829	$12,000

Total Cost (Design & Construction)	**Retrofit**	**If New Construction**
	$11.72/Sq.Ft.	$7.50/Sq.Ft.

Note:

1. The Burnsville site catchment area
2. Retrofit construction is 80% more

APPENDIX C

MISCELANEOUS PROJECT APPLICATION INFORMATION

- Schematic Overall Site Plan
- Basins Runoff Volume Calculations

Figure C.1 - Schematic Overall Site Plan

Basins A & B Runoff Volume Calculations - SCS

Recurrence Interval	1	2	5	10	25	50	100
24 Hour Rainfall **(P)** (in)	3.18	3.7	4.8	5.7	6.6	7.55	7.65
HSG (from survey)	B	B	B	B	B	B	B
Impervious Area %	16.76	16.76	16.76	16.76	16.76	16.76	16.76
Pervious Curve Number **(Cnperv)**	69	69	69	69	69	69	69
Composite Curve Number **(CN)**	74	74	74	74	74	74	74
Runoff Depth **(Qd)** (in)	1	1.4	2.2	2.9	3.7	4.5	4.7
Drainage Area **(Ad)** (ac)	64.73	64.73	64.73	64.73	64.73	64.73	64.73
Runoff Volume **(Qvol)** (af)	5.39	7.55	11.87	15.64	19.96	24.27	25.35
Runoff Volume **(Qvol)** (cu.ft.)	234,969.90	328,957.86	516,933.78	681,412.71	869,388.63	1,057,364.55	1,104,358.53

Basin C Runoff Volume Calculations - SCS

Recurrence Interval	1	2	5	10	25	50	100
24 Hour Rainfall **(P)** (in)	3.18	3.7	4.8	5.7	6.6	7.55	7.65
HSG (from survey)	B	B	B	B	B	B	B
Impervious Area %	17.49	17.49	17.49	17.49	17.49	17.49	17.49
Pervious Curve Number **(Cnperv)**	69	69	69	69	69	69	69
Composite Curve Number **(CN)**	74	74	74	74	74	74	74
Runoff Depth **(Qd)** (in)	1	1.4	2.2	2.9	3.7	4.5	4.7
Drainage Area **(Ad)** (ac)	16.86	16.86	16.86	16.86	16.86	16.86	16.86
Runoff Volume **(Qvol)** (af)	1.41	1.97	3.09	4.07	5.20	6.32	6.60
Runoff Volume **(Qvol)** (cu.ft.)	61,201.80	85,682.52	134,643.96	177,485.22	226,446.66	275,408.10	287,648.46

Basin D Runoff Volume Calculations - SCS

Recurrence Interval	1	2	5	10	25	50	100
24 Hour Rainfall **(P)** (in)	3.18	3.7	4.8	5.7	6.6	7.55	7.65
HSG (from survey)	B	B	B	B	B	B	B
Impervious Area %	16.11	16.11	16.11	16.11	16.11	16.11	16.11
Pervious Curve Number **(Cnperv)**	69	69	69	69	69	69	69
Composite Curve Number **(CN)**	74	74	74	74	74	74	74
Runoff Depth **(Qd)** (in)	1	1.4	2.2	2.9	3.7	4.5	4.7
Drainage Area **(Ad)** (ac)	5.86	5.86	5.86	5.86	5.86	5.86	5.86
Runoff Volume **(Qvol)** (af)	0.49	0.68	1.07	1.42	1.81	2.20	2.30
Runoff Volume **(Qvol)** (cu.ft.)	21,271.80	29,780.52	46,797.96	61,688.22	78,705.66	95,723.10	99,977.46