The Adoption of Low Impact Development by Local Governments

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Abstract

Low impact development (LID) is an innovative stormwater management technique that was introduced in early 1990s. However, the transition to use of this more sustainable method has been slow due to technical, institutional, and regulatory barriers to LID adoption.

The research questions for this study are: What constitutes LID adoption? Why do localities adopt LID? What are the major factors that influenced the level of LID adoption by local governments? Specifically, this study focused on motivations and key determinants of LID adoption by local governments. By answering these questions, we will have better knowledge about how to approach the adoption process of environmental innovations. The findings of the study will benefit any potential localities considering LID adoption.

The theory of diffusion of innovations is applied as it is very flexible to investigate complex topics like environmental innovation involving multiple factors and environments. To explore the role of local governments in LID adoption, sub-theories like organizational innovation and policy adoption are reviewed. Based on these theoretical foundations, four constructs of variables which include innovation, organizations, motivations, and surrounding organizational context are investigated.

The case study method is used for eight counties (Amherst, Bedford, Chesterfield, Fairfax, Isle of Wight, Roanoke, Stafford, and Spotsylvania) and two cities (City of Charlottesville, City of Roanoke) in Virginia. Key informants from each locality were selected for in-depth interviews and additional document reviews for each case are used to support multiple case studies.

LID adoption consists of various forms such as regulations, practices, and plans. A combination of all forms of LID activities and programs was used to measure LID adoption level. Based on nine criteria (i.e., adoption mode, use of the term “LID” in local codes, code details, LID manuals, demonstration projects, number of LID projects after LID code adoption, education programs, task force, and incentives), localities with three levels of LID adoption have been determined. Influencing factors of innovation adoption varied depending on level of LID adoption (high, moderate, and low). Therefore, strategies to promote environmental innovation should be developed in relation to the level of innovation adoption.

The research findings revealed two major determinants that influenced the level of LID adoption. One is strong champions, and the other is regulatory mandates. A champion-driven LID adoption model is found in high level LID adoption localities. Usually, individuals from local governments, NGOs, and development communities have played a critical role in LID adoption process. The local government organizations in this group are usually self-motivated for innovation adoption. Especially, the presence of strong champions was identified as a key factor to the higher level of innovation adoption. On the other hand, a regulation-driven LID adoption model is found in moderate to low level LID adoption localities. These localities are strongly influenced by state regulatory mandates. In these cases, external forces motivate local governments to adopt innovations.

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Chapter 1. Introduction

1.1 Problem statement

Urbanization has a profound impact on the natural environment. Natural land is converted rapidly into impervious surfaces (i.e. buildings, roads, parking lots) for development, and this conversion significantly increases stormwater runoff. More urban and suburban development is expected in the future due to population growth and economic development. Controlling stormwater is not limited to managing water quantity and quality but is also directly related to human land use and growth patterns. The scope of stormwater management includes engineering measures, land use planning and design as well as regulatory and incentive policies and institutional arrangements.

Conventional stormwater management has relied heavily on engineering-based methods like large retention ponds. Conventional approaches primarily focus on the removal of stormwater runoff and less on quality of stormwater runoff. Roy et al. (2008) argue that stormwater management policies in the US have been emphasized removal of stormwater for human health and property value protection, but have not addressed ecosystem preservation.

Since conventional stormwater management has failed to address issues about runoff quality and environmental protection, a new perspective to treat stormwater as a resource is required (Baxter, 2004). In early 1990s, there was an effort to search for alternative methods to control stormwater and an innovative approach called Low Impact Development (LID) was introduced in Prince George's County, Maryland. LID is one of the new trends which has been evolving in water quality management (EPA, 2007). More and more localities and private sector developers are actively involved in use of LID strategies and practices.

Unlike conventional approaches, LID uses the concept of natural hydrology and adopts on-site facilities to improve infiltration of stormwater runoff and to maintain the predevelopment hydrologic condition. LID practices such as bioretention, grass swales, green roofs, and permeable pavements have been widely used in many demonstration projects. A number of localities have successfully adopted LID. Of particular significance are Stafford County, VA; Prince George's County, MD; Washington, DC; Frederick County, MD; Philadelphia, PA; and Seattle, WA (NRDC, 2001).

Despite the adoption of LID techniques by many localities, awareness of urban runoff issues and potential solutions has not brought fast transition to more sustainable urban drainage design. This slow transition is due to many barriers and impediments within the complex nature of stormwater management. General categories for barriers of LID adoption which have identified through current literature are technical, economic, regulatory, and institutional aspects. Especially, local building codes and zoning ordinances have been identified as major impediments to LID adoption (Landers, 2004; EPA 2007; MacMullan, 2007). Therefore, this research will explore the influence of regulatory and institutional aspects of LID adoption.

The goal of this research is to identify the factors that have an impact on the LID adoption process by local governments. The question is how do these factors influence the level of adoption and the LID adoption process? The research will explore how LID has been adopted in early LID-adopting localities and what causes the localities to either be an early LID adopter or a late LID adopter. This research will investigate the kinds of factors that can be identified through early adopter case studies and how these factors are related to the level of LID adoption.

The factors influencing LID adoption are not limited to technical and financial matters. Beyond hydrologic and economic effectiveness, there are other factors to be considered to understand the LID adoption process as LID is more than a simple bundle of practices and techniques. More research has to

be conducted to identify the influencing factors like institutional, regulatory, and political aspects of LID adoption.

According to the LID literature, hydrologic performance and financial benefits of LID practices are the most important factors in LID adoption decision. The scientific measures of LID effectiveness are critical because LID can be a replacement or an enhancement of conventional stormwater management facilities. It is hard to persuade public or elected officials to adopt LID in localities without this information. As a result, more studies are using the monitoring datasets of runoff volume and water quality from LID demonstration projects to provide scientific information that LID is effective for controlling stormwater. In addition, the increased number of research projects on cost-saving information of LID over conventional stormwater (Alexander & Heaney, 2002; Dietz, 2007; EPA, 2007; Hoods, 2006) has drawn the attention of potential LID adopters.

To explore the trends and directions and to find a gap in LID research, master's theses and PhD dissertations from 2003 to 2008 were reviewed. Generally, major topics of LID studies have fallen into four areas: hydrology, cost-effectiveness, site design, and policy. Most of all, the majority of early studies focused on the performance of individual LID practices, the comparison between conventional stormwater management and LID, and the projection of LID practices with various hydrologic models which includes comparison between LID and conventional stormwater management (Alexander & Heaney, 2002; Beden, 2005), hydrological modeling (Obeid, 2005), hydrological efficiency (Bell, 2004; Dreelin, 2004; Hood, 2006; Hunt, 2003; Williams, 2003), and monitoring (Bachman, 2007; Bosley, 2008).

Other frequently investigated issues are costs and benefits of implementing LID practices. Many reports and manuals from government agencies and research centers have evaluated the early LID adopter cases and revealed the cost saving evidences of LID adoption in localities (EPA, 2007; MacMullan & Reich, 2007). Usually, the cost savings of LID can be achieved through site grading and preparation steps

in development projects, by installing less expensive stormwater infrastructure, and by satisfying landscaping requirements with LID. Total savings ranged from 15 to 80 percent by using LID over conventional methods (EPA, 2007).

LID research also includes studies of site design strategies and sustainable design methods, especially in the field of landscape architecture. Studies include: green infrastructure (Upchurch, 2005), site design projects (Young, 2005), and community walkability (Pelensky, 2007). On the other hand, the planning field has focused on policy-related resolutions like zoning and local ordinances to promote LID adoption in local communities. Planning LID studies investigate process and barriers (Singh, 2006) and policy (Ghode, 2007; Lebarron, 2007) because land use activities are the primary cause of and the solution for stormwater management. Many decision makers and organizations (i.e., governments, developers, engineers, environmental groups, and citizens) are involved in land use and stormwater management planning. Therefore, the role of local governments is significant as a major driver in the LID decision making process.

Federal (i.e., U.S. Environmental Protection Agency or EPA) and state agencies (e.g., Virginia Department of Conservation and Recreation or DCR) are vigorously promoting the adoption of LID. Still, LID practices and strategies are new to many local governments. In order to promote LID more effectively, we should know about how local governments are actively involved and successfully adopting LID. We should consider what motivates these local governments and what are the factors influencing LID adoption by them. We can learn lessons from the cases of early LID adoption. Ultimately, the answers to these questions will help us to understand the process and factors of environmental innovation adoption by public organizations.

Specially, this study is focused on motivations and key determinants of LID adoption by local governments. At the conclusion of this research, a set of effective strategies and guidelines for LID adoption will be proposed to local governments.

1.2 Research approach

The number of LID studies has increased, and LID topics have expanded their territories from technical and economic aspects to institutional and regulatory aspects. Yet, we lack understanding of LID adoption and diffusion by various organizations. The spanning of research boundaries is necessary to fill in the gaps of LID research.

In order to understand the LID adoption process and determinants of LID adoption by local governments, the theory of diffusion of innovations is reviewed. The theory is a widely adopted social theory that is very flexible to investigate complex topics like environmental innovation involving multiple factors and environments. To explore the role of local governments in LID adoption, sub-theories like organizational innovation and policy adoption are reviewed to identify potential determinants of adoption by local governments. Also, a clear definition of LID and LID adoption is to be established for the study.

The case study method is used to investigate the level of LID adoption, motivations, and determinants to LID adoption in Virginia localities. The case study method is known as an effective tool to answer "why" and "how" questions (Yin, 2003) like why some localities adopted LID earlier than others and how they expedited the LID adoption process. The target levels of local government cases are counties and cities in Virginia. The localities that have already adopted "LID" in their code and ordinances are selected as cases for data collection. In addition, review of governmental documents from federal, state, and local agencies and interviews with key persons are used for the triangulation of datasets.

By understanding the level of innovation adoption by local governments and the factors influencing innovation adoption, we will have better knowledge about how to approach the adoption process of environmental innovations. The findings of the study will benefit any potential localities considering LID adoption.

Expected outcomes from this research include:

- Identification of motivations and determinants to LID adoption by local governments
- Developing the categories for the level of LID adoption by local governments
- Finding the role of local governments in promoting LID to improve urban runoff conditions and sustainability
- Guidance to improve incentive programs and regulations for LID adoption by local governments

Chapter 2. Literature Review

2.1 Traditional stormwater management

Stormwater is a leading cause of pollution in streams and lakes in the USA. More development and urbanization is likely to increase stormwater pollution and runoff volumes (EPA, 2007). Under natural hydrologic conditions, undeveloped lands are covered with trees, vegetation and open space, and rainwater can be captured and infiltrated on-site. In such cases, less than 10% of rainwater typically turns into stormwater runoff (Kloss, 2006). However, the conversion of natural pervious surfaces to impervious surfaces by urban growth and development has generated a great amount of runoff. This has negatively affected the natural hydrologic process. Stormwater runoff cannot infiltrate through the impervious ground, ground water is not recharged, and runoff is not clean. As runoff washes over impervious surfaces like streets and sidewalks, it picks up oil, detergents, solvents, de-icing salt, pesticides, fertilizers and pet waste bacteria (Dooley, 2003).

From the 1950s to 1970s, the primary focus of stormwater management was to remove the highest volume of water off the land in the shortest amount of time. This approach changed the natural drainage courses and volumes by shortened travel times, less infiltrated volume, and increased pollutant loads. The conventional approach treated stormwater as a nuisance (Alexander and Heaney, 2002), and the response was an engineering based end-of-pipe treatment that was believed to be the only way to treat stormwater. The typical method for stormwater runoff control is detention storage which functions as a temporary holding place for runoff downstream from a development site.

The evolution of stormwater management from an engineering-based approach to a combined engineering/land use planning and design approach has been illustrated in Table 1 which indicates more infiltration-based techniques and strategies like LID is being used in current days (Randolph, 2004).

Table 1 The evolution of stormwater management

	Objectives	Means	Design methods	Financing and implementation
Before 1970: Engineered public works for quantity	Provide adequate stormwater drainage from developed land; try to control flood flows by upstream detention or levees or floodwalls	Structural methods: Increase drainage capacity: gutter streets, using under-ground pipes and culverts, enlarging and lining natural channels; "amor" natural channels with concrete and rocks to prevent channel erosion; use storm-water detention as necessary	Size capacities based on rational method and other rudimentary techniques	Public works funded by tax dollars
1970s to 1980s: Engineering On- and Off-site detention, BMPs	Provide adequate drainage, Manage new flood plain development, Mitigate storm flows closer to the source, Erosion and sediment controls, BMPs for runoff pollution	Structural methods: Mitigate storm flows by on- and off-site detention; Increase drainage capacity as necessary.	Analyze effects of land use change on stormwater quantity and quality; Size capacities using sophisticated computer modeling techniques	Stormwater ordinances require that developers bear costs in projects, Stormwater fees, tax dollars
1990s to 2000s: Engineering + Land Use Planning & Design (LID) for Infiltration, Detention, and Treatment, and Stream Restoration	Provide adequate drainage by on-site mitigation of stormwater flows; provide passage of flood flows through flood plain zoning and building relocation; Enhance infiltration to support base- and low- flows; Treat runoff maintain non-erosive channel velocities; Protect and restore streams	More effective on-site and other decentralized runoff control and treatment; Encourage or mandate "low impact" development designs and integrated stormwater control practices; infiltration; Bioengineering to restore natural channels	Use of both computer models and similar sizing and design methods to estimate land use impacts and apply appropriate on-site measures	More prescriptive and effective stormwater ordinances; Impact fees; Citizen volunteers and watershed associations (stream monitoring and restoration)

Source: Randolph (2004) *Environmental land use and planning*, P435 permission from the author

Even though on-site treatment is more desirable, detention is commonly used because the running hydrologic model for runoff prediction is more convenient. However, existing detention ponds do not perform well to protect the downstream drainage system. The shortcoming of existing detention ponds is due to only concerning peak discharge based on hydrologic models but not on duration (Booth, 1991). Therefore, the conventional system has caused an increase of runoff volumes, flows, and frequency of discharges.

Along with the limited capacity of typical storage facilities, water quality issues are not considered in conventional stormwater management. Standard infrastructure and controls have failed to effectively remove pollutants (Alexander & Heaney, 2002; Kloss, 2006). The conventional stormwater management approach also requires the development of infrastructures including drainage piping, culverts, curbing, gutters, as well as stormwater outlets and management ponds. These infrastructures require extensive site clearing and development with the associated capital outlays. In addition, the established stormwater conveyance infrastructure requires long-term inspection and maintenance. These inspection and maintenance costs are often a financial burden to property owners, developers and local governments (Kallen, 2005). In addition, conventional methods limit any opportunity of urban retrofits by depleting valuable and irreplaceable natural resources and open space (Weinstein, 2002).

Most of all, a fundamental difference between traditional stormwater management and LID depends on how to treat stormwater runoff as a nuisance or resource. It is a nuisance to remove stormwater runoff in conventional stormwater management. In contrast, LID treats stormwater as resource to protect.

2.2 Regulatory Requirements for Stormwater Management

The law and regulations of water quality and quantity provide a framework to protect the environment and natural resources. Federal, state, and local regulatory requirements are connected hierarchically. In terms of stormwater management, the role of localities is significant to implement stormwater related programs and regulations. Indeed, these laws and regulations provide legal foundations to encourage LID adoption voluntarily or mandatorily to local communities.

2.2.1 Federal Clean Water Act

The goal of the CWA is to restore all "waters of the United States" to their "fishable" and "swimmable" conditions. The CWA is the federal environmental law to protect and improve water quality and it is formerly referred to as the Federal Water Pollution Control Act (FWPCA) Amendments of 1972. The FWPCA passed the amendments to eliminate the discharge of pollution into the navigable waters and to protect fish and wildlife by 1985. Then, section 204 of the 1972 amendments established the National Pollutant Discharge Elimination System (NPDES) to authorize discharge permits by the USEPA. In 1977, the amendment known as "Clean Water Act" stated the need to develop statewide Best Management Practices (BMP) programs.

Generally, the CWA that requires states to protect water resources by developing and adopting tools and programs like (Virginia Save Our Streams [VASOS], 2008):

- Adopt water quality standards for streams, rivers, and lakes
- Monitor water bodies to determine whether or not water quality standards are being met
- Report to the Federal Government the results of the water quality monitoring efforts and which streams do not meet water quality standards
- Create a clean-up plan (Total Maximum Daily Load) for surface water bodies that do not meet water quality standards

- Establish a program to implement the National Pollutant Discharge Elimination System (NPDES) regulatory program. Point sources must obtain a discharge permit from the proper authority (usually a state, sometimes EPA, a tribe, or a territory).
- Develop a program to reduce the impact from non-point sources of pollution
- Create a program to protect wetlands
- Create a program to finance upgrades to municipal sewage treatment plants

In 1987, two phases of the CWA stormwater management program passed the Congress to enforce the implementation of the CWA to control stormwater discharge. In detail, the Phase I (1991) required NPDES permits for medium and large Municipal Separate Storm Sewer Systems (MS4s) with populations greater than 100,000. Land disturbance activities for five acres or more of land should have a permit. Phase II (2003) required permits for stormwater discharge in land disturbance activities of 1 to 5 acres of land (Yu, 2004). The Phase II expanded the standard to smaller municipalities of up to 50,000 people, especially in urbanized cities. The permit holders are required to implement post-construction stormwater management programs and mandated to use stormwater best management practices (BMPs) in new development and redevelopment projects. Currently, a majority of urban cities have to implement local stormwater management programs and, particularly, new developments should be regulated to mitigate stormwater quality impact (Girling, 2002).

Often, polluted stormwater runoff is transported to MS4 and then discharged into natural waterways. Especially, Phase II rule developed an MS4 program to reduce pollutants like oil and grease from roadways, pesticides from lawns, sediment from construction sites. The Phase II Rule defines a small MS4 stormwater management program as “a program comprising six elements that, when implemented in concert, are expected to result in significant reductions of pollutants discharged into receiving waterbodies”. The six MS4 elements, so called minimum control measures are: 1) Public

education and outreach; 2) Public participation/involvement; 3) Illicit discharge detection and elimination; 4) Construction Site Runoff Control; 5) Post-Construction Runoff Control; 6) Pollution Prevention/Good Housekeeping (EPA, 2000).

2.2.2 Virginia State Stormwater Management Law and Regulations

Virginia is granted authority to protect water quality and quantity from the EPA. Virginia also developed many "non-regulatory" programs to meet the CWA requirements. Periodically, Virginia should report on the state's implementation of the CWA to the EPA (VASOS, 2009). Virginia also has an extensive laws and regulations that deal with water quality issues, in particular, Virginia Stormwater Management Law and Regulations, and Chesapeake Bay Preservation Act. Especially, state stormwater regulations promote consistency among local stormwater management programs by developing technical criteria and administrative procedures.

The DCR oversees regulated activities undertaken on state and federal properties, while localities such as counties, cities and towns have an option to establish a local stormwater management program to regulate activities on private property within their jurisdiction (VADCR, 2007).

State level regulations that supports the LID adoption in Virginia can be found in Virginia Stormwater regulations §10.1-603.4(8). This regulation states, "Encourage low impact development designs, regional and watershed approaches, and nonstructural means for controlling stormwater ", in fact, allows counties and cities in Virginia to utilize LID practices and strategies.

1) **Virginia Stormwater Management Program (VSMP)**

The goals of VSMP are to issue, modify, revoke and reissue, terminate, monitor and enforce permits and impose and enforce requirements pursuant to the Federal Clean Water Act (VADCR, 2007).

Stormwater management legislation which passed the 2004 General Assembly has created a statewide comprehensive stormwater management program to control construction and post-construction activities. The DCR administers the Virginia Stormwater Management Program (VSMP), including the Municipal Separate Storm Sewer System (MS4) Program, under the Federal Clean Water Act. Specifically, the MS4 program requires urbanized areas to develop stormwater management plans and obtain discharge permits for stormwater outfalls (VADCR, 2007).

The lists of applicable MS4 are:

1) Owned or operated by a federal, state, city, town, county, district, association, or other public body, created by or pursuant to state law, having jurisdiction or delegated authority for erosion and sediment control and stormwater management, or a designated and approved management agency under § 208 of the CWA that discharges to surface waters;
2) Designed or used for collecting or conveying stormwater;
3) That is not a combined sewer; and
4) That is not part of a publicly owned treatment works.

Any locality within Tidewater Virginia as defined by the Chesapeake Bay Preservation Act and any locality designated as an MS4 must adopt a local stormwater management program under the VSMP by July 1, 2006. Localities not covered by MS4 permits or not within the CBPA Area may elect to adopt a local stormwater management program.

2) Chesapeake Bay Preservation Act (CBPA)

CBPA (Section 10.1-2103 & 10.1-2107 of the code of Virginia; 9 VAC 10-20-10 et seq.) was adopted by the General Assembly in 1988 and the regulations were promulgated in 1990 and amended in 2001. The Act is mandatory to all localities within the Tidewater region (Figure 1) of Virginia while adopted voluntarily by the rest of the state. The goal of the Act is" to address the degradation of the

waters of the Bay by non-point source pollutants such as sediment, nutrients and toxics. To implement the Act, the Chesapeake Bay Local Assistance Board issued regulations which Tidewater local governments must adopt into comprehensive plans, zoning ordinances and subdivision ordinances. The regulations apply to all land use and development activities within Chesapeake Bay".

The Chesapeake Bay Preservation Areas are divided into two classifications: Resource Protection Areas (RPAs) and Resource Management Areas (RMAs). RPAs are those lands and features which have a direct water quality function and impact. On the other hand, RMAs are lands which, if not properly managed, have the potential to degrade water quality or impact the functioning of RPAs (Yu, 2004). The designated CBPA localities are 29 Counties, 17 cities and 38 towns in the Bay watershed: Counties of Accomack, Arlington, Caroline, Charles City, Chesterfield, Essex, Fairfax, Gloucester, Hanover, Henrico, Isle of Wright, Northumberland, Prince George, Prince William, Richmond, Spotsylvania, Stafford, Surry, Westmoreland, and York. Cities of Alexandria, Chesapeake, Colonial Heights, Fairfax, Falls Church, Fredericksburg, Hampton, Hopewell, Newport News, Norfolk, Petersburg, Poquoson, Portsmouth, Richmond, Suffolk, Virginia Beach, and Williamsburg.

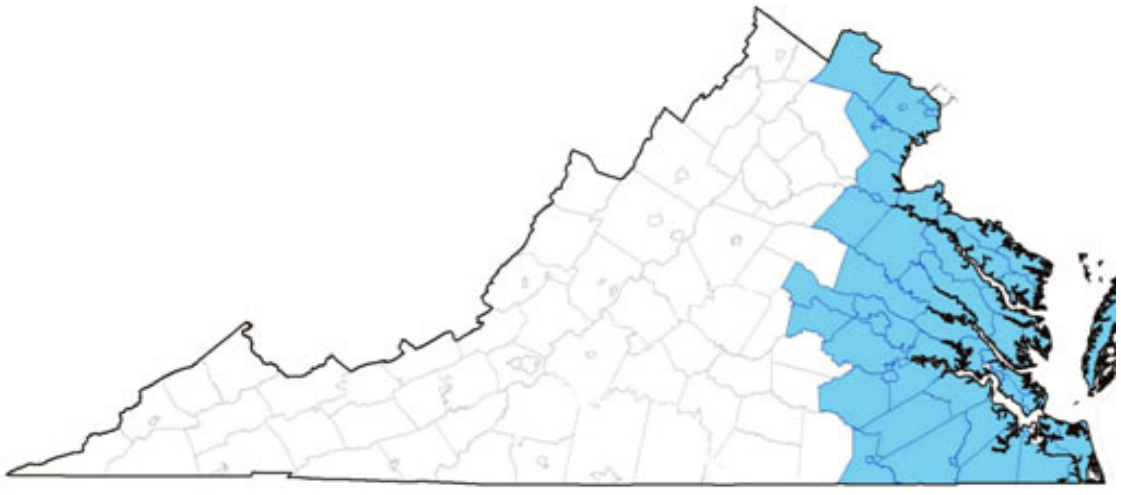

Figure 1 Tidewater Virginia

GIS data source: National Transportation Atlas Database (2009) Retrieved from U.S. Department of Transportation (US DOT), http://www.bts.gov/publications/national_transportation_atlas_database/2009/
2009 TIGER/Line® Shapefiles for Virginia, Retrieved from U.S. Census Bureau http://www2.census.gov/cgi-bin/shapefiles2009/state-files?state=51

3) **Virginia Pollutant Discharge Elimination System (VPDES)**

Virginia is a NPDES authorized state. The VPDES is modeled after NPDES and regulates all point source discharges to surface waters. DEQ and the DCR separately coordinate the state programs that regulate the management of pollutants carried by stormwater runoff. DEQ regulates stormwater discharge associated with "industrial activities", while DCR regulates stormwater discharge from construction sites and from MS4s (VADEQ, n.d.).

Phase I regulates large and medium size municipalities which have populations over 100,000: Arlington County, Chesapeake, Chesterfield County, Fairfax County, Hampton, Henrico County, Newport News, Norfolk, Portsmouth, Prince William County, and Virginia Beach. Phase II regulates the localities within urbanized areas according to the 2000 U.S. Census. This program is also referred as MS4 and it includes six required program areas, referred to as “minimum control measures” (also refer to Federal CWA, NPDES Phase II small MS4 program).

4) **Proposed Virginia Stormwater Regulations**

VADCR (2009) announced that the proposed revisions to Virginia stormwater regulations will emphasize reducing runoff volumes and improving water quality requirements. The new Virginia stormwater regulations will be applied uniformly across the entire state with the same water quality and quantity criteria.

According to proposed (4VAC50-60-63) regulations, the modifications to the existing stormwater water quantity and quality requirements will be applied to every land disturbing activity of 2,500 square feet or more in the Chesapeake Bay Preservation Act areas and disturbances of an acre or more elsewhere in the state requirements. The proposed regulations establish statewide water quality design criteria for land disturbing activities.

- For new land development projects, water quality plans must be designed so that the total phosphorus load shall not exceed 0.28 pounds per acre per year (4VAC50-60-63).
- For development that occurs on prior developed land, the designs must allow for the total phosphorus loads to be reduced by 20% below predevelopment levels.
- Proposed approaches to reduce phosphorus loads are: 1) managing land use conversion (forest, turf, and impervious cover), 2) reducing runoff volumes, and 3) treatment of stormwater runoff.

2.2.3 Local policies and regulations for stormwater management

Counties, cities or towns can either use the state stormwater management program or develop their own stormwater management program. In local stormwater management programs, various approaches like local ordinances, policies and guidelines, technical materials, inspections, enforcement and evaluation can be applied to control stormwater runoff from land development activities (VADCR, 2007).

Specifically, LID can be integrated into local government level applications such as:

- Incorporating LID into the comprehensive plan
- Incorporating LID into stormwater ordinance
- Amending local zoning and subdivision ordinances to be made LID friendly
- Developing incentive programs to promote LID
- Implementing LID demonstration projects

Virginia legislation states that local government has the police power of zoning and other land use controls. Local zoning and subdivision ordinances determine development rights in each locality and a local comprehensive plan guides the course of future development (Phillips, 2009). The local code and ordinances are more stringent tools to adopt LID in localities. For instance, the most common and effective way to adopt LID is through amending road width (narrower roadways), parking space

requirements, set-back requirements, curb and gutter requirements and center Island requirements in local zoning and subdivision ordinances.

A comprehensive plan is a guide for a community's future. The basic purpose of the plan is established in the Code of Virginia, Section 15.2-2223, which states: "The comprehensive plan shall be made with the purpose of guiding and accomplishing a coordinated, adjusted and harmonious development of the territory which will, in accordance with present and probable future needs and resources, best promote the health, safety, morals, order, convenience, prosperity and general welfare of the inhabitants." It is a legal foundation for local land use laws, therefore, it is important to acknowledge the importance of LID in the plan and relates LID to protecting the health, safety, and welfare of its residents. Other ways to integrate LID into other community plans are through greenway plans, recreation plans, stormwater plans and watershed management plans.

2.3 Low Impact Development

During the 1990s, the paradigm shift in stormwater management emerged. The major factors driving this phenomenon were regulation and scarce natural resources. Many communities were forced to meet National Pollutant Discharge Elimination System (NPEDS) regulation (NPDES Phase I, 1990; NPDES Phase II, 1999) and they researched various ways of directing stormwater flows. In addition, loss of usable land and declining water quality made people consider how to use valuable resources in better ways (Baxter, 2004). Most of all, the concepts of sustainable development and environmentally sensitive design had a great influence on stormwater management. The principles from these concepts like conservation of natural resources, minimization of development impact and mimicking natural hydrology were applied to innovative stormwater management techniques.

2.3.1 What is Low Impact Development?

In early 1990s, LID was developed in Prince George's County, Maryland. The county was frustrated with the technical, environmental, and economic deficiencies of conventional stormwater management and developed LID as an alternative stormwater management.

The Somerset subdivision in Prince George's County, MD was one of the first residential developments which included rain gardens. Local developers, Dick Brinker and Theresa Brinker, president of the TABCO land development company, worked with a local official, Larry Coffman, associate director of the county's Department of Environmental Resources, to replace conventional stormwater facilities with innovative LID facilities. Their attempt to use bioretention and grass swales on each lot instead of conventional BMP ponds, curbs, gutters, and sidewalks resulted in a reduction of infrastructure and construction costs. Collaboration between the local government and developers was made possible by successful implementation of the innovation (EPA, 1995).

LID becomes a significant change in stormwater management tradition as it incorporates environmentally sensitive designs of stormwater control. It also brings technological innovation to stormwater management. Larry Coffman (2002) claims that LID has multiple benefits and uses landscape features not only to control stormwater but also to achieve environmental, economic, aesthetic, and natural resource benefits.

The first national LID manual from Prince George's County, Maryland (EPA, 2000) presents a set of practices and strategies for describing LID applications in communities. The manual was developed through the collection of case studies, pilot projects, BMP technology development and research conducted by Prince George's County over the past ten years (Coffman et al., 1998). Based on the Prince George's County manual, many other states and local governments have developed LID manuals and reports for their own uses.

Then, what exactly defines LID? Coffman (2002) defines LID as "an innovative technological approach to stormwater management and ecosystem protection where hydrologic controls are integrated into every aspect of a site's design to mimic the predevelopment hydrologic regime". However, the terms used for defining LID are extensive and broad. Therefore, the definition and characteristics of LID should be clarified for this study.

Most importantly, LID mimics natural hydrological patterns and prevents or reduces the impact of development. Especially, the technical aspect of LID has been emphasized as the primary goal of LID which is to control stormwater using on-site small scale practices and technology. The EPA (2003) also focuses on the hydrologic functions of LID like infiltration, peak and volume of discharges and groundwater recharge and these characteristics make LID more a technical issue.

The major principles of LID are to maintain natural hydrologic functions, improve water quality and pollutant removal and to protect natural resources. However, there is no unified definition throughout literature; only similar ideas and words are shared to define LID in most cases.

A number of different definitions for LID are presented in Table 2 to compare various aspects and focuses on LID. Many manuals and government reports about LID, which are referred to nationwide, perceive LID as a technology based approach for site design strategies. Commonly used terms that describe LID are innovative stormwater management technology, site design strategies, and small scale practices. In addition, the concepts of using natural hydrologic cycles and land development strategies are emphasized throughout different references.

Therefore, LID is defined in this study as an innovative stormwater management approach using small scale on-site practices and site design strategies to manage stormwater runoff on-site. Both practices and strategies are emphasized for a full scale implementation of LID.

Table 2 Definitions of LID

Title/ Author	Definition of Low Impact Development
LID Strategies – An Integrated Design Approach Prince George's County, MD, By EPA (1999)	"LID is a comprehensive technology-based approach to managing urban stormwater." "The low-impact development (LID) approach combines a hydrologically functional site design with pollution prevention measures to compensate for land development impacts on hydrology and water quality"
LID: A literature Review By EPA (2000)	"LID is a site design strategy with a goal of maintaining or replicating the predevelopment hydrologic regime through the use of design techniques to create a functionally equivalent hydrologic landscape."
The Practice Of LID by NAHB Research Center, U.S. Department of Housing and Urban Development (2003)	"An approach to land development that uses various land planning and design practices and technologies to simultaneously conserve and protect natural resource systems and reduce infrastructure costs. LID still allows land to be developed, but in a cost-effective manner that helps mitigate potential environmental impacts"
Unified Facilities Criteria-Design: LID manual by Department of Defense (2004)	"A stormwater management strategy concerned with maintaining or restoring the natural hydrologic functions of a site to achieve natural resource protection objectives and fulfill environmental regulatory requirements"
LID-Technical Guidance Manual For Puget Sound by Puget Sound Action Team, WA (2005)	"A stormwater management strategy that emphasizes conservation and use of existing natural site features integrated with distributed, small-scale stormwater controls to more closely mimic natural hydrologic patterns in residential, commercial, and industrial settings".
Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices by EPA (2007)	"LID comprises a set of site design approaches and small-scale stormwater management practices that are designed to reduce runoff and associated pollutants from the site at which they are generated. By means of infiltration, evapo-transpiration, and reuse of rainwater, LID techniques manage water and water pollutants at the source and thereby prevent or reduce the impact of development on rivers, streams, lakes, coastal waters, and ground water."
LID Manual for Michigan: A Design Guide for Implementers and Reviewers by SEMCOG (2008)	"Low impact development (LID) is the application of techniques that emulate the natural water cycle described in the previous section LID uses a basic principle modeled after nature: manage rainfall by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to its source."

1) **LID principles and practice**

In nature, stormwater is controlled by a variety of mechanisms: interception by vegetation, small depression storage, channel storage, infiltration and evaporation. Fundamentally, LID mimics natural hydrologic mechanisms by distributing infiltration, storage, retention, and detention facilities throughout the landscape (Coffman, 2000).

LID is not a single technical innovation but rather a bundle or package of principles and practices. As a result, many kinds of LID practices are introduced to developers and engineers. What, then, are the most commonly used principles and practices?

LID can be categorized into structural and nonstructural technologies. Structural technologies include facilities like bioretention or rain gardens, grass swales, rooftop gardens and rain barrels. These LID practices control excessive stormwater runoff on-site and particularly bioretention and grass swales are showing multiple functions such as detention, retention, and water quality for stormwater runoff (Coffman, 1998). Bioretention and grassed swales are the most commonly used LID practices in residential, commercial and municipal projects. Most of all, bioretention has been used in urban and suburban settings like Alexandria, VA; Montgomery County, MD; Baltimore County, MD; Chesterfield County, VA; Prince William County, VA; Smith Mountain Lake State Park, VA; and Cary, NC since 1992 (EPA, 1999).

A recent study by Dietz (2007) reveals that the number of bioretention, pervious pavements and grass swale practices has increased and these practices have proved to be effective in retaining runoff volume and filtering pollutants on sites.

Unlike structural and device based LID practices, the nonstructural approach guides land use and site design strategies. Four major strategies of the nonstructural approach are decreasing impervious surfaces, reducing roadway surfaces, planning site layout and grading to natural land contours, and natural resource preservation (NAHB, 2003). To reduce the impact of land development, LID site design strategies incorporate hydrology and spatial site layout options. A simple strategy is to reduce impervious surfaces which prevent natural infiltration of runoff through site design methods. For example, site design strategies to reduce roadways include shared driveways, reduced street frontage, landscaped detention islands within cul-de-sacs, or alternate designs for turn-around areas (PGCDER, 1999).

2.3.2 Actors in LID adoption

Many stakeholders are involved in adoption and implementation of LID. Figure 2 illustrates seven different stakeholder groups. Local government, homeowners/buyers, developers, and environment are directly related to the adoption of LID policies and practices as end-users. Federal/state government, environmental groups, and citizen groups indirectly influence the overall LID adoption process by mandates, incentives, and public pressure to encourage LID adoption. Especially, citizens and environmental groups can play a significant role in the LID adoption process by demanding their local governments to consider more environmental and sustainable stormwater management methods through the decision making process.

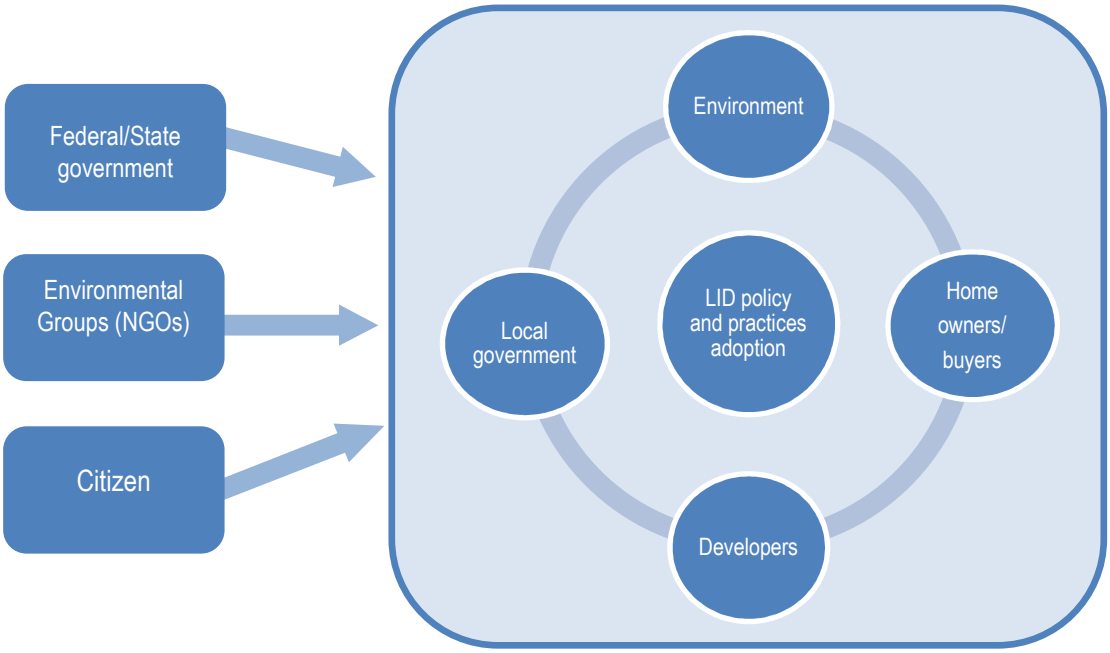

Figure 2 Actors in LID adoption process

To continuing the process and maintenance of LID program, achieving consensus from each group is a crucial factor. However, each group of stakeholders has a different reasoning and focus for LID adoption. For example, the greatest concern of developers and builders is obtaining plan review and approval in the shortest time. Their work process is based on cost and benefit model from the moment

they buy land for development to the completion of the project. Developers are in favor of fast processes for permits (NAHB, 2003). Therefore, if LID process requires more time to get an approval for development, it will be a big obstacle to widespread LID (Lebarron, 2007). In addition, developers concern the benefit of cost saving through reducing land clearing and grading costs, infrastructure costs (streets, curbs, gutters, and sidewalk), storm water management costs as well as increasing lot yields and lot and community marketability (NAHB, 2003; SEMCOG, 2008).

On the other hand, home owners are concerned about amenities and market value of their properties by adopting environmentally friendly techniques. If they can find the benefits of LID such as reducing maintenance efforts and increasing amenities to their properties, it would be a great option for homeowners to adopt LID as an alternative stormwater management method (NAHB, 2003).

At last, the role of local governments is the most significant in the process of LID adoption. There are elected officials, planning staff, engineering staff and plan reviewers in a local government and all of them are intensely involved in LID adoption (SEMCOG, 2008). The LID adoption in local code and ordinances and comprehensive plan guide a future direction of local governments. For local governments, the benefits of LID are regional flora and fauna protection, growth management with environmental protection, the reduction of municipal infrastructure and utility costs, and the development of private and public partnerships (NAHB, 2003; SEMCOG, 2008).

Among many stakeholder groups, developers and municipalities are major key players with strong opinions and leadership. The presence of opinion leadership tends to maintain the continued uses of innovations like LID. Ultimately, LID adoption can increase environmental benefits such as preservation of the ecological and biological integrity as well as protection of regional water quality and natural resources (NAHB, 2003).

2.3.3 Barriers to LID adoption

LID is still new to existing stormwater management systems. As a result, there are technical, economic, institutional and regulatory conflictions to the adoption and diffusion of LID. Lewis (2006) identified three major barriers to LID adoption: financial, technical (regulatory, construction /engineering, maintenance) and educational (cost/ benefit, environmental, conceptual/engineering).

Table 3 Barriers to LID adoption

Source	Barriers
LID Task Force Report on "Impediments to Low Impact Development and Environmental Sensitive Design" (2002) By Chesapeake Bay Program	1) Lack of education about economic and other benefits of LID 2) Need enabling authority for performance standards, rezoning process 3) More LID flexibility to local governments. 4) Lack of clear characteristics of LID: criteria for using LID: residential versus commercial versus redevelopment 5) LID has not been incorporated into policy decisions at all Levels. 6) Overall fragmented Process. 7) Impact of approved lots in the pipeline. 8) Uncertainty of trying something new. Need for legal documentation. Will it work? 9) Lack of expertise and resources at local and state level. 10) Lack of site specific data (such as GIS) early in the process. 11) Need more maintenance, monitoring, and enforcement. 12) Lack of consistent local regulation. 13) Lack of trust between development and planning.
Impediments and Solutions to Sustainable, Watershed-Scale Urban Stormwater Management (2008) By Roy et al.	1) Uncertainties in performance and cost 2) Insufficient engineering standards and guidelines 3) Fragmented responsibilities 4) Lack of institutional capacity 5) Lack of legislative mandate 6) Lack of funding and effective market incentives 7) Resistance to change
Low Impact Development Manual for Michigan, (2008) By SEMCOG	1) Number of institutions with jurisdiction over stormwater 2) Restrictive regulations that may not allow for LID techniques 3) Resistance from internal sources and/or the community, 4) Lack of technical knowledge, 5) Lack of resources (financial resources and staff time; expenses to additional resources (e.g., sponsoring LID tours, developing and printing educational materials, updating ordinances and plans). 6) Site constraints that may pose challenges to implementing LID (e.g., historical contamination, clay soils)

Table 3 presents the barriers and impediments identified by LID Task Force report (STAC, 2002), Roy et al. (2008), and LID manual for Michigan (SEMCOG, 2008) to LID adoption which indicated that the prevailing obstacles to LID adoption were the lack of leadership (authority, responsibility, and fragmented institutions), resources (funding, expert knowledge), education, and regulations.

Among identified barriers and impediments, policies and regulations such as local codes and ordinances were identified as major causes to delay the adoption and diffusion of LID. Delays are primarily due to the complex and time consuming process of amending or creating local codes and ordinances in favor of LID adoption (NRC, 2008).

Most of all, many researchers (Landers, 2004; MacMullan & Reich, 2007; Nowacek et al., 2003) claimed that the local codes and ordinances as major barriers. For example, in the study of social and institutional barriers to infiltration stormwater, Nowacek et al.,(2003) interviewed key players in stormwater management and found that the outdated existing municipal ordinances were the barriers to adopt infiltration stormwater. Landers (2004) and MacMullan and Reich (2007) argue that local building codes and zoning ordinances are often the major hurdles to LID adoption even though LID is gaining more favor from many jurisdictions. According to the Center for Watershed Protection report so called (COW worksheet), the existing local codes and ordinances often require inflexible standards such as overly wide residential streets, expansive parking lots and mass clearing and grading of forested areas. At the same time, local codes often give developers little or no incentive to conserve natural areas.

2.4 Diffusion of Innovations Theory

Why do localities adopt LID? How are the factors affecting LID adoption by localities? To answer theses question, the literature about innovation, organizations, and surrounding organizational context are explored.

For many decades, the diffusion of innovations theory has addressed the topics of the determinants of innovation adoption, the rate of innovation adoption, and regional diffusion. Many researchers (Daley & Galand 2005; Matisoff , 2008; Vasi, 2006; White & Boswell 2007) have focused on the factors influencing to innovation adoption in organizations by applying internal determinants model and regional diffusion model. As shown in Table 4, at least two models have been applied to explain the innovation adoption phenomenon: the internal determinants model and the regional diffusion model. While the internal determinants model considers the internal factors of organizations to innovate, the regional diffusion model focuses on the external factors of organizations to innovate. In addition to these two models, organizational motivations to innovate are also considered as a significant factor to innovation adoption.

Table 4 Innovation adoption models

Authors	Daley & Galand (2005)	Vasi (2006)	White &Boswell (2007)	Matisoff (2008)
Theory	Internal determinants Regional diffusion	Diffusion of organizational innovations	Policy innovation Internal determinants	Internal determinants Regional diffusion
Themes	Hazardous waste management	Cities for Climate Protection (CCP) program	Stormwater management-NPDES phase II	Climate change policy, renewable portfolio standard
Factors	<u>Internal determinants</u> 1) Problem severity and need-based policymaking: larger problem most likely adopt the new policy 2) Political influences on policymaking: more liberal population with strong program 3) Interest group influence: state with active environmental group 4) Socioeconomic resources: wealthier states <u>Regional diffusion</u> 1) Horizontal: Pressure from neighboring states 2) Vertical: more EPA support	1) Geographic and administrative proximity 2) Association with international change agencies 3) Compatibility of the innovation 4) Organizational needs: seriousness of the problem 5) Organizational characteristics: size, structure (centralization), resources 6) Environmental context: level of education, political orientation, environmentalist orientation	1) Innovation Funding Staff numbers Staff expertise Consultants 2) Innovators Collaboration EPA Officials State Officials Stormwater engineers Planning staffs EPA websites 3) Local context Interested citizens Community Salience Water quality data	1)Motivation Environmental conditions Demands of citizens 2)Resources Financial resources Geographical resources 3)Obstacles Reliance on existing industry

Therefore, this study is focused on these two models (i.e., internal determinants, regional diffusion) and four categories of theoretical examinations (characteristics of innovation, characteristics of innovation adopting organization, motivations to innovation adoption, and organizational context) are reviewed in the following sections.

2.4.1 Innovation

1) Definition of Innovation

Rogers (2003) defines innovation as an idea, practice, or object that is perceived as new by an individual or a unit of adoption. Basically, any knowledge, idea, norms, beliefs, services, and products can be considered as innovations in diffusion studies. In the case of practitioners, they use innovation as an all-inclusive term even though they may be referring to very different events or processes (Cooper, 1998). As a result, these extensive and vague terms like " really new", or "radical", or " discontinuous" have brought some confusion about innovation definition (Garcia & Calantone, 2002).

The definition of innovation should be considered to be more than just an idea. More specifically, in policy change, innovation should include the following three criteria: 1) originality and newness to the environment that it is being introduced to; 2) practical application and action; 3) significance and impact (Walker, 2006). Most of all, the actual use of an idea should be presented to develop a new idea into an innovation.

2) Innovation adoption

Rogers (2003) defines adoption as "a decision to make full use of an innovation as the best course of action available". Adoption process begins with the first hearing of an innovation and ends with the final adoption. Adoption process can be broken down into five stages; awareness, interest, evaluation, trial, adoption.

- Awareness: the individual is exposed to the innovation but lacks complete information
- Interest or information: the individual becomes interested in the new idea and seeks additional information about it
- Evaluation: individual mentally applies the innovation to his present and anticipated future situation, and then decides whether or not to try it
- Trial: individual makes full use of the innovation
- Adoption: the individual decides to continue the full use of the innovation

Even after the adoption, the extent and degree of innovation can be varied from simple use to routine use within an organization. Therefore, a limited dichotomous approach (adoption/non-adoption) can not address the full magnitude of innovation adoption process. For example, Glicks and Hays (1991) conceptualize the degree of innovation adoption to "superficial" and "deep" adoption. Superficial adoption is largely symbolic adoption, however deep adoption involves an extensive commitment of resources through investigatory and enforcement actions. Both categories of adoption can be called adoption and can be treated as functionally equal but the various stages of innovation adoption might be overlooked.

To measure the outcome of the innovation adoption in organizations, Damanpour (1998) examines the rate of adoption which includes magnitude of innovation that is the number of innovations adopted by an organization within a given period. Most of all, the success of innovation adoption can be achieved through accepted and integrated stages of innovation in the organization and commitment for continuing uses of the innovation (Frambach, 2002).

For this study, adoption is defined as regulatory and administrative decisions or activities that encourage the utilization of LID practices and strategies: for example, adopting new policies, demonstration projects, and education programs. Therefore, LID adoption means the adoption of LID projects and regulations that encourage the applications of LID practices and strategies in localities.

3) **Innovation characteristics**

The perception of an innovation influences the decision to adopt or reject an innovation. If an innovation is perceived to exceed the benefits and costs of existing alternatives, the possibility to consider an innovation adoption will be increased. Many researchers consider that innovation characteristics are a significant factor to innovation adoption (Damanpour, 2008; Frambach, 2002; Koebel, 2006; Tornatzky & Klein, 1982; Walker, 2006). The types and number of innovation characteristics can be varied. In the meta-analysis by Tornatzky and Klein (1982), compatibility, relative advantage, complexity, cost, communicability, divisibility, profitability, social approval, trialability, and observability are identified as ten most frequently addressed characteristics of innovation. The study of Damanpour (2008) which is based on the review of 75 studies states that compatibility, relative advantage, and complexity are the most consistent significant factors to innovation adoption.

However, the most prominent distinction of innovation characteristics is based on Rogers (2003) model. When innovations are perceived to have the following characteristics, the innovations are likely diffused more rapidly.

- Observability: The degree to which the results of an innovation are visible to potential adopters
- Relative Advantage: The degree to which the innovation is perceived to be superior to current practice
- Compatibility: The degree to which the innovation is perceived to be consistent with socio-cultural values, previous ideas, and/or perceived needs
- Trialability: The degree to which the innovation can be experienced on a limited basis
- Complexity: The degree to which an innovation is difficult to use or understand

2.4.2 Characteristics of Organizations

The earliest studies in diffusion of innovations have focused on the decisions made by individuals, for example, studies of farmers who adopted new agricultural technologies. Recently, researchers have been focusing more on the organizational level. For example, studies like the adoption of innovative policies by the state governments, the spread of new consumer products via the marketplace, and methods of fertility control (Wejnert, 2002) are done to investigate the factors affecting organizational innovations.

Even though diffusion studies have started with individuals as the unit of analysis, actually, many innovations are adopted by organizations. An organization is a stable system of individuals with common goals through a hierarchy of ranks and a division of labor (Rogers, 2003). All types of organizations adopt innovations to respond to changes in their external and internal environments. Innovations are usually introduced into organizations in two ways. They can be generated by an organization or they can be adopted from another organization (Damanpour & Gopalakrishnan, 1998).

Past research proves that the size of an organization is the most consistent determinant (Damanpour 1992). Obviously, larger organizations have more resources for attempting innovations within their own organizations and adopting innovations from other organizations.

There are other essential characteristics which have impacts on innovation adoption by organizations. Berry and Berry (1999) argue that policy diffusion strongly depends on the internal characteristics of a unit which adopts a policy. The economic, political, and social characteristics of organizations are related to the motivation to innovate, the strength of obstacles, and resource availability. The importance of adopter's characteristics on the innovation adoption process is also reflected in the study of innovation diffusion by the residential building industry by Koebel (2003). Koebel identifies nine categories of determinants of innovation and diffusion, and out of the nine, four categories fall into

adopter's characteristics, that is, adopter's human resources, adopter's organizational structure, adopter's organizational culture and decision process and adopter's market context.

The characteristics of innovation-adopting organizations are the most crucial factors in innovation adoption process. Many researchers reveal the positive relationship among the size and resources of organization and innovation adoption by organizations. More researchers are focusing on the significance of the role of champion in an organization. The focus of this study is to identifying more specific sub-factors based on these three major components of organizational size, resources, and the role of champion.

1) **Size of an organization**

The most important predictor of early adoption is the size of an organization. The positive relationship between the size of an organization and its innovativeness has consistently been revealed from past empirical research (Damanpour, 1991; Driessen, 2002; Kwon et al., 2009; Mohr, 1969). The size of an organization can be measured by several dimensions of an organization: total resources, slack resources, employees' technical expertise, and organizational structure (Rogers, 2003). For example, Berry (1994) has used the full-time equivalent of staff in the agency. And Vasi (2006) has used city population for the size of an organization.

Even though the size of an organization is the most constant variable to predict adoption, some studies have shown different results depending on which measures they have used for the size. For example, White (2006) argues that the statistical analysis of the correlation between population or population growth and NPDES phase II adoption shows less relevance of the size factor. The study concludes that small local governments also can accomplish successful adoption if they have sufficient funding. Therefore, the selection of relevant size measures is the important. Driessen (2002) suggests that both small and large organizations have benefits to innovate. Larger organizations have more resources or more need to innovate, while small organizations tend to be more flexible with innovation.

2) **Organizational resources**

Many researchers support the positive impact of slack resources to innovation adoption. Slack resources are the degree of uncommitted resources available to an organization (Perry, 1980; Rogers, 2003). Underutilized or unproductive resources are necessary to innovation adoption in the organizational environment (Bingham, 1978) and they are considered as overall resource availability. Berry (1994) also finds that organizations with abundant or slack resources have more propensities to innovate than agencies with restricted resources. Slack resources generally encourage innovation adoption by offering flexibility to organizations.

With slack resources, an organization can create new resources or reallocate existing resources (Perry, 1980). Slack resources are typically measured by changes in an organization's budget and sources of finance or changes in expenditures for the organization's main activity. Vasi (2006) measures the variable for organizational resources using data of government expenditures from the 1991 United States Census Bureau survey of local governments' finances. The government expenditures were measured in per capita dollars.

Technical knowledge and resources in organizations are also significant factors to organizational innovation. Technical resources have a positive relationship to propensity of innovation adoption as they are reflecting an organization's technical potential and capacity to manage innovations. Technical resources can be measured by presence of technical groups and personnel. This also reflects how the role of professional members' knowledge is important in the adoption of innovations (Damanpour, 1991).

3) **The champion of innovation in organizations**

The presence of a charismatic individual who throws his or her weight behind an innovation may provoke an organization to overcome indifference or resistance of a new idea. An innovation champion

has an important role in advancing a new idea in an organization. Innovation champions come in all ages with varying degrees of formal power and abilities (Rogers, 2003).

A champion plays a crucial role in overcoming the indifference and resistance that major technological change creates. A champion is required to identify the idea as his or her own, to promote the idea actively and vigorously through informal networks, and to risk his or her position and prestige to ensure the innovation's success. A champion emerges informally in an organization and makes "a decisive contribution to the innovation by actively and enthusiastically promoting its progress through the critical stages". Therefore, the presence of a champion is strongly related to the success of innovation adoption (Howell & Higgins, 1990). For example, a product champion is a strong supporter of a certain innovation, and actively promotes the innovation within an organization. Research shows that the presence of a product champion within an organization has a major positive influence on adoption (Driessen, 2002; Maidique, 1980).

2.4.3 Motivations to innovation adoption

Motivation is one of the driving forces for the adoption and implementation of innovations. The continuation of using innovations depends on the orientation of motives. However, these “why” questions for adoption are rarely studied as a research question because these questions are difficult to measure. Among different types of motivations, economic motivations are the major reason for innovation adoption. Prestige motivations are considered less often but the desire for prestige is very important to make a decision to innovation adoption (Rogers, 2003).

On the other hand, Berry and Berry (1999) argue that problem severity is an important motivational factor as it can influence state officials to adopt a policy to solve the problem and satisfy needs. Public opinion and electoral security are presented as another motivational factor to innovation

adoption. Popular new polices among the public are likely to be adopted because politician can have positive electoral security as they support popular new policies.

In the case study of successful programs by Ford and the Kennedy School innovation awards program, Walters (2002) identifies six motivations of innovation adoption:

- A frustration with the status quo: Frustration comes from internal or external sources in an organization. Frustration causes members of organizations to act as change agents and makes them push for changes. Examples of frustrations are a complex administrative and legal system, conflicts in decision making systems or old-style fragmented, disjointed, end-of-pipe problem solving approaches.
- A response to crisis: Crisis is visible to the public and it becomes a powerful catalyst for making changes. An immediate and highly visible response is demanded for crisis. However, it shows a passive reactive tendency of typical government organizations rather than a preventive action.
- A new emphasis on prevention: Environmental protection takes a more proactive approach to policy and administration. Still prevention-focused programs can be hard to implement as there is no measure for the results yet. More numbers of government programs and initiatives are targeting the results-oriented approach.
- An emphasis on results: Good measurable results are one of the most significant measures to evaluate the progress and success of innovations.
- An adaptation of technology: Some innovations are inspired by technology and technology has been used to get rapid and meaningful performance measures.
- A moral imperative: This means to do the right thing. Ultimately potential innovation adopters can get help by identifying these drivers for innovation push.

Based up on the previous literature review, specific motivations which influence LID adoption are presented in this study. There are various reasons why some localities adopt LID. The motivations of

LID adoption to be considered in this study are protecting the environment, meeting regulatory requirements, and obtaining incentives for development.

Other motivations are to save development costs and improve hydrologic performance results over conventional stormwater management tools. Physical conditions of localities also influence the feasibility of stormwater management practices. Additional factors to be considered are topography, maximum drainage area, depth to water table, soils, slopes, terrain, hydraulic heads and location in relation to environmentally sensitive features (City of Roanoke, 2007). Publicly available GIS datasets for each locality will be gathered and analyzed to illustrate geographical representation of LID adoption levels by localities.

Most importantly, new ideas need a push to be adopted (Kettl, 2000). Not just one single motivation inspires innovation. Innovation adoption is a comprehensive process and various motivations will influence the decision making process. Therefore, the following list of motivations is assumed to be relevant with LID adoption.

- Severe environmental problems and physical characteristics of localities: water quality issues, increase of impervious surfaces, other local environmental factors
- Frustration with conventional stormwater management
- An emergence of new LID technology
- Physical characteristics of localities

2.4.4 Organizational Context

The adoption of innovation is not an independent process separate from its organizational context. External forces and resources influence to an organization to adopt innovation. Daley and Galand (2005) say that internal characteristics of organizations are not sufficient to capture the innovation adoption

process and external influences should be concerned. For example, while states are adopting new policies, they are influenced by federal and other state governments.

The regional diffusion model by Berry and Berry (1999) has been used to explain the external influences to policy adoption. Especially, horizontal diffusion and vertical diffusion models are used to explain policy making process. Horizontal diffusion occurs because (a) states learn about different policies from other states, (b) states compete with each other, and (c) public pressure may force a state to adopt a policy that neighboring states have adopted. On the other hand, vertical diffusion means hierarchical influence. Programs and policies by federal government have a great impact on state governments.

Berry and Berry (2007) also suggest that governmental jurisdictions learn from or copy each other. Primary four reasons of regional diffusion are learning, competition, public pressure, and vertical influence from oversight governments or bodies. As a result, Berry and Berry present four models of diffusion to describe in depth the policy adoption process: national interaction model, regional diffusion or geographic proximity, isomorphism, and leader-laggard. In addition, any potential pressure from environmental organizations and citizen's interest group should be considered as a factor to local LID adoption.

Along with vertical and horizontal impacts to innovation adoption, the characteristics of local conditions also can be used to investigate any relation with localities of certain characteristics and their propensity to adopt innovations. For instance, the study of White and Boswell (2006) applied six census variables to investigate the influence of local conditions on local policy response to a federal program.

They used the variables like total population, percent of annual growth rate, percent of high school education or higher, median household income, median home value, and percent of families above poverty line. The study concludes that well-educated/wealthier populations and larger and more rapidly-growing localities put pressure on local governments to adopt environmental protection policies.

In terms of federal influence to LID adoption, the EPA is a major player that writes regulations for the Clean Water Act and promotes environmental innovations. From the early 1990s, the EPA has engaged in nationwide LID promotion and has funded for developing a major national LID design manual by Prince George's County. The EPA also encourages municipalities to incorporate LID with NPDES requirements (Landers, 2004).

For state level involvement, the Virginia Department of Conservation and Recreation (VADCR) and the Chesapeake Bay Local Assistance Department (CBLAD) are promoting the use of LID as an alternative and supplement to existing stormwater programs. The Virginia Department of Environmental Quality and the U.S. Army Corps of Engineers (Corps) are promoting the use of LID as a tool to avoid and minimize impact to surface water and to mitigate water quality impact due to development. Localities can determine the type and amount of practices to be used in an LID design (VADEQ, 2003).

Based on innovation adoption and policy adoption theories, this study establishes four major constructs to determine influencing factors to LID adoption by local governments: innovation characteristics, organizational characteristics, motivations, and organizational context (Table 5).

Table 5 Four categories with variables

Innovation characteristics	Organizational characteristics	Motivations to adoption	Organizational context
• Relative advantage • Compatibility • Trialability • Observability • Complexity	• Size of organizations • Economic resources • Technical resources • Human resources • Champion	• Severe environmental problems • Physical characteristics of localities • Frustration with conventional method • Development of new technology	• Horizontal influences (Neighboring localities) • Vertical influences (Federal/State level incentives and regulations) • Pressure from environmental groups • Local conditions

Chapter 3. Research Methodology

3.1 Research questions

LID adoption by local government is a complex process because multiple practices, strategies, and policies constitute LID. Revising existing stormwater management practices, procedures and regulations or newly developing policy and regulations in localities can take very long time. Moreover, there are many stakeholder groups such as developers, citizens, local government officials and environmental groups that are directly or indirectly involved in LID adoption process. Therefore, a full spectrum of LID adoption processes for localities will be investigated using the characteristics of LID, key organizational characteristics, motivation factors and organizational context.

The research questions for this study are:

- What constitutes LID adoption?
- Why do localities adopt LID?
- What are the major factors that influenced the level of LID adoption by local governments?

More detailed research questions regarding influencing factors are subcategorized into innovation, organizations, motivations, and surrounding organizational context.

1) **Innovation characteristics (LID)**
    - Did the characteristics such as types of LID practices, relative advantage, compatibility, trialability, and demonstration of benefits-costs-risks influence LID adoption to the level of LID adoption? What other characteristics of LID have been recognized by local governments?
    - How did the complexity of LID influence the level of LID adoption?

2) **Organizational characteristics (Local governments)**

- The size of organizations has been identified as one of the most consistent determinants. How does the size of responsible agencies influence to LID adoption by local governments?
- What organizational characteristics can be identified as determinants? How did these determinants influence the level of LID adoption?
- Were there any LID advocates or key persons in the process of LID adoption? If so, what was their position in local governments? How critical was the role of LID key person?
- Which agencies in local governments are responsible for LID adoption? Is there any difference in the level of LID adoption depending on a responsible agency?

3) **Motivations for local governments to LID adoption**

- How did the severity of local environmental problems or frustration with traditional stormwater management system influence to the level of adoption by localities?
- What other motivations (e.g., physical conditions of localities, development of new technology) did inspire the LID adoption?

4) **Organizational context**

- What kinds of regulations and financial incentives in federal and state government level do support LID adoption by local governments?
- How does the pressure from peers and neighbor localities influence to the level of LID adoption by local government?
- Are there any pressures from environmental organizations that influence to the level of LID adoption by local governments?
- Do community characteristics (e.g., demographical settings, level of education, political settings, and level of urbanization) influence LID adoption? How critical these factors are to the level of LID adoption?

3.2 Case study Method

The focus of this study is to investigate the factors affecting LID adoption by local governments. It is difficult to employ standard quantitative methods to conduct in-depth inquiry about LID adoption by local governments. The case study method is suitable for exploring the processes and interactions in organizations; we learn how these processes interact and function within the entity itself (Baxter, 2008; Fishler, 2000; McNabb, 2002). In diffusion of innovations studies, the case study method has been dominantly used since the 1970s (Franzel, 2008; Rogers, 2003).

Among different types of the case study method, a multiple case study can be used to explore and analyze differences within and across cases. By replicating findings across cases, researchers can either predict similar results or contrast results across cases based on a theory (Baxter, 2008; Yin, 2003). Therefore, multiple case studies are used to investigate the factors affecting LID adoption in local governments. Selected cases are localities which already have adopted LID in their codes and ordinances. By examining early LID adopted localities, we will learn more about factors in the LID adoption process and might be able to apply the findings of this study to potential LID adopters.

The unit of analysis of this research is local governments like counties and cities in Virginia, U.S. According to previous literature reviews, stormwater issues are directly related to human land use. The major control of land use and zoning decisions are typically governed at the local level.

Typically, the role of the government has been neglected by researchers even though it might have a greater influence on green innovations than in the case of other innovations. Indeed, it is necessary to have more emphasis on the role of local government for environmental innovation adoption (Driessen, 2002). Local governments have important environmental responsibilities to control local environments and natural resources such as managing solid waste, ensuring clean drinking water, developing and enforcing land-use plans, inspecting local restaurants and other establishments for health and safety and

providing emergency services. Local governments have administered these environmental issues by implementing taxes and enforcing local codes (Commission for Environmental Cooperation, 2009).

Therefore, the unit for data collection of this study is focused on county and city governments to provide a better measurement and understanding of land use and stormwater management as well as to maintain consistency in institutional, legislative, economic, and social arrangements for data collection and analysis (Roy et al., 2008).

3.2.1 Case selection

According to Stake (1995), collective case or a multiple case study design contribute to greater understanding of a phenomenon or some general organizational condition. However, one of the most important issues in using multiple case studies is the question of how to select appropriate cases for data collection. The case selection process should be conducted based on rational process with replication.

Flyvbjerg (2006) emphasizes that strategically chosen cases can increase objectivity of research results. Flyvbjerg categorizes two types of case selection methods: random selection and information-oriented selection. Random selection generally is chosen to avoid systematic sample bias; therefore the size of the sample is a significant factor. On the other hand, information-oriented selection is used to maximize the information that is available.

The case selection process is based on information driven and purposive sampling to choose the cases only that have adopted LID. To select counties and cities for this study, standard criteria and protocol have been applied uniformly. Two criteria that have used to select multiple cases are population and code adoption condition. Especially, to select only the localities with LID adoption, this study assumes that localities with LID related codes and ordinances might have put more time and resources to

adopt LID. Generally, amending or creating local codes and ordinances require a long time for a locality than just adopting plans, programs, and guidelines.

Total 95 counties and 39 county equivalent independent cities are identified in Virginia. Among them, the localities with populations greater than 25,000 people were selected and it end up with 48 counties and 18 cities. Then, the words "low impact development" and "LID" were used for a keyword searching in local codes and ordinances of 48 counties and 18 cities. As a result, eight counties (Amherst, Bedford, Chesterfield, Fairfax, Isle of Wight, Roanoke, Stafford, and Spotsylvania) and two cities (the City of Charlottesville City, the City of Roanoke) were selected for in-depth multiple case studies.

The following procedure presents more detailed information on case selection process.

a. Select counties and cities with population of 25,000 and more: 48 counties and 18 cities
b. Online municipal code library, http://www.municode.com/, was accessed to retrieve all 66 localities' code and zoning ordinance information. Some localities had no code information in municode.com website. In that case, local codes and ordinances were retrieved from individual local government websites.
c. To select the localities with LID adoption, the words "Low Impact Development" and "LID" were searched through all 66 localities' codes and ordinances.
d. As a result, ten localities (8 counties and 2 cities) were chosen for multiple case studies. Figure 3 represents the geographical diversity of selected localities in Virginia.

Figure 3 Location of selected cases

GIS data source: National Transportation Atlas Database (2009) Retrieved from U.S. Department of Transportation (US DOT), http://www.bts.gov/publications/national_transportation_atlas_database/2009/
2009 TIGER/Line® Shapefiles for Virginia, Retrieved from U.S. Census Bureau http://www2.census.gov/cgi-bin/shapefiles2009/state-files?state=51

3.2.2 Data sources

There are various data sources for each case. Yin (2008) identifies documentation, archival records, interviews, direct observation, participant observation and physical artifacts as the most commonly used sources of data for the data collection method. Among these six sources of data, interview data is considered the primary data source. Generally, the interview method can be categorized into two types: in-depth interview and focused interview. The in-depth interview can provide insights into a matter and can be done through an extended period of time. On the other hand, the focused interview can be done for a shorter period of time such as an hour. A researcher usually follows a guided set of questions from the case study protocol.

The primary data source for this study is in-depth interviews with key persons who are decision makers and experts in local governments. The assumption is that the opinions and evaluation from the experts in executive level will be more thorough and useful to understand the LID adoption process and

the relationship among determinants in a locality. Essential members in local governments such as administrator level officials, planning directors and staff and engineering staff are contacted for in-depth interview.

Types of documents used are agenda, minutes of meetings, other written reports of events, and administrative documents such as progress reports. Documents are useful to verify primary data sources like interviews. Information from archival records can be collected from computer files and records such as the U.S. Census data. Statistical data and public use files or maps and charts of geographical characteristics of a place can be a form of archival records.

To validate and support the interview data as well as to obtain more objective evidence on LID adoption, documents such as special reports and manuals about LID by federal agencies and state governments are reviewed concurrently. Various maps and graphic resources are also reviewed to investigate the local conditions and geographical proximity in neighboring counties as influencing factors. Maps are a powerful tool for visualizing and analyzing land use patterns which result of urbanization and environmental problems.

Most of all, the amount of case study data can be overwhelming and extensive. Therefore, a systematic approach for collecting relevant documents can save time and money in data collection.

3.3 Data collection protocol

Yin (2003) emphasizes the importance of developing a protocol for data collection and conducting a pilot case study in multiple case studies before the data collection. A pilot case study was done with the case of Fairfax County. All available documents about LID adoption by the county were collected to evaluate the level of LID adoption and to validate the interview data. In addition, preliminary

test interview was conducted to test interview questionnaires before the actual face-to-face interviews with interview participants in each locality.

Data collection protocol consists of three parts: interview contact list, face-to face interview, and documentation collection. The following data collection protocol has been used to collect data for ten cases.

1) **Establishing contact list for interviews**

   a. Retrieve email lists of preliminary contacts from each local government: chief executive official, planning director, and environmental program director/staff (Appendix A)
   b. Send email and identify the key informants: who are the key persons to talk about LID?
   c. Identifying the final interview contacts (Table 6)

To conduct interviews with local officials and staff members, semi-structured interview questions (Appendix B) are developed based on a theoretical framework of diffusion of innovations and four major constructs of determinants.

At first, to collect extensive contacts that were involved in LID adoption process from 10 localities, directors of all three departments (i.e., administrators, the planning department, and the engineering department) in local governments were contacted via emails. Initially, the number of contacts started with 30 people but later the number increased to 37 people. During the communication to identify the appropriate persons to interview, only one or two persons who were knowledgeable about LID were referred for interviews. Usually, local officials with limited or general knowledge about LID chose not to engage in the interview process.

As shown in Table 6, the majority of interviewees were the planning department directors and the environmental engineering department directors. Only one local administrator agreed to have an interview.

During the communication via emails and phone calls, a watershed coordinator from Robert E. Lee Soil & Water Conservation District in Amherst County and a director of Friends of Rappahannock (nongovernmental organization or NGO) in Stafford County were strongly recommended by local staff members to have interview with. Subsequently, both of them were contacted for face-to- face interviews also. As a result, total 22 (20 from local governments, 1 from NGO, 1 from regional soil and water conservation district) people were participated in interview process.

Table 6 List of interviewees

Dept. / Locality	County/City Administrator	Planning Department	Engineering	Other contacts
Amherst County	-	Director	-	Director of Public Utilities; Watershed Coordinator from Robert E. Lee Soil & Water Conservation District
Bedford County	-	Director	-	-
Charlottesville City	-	Neighborhood services contact	Civil engineer	-
Chesterfield County	County Administrator	Senior Planner	Director of Environmental Engineering	-
Fairfax County	-	-	-	Director of Public Works & Environmental Services; Engineering staff of Public Works & Environmental Services
Isle of Wight County	-	-	Environmental Programs Manager	-
Roanoke City	-	Director, Planning Administrator	-	-
Roanoke County	-	Principal planner	County engineer, Civil Engineer	-
Spotsylvania County	-	-	Senior Environmental Engineer	-
Stafford County	-	Director of planning and zoning,	Senior engineer	Environmental Division manager, (Public Works) Friends of Rappahannock (NGO)

2) Face to face interview

a. Preparing available documents about local LID adoption status: local codes and ordinances, manuals, and reports

b. Semi-structured interview

- LID adoption status in general: education program, number of LID demonstration projects, number of approved LID project sites, local incentives
- County government information: local government resources(number of LID specialists, funding capacity, and other resources), identifying target agencies (staff numbers, staff expertise)
- Determinants that influenced LID adoption

Before face-to-face interviews, local information from other sources such as local comprehensive plan, local codes and ordinances, stormwater manuals and reports were collected and summarized for preliminary analysis of localities.

Then, site visitations and interviews were conducted from September 2009 to November 2009. Interviews were successfully conducted in 9 out of 10 localities. However, in case of Isle of Wight County, face-to-face interview was not available as staff persons could not offer any time for face-to face interview as the county "really understaffed and have some major issues to deal with (according to a staff person)". Therefore, open-ended questions were sent out by email for data collection from a staff person.

3) Secondary data collection

a. Case background

- Case site name and location maps
- Land cover land use maps
- Research each local government website for historical background of the localities

- Demographic information: Search each local government website and U.S. Census website for population, population density, percent change of population, median household income

b. Documentation

- Policy and regulation: local codes and zoning ordinances, stormwater management regulations, local comprehensive plan
- Meeting minutes: the Board of Supervisors meeting minutes and the planning commission meeting minutes were reviewed to support the arguments of interview data.
- Technical reports and manuals: LID project report and LID manuals were searched to investigate available detailed information on LID.

Chapter 4. Analysis

Extensive amount of textual data was collected for this study through interviews and documentation reviews. As Birmingham (2003) claims, with text data, analysis can "reveal meanings, priorities and understandings, the ways of organizing and seeing the world". The question is what the most effective way is to organize and analyze this large amount of text data. As Kohn (1997) claims, traditional statistical analyses cannot be used for this kind of case analysis, therefore, different techniques need to be applied to organize and review large amounts of information.

Analysis method for this study is based on coding and sorting of data to highlight the themes and status of LID adoption by ten local governments. Nine criteria were used to measure LID adoption levels by local governments and the results were ranked and categorized into three levels of LID adoption. Then, the localities in the same group of LID adoption level were grouped together. Case descriptions, in-depth information on LID adoption condition, maps, and demographic information were presented for each case.

To identify and compare factors influencing the level of LID adoption by local governments, a tabulated matrix comparison which is considered as an effective tool to determine any similarities and differences among cases was used as an analysis tool.

4.1 Level of LID adoption in localities

Local governments adopt LID in various forms. The most commonly recognized adoption type of LID is policy and regulation adoption as localities should make changes in local codes and ordinances to promote LID. The number and size of demonstration projects and completed projects in localities represents the level of LID adoption intensity.

LID can be adopted simply or comprehensively in localities. A simple adoption means implementing LID demonstration practices like bioretention, grass swale, and green roofs and site design strategies on a site. However, there are various scales and stages of LID adoption. The comprehensive means of LID adoption is far more than just placing LID practices on a site. The complex level of LID adoption occurs with regulatory and institutional changes at the local governmental level to promote the uses of LID. Some examples are modification and new additions to local codes, ordinances and incentives for existing stormwater management measures (SEMCOG, 2008).

There are several ways to measure and evaluate the level of adoption. In the case of Daley and Galand (2005), they have used an index score based on the presence or absence of 11 characteristics within state hazardous waste programs. A higher score indicates a more active and stringent state hazardous waste program and one that closely resembles the federal Superfund program. It is scored for either presence (1) or absence (0) for the components of the state program.

Several studies (Brown, 2005; JRA, 2007; Lassiter, 2007) used the "Code and Ordinance Worksheet (COW)" developed by the CWP to assess the level of impediments to LID adoption in the Chesapeake Bay Watershed area. This COW model has been used frequently to evaluate the environmental friendliness of local codes and ordinances toward water quality and better site design principles.

LID adoption consists of various forms such as regulations, practices, and plans (Figure 4). Therefore, it is more accurate to measure a combination of all forms of LID activities and programs to determine the levels of LID adoption in the selected localities.

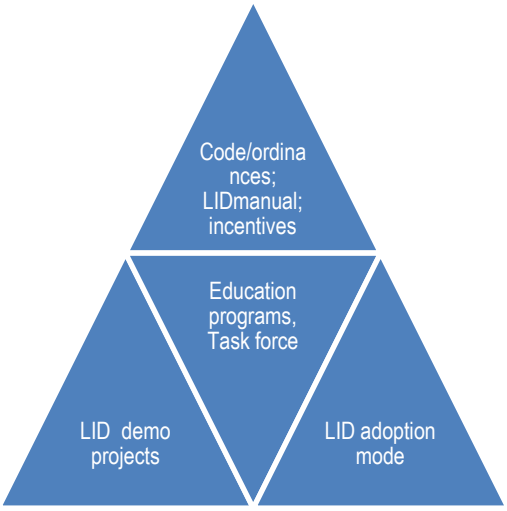

Figure 4 **Forms of LID adoption**

The levels of LID adoption in localities are determined based on interview information and local government documents (i.e., comprehensive plans, stormwater management plans and local code and ordinances). All of the LID activities contribute to the levels of LID adoption in each local government. Thus, the following nine criteria were used to categorize the selected 10 localities into high, moderate, and low levels of LID adoption.

1) Adoption mode

Adoption mode is an overall attitude toward LID adoption in local government. The mode has two aspects: voluntary and mandatory LID adoption. The interview results and the language in codes and ordinances and local officials' evaluations on their LID policies were used to categorize localities either in voluntary or mandatory category. For example, some localities encourage LID as a voluntary option but the others promote LID actively by implementing mandatory tools such as local zoning and subdivision ordinances. The localities that consider LID as a voluntary option typically depend on developers' requests.

However, this dichotomy of voluntary and mandatory mode is not sufficient to determine the mode of LID adoption. Even in the localities with the same voluntary mode, various levels of encouragement and engagement to LID implementation have found. Therefore, two categories (active/ inactive) of encouragement level to use LID by local governments also have to be measured to determine the various LID modes toward LID adoption. As a result, a locality's attitude toward LID adoption was measured by a combination of voluntary /mandatory option and active /inactive uses of LID.

Among the ten cases, Stafford County has mandatory LID uses for local land development. The county takes relatively aggressive measures to LID adoption. Unlike Stafford County, Spotsylvania County made LID as a voluntary option but the county has been actively involved to offer LID in every development project.

In the case of the City of Charlottesville and Fairfax County, basically they rely on developers' voluntary decision to LID adoption. However, those localities are actively engaged in every aspect of land development process to encourage LID.

At last, the rest of the six localities have revealed either they are in partial engagement to LID or very passive engagement to LID adoption. In the case of Chesterfield County, LID was encouraged only in one watershed area. In other localities such as Amherst, Bedford, Roanoke County, Isle of Wight and the City of Roanoke, LID was not actively utilized and only a small number of staff members encouraged LID uses to local developments.

2) Numbers of the term "low impact development" or "LID" in code

Word count of the term "low impact development" and "LID" in local codes and ordinances was used for this criterion. It is based on an assumption that as greater numbers of the term LID is used, a greater intensity or development of LID is expected in localities.

3) Code details

LID practices and principles provide many guidelines for land development and LID can be adopted in various parts of local codes and ordinances. Therefore, the legitimate use of LID in codes and ordinances is important to determine the robustness of LID programs in localities.

Specifically, local subdivision ordinances are considered as a preferable tool as local governments manage the housing development by providing specifications for streets, sidewalks, water and sewer, drainage, curbs and gutters, street signs and landscaping. Regulations such as reducing the amount of paved roads and parking lots and narrowing the road width are particularly effective to address LID (NAHB, 2007). Therefore, zoning and subdivision ordinances which regulate residential and commercial development are evaluated as the most appropriate section for LID adoption. In addition,

stand alone stormwater management ordinances, erosion and sediment control ordinances and other related codes and ordinances are reviewed in-depth to determine the level of LID adoption (Appendix C).

4) LID manuals

Besides local codes and ordinances, technical and design manuals for LID were considered as an instrument to LID adoption and implementation. To determine the level of LID adoption, technical details presented in manuals and localities' utilization of their manuals was evaluated. The manuals from five localities, the City of Charlottesville, Fairfax County, Spotsylvania County and Stafford County provided a great detail of technical information about LID practices.

For example, the Standards and Design Manual of the City of Charlottesville illustrated the use of LID in two sections: curb and gutter designs and sustainable stormwater management plan. It particularly emphasized the uses of LID for sustainable stormwater management.

In the case of Fairfax County, the county's public facility manual (PFM) was greatly amended to update the facts and guidelines of LID; the letter to industry on July 16, 2007 (Fairfax County, 2007) specifically addressed the details of LID amendments to the public facility manuals. The PFM typically deals with "all the technical details of how you design a stormwater management facility or sewer system, or drainage system, or road system….the ordinances are essentially for listing of requirements so the technical details are usually in some sort of designing construction standard manual" according to a Fairfax staff. The PFM allows six LID practices to be adopted by local developers which include pervious pavement, bioretention filters and rain gardens, vegetated swales, tree box filters, vegetated roofs and reforestation but does not include any LID site design strategies.

The City of Roanoke also offers the stormwater design manual to "provide guidance to developers, property owners, and design professionals and to assist them in meeting Stormwater

Management Ordinance requirements." The manual includes LID practices such as bioretention (rain gardens), pervious pavement, vegetated swales and filter strips and constructed wetlands.

Spotsylvania County adopted four manuals to allow the county and the engineers to have a greater flexibility in the design of stormwater facilities. According to planning commission meeting minutes of April 16, 2003, the county adopted a Design Standards Manual, the Virginia Stormwater Management Handbook and two EPA Low Impact Development manuals for county staff and private engineering firms.

Stafford County officials said that they supported continuous efforts to revise stormwater management manuals to update on LID. According to an official, "We did do an updated on our stormwater management design manual that was completed in late 2007 - early 2008. And the purpose of that update was to provide more detailed information on LID because once we got into the day to day implementation we realized that there were a lot of policy issues and some technical issues that we failed to address." Other staff also added that "We are continuously revising our SWM design manual, the manual in 2003 had enough guidance through it but we had to answer so many questions raised by the engineers and the new manual as Steve said we tried to provide enough guidance so that it can almost completely self-explanatory."

5) Demonstration projects

Each of the ten localities has a number of LID demonstration projects to showcase their success for LID adoption. These projects have been done by either local governments or private sectors. Demonstration projects have been recognized as an effective tool for potential users to determine the performance and feasibility of innovative measures.

Usually, demonstration projects commonly use bioretention, green roofs, porous pavers, grass swales and biofilters which are small scale projects rather than full scale site design strategies. All

localities except Bedford County have shown some type of demonstration project and bioretention, grass swales and permeable pavers are most commonly used LID practices.

6) Number of LID projects after LID code adoption

After the adoption of codes and ordinances which encourage LID use, some localities experienced a change in numbers of development projects incorporating LID practices and principles. The City of Charlottesville, Fairfax County, Spotsylvania County and Stafford County showed some increase in numbers of projects with LID practices. However, the exact number of projects with LID was difficult to track as sometimes the changes were not noticeable or almost every project had incorporated some sorts of LID practices.

7) Education programs

Several localities such as Fairfax County, Spotsylvania County and Stafford County emphasized the importance of LID education programs. Regular education programs and training workshops which were supported by local governments offered opportunities to inform public officials, elected officials and local developers and engineers about LID. In the case of the City of Charlottesville and Fairfax County, they even provided a technical bulletin or a letter to industry to educate and enforce LID to local developers and engineers.

8) Task Force

One of the routine procedures for local governments to develop new regulations or revise regulations is establishing a technical advisory group or a task force to support the Planning Commission or the Board of Supervisors. The City of Charlottesville has a number of task forces which represents the public, with stakeholders and home owners. Currently the Citizen's Environmental Task Force is discussing LID. Especially, the members of these task forces are from different local and regional

environmental groups and planning districts, therefore, the input from various groups can be integrated into the City's decision making process.

Examples of task forces from other localities are Fairfax County which has the Environmental Quality Advisory Group (EQAG), the Engineering Quarterly from Spotsylvania County and the Better Site Design roundtable from Stafford County. All of these were formed to support LID adoption.

9) Incentives

Another form of LID adoption in local government is incentive programs. Incentives are considered as an effective tool to encourage LID in local governments. For example, Maryland uses an incentive tool such as the reduction of required volume for the permanent pool of a wet pond if green roofs are used for on-site LID practices. Green roofs allow rooftop areas to be subtracted from the total impervious areas. Additionally, the impact fee is smaller for LID projects because they are considered to have less of an environmental impact (EPA, 2007).

Various types of incentives are promoted through several reports. For example, a recent LID manual by the Southeast Michigan Council of Governments (2008) presented a number of incentives to be implemented at various levels of government:

- Allow for a state income tax credit for qualifying LID techniques.
- Offer a bonus such as increased floor area (e.g., floor area ratio) if LID practices are used that accomplish stormwater management goals.
- Accelerate plan reviews for site plans implementing LID techniques.
- Reduce fees charged to the applicant (e.g., plan review fees, utility fees) for site plans implementing LID techniques.
- Offer a density bonus (e.g., allow for an additional lot) to developments that implement LID practices.

- Initiate a recognition program for sites using innovative stormwater management.
- Provide free technical assistance to projects implementing LID techniques.
- Focus grant money on LID implementation such as funding demonstration projects, tours, Web sites, technical assistance, and other educational materials.
- Provide credits on stormwater utility fees to users implementing LID techniques.

For example, Stafford County employs an incentive tool like relaxing standards on development permits by waiving curb and gutter requirements if developers use LID practices and site design principles. The City of Roanoke utilizes fast track processing for innovative stormwater management methods.

Table 7 Levels of LID Adoption

#	Locality	Adoption mode	# LID	Code details	LID manual	Demonstration project	# project after code adoption	Education programs	Task force	Incentives
1	Amherst	Voluntary/ Inactive	1	Appendix A. zoning & subdivisions	None	About three LID projects- biofilters, rain gardens	2 rezoning cases- LID being encouraged	For contractors and landscape architects	None	None
2	Bedford	Voluntary/ Inactive	1	Ch7. Erosion & Sediment Control	None	None	None	None	None	None
3	Charlottesville City	Voluntary/ Active	8	Ch 34. Zoning- Special use permit	City Standards & Design Manual; LID worksheet	Lists of demo project- by public and private sectors	Many rezoning and LID cases	LID training and workshop for staff	Green infrastructure; Citizen's Environmental Task Force	None
4	Chesterfield	Voluntary/ Inactive	7	Ch19. Zoning- Upper Swift Creek	None	A lot of Filterra; fire station (2009), Schools (2005) Community Development; Building (2007)	None	LID Workshops for engineers	None	None
5	Fairfax	Voluntary/ Active	1	Ch122. Tree conservation- tree canopy for LID	Public Facilities manual	Green roof project and many more	Difficult to measure but more projects	A letters to industry; local education effort	Environmental quality advisory group (EQAG)	None
6	Isle of Wight	Voluntary/ Inactive	2	Appendix B. Zoning- Overlay districts& Vehicle parking facilities	None	Riverside health services building parking lot.	None	None	None	None
7	Roanoke City	Voluntary/ Inactive	6	Ch11.4 SWM Ch36.2 Zoning	2007 SWM design manual	Pervious pavers (city, Roanoke River greenway); Fishburn park- rain gardens; infiltration trenches for single family house; green roofs	Difficult to measure; incremental and cumulative effect	None	Ad-hoc for stormwater ordinance	Fast track processing; LEED 10% tax rate reduction for 5 yrs
8	Roanoke	Voluntary/ Inactive	4	Ch23. SWM Appendix A. Zoning	None	Bioretention (High school)	None	Education programs that mention LID	None	None
9	Spotsylvania	Voluntary/ Active	28	Ch12. SWM Ch20. Subdivisions	Design standard manual	Church, commercial development; bioretentions; and many more	Impossible to count; LID offered to every project	Engineer quarterly; semi-annual meetings; LID work sessions	Use engineer quarterly as technical advisory group	None
10	Stafford	Mandatory/ Active	32	Ch21.5 SWM Ch22. Subdivisions Ch28. Zoning	SWM design manual (2007 update)	County building and many more - Filterra, permeable pavers, bio-retentions	Over 100 projects; all types of new development	Training class for engineers/ surveyors; maintenance class for staff	Better Site Design Roundtable- Adopted LID principles	Relaxing standards on curb /gutter for developers

For the next step of the analysis, the summary of ten localities (Table 7) was classified into four categories: none, low, moderate and high level of adoption. These four categorical values were converted into numeric values: None (0), Low (1), Moderate (2), High (3). These values were then added up to get a total score for each locality. The ranges of total points were from 3 to 26.

In Table 8, the results of the numeric calculation were used for categorizing ten localities into three groups: low, moderate and high level LID adoption. The localities having less than 10 points were labeled as "low level LID adoption". The localities have a total point between 10 and 20 were categorized as "moderate level LID adoption". At last, the localities have a greater than 20 points were labeled as "high level LID adoption" localities.

Table 8 Codifying the level of LID adoption

Locality	Adoption mode	# LID Code	Code details	LID manual	Demo-project	# project after adoption	Education program	Task force	Incentive	Total score	Adoption Level
Stafford	High	High	High	High	High	High	High	High	Mod	26	High
Spotsyl-vania	Mod	High	High	High	High	High	High	High	None	23	High
Charlotte-sville City	Mod	Mod	Mod	High	High	High	Mod	Mod	None	19	Mod
Fairfax	Mod	Low	Low	High	High	High	Mod	High	None	18	Mod
Roanoke City	Low	Mod	Mod	Low	Mod	Mod	None	Low	Low	12	Mod
Chester-field	Low	Mod	Low	None	Mod	None	Mod	None	None	8	Low
Amherst	Low	Low	Low	None	Low	Low	Low	None	None	6	Low
Roanoke	Low	Low	Mod	None	Low	None	Low	None	None	6	Low
Isle of Wight	Low	Low	Low	None	Low	None	None	None	None	4	Low
Bedford	Low	Low	Low	None	None	None	None	None	None	3	Low

None (0), Low (1), Moderate (2), High (3)

The geographical distribution of the final three groups of localities (low, moderate or high level of LID adoption) presented in Figure 5 also reveals that localities within the same category of LID adoption are geographically closer than others. Even though it is hard to generalize the impact of

geographical proximity, it is fairly noticeable that the localities like Fairfax County, Spotsylvania County, and Stafford County located near the Washington D.C. area show relatively a higher level of LID adoption than the rest of cases.

Figure 5 Geographical distribution of localities with three levels of LID adoption

GIS data source: National Transportation Atlas Database (2009) Retrieved from U.S. Department of Transportation (US DOT), http://www.bts.gov/publications/national_transportation_atlas_database/2009/
2009 TIGER/Line® Shapefiles for Virginia, Retrieved from U.S. Census Bureau http://www2.census.gov/cgi-bin/shapefiles2009/state-files?state=51

4.2 Determinants to the level of LID adoption

This chapter consists of two sections: case descriptions and a matrix of determinants. First, the case description includes general characteristics and development patterns of a locality. The information for each case description was collected from interviews and document reviews and it. Second, four constructs of determinants were compared in a matrix format to identify influencing factors for LID adoption by localities within the same level of LID adoption.

The following four categories of determinants are developed based on the theoretical framework for this study: 1) characteristics of LID, 2) characteristics of local government, 3) motivations to LID adoption, and 4) organizational context.

The first category to be considered is the characteristics of LID. Many advocates of LID are usually promoting the economic advantages of LID by using bioretention, grass swales, and LID site design principles instead of conventional methods. Hydrologic efficiencies of improving water quality and reducing water quantity as well as aesthetic benefits are revealed as influencing factors for LID adoption. Some localities are actively involved in implementing LID because they find the relative advantages of LID over existing stormwater management system. Compatibility with existing practices and visibility of pilot projects or successful demonstration projects are also considered as influencing factors to LID adoption. The primary data for this research used face-to face interviews with key persons from local governments and NGOs. Local planning and engineering staff persons usually provide necessary information to elected officials and developers in localities.

The second category measured is the characteristics of local governments which have a direct influence on local LID adoption process. Therefore, the characteristics of each county and city have been investigated using the following criteria:

- Identifying the responsible agency: for example, planning department, environmental engineering department, public works and public utilities
- Financial, technical, and human resources of cities and counties: staff numbers, staff expertise, funding capacity
- Presence of LID champion in local governments

The third category is motivation to LID adoption. Motivation is one of the driving forces for making changes. For example, some localities adopt LID relatively earlier than other localities because they are in need of change due to severe environmental problems. Above all, heavily urbanized localities

are normally confronted with stormwater quality and quantity problems caused by increase of impervious surfaces which generate nonpoint source pollution and excessive stormwater runoff. Some localities have to look for alternative methods to resolve stormwater issues due to the frustration with traditional methods. On the other hand, emergent new technology and learning about new things becomes a motivation for local staff and elected officials to adopt LID. In that case, educational seminars and workshops play a significant role for LID adoption.

The fourth category is organizational context. Federal and state mandates for stormwater management are assumed to play a crucial role in adoption process. Along with this vertical influence, horizontal level influence from neighborhood localities with successful LID adoption cases may pressure local government to adopt LID. Other factors to explore are pressure from environment organizations and interest groups and political and demographic characteristics of localities.

4.2.1 Localities with high level of LID adoption

1) Stafford County

Stafford County faces severe development pressure and the predominant land use of developed land is residential development, primarily single family detached. Yet nearly eighty-five percent of the existing land use is forested, vacant, institutional, agricultural, or low-density residential (Stafford County, 2003).

Stafford County is under the NPDES Phase II permitting requirements. According to the 2000 census, urbanized areas are required to have a permit for MS4. The county is also in the Chesapeake Bay Preservation Area. The county's zoning, subdivision, erosion and sediment control and stormwater management ordinances regulate land use and site development.

LID was mentioned in Chapter 3 (Analysis of the Natural Environment) of the county's comprehensive plan in February, 2003; "Encourage development designs which complement rather than disrupt the natural environment, including Low Impact Development designs. Low Impact Development (LID) practices should be encouraged for stormwater management." The language of encouraging LID in the plan is very aggressive as it said that "LID should be encouraged".

The county's overall stormwater management ordinances started in 2000-2001. In 2003, the county adopted the revised stormwater management ordinance and had an option for low impact development in addition to conventional stormwater management. In 2004, the county went a step further and required the use of LID on new development projects. "The stormwater management concept plan shall utilize to the maximum extent practicable low-impact development site planning in accordance with the low-impact development design manuals."

Later, the board changed LID to be a requirement that new development projects have to evaluate the use of LID technologies on their site and implement to the maximum extent practicable. During late 2007 and early 2008, the stormwater management design manual was updated on some incentives. The county also provided demonstration project facilities in the County Administration Center parking lot to show successful adoption of LID practices.

The Stafford County Department of Planning and Zoning is responsible for the review of stormwater management plans that have been prepared for development projects (Stafford County, n.d.).

LID in codes and ordinances

Stafford County has a standalone stormwater management chapter and the national LID manuals (EPA 841-B-00-003, June 1999; EPA 841-B-00-002, June 1999) are incorporated into stormwater management ordinances as reference.

The county adopted LID in three sections of their codes and ordinances: stormwater management, subdivisions and zoning ordinances. First, in chapter 21.5 Stormwater Management section (e), the use of LID site planning strategies and practices is encouraged as stormwater runoff control measures. For example, stormwater runoff from parking lots is required to be treated by infiltration facilities or bioretention filtering systems. The county stormwater management codes basically require that LID be evaluated for all new development projects by saying "The stormwater management concept plan shall utilize to the maximum extent practicable low-impact development site planning in accordance with the low-impact development design manuals (Section. 21.5-4. Stormwater management plans)." Consequently, LID became the first option for stormwater management in Stafford County and all new development projects are considering LID before opting for conventional stormwater management.

Second, in chapter 22 Subdivisions (Article VII. Streets and sidewalks- Division 5. curb, gutter, and sidewalks), the evidences of support for LID use are also provided by saying that "engineered vegetated swales" may waive curb and gutter requirements with lots larger than 10,000 square feet.

Third, LID is adopted in Chapter 28, zoning ordinances section. Article IV. Planned Development and Overlay District regulations require parking materials to be waived for LID sites with pervious paving blocks and other similar materials. Landscaping for LID facilities is allowed in required parking lot landscaping areas and this may count toward landscaping requirements in County Zoning ordinances. The adoption in zoning ordinances appears to provide some incentives for LID adoption.

2) Spotsylvania County

Spotsylvania County is one of the fastest growing counties in the nation; the Census Bureau reported that the population of the county in 2007 increased 32 percent since 2000. The county emphasizes the goal of maintaining a high-quality environment by managing growth as well as preserving the natural environment in the county's comprehensive plan (Spotsylvania County, 2008).

Especially, the comprehensive plan recognizes LID as one of the tools to protect air quality. A quote from the plan said "Protect air quality through local ordinances by researching and promoting a holistic approach to air quality management. Examples of approaches to accomplish this could include: green space, tree preservation, stream restoration, low impact development (LID), and Leadership in Energy and Environmental Design (LEED) guidelines (Chapter1. Introduction and vision: A. Growth shall preserve or enhance our natural environment)."

It is rather unusual to promote LID as a tool for air quality protection. However, the county recognizes and allows LID language in comprehensive plan. The county is in CBPA and NPDES Phase II community and MS4. The county has a standalone stormwater management ordinance and its own design manual. Local ordinances are considered as a major control measure to accomplish the county's goal of protecting the environment and managing growth. In terms of LID, it was adopted in local zoning, subdivision, and stormwater management ordinances as one of the alternative measures of stormwater and growth management.

LID code adoption was approved on May 13, 2003 at the Spotsylvania County Board of Supervisors' meeting. The board adopted an amendment to the Spotsylvania County Code (Chapter 19A, Stormwater Management Ordinance in Sec. 19A-21.) to include LID as one of non-structural stormwater practices to reduce the volume of stormwater runoff. By incorporating LID, LID practices and principles in the county would help to minimize the reliance on structural practices, which require ongoing maintenance in order to be effective.

LID in codes and ordinances

The county's planning commission is established to support the Board of Supervisors by recommending any updates to the comprehensive plan, zoning, site plan, and subdivision ordinances. LID code adoption process is also recorded in county's planning commission meeting minutes in detail. The following description illustrates the historical background of LID program in the county.

- July 17, 2002

The planning commission meeting minutes (July 17, 2002) reported that the Friends of the Rappahannock (FOR) encouraged the LID approach to site design and stormwater management. This recommendation was particular to the Massaponax Watershed Planning Study but was not applicable for the entire county. This process began to build the partnership between FOR and planning staff.

- April 16, 2003

Amendments will also be made to the Water Quality and Quantity sections. The proposed water quality criteria were taken from the Chesapeake Bay Preservation Ordinance. Instead of having differing criteria to meet the standards of the two ordinances, one criterion can be referenced to meet both. The Water Quantity Section will now be broken into three sections, a section for flooding, stream channel erosion and low impact development sites. The key changes in these ordinances is the use of the one-year extended detention method for releasing runoff from stormwater ponds and the introduction of Low Impact Development. The inclusion of the LID into the ordinance makes this an option that may allow sites to be developed without stormwater management ponds.

The planning commission and the county staff recognized the importance of LID word adoption in the codes and ordinances by saying that "amendment would put the language into our ordinance, giving developers the opportunity to use LID. He stated that by no means does approving the amendment require developers to use LID."

These meeting minutes also revealed the communication between the Department of Conservation and Recreation (DCR) and the county. The DCR reviewed the county's stormwater management program to ensure consistency with state regulations and the DCR promoted LID as a good alternative for stormwater management.

The planning commission asked for more information on LID which included scientific evidence, cost effectiveness and promotional approaches. The planning commission worried about making LID as an option because it could miss opportunities for utilizing LID.

"Mr. Ervin asked if the county would be waiting for the applicant to use LID or would the county be recommending the use. Mr. Edwards stated that the use of LID would be voluntary but LID sites could be encouraged rather than the use of Stormwater Management ponds, depending on the type of development proposed. Mr. Ervin stated that if we give the applicant the option, that we might miss opportunities."

- May 13, 2003

The actual adoption of the amendments on the code as well as including amendments to the Spotsylvania County Design Standards Manual and adoption of the Virginia Stormwater Management Handbook and two Environmental Protection Agency Low Impact Development manuals. The County had to take an action to the code amendment due to a strict deadline of May 15, 2003 for adoption of the amendment for corrective action agreement with the State of Virginia.

- July 16, 2003

There were two informed LID work sessions arranged by an environmental engineer staff to speak about LID to the commission members. The LID professionals from private sectors provided information about LID which included concepts of LID, comparison between conventional stormwater management versus LID and their experiences with using LID in development. Some commission members still worried about putting LID in the codes so quickly.

LID language is adopted in two sections of local codes and ordinances. The standalone stormwater management ordinances (Chapter 19A) have a greater number of explanations on general LID definitions and technical criteria and Chapter 20, Subdivision ordinance mostly addresses the maintenance issues of LID.

Chapter 19 A (Stormwater Management) stated the four standard references of LID: Virginia Stormwater Management Handbook; Spotsylvania County Design Standards Manual; Low-Impact Development Design Strategies: An Integrated Approach (ref. EPA 841-B-00-003); Low Impact Development Hydrologic Analysis (ref. EPA 841-B-00-002). These four references include specifications and standards of LID facilities and utilization.

When any developer plans for land developments in the county, the stormwater management plan should be submitted and approved by the program administrator. LID is encouraged by the county as non-structural stormwater practices (Sec.19A-21 (p)) in accordance with existing federal, state or Spotsylvania County laws, ordinances, regulations or policies.

In Chapter 20, Subdivisions, the need for maintenance responsibility is stated by saying that "(v) All subdivisions including those containing on lot LID integrated management practices must provide restrictive covenants stating that the homeowners association is responsible for any maintenance of the facilities and that in the event of default by the homeowners association all lot owners are equally responsible for the maintenance."

According to a local official, the enforcement of LID was sporadic at best. About 3- 4 years ago, only about 1 project out of 30 projects would adopt LID. The situation changed after the county hired a full time LID specialist. Education programs were developed for the development community on what LID is and how it works for their advantage.

From LID adoption stand point, the most important turning point happened to be a decision made by the planning commission. About three years ago, the planning commission announced that "we want a minimum of 20% LID on every project that comes in here." According to a county staff, "once the planning commission said that, that was it. We could push it on everybody." Now every project like rezoning, specific use permit site plan and subdivision offers LID in the county. LID is an option that is available to all developments.

4.2.2 Factors influencing localities with high level LID adoption

Stafford County and Spotsylvania County were determined as high level LID adoption localities. Both counties have adopted LID in local codes and ordinances in 2003. In order to identify the influencing factors for LID adoption, four categories of grouped determinants were compared in table 9.

1) LID characteristics

It was critical to discern the characteristics of innovation itself to understand how these characteristics were perceived by adopters and how influential these characteristics were in innovation adoption process. The applied criteria for LID characteristics were concept and definition of LID and its complexity, advantages of LID, and presence of LID pilot projects.

First of all, both Stafford and Spotsylvania counties perceived LID as simple and straightforward. Both were concerned that some confusion existed over LID definition but they claimed that LID is simple and easy to understand.

Secondly, both counties well aware of a full spectrum of LID advantages compared to conventional stormwater management techniques. Especially, the multi-functionality of LID was appealing to local staff and officials. For instance, an environmental engineer from Spotsylvania County

emphasized the economic benefits of using LID one of which was saving cost from long term maintenance. Staff members from Stafford County mentioned the importance of hydrologic and aesthetic benefits of LID practices and strategies.

At last, these two localities have numerous LID pilot projects on church properties, county buildings, and residential and commercial development. For example, Stafford County has several LID practices installed in parking lots of the county buildings. In 2004, the county installed two bioretention areas and then also installed one Filterra which is a manufactured product. A demonstration project for permeable pavers is installed in the parking lots of another county building. They were both funded through grant money partially funded through DCR.

2) Characteristics of local government

The criteria used to examine the local government characteristics are 1) size of responsible agencies for LID adoption, 2) available resources in local government, and 3) presence of a champion. The responsible local government departments for LID adoption were the planning department, the environmental engineering department and the public works department in both counties. Most importantly, the collaboration among local departments turned out to be the essential criteria for the adoption and implementations of LID. The size of responsible agencies was based on the number of full time positions of each responsible department.

Available county resources like staff and funding for LID adoption for both counties showed very different patterns to approach LID. Stafford County has quite a few staff members who are actively involved in LID related work. They did not have special training programs or opportunities available only for LID but existing departments and staff members naturally have embraced the need of LID program. The county has invested on LID by installing several LID type facilities in the county's development projects.

On the other hand, Spotsylvania has a very limited number of staff who is active and knowledgeable about LID. Actually, only one environmental engineer was in charge of LID program. Due to the economic downturn and budget cuts of the county, a junior engineer who supported LID program implementation was fired and there was no funding for any aspect of LID development.

Above all, Spotsylvania County heavily relies on LID education program and interactive relationship with the local development and engineering community. Specifically, engineer quarterly meetings and semi-annual meetings with the local engineers and developers have been a venue for sharing information and educating end-users of LID. Funding needs for these meetings are usually resolved by sponsorship from vendors or the county look for the funding from external sources. A staff said that: "What we tend to try to do is look for the small state and federal grants that will help us with education and outreach. Sometimes we work with the soil and water conservation district. And we dealt with FOR several times. We try to work together."

Both counties had champions who advocated LID adoption but they took considerably different paths for the role of champion. In Stafford County, one board member and a local NGO, Friends of Rappahannock (FOR), played a crucial role for LID adoption in the county. FOR sponsored a number of work groups to educate the local government about LID practices. Two very different patterns are presented in the characteristics of champion. Stafford County has a NGO and a willing elected official, on the other hand, Spotsylvania County has a strong advocate staff person. In case of Spotsylvania County, a staff person became a key player of LID program adoption in the county. He has all the knowledge and experience that drives the county's LID program. There are some concerns about this person becoming absent which will cause chaos in the county's LID program.

3) Motivations to LID adoption

According to a recall from staff members who participated in the interview, a big storm around 2001 encouraged everyone to seek alternative stormwater control measures in Stafford County.

Environmental issues like drainage, flooding, and erosion control problems created by a storm event politically inspired elected officials in the county and that became the motivation to LID adoption.

Very similar to the Stafford County case, the motivation to adopt LID for Spotsylvania was frustration with traditional stormwater management measures. The traditional method only caused continual drainage, flooding, and erosion control problems in downward streams. A staff champion specifically raised the importance of the problem and educated local developers and engineers as well as local staff about LID. Above all, this staff person emphasized the importance of building a trustworthy relationship between local developers and engineers and the county which showed local developers and engineering groups what they could do with LID.

4) Organizational context

Both counties have been under CBPA and MS4 so they should be aware of environmental issues. Both counties have seriously considered water quality issues. Regarding influence or pressure from federal and state regulations for LID adoption, staff members from both counties stated that there was no direct influence whatsoever because they adopted LID even before the federal and state requested. Currently, they are doing more than what the state laws require them to do. The requirements to meet water quantity and quality standards by federal and state regulations are considered duplication for them.

According to a staff member from Stafford County, "The federal and state policy guidance is helpful for us because it validates our work. And also keeps us on track. Policy makers do change over time and the emphasis changes over time but having that in the background is helpful." In this point of view, we can say that NPDES, VPDES, MS4, and CBPA strongly influence the county's LID adoption. It is not directly affecting the LID adoption process but it is rather a support for continuing the county's LID implementation efforts. For example, a Spotsylvania County staff stated that MS4 actually help the county to install and monitor BMPS. Stafford County staff members also stated that those requirements are not directly influenced for LID implementation but "They are helpful in setting a requirement, what

percent is a quality control, what year stormwater control, and things like that. They provide us a guideline but not specifically help for LID."

Regarding the pressure from neighborhood localities, there was no direct or indirect influence from surrounding localities because both counties were the first localities which adopted LID in the regions. Both counties considered themselves as leaders in the region.

The pressure from environmental NGOs was a key factor for LID adoption in both counties. The NGO called Friends of Rappahannock (FOR) had the loudest voice and actually got people to look at LID. In particular, FOR put forth an effort to educate local developers and also provided seminars to elected officials and staff members so they could build a strong partnership with local development communities and local government staff.

In response to the question of whether the county was influenced by model codes and ordinances developed by other localities or federal and state governments, both counties stated that there was no influence from model standards or codes. In the case of Stafford County, their LID codes and ordinances were a model code to other potential localities. According to a staff member, "I think actually ours is the one that is kind of used as model now. At least until they kind of overhauled all the regulations". The EPA and the DCR provide the case of Stafford County as an example for LID education.

At last, geographic, demographic, and economic characteristics of Spotsylvania and Stafford County were reviewed in recent reports of U.S. Census Bureau. Both counties are very urbanized and have very high population density. The geographical proximity to the Washington D.C. metropolitan area and Interstate 95 (Figure. 6) has caused development pressure and population growth in the region.

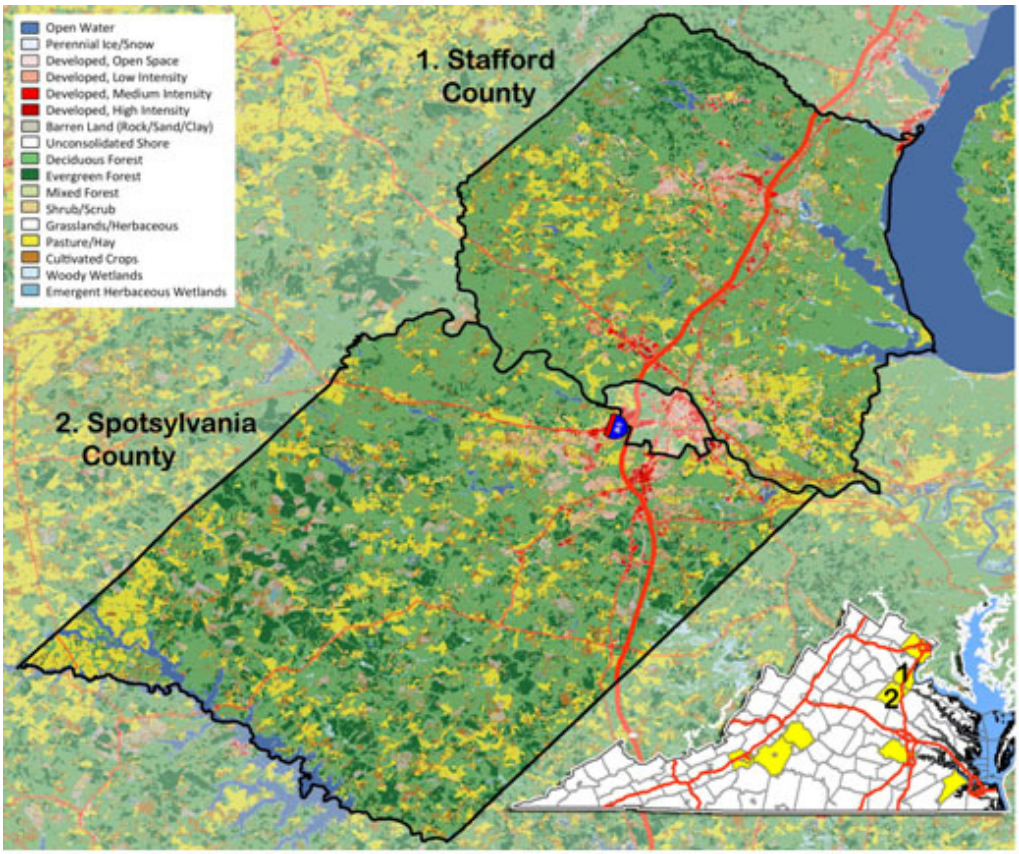

Figure 6 Stafford County and Spotsylvania County: The National Land Cover Database (2001)
Data source: USGS National Land Cover Dataset 2001(NLCD): Retrieved from http://seamless.usgs.gov

According to the percent change of population from April 1, 2000 to July 1, 2008, Spotsylvania County (32. 80%) and Stafford County (31.70%) implied that there was an extreme increase in population growth compared to the average population change in Virginia (9.70%). In addition, persons per square mile (2000) is higher than the Virginia average (178.8): Spotsylvania County (225.4); Stafford County (342.4). At last, both counties showed fairly high Median Household Income (2007): Spotsylvania ($74,374); Stafford ($86,865); Virginia ($59,575). (Source: US Census http://quickfacts.census.gov).

Table 9 Determinants of high level LID adoption

Variables \ Localities		Stafford	Spotsylvania
LID adoption in code (Year)		2003	2003
LID characteristics	Complexity	Not particularly complex	Simple and easy
	LID advantages	Hydrologic benefits; aesthetic aspect; benefits of LID and from the long term aspect of community development	Hydrologic and aesthetic aspect; Economic is the last concern; LID can save cost through long term maintenance
	LID projects	Many LID projects are used to promote LID, especially, permeable pavers, bioretentions in county buildings and many more	Many LID projects are used for LID promotion: church, commercial development; bioretentions
Local Government characteristics	Responsible agencies (size)	Planning Department (25 persons); Public works dept (8 persons).	Planning Department (13) Code Compliance (38)
	Resources	2 engineers/ 4 inspectors/ 2 inspectors for post construction	1 staff from Code Compliance
		Engaged board member and a willing staff; training class for engineers/ surveyors; a training class on maintenance of stormwater facilities for staffs ; training budget in general	Engineer quarterly meetings; semi-annual meetings with engineers /developers
	Champion	Multiple county staff members Board of Supervisors	1 county staff; Planning Commission
Motivations to LID adoption	Environmental Frustration; New technology; Physical conditions	Environmental issues (damages from big storm in 2001)- inspired politically elected people; drainage, flooding, and erosion control problems (frustration with traditional method)	Continual drainage, flooding, and erosion control problems with traditional measures (Frustration)
Organization-al Context	Local characteristics	Urban; high population change; Median Household Income ($86,865)	Urban; high population change; Median Household Income ($74,374)
	Federal/State regulations or incentives	MS4; CBPA (Zoning Overlay; Chapter 28, Article IV, Section 28-62)	MS4, CBPA (Stand Alone; Chapter 118)
		No need of need federal CWA ; already did via state law and local ordinances	No influence; we actually had the adoption before they were; MS4 help us to approve, install and log BMPs
	Pressure from NGOs	FOR- education to development community; seminars to elected officials;	FOR
	Neighborhood locality pressure	A leader in the region	No influence
	Model code and ordinances	No influence, but the County's code is the exemplary model to others	No influence

4.2.3 Localities with moderate LID adoption

1) City of Charlottesville

The City of Charlottesville is very developed and fully built-out (Figure.7). According to a city official, the city is surrounded by waterways which are not in the best shape because of practices of the past. As a progressive community, the city is trying to use all of the available tools to minimize impacts on the natural environment. Because development pressure is higher and available land areas are very limited, it is important for the city to practice sustainable development. The protection of environmental resources is important in the city.

The city's approach to environmental issues is stated in the 2025 Vision Statement saying that the role of the city is "A leader in innovation, environmental sustainability, and social and economic justice." Above all, one of the city's goals is to be "a Green City" that provides a community with clean air and water, and greener environment. The city emphasizes recycling and reuse, and minimizing stormwater runoff.

The comprehensive plan (2007) recognized the importance of LID in Chapter 8, Environment section. The plan stated the goals of reducing the overall amount of runoff within the city and improving stormwater quality. To achieve these goals, the City emphasizes "the importance of using water quality protection strategies such as low impact development (LID) measures for new development and re-development projects within the city." LID is clearly defined as "techniques aim to protect the environment and water resources by attempting to replicate the pre-development hydrology of an area undergoing development by helping to infiltrate, evaporate, store, filter and detain stormwater." The suggested types of LID practices include bioretention (rain gardens), green roofs, permeable pavers, rain barrels and cisterns, soil amendments, tree box filters and grassed swales.

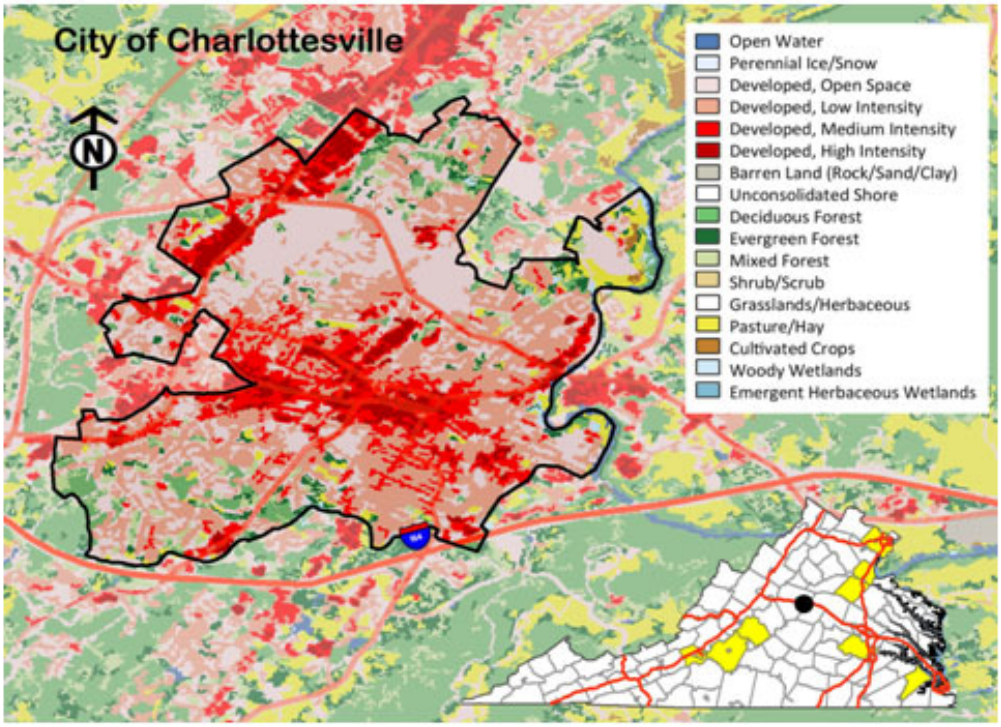

Figure 7 The City of Charlottesville: The National Land Cover Database (2001)

Data source: USGS National Land Cover Dataset 2001(NLCD): Retrieved from http://seamless.usgs.gov

As required by the EPA's Stormwater Phase II regulations created under the CWA, Charlottesville operates a stormwater management program. Since March 2003, the city has been covered by a Virginia Pollution Discharge Elimination System (VPDES) permit for municipalities with separate storm sewer systems. The city's permit requires certain actions to reduce the discharge of pollutants to the city's MS4 to the maximum extent practicable, to protect water quality, and to satisfy water quality requirements of the Clean Water Act.

A city staff said that typical policy adoption process in the city usually starts from informal encouragement and then the staff provides technical resources. In the case of LID, the director of neighborhood development services instructed LID uses, and from there a procedure was adopted and

later related language was adopted in the code. The city took the lead in promoting these measures and the community supported it.

A number of important city manuals and reports also described the city's LID adoption process.

- Stormwater guidance manual (BMP), 2005

  The city has been using the manual but it is going to be phased out due to the new state stormwater regulations. If developers want something not in that list, they have to prove that the requirement is matched with the bluebook. This manual is for the water protection ordinance; chapter 10 of the city code, article III.Stormwater Management.

- The Director of Neighborhood Development Services' Memo, 2006

  The memo stated a policy that all developers were to initially try to use LID design and show us why they could not use it. The memo was mailed out to all developers, designers, surveyors. Developers need to show at least they have tried before they adopt traditional methods and it needs to be a significant reason other than monetary.

- The city standards and design manual, 2007

  The manual contains everything about development and not is limited to stormwater. It has an official stormwater chapter. In Chapter 3 (Stormwater management), it states that " Sustainable stormwater management plan (SSWMP) requires all sites greater than 1 acre, all sites between 6000 sf and 1 ac must submit a SSWMP after it meets the requirements based on the preliminary drainage study. Part 1 and 2 of stormwater quality and quantity plan should consider LID components according to the Director of NDS's Memo."

LID in codes and ordinances (2006)

LID is adopted in Chapter 34 Zoning Ordinance in the section of special use permits (SUPs). According to the code, "for development including any non-residential uses, and developments proposing the construction of three (3) or more single- or two-family dwellings, the applicant shall provide a completed low-impact development ("LID") methods worksheet."

The goal of SUPs is used when land is not zoned for what developers want to use it for developers ask for SUPs so that, for example, an owner of a daycare in a house which is in a residential zone wants to do business there. In that case, developers should fill out an LID worksheet with a rating system and they have to get a minimum of 10 credit points to get the permit.

2) Fairfax County

Fairfax County is the largest populated county in Virginia (VEDP, 2009) and it is heavily urbanized (Figure 8). Since the early 2000, LID has been actively used in the county. In the 2007 amended comprehensive plan, LID was adopted LID throughout two sections: environment and land use. In the environment section, LID was encouraged for new development and redevelopment (Policy k). Better site design and low impact development (LID) techniques such as those described below should be considered where not in conflict with land use compatibility objectives:

- Minimize the amount of impervious surface created.
- Site buildings to minimize impervious cover associated with driveways and parking areas and to encourage tree preservation.
- Where feasible, convey drainage from impervious areas into pervious areas. Where feasible and appropriate, encourage the use of pervious parking surfaces in low-use parking areas.
- Maximize the use of infiltration landscaping within streetscapes consistent with County and State requirements.

In the land use section (Appendix, amendment; 12-3-2007), LID was encouraged to minimize development impact on water quality and to utilize the state's BMPs for stormwater management, better site design and low impact development (LID) techniques. Especially, Policy h mentioned that "Where appropriate and feasible, apply better site design and low-impact development (LID) techniques in park development to reduce environmental impacts of development."

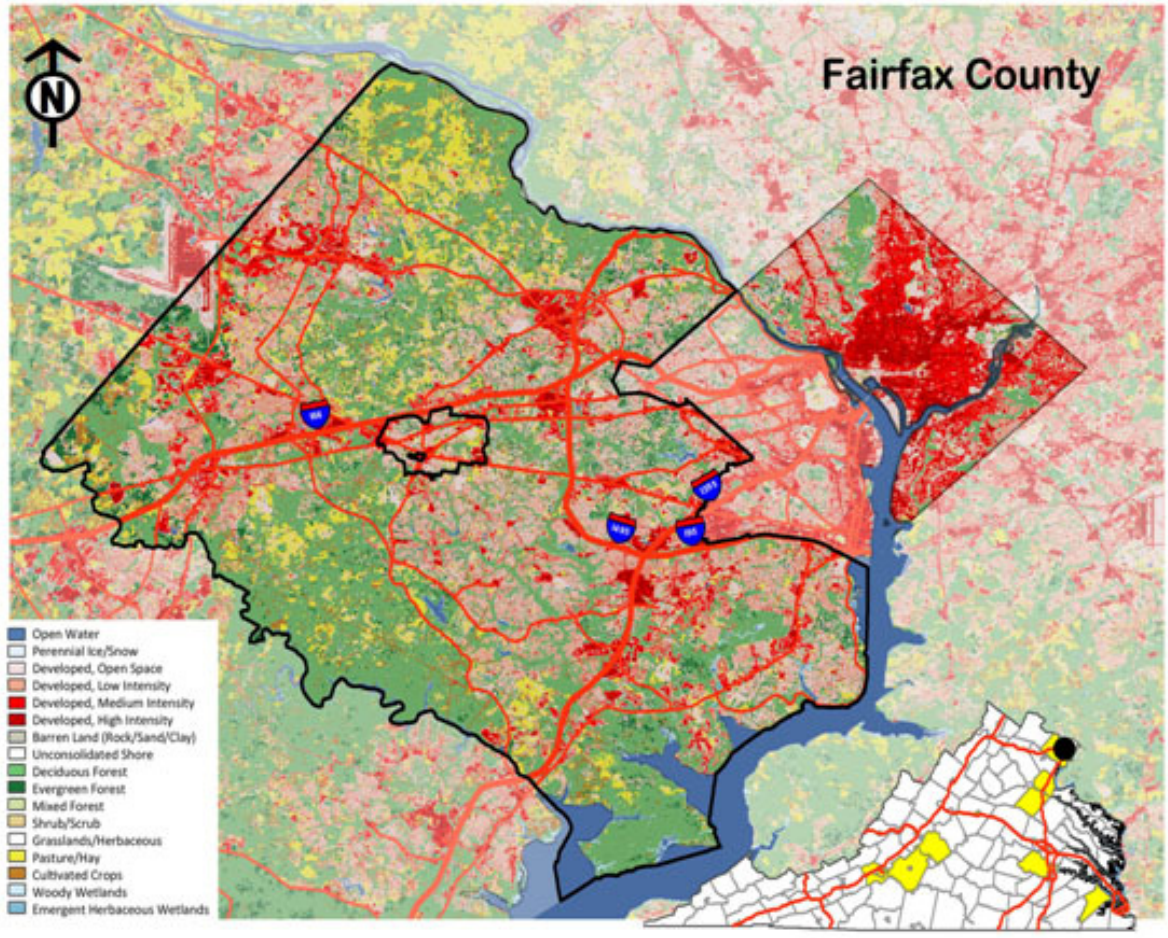

Figure 8 Fairfax County, VA: The National Land Cover Database (2001)

Data source: USGS National Land Cover Dataset 2001(NLCD): Retrieved from http://seamless.usgs.gov

LID policy adoption process

- 2000, October: Policy plan amendment supports the application of low impact site design techniques to reduce stormwater runoff volumes and peak flows to increase groundwater recharge and preserve undisturbed areas.
- 2003, March: The staff report on "The Role of Regional Ponds in Fairfax County's Watershed Management" has recommended a number of better ways to manage storm water runoff.
- 2004 MS4 report: Chapter 2, Capital Improvements and Infrastructure Retrofit mentioned Innovative BMPs in Fairfax County
- 2007 county letter to industry: Amendment to the Public Facilities Manual incorporating 6 LID practices (Public Facilities Manual: 6-1300 retention, detention, and low impact development)
- 2007 amended PFM and incorporated several LID techniques into our PFM to permit them to be utilized on the projects within the county and we have a typical procedure
    - PFM (construction standards)
    - Using some consultant services to produce the initial draft
    - Focus groups were organized to look at 6 LID practices for implementing and developing full design standard for it.

Along with references to the comprehensive plan (2007) and in the tree conservation ordinance (2006), the PFM has a large portion of LID. Currently, the county delayed publishing another LID manual to avoid any confusion with new state stormwater regulations.

LID in codes and ordinances

According to a county staff, LID is incorporated into a tree conservation ordinance which is considered as very progressive. The tree ordinance is very extensive and related to LID as it addresses the issues of protecting and improving environmental quality through green space. LID is mentioned one

time in Chapter 122. Tree Conservation Ordinance. Article 2. Tree Conservation during Land Development, "(b) Tree canopy credits shall be given to tree seedlings, shrubs and woody seed mix planted in large open spaces, low-density residential settings, or in low-impact development projects".

LID in Public Facilities Manual (PFM)

The ordinances are essentially used for listing requirements but there are certain public facilities that have to be prepared for development such as roads, sewer system, and stormwater management systems. According to a staff member, usually a lot of the site design concepts from LID occur during the rezoning process and LID is heavily related to PFM in the county. All of the technical details of how you design these systems are in the manual. The PFM states construction standards and 2007 amendments incorporate the six LID techniques which include pervious pavement, bioretention filters, vegetated swales, tree box filters, vegetated roofs, and reforestation into the PFM to permit them to be utilized on the projects within the county.

In addition, "Letter to Industry (July 16, 2007)" by the Department of Public Works and Environmental Services detailed the amendments on the LID portion. This letter is to inform all architects, attorneys, builders, developers, engineers, and permit services practicing in Fairfax County about LID practices.

3) City of Roanoke

The City of Roanoke is a fully developed urban area (Figure. 9). According to the city's Comprehensive Plan, *Vision 2001 – 2020*, the City of Roanoke is "a mature city in which most of the land has been developed for particular uses. Recent developments have been infill, renovation, or expansion of existing planned uses." The city placed value on sustainable development and providing livable

community to residents which sustains economic and environmental health. As a result, city planning is focused on Brownfield development, greenway planning, bikeway planning, and urban forestry planning.

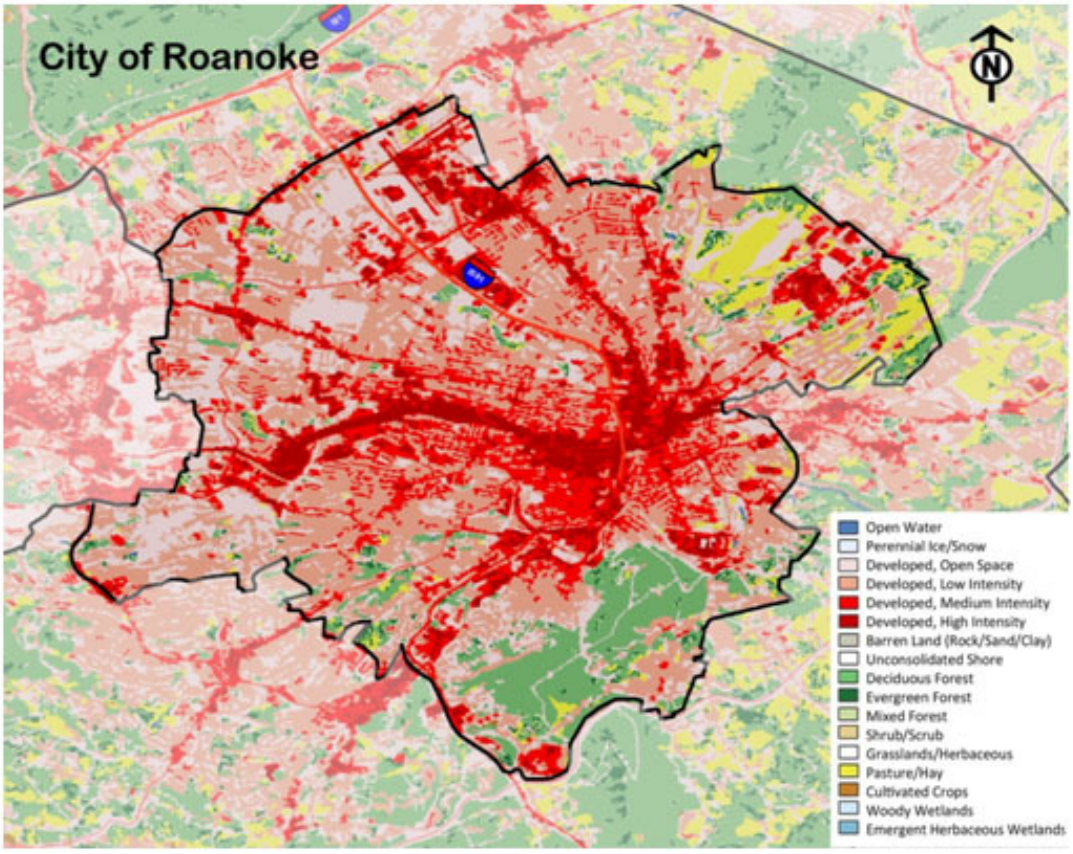

Figure 9 The City of Roanoke: the National Land Cover Database (2001)

Data source: USGS National Land Cover Dataset 2001(NLCD): Retrieved from http://seamless.usgs.gov

The city also recognizes the importance of stormwater issues by stating that, "Roanoke will protect the environment and ensure quality air and water for citizens of the region. Special emphasis will be placed on the Roanoke River and its tributaries. Stormwater management will be addressed on a regional as well as local level."

The City of Roanoke has issues with periodic flooding and non-point source pollution from storm water runoff due to increased development. The city's involvement with the stormwater management plan

started with 1998 regional stormwater management plan that recommended regional policies for stormwater management. The city is in Phase II of the National Pollutant Discharge Elimination System (NPDES) and has adopted a standalone stormwater management code (Ch11.4) in 2007.

Basically, the city uses four major ordinances to implement the comprehensive plan which includes subdivision ordinance, zoning ordinances, the stormwater management ordinances, and the erosion and sediment control ordinance.

First of all, the comprehensive plan called "Vision 2001-2020" states that the City of Roanoke emphasizes the importance of water quality in the Roanoke River and its tributaries and the role that stormwater management plays in meeting water quality objectives. The city also recognizes that innovative stormwater management practices are necessary to allow for continued development that maintains a balance of green space and tree canopy while reaching water quality goals. To that end, the city recognizes the importance of LID and green infrastructure principles in reaching goals for both aesthetically pleasing design and water quality objectives as outlined in Vision 2001 – 2020.

In new stormwater management ordinances, LID is regarded as a tool to deal with water quality and it was developed in conjunction with Roanoke County. The city and county got together and they decided to hire a consulting firm back in 2005 and 2007 to develop an ordinance and manual. The mandate by the state motivated the county and the city to adopt stormwater management ordinances together. These ordinances are applied to any land disturbance of 5000 square feet which is really a pretty small area.

The city also developed a stormwater management design manual in 2007 which has a section for use of LID/Green Infrastructure in chapter 2. The manual encourages the innovative way of dealing with or meeting the goal of stormwater runoff quality and rate and as long as they can shows that it will work they can use it. Other than stormwater management ordinances, embedded in zoning ordinances and subdivision ordinances, for example, are maximum parking regulations to reduce imperviousness.

In terms of LID adoption, LID is a voluntary option in the city and according to a city staff "as long as you get there, we don't really care how you do it. So you can prove that you can serve if they want to use very conventional techniques that are fine. If they want to use a more innovative technique, that's fine too. We don't say that you have to do it this way or this way."

LID in codes and ordinances

LID is adopted in Chapter 11.4, Stormwater management ordinances. In the code, nonstructural stormwater practices and LID practices are encouraged to be used to reduce the volume of stormwater runoff and to minimize the reliance on structural practices that require ongoing maintenance in order to be effective.

The city's objectives to be greener and reduce impervious is translated into changes in the ordinances. LID development measures may include but are not limited to," maintaining undisturbed naturally vegetated areas, minimization of impervious surfaces, stream buffer restoration, providing additional stream buffer areas, wetland restoration, water reuse and recycling, and development design that reduces the rate, time of concentration, and volume of stormwater runoff."

Chapter 36.2, Zoning listed an incentive for using LID practices that "exclusive of single-family detached dwellings, all off-street parking areas shall be bordered by a curb of concrete, asphalt, or other material acceptable to the Zoning Administrator. Curbing shall not be required if the applicant incorporates low-impact stormwater design practices consistent with the United States Environmental Protection Agency, low impact development Design Strategies: An Integrated Design Approach (June 1999) and low impact development Hydrologic Low Impact Development Hydrologic Analysis (July 1999)."

4.2.4 Factors influencing localities with moderate level LID adoption

The City of Charlottesville, Fairfax County, and the City of Roanoke are determined as localities with the moderate level LID adoption. To explore influencing factors to their LID adoption, four categories of grouped determinants are compared for three localities. The following sections provide the detailed descriptions of these factors. A tabulated matrix of the comparing factors is summarized in table 10.

1) LID characteristics

First of all, regarding complexity of LID definition, all three localities within the category of moderate level LID adoption said that LID is very complex. For instance, PFM amendments by Fairfax County showed how complex the LID adoption process was. A staff of Fairfax County said that "I don't know if there was any more complex than any other large amendment. It was a fairly large amendment to our PFM." An environmental engineer in the City of Charlottesville also said that "Things (LID) are very complex. From a regulation perspective, it's very hard to do because we don't always know the factors over on another side." One of the planners in the City of Roanoke also pointed out that "It's the most complex. Stormwater management requirements require engineering calculations of runoff, soils, how those affect runoff, drainage areas, it's just an extremely complex process and it is probably the most difficult aspect of development." Interestingly enough, a completely opposite perception toward LID definition has been found in the cases of moderate LID adoption.

Regarding LID benefits and advantages, all three localities answered that environmental sustainability and environmental benefits are the major reason why they adopted LID. In most cases, LID is considered as more green and it satisfies the requirements of city's objective to be greener. More specifically, the City of Roanoke and the City of Charlottesville are concerned with a "green image" for the city and they adopt many programs such as greenways, green infrastructure and urban forestry to

enhance the city's greener image as well as improving the city's urban environment with much greener measures. Other LID benefits which are recognized by localities are aesthetic/amenity benefits through LID based landscaping and hydrologic benefits (Fairfax) which can also satisfy the state requirements (City of Charlottesville). Interestingly, economic benefit was not even mentioned. Only Fairfax County mentioned economic benefit of LID, but it was to say that "economic benefit is not our concern; it's the developer's concern".

2) Characteristics of local government

This section focuses on the characteristics of local government which influence to LID adoption process. To explore the factors that have more impact on the localities with moderate LID adoption, three categories of factors are compared.

First, the case study identified the responsible agencies for LID adoption and their size in local government. Usually, a couple of departments in a locality are involved in LID adoption process. Because stormwater management is related to land use and public utility matters, the departments like Planning Building & Development, Neighborhood Development Services, Environmental Engineering as well as Public Works are partly all responsible to LID adoption. For example, the City of Charlottesville has three sections of departments that deal with stormwater management in the City: Neighborhood Development Services (NDS), Public Works Department (Maintenance), Public Works Department-Environmental Section (VSMP for MS4).

Second, financial, technical and human resources in local government that are available for the LID adoption process were compared among three localities with moderate level of LID adoption. Even though all three localities have not allocated specific funds or personnel for the LID program, a number of staff from planning and environmental engineering department s was available for the LID program. The localities in the moderate adoption category also have some funds for education programs for the staff and elected officials (Charlottesville; Fairfax). They even utilized a private consultant's help to develop

ordinances and manuals for LID. The education effort was not as extensive as the cases in high level adoption localities but there were some opportunities and support for LID adoption at the local government level. In addition, the LEED program stated some indirect incentives for LID adoption.

At last, the role of champions was also considered as an essential factor to the LID adoption process in Charlottesville City and Fairfax County. In the case of the City of Charlottesville, the director of neighborhood development services and a local private developer became advocates for LID adoption. In Fairfax County, an EQAG member appointed by BOS became a champion; in fact, a county staff said that "the county should be using LID. That the regional ponds are past practices haven't been as effective as should be." The Center for Watershed Protection (CWP), an environmental NGO, has played an active role in the region. The CWP communicated with other members of EQAG and worked closely with the state. On the other hand, the City of Roanoke revealed that there was no influence of a champion to the LID adoption process. After all, "there was a mandate from the state DCR for us to have in order for us to address the water quality in addition to the rate of runoff. But we went into together with the county…didn't need to be a champion. We had a mandate. We had to do it. It was a matter of. It wasn't a question of if."

3) Motivation to LID adoption

In the City of Charlottesville, pursuing a green city image and environmental concerns on stream protection became key motivations to LID adoption. The city sees itself as a green city and considers using more LID will increase the image of being a green city. A staff also said that "As a progressive community, we try to use all the tools available to minimize impacts on the natural environment." The city believes that encouraging LID can have less negative impact on the environment. In the case of the City of Roanoke, environmental concerns are the major motivation to adopt LID. The city cannot annex, therefore, it values greatly conserving the environment. They put great effort into improving the quality of

life and amenities of the city through urban forestry and green space. In fact, a planning staff said that "we have limited amount of land resources, so it's very important that we use it as efficiently as possible."

On the other hand, Fairfax County adopted LID due to a political reason. A staff said that "There were just pressures from environmental groups. Even some of our board members were saying that the county was behind the times that we weren't using the state of the art technology. A lot of them believed the county wasn't keeping up with modern day technology, and LID was the way to go." In addition, there was doubt about the effectiveness of traditional stormwater management methods. One of the county streams, Accotink Creek, was declared by the state as an impaired stream due to the failure of sediment control. According to a staff "there was a feeling that the traditional facility just wasn't doing the job they need to do in the environmental community. So that was a kind of the underlying political pressure from the environmental groups." Therefore, Fairfax County adopted LID because the county faced the combination of motivations from political and environmental pressures.

4) Organizational context

All three localities are heavily urbanized. The City of Charlottesville and the City of Roanoke are fully developed so that the percent of population change is very minor (less than 1%). Fairfax County also shows low population change of 4.70% which is less than Virginia average of 9.80%. Even though all three localities show very low population change, their population densities are extremely high. According to the U.S. Census report (2000), the average persons per square mile for Virginia are 178.8 and these three localities have extremely high population density: City of Charlottesville (4,390.70), City of Roanoke (2,213.40), and Fairfax County (2,455.10). As densely developed urban communities, they are designated MS4 communities. They have to meet MS4 requirements, especially satisfying six Minimum Control Measures (MCMs) to receive a permit to discharge stormwater into US waters (White, 2006).

Unlike the localities in high level LID adoption, all three localities claim that influence and pressure of federal and state level regulations were a critical factor for them to adopt LID. In fact, a Fairfax County staff was concerned with the impact of proposed new state stormwater regulation and he argued that "the state is getting ready to adopt regulations that pretty much are going to require we use LID or if developers want to use them and they propose them to meet the water quality and quantity standards we are going to have to accept them. So the state's role is huge even EPA is getting more active in." The condition is very similar in the City of Charlottesville and the City of Roanoke. The federal and state mandates are really an important factor for LID adoption. All three localities put forth great effort to meet the state requirements. In the case of the City of Roanoke, the mandate by the state has motivated the city to adopt a stormwater management ordinance with Roanoke County while incorporating LID concepts and principles in codes and ordinances. As a result, state mandates directly influenced them to adopt LID.

Moreover, the pressure from environmental NGOs was not a direct cause of LID adoption. Unlike the cases in high level LID adoption, the influence from NGOs was not apparent during LID adoption process. The influence came rather from individuals in those groups as they worked in task forces in localities (i.e., City of Charlottesville, Fairfax County).

At last, Fairfax County and the City of Charlottesville were influenced by neighborhood localities. From the perspective of sharing information, the technical information on sand filters for example, available in the City of Alexandria actually helped Fairfax County. According to a staff, "the city of Alexandria was pretty much on the forefront starting to use sand filters. And so, they did a lot of original research on sand filter design requirements…..the example of the Alexandria case incorporated into a supplement to the Northern VA regional commission's BMP manual. And so, there is transference from local counties to local counties that go on and so, some of the standards we developed for our PFM for the LID practices maybe used in Prince William County." In short, successful cases from neighboring localities helped them to persuade BOS members or planning commission members to adopt LID.

Table 10 Determinants of moderate level of adoption

Variables \ Locality		Charlottesville City	Fairfax County	Roanoke City
LID adoption in code (Year)		2006	2008	2007
LID characteristics	Complexity	Very complex	Technically complex	Most complex
	LID advantages	Benefit for meeting state requirements; Environmental benefits (sustainability, natural resources); Aesthetics/amenity for homeowners and citizens	Hydrologic benefits (improve water quality; water quantity control-stream erosion); Environmental benefits; Not much on economic concern	Environmental benefits: LID certainly tends to be more green; objectives to be greener and reduce imperviousness
	LID projects	Many LID projects (by public and private sectors) are used for LID promotion. Greenleaf Park rain garden(Grant from the EPA, the DCR)	Many LID projects are used for LID promotion. Providence Supervisor's Office (green roof, permeable pavers and a rain garden); green roofs	Pervious pavers (by the city). Parking areas with pervious pavement (aligned Roanoke River greenway); Fishburn park (rain gardens); infiltration trenches for single family house; green roofs
Local Government characteristics	Responsible agencies (size)	Neighborhood Development Services; planning and engineering (31peprsons)	Public works and Environmental Services- Stormwater management (139) (No LID staff but collaboration among agencies)	Planning Building & Development; Planning division (20)
	Resources (Financial, technical, human resources)	5 engineering inspectors for construction; 3 planners, 2 engineers for review; 6 engineers for BMP program	Relying on local engineering community (private)	1 development review coordinator (civil engineer); 2 development review engineers, civil engineers; planners
		Training for staff; Webinars with the county staff	A letters to industry on LID; local education effort	hired a private consulting firm to develop ordinance/manual
	Champion	The director of Neighborhood Development Services; City took the lead in promoting LID	Environmental quality advisory group (EQAG) committee members appointed by BOS	No champion- LID is adopted due to state mandate
Motivations to LID adoption	Environmental Frustration; New Tech Physical conditions	Green City Image, Environmental concerns, Dilapidating infrastructure	Pressure from Environmental groups; Traditional method not working; Environmental pressure from a special report on regional pond	State mandate; limited natural resources; conserving good environment; quality of life (amenities) and economic development
Organizational Context	Local characteristics	Ultra urban, very high population density (4,390.70) :	Ultra urban, very high population density (2,455.10)	Ultra urban, very high population density (2,213.40)
	Federal/State regulations or incentives	MS4	MS4,CBPA (Stand Alone; Chapter 118)	MS4
		Meeting the state requirements, Important factor (the existing standards will be phased out due to the new regulations).	Huge influence- required us to adopt LID	Mandate by the state motivated them to adopt SWM ordinance with the County (really important fact)
	Pressure from NGOs	Not directly related but individuals in those groups working in task force(James River watershed; Thomas Jefferson Planning district)	The Center for Watershed Protection (CWP)	There are some but not directly related to LID
	Neighborhood locality pressure	Albemarle County shows a good example.	Technical info from other localities (e.g. sand filter from the city of Alexandria)	No- only urban in the region- surrounded by rural areas; so far ahead of surrounding counties.
	LID model code	helpful; less resistance (a successful case is always helpful)	No- All localities have different system for putting LID.	No- we're very unique.

4.2.5 Localities with low LID adoption

1) Chesterfield County

Chesterfield is largely undeveloped however, as far as suburban growth in the surrounding region which is the Richmond area, the growth of the county exceeds neighboring localities (Figure.10). According to a county staff, stormwater management is a typical issue in a suburbanizing locality and it is not a high priority to most citizens or officials.

Chesterfield County has countywide Erosion and Sediment Control and is a CBPA as well as MS4 locality. Especially, the MS4 program motivated the county to implement more outreach programs.

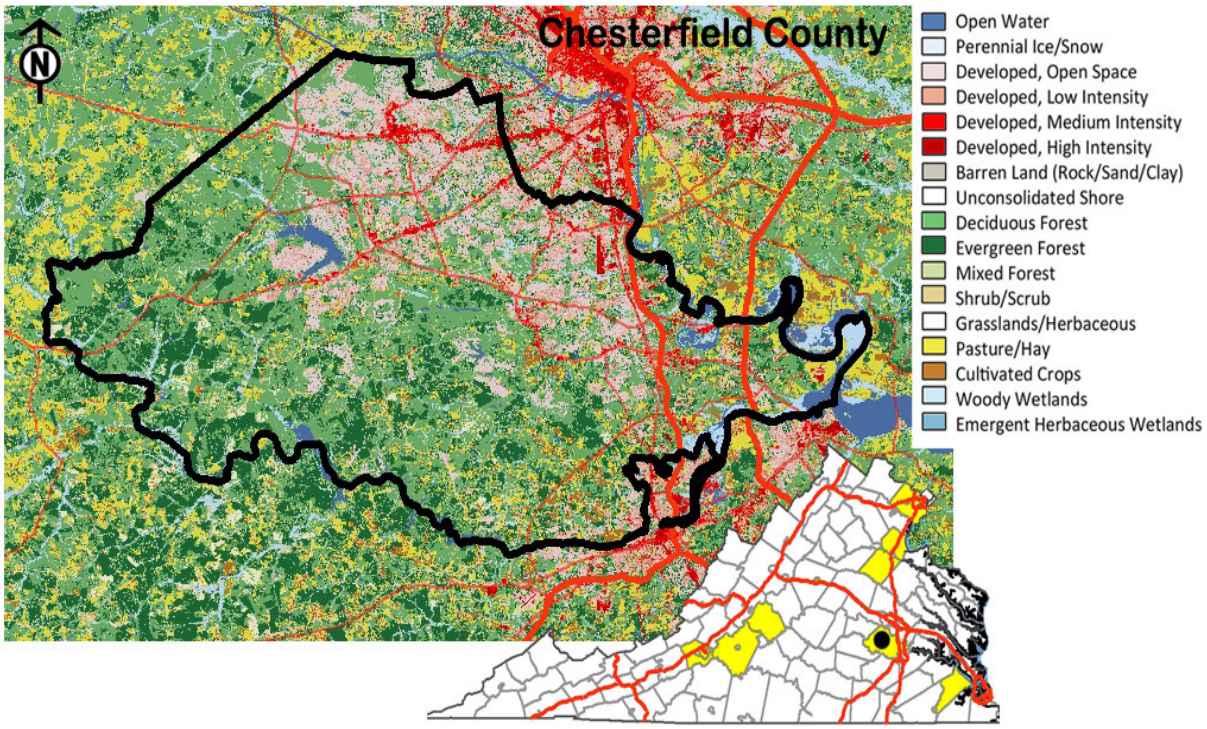

Figure 10 Chesterfield County, VA: The National Land Cover Database (2001)

Data source: USGS National Land Cover Dataset 2001(NLCD): Retrieved from http://seamless.usgs.gov

In the case of LID, it is considered and utilized on a case by case basis by Chesterfield. The county encourages LID which leaves it as a voluntary option for developers. In addition, the county is very open to innovation. For example, the county is very proud of being an LEED leader in the region.

There are no countywide policies or regulations for LID. The county is limited to the use of LID only on a specific watershed called the Upper Swift Creek Watershed to protect water quality in the region.

Policy adoption process

The process that the County used for adoption of LID was to have staff and consultants develop LID standards and manuals and then draft ordinances to implement the standards. Two public hearings were held to adopt those ordinances. One hearing was held at the planning commission, and then the Board of Supervisors held a public hearing based upon a recommendation submitted by the planning commission and made the final decision. Ultimately, the elected officials adopted the ordinance that caused the implementation of the standards.

However, making policy changes for the entire county takes a long time. By concentrating on environmentally sensitive areas, the County was able to put LID in their codes and ordinances. Currently, LID adoption is only applicable to the Upper Swift Creek Watershed area. The process of partial LID adoption was started in January, 2007 and done by the director of Environmental Engineering in the county. To change a group of ordinances in the watershed, the director of EE talked with eight individual stakeholder groups (i.e. developers, engineers, single family home developers, HOAs and environmental group called Hands Across the Lake (HAL), engineering department, planning department, zoning department, site planning group in the county). Then, he started to collect common ideas from all groups and used this as a starting point for a change.

LID in codes and ordinances (2007)

Chapter 19. Zoning

Article IV. Countywide Development standards

DIVISION 5. UPPER SWIFT CREEK WATERSHED

Sec. 19-238. Development regulations.

Any use, development or redevelopment of land in the Upper Swift Creek Watershed shall meet the following performance criteria:

(d) (1) Stormwater runoff shall be controlled to achieve the following:

a. For any new use or development, the post-development, nonpoint-source pollution runoff loads of phosphorous and lead shall not exceed the following:

(2) Compliance with the requirements of subsection (d)(1) shall be achieved on site through incorporation of best management practices including **low impact development** practices that achieve the required control, unless the director of environmental engineering determines that one of the following stormwater management options has been satisfied.

Article VII. Development standards manual

Secs. 19-514. Design standards for off-street parking

(d) Surface treatment

Except as detailed in the Environmental Engineering Department's Reference Manual, concrete curb and gutter shall be installed around the perimeter of all paved driveways and parking areas. Other curbing material of similar quality, such as brick or cobblestone, may be permitted through site or schematic plan review. In the Upper Swift Creek Watershed, an alternative means of defining pavement edges as determined by the director of environmental engineering may be substituted for curb and gutter when low impact development practices are used. Drainage shall be designed so as not to interfere with pedestrian traffic.

2) Amherst County

Amherst County is a very rural community with 18.5% of the county land in national forest (Figure 11). Development pressure is not high compared to other urban localities. Moreover, since the end of 2006, there has been less development due to national wide economic downturn.

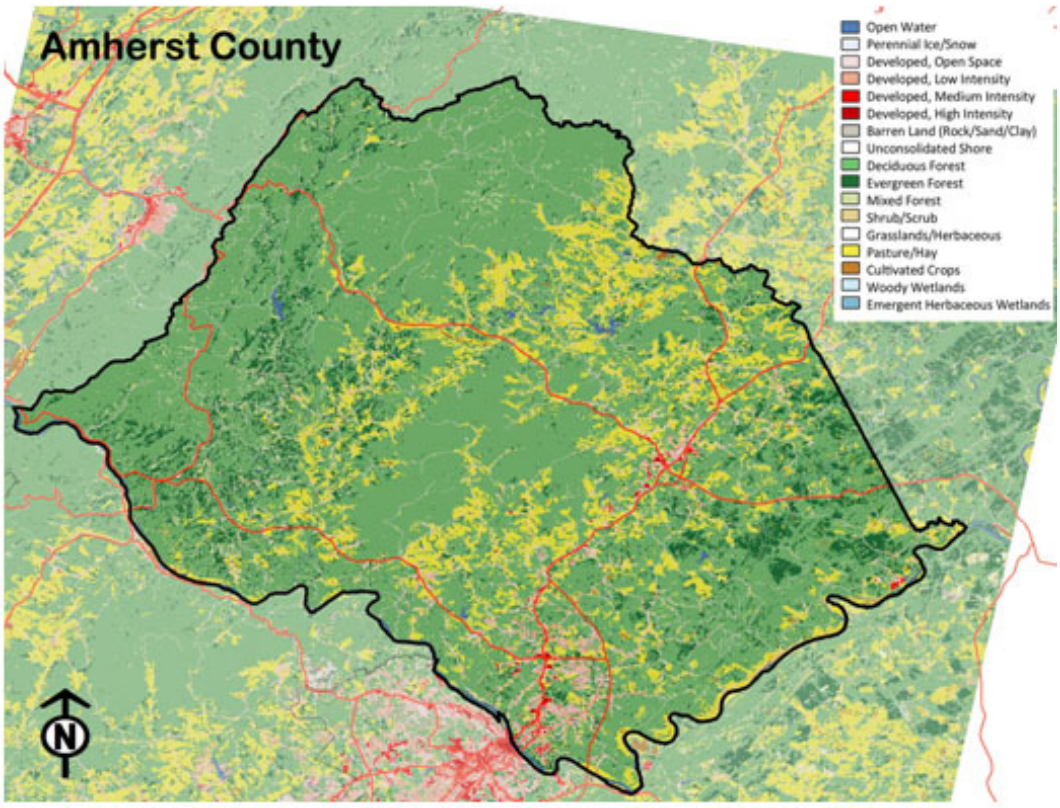

Figure 11 Amherst County, VA: The National Land Cover Database (2001)

Data source: USGS National Land Cover Dataset 2001(NLCD): Retrieved from http://seamless.usgs.gov

The county has managed stormwater issues in response to the state requirements. A county planner mentioned several times about the county's high dependency on the state requirements. For example, the county is "relying on the state regulations", "dealing with what the state requires local governments to do", and "people don't do it unless typically required".

The overall county's approach toward LID adoption is optional and voluntary. The county recognizes the benefits of LID techniques which are applicable to the entire county, even though current emphasis of LID adoption is limited to environmentally sensitive areas such as watershed protection areas (Amherst County, 2007). The timeline from 2004 to 2007 of LID adoption provides the details of how the LID program evolved in Amherst County:

- In 2004, a report on "Technical Assistance for Sound Land Use Tools" by Robert E. Lee Soil & Water Conservation District recommended LID adoption. It was a supplementary report for the county comprehensive plan.
- In 2006, LID was adopted in local codes and ordinances: Appendix A. zoning and subdivisions, Article IX. Special Provisions, 916. Short-term tourist rental of dwellings
- In 2007, LID was adopted in county comprehensive plan.

  Chapter 4. Community facilities- transportation

  Goal #2: To improve and preserve the safety, efficiency, and aesthetics of all roads.

  Strategies: Include Low Impact Development techniques in all road and parking design to minimize environmental impact.

  Chapter 6. Land use – Environment

  Goal # 3: Minimize the negative environmental impacts of new and existing residential, commercial, and industrial development.

  Strategies: Consider requiring the use of low-impact development techniques in the County's Zoning and Subdivision Ordinances. Adopt mandatory low-impact development standards for the County's Watershed Protection Districts and other environmentally sensitive areas. Also establish zoning and subdivision ordinance incentives for the use of these techniques in other portions of the County. Adopt available models to design a low-impact manual for Amherst County use.

Currently, there is no requirement from the state about LID uses other than just encouraging it; the county is neither in the Chesapeake Bay Preservation Area nor a designated MS4 community. As a result, there is very limited activity to LID adoption at the local government level. A county planner expressed his personal opinion by saying that "LID needs to be pushed down from the state level regulations to tie in with the stormwater regulations".

LID in codes and ordinances

According to Amherst Zoning and Subdivision ordinances, LID was adopted in 2006 and promoted for "Short-term tourist rental of dwellings", a type of cabins. This type of development is rare in this region; therefore, currently the use of this code is very limited.

Appendix A. Zoning and Subdivisions

Article IX. Special Provisions

916. Short-term tourist rental of dwellings

The following regulations shall apply to all short-term rentals of residential dwelling units:

1. Site Plan. Before a building and zoning permit shall be issued for any dwelling to be rented to transients for any period less than thirty (30) consecutive days, a site plan of the proposed development shall be approved by the planning commission or the zoning administrator, whichever is applicable, in conformance with Section 1003 and Article XI herein. In addition to the requirements thereof, site plans pursuant to this section shall include a maintenance schedule proposed by the developer or property owner, and shall incorporate low impact development techniques, such as those about which information is available from the Virginia Department of Environmental Quality. (Ord. of 10-17-06(4))

Even though the county has adopted LID in codes and ordinances, no one in the county knew that that they had LID in their codes and ordinances. Currently, LID is not active in the county's codes and

ordinances. In particular, the section in which LID is adopted in ordinances, that is, short-term tourist rental of dwellings, is not an appropriate section to adopt LID for future applications. As a county staff said that "I have to go back to the DEQ ordinance website to implement if someone asks for it."

Ultimately, the perspective of LID adoption in Amherst County is very different from Northern Virginia. Stormwater issues are not the priority in Amherst County and the county's resources such as funding and staff expertise are very limited to pursue an active role in LID adoption process. Therefore, the future of LID in the county is still in a vague stage even though the county has LID adoption in their codes and ordinances.

3) Roanoke County

Roanoke County is a rural community (Figure 12). There is no public demand for the removal of traditional ponds which means there is no objection to traditional stormwater management methods. Land values are so inexpensive so building traditional ponds for drainage is not as detrimental as in urban areas. The county has followed the state model ordinance and will parallel adopt the new state stormwater management regulations.

LID is still very new. In January, 2008, LID was adopted in the stormwater management ordinances. However, there are no rigid LID requirements. The County code says that they encourage LID practices (January, 2008 adopted) but are not requiring developers to use LID. So, it is basically a voluntary option to adopt LID. Staff members are still not sure about LID efficiency for controlling runoff.

In May, 2009, the zoning ordinance was also amended to have LID in that section. Different from the stormwater management ordinance, zoning ordinances have a complementary document called Roanoke County Design Handbook (a graphical representation of the zoning ordinance). According to a

county planner, they did have some low impact design recommendations for parking areas and pervious pavers. They have some illustrations showing some examples of permeable asphalts and porous concrete.

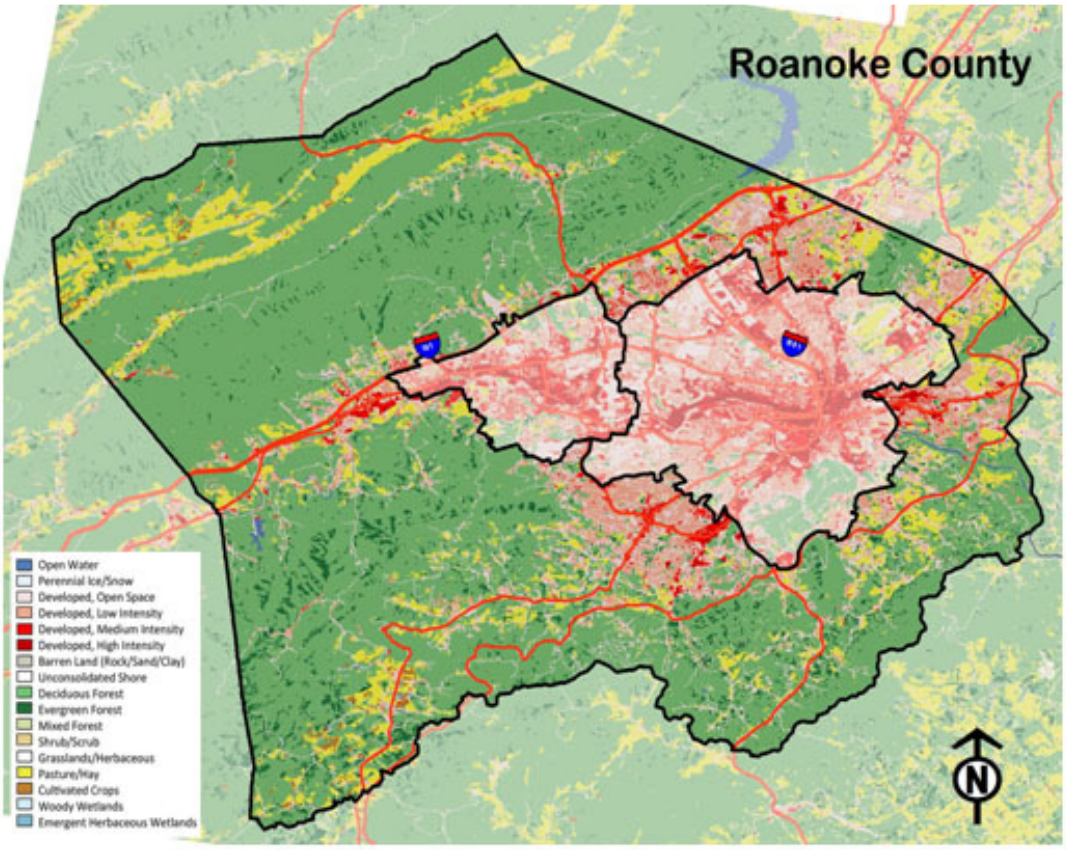

Figure 12 Roanoke County, VA: The National Land Cover Database (2001)

Data source: USGS National Land Cover Dataset 2001(NLCD): Retrieved from http://seamless.usgs.gov

LID in codes and ordinances

LID is adopted in Chapter 23. Stormwater management and Appendix A. Zoning sections. The benefit of LID was recognized and LID use was encouraged. Stormwater management ordinances state "Nonstructural stormwater practices and low impact development practices designed to reduce the volume of stormwater runoff are encourage to reduce the amount of stormwater runoff that must be managed. This will help to minimize the reliance on structural practices which require ongoing maintenance in order to be effective".

Appendix A. Zoning also mentioned LID in the section of parking areas. The county encouraged "The integration of low impact design alternatives, including but not limited to bioretention areas, infiltration devices, grass swales, vegetated filter strips and permeable or pervious pavers are encouraged to address stormwater quality and quantity and to improve the appearance of the parking area, in accordance with the Roanoke County Stormwater Management Design Manual, as amended".

4) Isle of Wight County

The county has remained predominantly rural in the past but in recent years due to the development and expansion of the Hampton Roads region, the development within Isle of Wight has been increasing (Figure.13). The development pattern for Isle of Wight is significantly residential subdivision development and it is expected to continue to be the major form of development in coming years (Isle of Wight comprehensive plan, 2008).

Isle of Wight County is in the Chesapeake Bay Preservation Area and designated Phase II, MS4 community. The county has a standalone stormwater management code and both the 2001 and 2008 comprehensive plans encourage LID for new developments in the County. In 2008, in the county comprehensive plan, LID is mentioned in Chapter 12 of Implementation section as one of the strategies to "establish provisions that will reduce storm water runoff utilizing low impact design standards for new development".

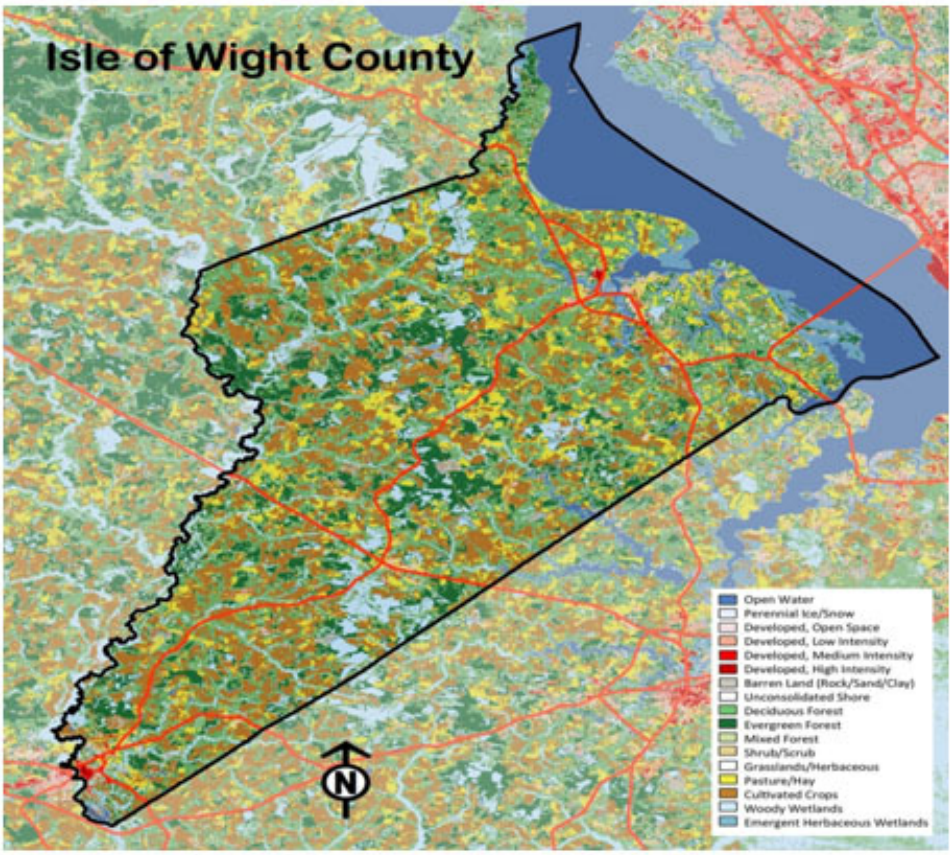

Figure 13 Isle of Wight County, VA: The National Land Cover Database (2001)

Data source: USGS National Land Cover Dataset 2001(NLCD): Retrieved from http://seamless.usgs.gov

LID in codes and ordinances

Even though there is LID adoption in local zoning ordinances, local staff members did not know about their adoption status. According to a local staff "No regulations or policies have been adopted to date. However, we encourage LID in the site plan process and some projects have proffered LID. Riverside Health Services building has some LID features in the parking lot. Some single family homes in Founder's Pointe will be using pervious pavers".

LID is adopted in Appendix B. Zoning, Article VI. Overlay Districts (Part 2. Newport Development Service Overlay (NDSO) District). Apparently, the code of overlay districts is not

countywide. Probably that caused local officials not to know of LID adoption in their codes and ordinances. The code promotes "best management practice (BMP) facilities and low impact development design standards (LIDDS) that enhance the site design and promote health and safety"

Currently, Isle of Wight handles LID on a case-by-case basis. According to a planning staff, the county is "with no specific list of approved practices. The county is developing some specifications for porous pavement/pavers." However, LID seemed to be a very technical and specialized area that planning staff did not have much of information on. Only one person in the county, the environmental programs manager, reviews stormwater management plans.

The county is planning to develop a Green Certification for site plans that meets certain criteria that will include LID features which are influenced by MS4. According to a staff, "LID principles will not make it happen if it is not required."

5) Bedford County

Bedford County is a very rural area (Figure 14). There is not much development. According to a county staff, the priority of the county's land use is focused on preserving farmlands. The 2007 comprehensive plan supports this argument by saying that "Citizens of the county are strongly committed to maintaining agricultural areas and protecting the natural environment within and around the county." Regarding the issue of stormwater management, the county considers stormwater management as a safety issue and sees the necessity of having it, but basically focuses on meeting the state stormwater codes.

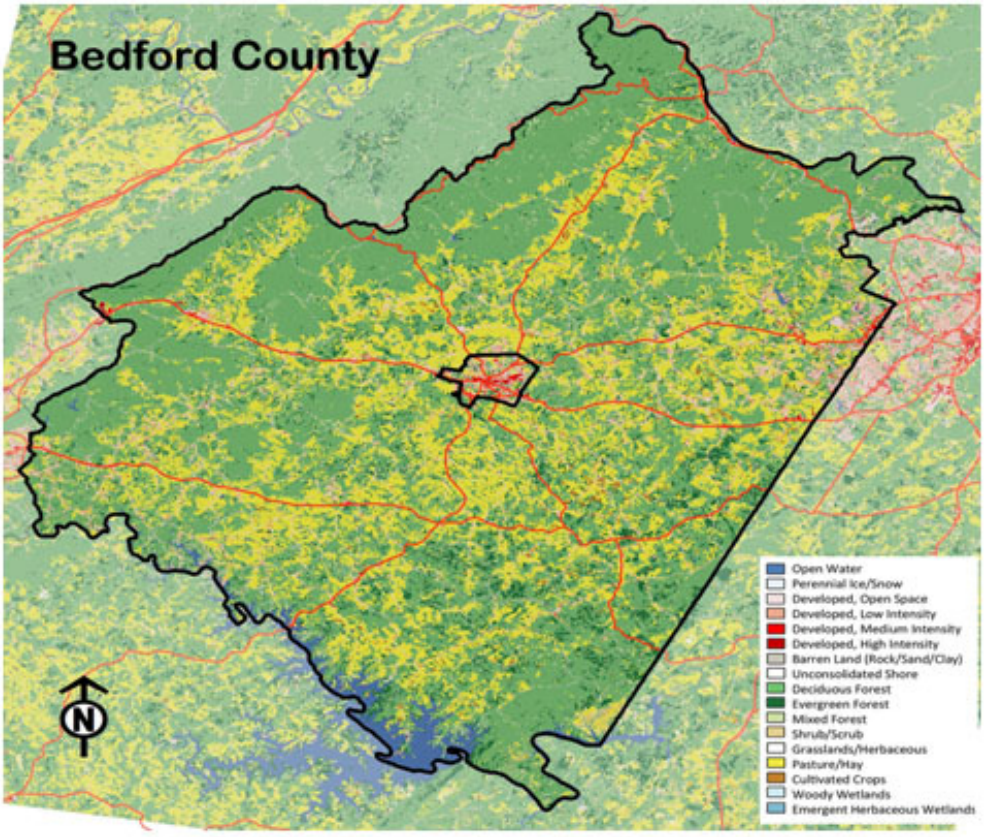

Figure 14 Bedford County, VA: The National Land Cover Database (2001)

Data source: USGS National Land Cover Dataset 2001(NLCD): Retrieved from http://seamless.usgs.gov

In 2007, LID was adopted in the new comprehensive plan. The introduction of the LID concept to the plan was done by a private consultant who was hired for revising the plan. What this private consultant recommended for preservation and smart design and development was LID in the plan. LID was mentioned several times throughout chapter 5. Natural Resources and chapter 9. Land use:

- Chapter 5: Natural Environment ; Objectives and Strategies

  5.1 Surface water that meets or exceeds the appropriate state and federal water quantity and quality standards, consistent with the general needs for the County's residents, wildlife and livestock

5E. Low Impact Development (LID) Standards. Research and evaluate alternative storm water management solutions, including LID standards to be defined and regulated through code updating and enforcement.

- Chapter 9: Land Use ; Objectives and Strategies

  9.2 Preservation of farmland, forested land, open space, and rural character

  9H. Zoning Ordinance Revisions. Revise the Zoning Ordinance to address land use issues including, but not limited to, decreasing densities as indicated by the FLUM, allowing conservation subdivisions (clustering), allowing Low Impact Development (LID) concepts, preserving trees and existing vegetation in developments, and increasing landscaping and buffer standards.

  9I. Subdivision Ordinance Revisions. Revise the Subdivision Ordinance to address land use issues including, but not limited to, promotion of conservation subdivisions and Low Impact Development (LID) concepts, and preserving trees and existing vegetation in developments.

In both sections, LID was recommended as an alternative stormwater management strategy. According to the county planning director, “That language tells me we weren’t going to force people to do it because we are saying allow it. We are going to make it easier for them to do it but not incentivize it. That’s not something we are going to require. We’re going to make it voluntary based on that. “In Chapter 5. Research and evaluate.” which means we are not going to require it at this time. We are going to study how to do it.”

LID in Codes and Ordinances

LID is included in the Erosion and Sediment Control (ESC) section of local codes in 2005 by the request of a staff in the Natural Resource Department who left the county later. In general, ESC codes are based on the Virginia Erosion and Sediment Control Handbook and these 2005 amendments recommended LID techniques as stormwater quality control measures.

Sec. 7-7. Standards to be used in preparation and consideration

(e) Stormwater management facilities shall be designed to hold a twenty-five-year storm of twenty-four-hour duration and release it at the pre-development rate, maintain structural integrity and shall include ultimate development of the project site. In the event stormwater quality measures or Low Impact Design (LID) techniques are incorporated in the overall stormwater proposal, the twenty-five-year-design storm event can be reduced as approved by the administrator. Incorporation of bioretention, infiltration and use of existing vegetation are highly recommended.

The awareness of LID in the county was very low; even though LID was introduced in the code of 2005, no staff members in the county actually knew about LID code adoption in the county. As a result, LID has not been actively pursued after the code adoption.

For more intense use of LID, the county comprehensive plan recommended to add LID into Zoning and Subdivision ordinances. In addition, the county staff members will prepare LID education programs or training workshops for the county BOS members and the planning commission who are still very new to the concept of LID.

4.2.6 Factors in low level LID adoption Localities

Amherst County, Bedford County, Chesterfield County, Isle of Wight County, and Roanoke County fall into the category of localities with low level LID adoption. These five counties adopted LID in codes and ordinances between 2005 and 2007. Four categories of grouped determinants are summarized to compare determinants in table 11.

1) LID characteristics

All five counties perceived LID as complex or very complex. Several staff members from Amherst County and Roanoke County stated that they were confused by LID definitions. Various professionals defined LID in a different way which caused confusion and the definitions were vague and complex. In particular, the hydrology part was perceived as complex and difficult. For example, a staff from Chesterfield County said that " I think it's very complex about all the different things and how they come together."

The counties with low LID adoption tend to have very limited understanding of the LID advantages. In comparison to high level and moderate level localities, the most common concern of low level adoption counties was the economic benefit. Except for Chesterfield County, which adopted LID only partially in the Upper Swift Reservoir Watershed protection area to protect and resolve stormwater quality issue, the rest of four counties considered the least expensive cost for development by using LID or worrying about cost for LID implementation in the development projects.

These counties consider LID as a tool or package to sell to the development community and elected officials. Therefore, they wanted to know more about successful case studies which showed cost saving information with LID adoption. The number of LID demonstration projects was very limited and mostly done in parks and schools. Not many pilot projects were in private and commercial levels of development and these demonstration projects only showed an adoption of one or two LID practices like bioretention and Filterra.

2) Characteristics of local government

Most of the time, the responsible agencies for LID adoption in these localities were the planning department and the environmental engineering department except in Bedford which had no agency involved in LID at the moment. There was not much collaborative work going on but rather showed the

fragmented nature of LID in these localities. There was no strong champion in LID promotion. Planning and engineering staff usually were recognized as experts on the topic in the county and automatically became a champion in these areas. However, their role as champion was a bit vague as their knowledge also was very limited.

Available resources such as technical experts and funding opportunities in local government were very limited. Isle of Wight and Roanoke County are considering LID as a part of MS4 stormwater permit requirements so that they can use some funding and education sources for LID to meet the state regulation requirements. On the other hand, Chesterfield County received some grants for LID education and also for considering LEED programs for LID adoption. It appears to be localities within the Chesapeake Bay Watershed area which have more opportunities in funding in general.

3) Motivation to LID adoption

In the majority of cases, meeting state requirements was the biggest concern for localities with low LID adoption. They usually were aware of the importance of environmental protection; however, in some cases such as Bedford County and Roanoke County, these localities have no problem with traditional regional stormwater management systems. There was no demand from environmental groups or citizen groups for innovative stormwater management methods. These counties' biggest concern was the proposed new state stormwater management regulations. If LID can meet those requirements of new regulations in addition to protecting and improving environmental quality, they will actively pursue LID adoption. However, the case of Chesterfield County is somewhat unique from others because the county's major concern is environmental quality, reservoir protection and health. The county was utilizing LID in terms of a land development tool for sustainable development.

4) Organizational context

The influence of state and federal regulations to LID adoption turned out to be the most important factor for localities with low level LID adoption. All five localities revealed that they heavily rely on state regulation. Meeting the state requirements is a critical factor for them. Amherst and Bedford County expressed an interest in adopting LID if the state regulations require LID. Currently, there are no requirements to do so, therefore, LID is not a priority for these localities. In the case of Chesterfield County, they delayed a contract to develop LID regulations due to the upcoming new state regulations. They wanted to comply with the state regulations so they stopped the progress of local code development for LID to wait for the new state stormwater management regulations. A staff in Isle of Wight said "the laws are the only way to make LID common place". Roanoke County officials also said that "We follow the state model code….it is harder to mandate if the state doesn't mandate it."

The influence of environmental NGOs was very weak. Only a couple of NGOs were mentioned during the interviews but their direct input to LID adoption process was not evident. There was not much of neighboring influence in this group because the localities are either too rural or surrounded by rural communities. One more interesting result in this group was localities' attitude toward standard model code for LID which was completely opposite from localities with high and moderate level adoption. All of them said the LID model code will be very useful and helpful. A Bedford County official mentioned a need of a package deal of LID to sell the idea to BOS members. An Amherst County official said that it might be a useful tool to convince the public.

Table 11 Determinants of low level of adoption

Variables \ Localities		Chesterfield	Amherst	Roanoke	Isle of Wight	Bedford
LID adoption in code (Year)		2007	2006	2007	2005	2005
LID characteristics	Complexity	Complex (hydrology): LID is a combination of toolbox	Definition varies; not complex but new	Very complex; Definition is vague	Depends on profession; Definition varies;	Complex
	LID advantages	Environmental benefits, hydrologic benefits	Economic is big; Hydrologic factor; Environmental factor	Economic (cheapest cost for developers)	Economic (too expensive), Environmental benefits	Economic benefit is big; Hydrologic factor; Aesthetic is not concerned yet
	LID projects	Fire station(2009), schools(2005);Community Development Building(2007), Filterra	3 demo projects- only LID practices (biofilters, rain gardens)	bioretention(high school)	Riverside health services building has some LID features in the parking lot.	None
Local Government Characteristics	Responsible agencies (size)	Environmental Engineering (9); Planning (43)	Planning (2); Public Utilities(1)	Community Development (26)-Engineering, Planning	Planning (11), Environmental Program(4)	Planning (12); Natural resource coordinator (1)
	Champion	Director Of Environmental Eng.; Senior planner staff;	Planning staffs, Public water staff; 1 or 2 BOS members	Zoning administrator; Deputy Director for planning; Clean Valley Council	Planning and Engineering staff	A previous natural resource coordinator; A private consultant
	Resources (Financial, technical, and human resources)	Community Department (Planners, and environmental engineers), an outreach person	2 planners; 1 Public water; 1 Watershed Coordinator (Robert E. Lee Soil & Water Conservation district)	None	None	4 planners, 1 natural resource coordinator, 1 engineer
		Grants awarded for EE dept. (the design and application for LID in CB watershed); Grants for LID education; LEED	DCR grant on a technical report on LID	MS4; Education programs on water quality; County Design Handbook: site design, landscaping	Plan to use LID as a part of MS4 stormwater permit requirements	None
Motivations to LID adoption	Environmental issues; Frustration; New Tech; Physical conditions	Environmental concerns, Motivated by LEED certification, Water quality,	Traditional method is not working, Cheaper to prevent pollution; Environmental reason	To comply with the state regulation, For better environment, Environmental reason	To meet regulation	To meet state regulations; Public health safety; new technology for engineers to use
Organizational Context	Local Character	Suburban	Very rural	Suburban	Rural	Very rural
	Federal/State regulations or incentives	MS4; CBPA (Zoning; Ch19, Article IV)	None	MS4 (additional enforcement to LID)	MS4; CBPA (Stand Alone; App B-1)	None- but soon to be MS4
		Very important - delayed LID regulations due to the new state regulation	Relying heavily on state regulations- but there is nothing on LID requirements.	Very Important; Follow the state model code- it's harder to mandate if the state doesn't mandate it	Need to be required; the laws are the only way to make LID commonplace	Meeting the state code is a big thing; mandates are helpful from state and federal
	Pressure from NGOs	Hands Across the Lake; Friends of Chesterfield's Riverfront; James River Association	Peddler River Institute; Central VA Land Trust; VA Outdoors Foundation	None- no public demand for the removal of traditional pond	None	None
	Neighborhood locality pressure	A leader in the region	Surround areas are all rural so no influence	From Roanoke City (adopted the SWM ordinances together)	No-but helpful in swaying public opinion.	None, but Roanoke County case will be helpful
	LID model code	Very helpful	Useful; convincing the public	Used different sources of model code	None	Very helpful; need a package to sell it to the BOS

Chapter 5. Conclusions

This study investigated the levels of LID adoption by local government, determinants of the LID adoption process, and the relationship between the level of LID adoption and the influencing factors. An internal determinants model and a regional diffusion model were used to identify variables and relationships between organizations and influencing key factors.

First of all, in terms of level of adoption, previous research defined innovation adoption as a complete set of generation, development, and implementation (Damanpour, 1991) and emphasized the importance of "make use of an innovation" by continuing use of the innovation (Frambach, 2002). In addition, after the adoption, the degree of innovation adoption can be varied from simple use to routine use within an organization (Glicks & Hays, 1991). According to the analysis of ten case studies, various forms of LID adoption were defined: policy and regulation, practices and strategies, and educational program. And each locality was staged in different levels of LID adoption even after the LID code adoption. Depending on level of adoption, different strategies to promote LID can be developed. Therefore, a complete set of LID adoption activities should be considered to encompass the full range of LID adoption condition by local government.

Second, this study developed four constructs of innovation adoption determinants: 1) LID characteristics, 2) local government characteristics, 3) motivations to LID adoption, and 4) organizational context. According to case analysis, key determinants of LID adoption were varied depending on high, moderate, and low level of adoption. The following section summarizes general characteristics of each determinant group.

1) LID characteristics

An innovation perceived to be simple and easy is possibly much easier to be diffused and implemented (Rogers, 2003). This general proposition might be applied to LID adoption. The concept of

LID is simple: maintaining pre-development hydrology by mimicking natural hydrology of infiltration and small scale on-site treatment. However, in many localities, the definition of LID was used vaguely. The interviewees knew what LID was when they were asked for a definition, but only a couple of interviewees were able to give a clear definition.

One possibility for the confusion is the complex and technical nature of the LID body of knowledge. Even though the concept of LID is considered simple, the components of LID are complex and consist of various practices and site design principles. Not everyone has accurate information about LID, and the meaning of LID has been used vaguely throughout multiple localities.

Another important factor in considering LID characteristics was to identify which LID advantages promote LID adoption. It is assumed that the localities' highest interest might be the economic benefits of LID. However, according to the case studies, it turned out that hydrologic benefits and environmental benefits of LID were as important as economic benefits of LID to local governments. Localities that exhibited high and moderate levels of LID adoption stated that their major reasons for adopting LID were hydrologic efficiency and environmental benefits of LID. On the other hand, localities with a low level of LID adoption stated that inexpensive LID construction and maintenance costs were their major reason for LID adoption.

2) Local government characteristics

According to the director of FOR, the role of local government is fundamental for LID adoption in Virginia. It is difficult to change the state level political and regulatory environment in a short time to facilitate LID policy development. Therefore, local government involvement is crucial to make changes to increase the LID adoption. As a strategy to promote LID, it is rather effective to reach out to local governments and help them make changes in their political and regulatory environment. Throughout the case studies, the role of a champion was crucial for making changes in local government. This finding is

in line with previous research showing that the presence of a strong champion within an organization has a major positive influence on adoption (Corbett &Hayden ,1981; Driessen, 2002; Maidique, 1980).

For all three levels of LID adoption, the local planning department and engineering department were considered to be responsible agencies for LID adoption. The role of strong champions in these departments was considered one of the most important factors for high and moderate level LID adoption localities. Usually, a staff expert became the champion for LID adoption. Eventually, those staff members who raised their voices to adopt LID provided LID education programs or became mediators who actively collected opinions from various groups for LID adoption in their localities. Therefore, the presence of staff experts is very critical to the LID adoption process. In the localities with high to moderate levels of LID such as Stafford County, Spotsylvania County, and Fairfax County, members of the planning commissions and board of supervisors (BOS) also played the role of champion in the LID adoption process.

While staff expertise is important for providing technical support, the members of BOS and the planning commission are important for political support. The planning commission and the board of supervisors are ultimately the decision makers who adopt or reject LID. When a locality has elected officials who are interested in LID, these officials can guide staff toward actions that will bring about LID adoption. Obviously, staff can have great ideas, but, if the BOS members or elected officials do not want to pursue those policies, then the ideas will not be accepted. In other words, the balance of political makeup of the board is crucial to making policy change in local government.

Finally, localities in the category of high level LID adoption stated that local LID education programs and training workshops played a key role for LID adoption. In addition, technical documents and manuals prepared by local governments assisted local developers and engineers to adopt LID practices and principles in their development projects.

3) Motivation to LID adoption

The role of motivation in LID adoption is indirect or somewhat hidden in the LID adoption process. However, identifying what motivates LID adoption took into account historical and political backgrounds of LID adoption process. Three major motivational factors were identified through this research: environmental concerns about stormwater runoff, frustration with traditional engineering methods, and state regulations. Level of commitment to LID program development depended on what motivated the local governments to adopt LID. There were two trends in motivation. Motivation such as recognition of environmental problems and frustration with traditional methods inspired local government to act to resolve these issues. The motivation such as pressure from state mandates made local government rather passive on LID adoption.

4) Organizational characteristics

Berry and Berry (1999) emphasize the importance of external influence to innovation adoption. Especially, horizontal diffusion from competition and learning among neighboring states and vertical diffusion like influence from federal and state level regulations and programs generally have a great impact on state governments. However, this research, which is focused on local government level, found diverse tendencies depending on the level of LID adoption.

Five factors under organizational context were compared to three levels of LID adoption, and the results show high dependency on localities' level of LID adoption. First, from high to low level of adoption, the role of federal and state regulations or incentives played a much larger role in the LID adoption process. In other words, informants in localities exhibiting a high level of LID adoption stated that there was no influence from state regulations for their LID adoption as they had already adopted LID even before the state required it. On the other hand, informants in localities with moderate and low levels of LID adoption stated that the federal and state mandates were extremely influential to their LID

adoption. Low level LID adoption localities relied on the state regulations much more than the localities with higher levels of adoption.

Second, environmental NGOs played a critical role in the high level LID adoption localities such as Spotsylvania County and Stafford County. However, the localities with moderate and low level LID adoption stated that there was no direct influence from NGOs. This result implies that the presence of a good environmental group that local government can work with is another important factor for LID adoption. For example, Friends of Rappahannock (FOR) is an environmental advocacy NGO that works in three main areas: advocacy, restoration, and education. LID is one of their primary tools for advocacy work. While this study focuses on local governments, FOR has been focusing on building relationships with the development community.

Figure 15 shows FOR's strategic approach to work with Stafford County and development communities in the region. FOR started with small-scale pilot projects and ended up with code change. Both Spotsylvania and Stafford County recognized the significance of having FOR in the region to make code changes of their own.

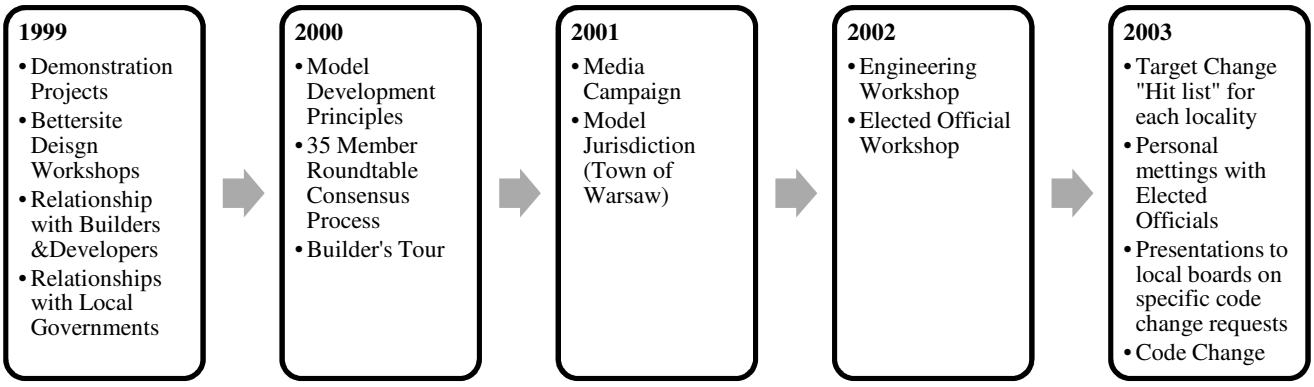

Figure 15 F.O.R. Low Impact Development Advocacy Strategies

Third, the pressure from neighborhoods to successfully adopt LID was minor. The influence of neighborhood pressure was not detectable except in two localities, namely Stafford and Spotsylvania because they considered themselves as leaders in the region. Some localities in the low level LID adoption said that neighborhood pressure would help them to manage public opinion and the BOS.

The LID model code influenced localities in a way that was very similar to the influence of neighborhood pressure. The LID model code was treated as a very helpful tool by low level LID adoption localities, while the high and moderate level LID adoption localities showed no or mixed interests in the model code. In the case of high level LID adoption localities, their codes and ordinances were considered to be model codes, and the moderate level localities said that every locality has different systems for LID so they were negative about the use of model code.

Demographic and economic facts were compared to each level of LID adoption in table 12. These facts were indirectly influential in LID adoption, but they provide a greater understanding of environmental and development pressures in the localities. Usually localities with higher population density, median household income, and population change were conscious of environmental issues and showed higher levels of LID adoption. Similar results were found from White and Boswell (2006) study which concluded that well-educated/wealthier populations and larger and more rapidly-growing localities put pressure on local governments to adopt environmental protection policies.

Even though it is difficult to generalize the results based on ten case studies, the final comparison of determinants summarized in table 13 shows that there are common characteristics and a clear tendency to LID adoption in localities within the same level. According to case analysis, determinants of innovation adoption were varied depending on high, moderate, and low level of adoption. Therefore, strategies to promote environmental innovation should be developed in relation to the level of innovation adoption.

Table 12 Demographic and economic facts

	Virginia	High		Moderate			Low				
		Spotsyl-vania	Stafford	City of Charlottesville	Fairfax	City of Roanoke	Amherst	Bedford	Chesterfield	Isle of Wight	Roanoke
Land area, 2000 (square miles)	39,594.07	401	270.35	10	395.04	42	475	754	426	316	251
Population, 2008 estimate	7,769,089	120,031	121,736	41,228 (2007)	1,015,302	91,552	32,539	66,831	303,469	35,472	90,867
Population, percent change, April 1, 2000 to July 1, 2008	9.70%	32.80%	31.70%	0.60%	4.70%	-3.50%	2.00%	10.70%	16.80%	19.30%	6.00%
Persons per square mile, 2000	178.8	225.4	342.4	4,390.70	2,455.10	2,213.40	67.1	80	610.1	94.1	341.7
Median Household Income (2007)	$59,575	$74,374	$86,865	$37,195	$104,984	$37,103	$43,890	$53,823	$69,583	$58,840	$59,060
County Characteristics	-	Urban	Urban	Urban	Urban	Urban	Very rural	Very rural	Suburban	Rural	Suburban
Standalone SWM Code	-	SWM	SWM	SWM	SWM	SWM	N/A	N/A	N/A	SWM	SWM
CBPA/MS4	-	CBPA/ MS4	CBPA/ MS4	MS4	CBPA/ MS4	MS4	None	None	CBPA/ MS4	CBPA/ MS4	MS4

Data source: US Census http://quickfacts.census.gov

Table 13 Determinants and level of LID adoption

Determinants \ LID adoption level		High	Moderate	Low
Year LID adoption in code		2003	2006-08	2005-07
LID characteristics	Complexity	Simple/not complex	Very complex	Very complex, definitions are vague and varied
	LID advantages	Hydrologic benefits	Environmental benefits; Hydrologic benefits	Economic benefits (cost saving); environmental benefits
	LID projects	Numerous projects; majority of developments applied LID and used to promote LID	Lists of demonstration projects from public and private sectors	Several projects done by public sectors; mainly practice based (bioretention and Filterra)
Local Government characteristics	Responsible agencies	Planning and engineering	Planning and engineering	Planning and engineering
	Champion	Strong championship from staff experts, BOS, Planning Commission	Staff experts	Weak and vague distinction of a champion, maybe staff members
	Resources	Strong education and training programs	Try to utilize LEED for LID; Local government documents for LID education	Very limited resources
Motivations to LID adoption	Environmental issues, Frustration, New tech, Physical conditions	Environmental problems, Frustration with traditional method	Mixed reasons: - Environmental concerns(green image) - Pressure from environmental groups - State mandates	Meeting state mandates
Organizational Context	Federal/State regulations or incentives	No influence : we did it before the state	Huge influence from state mandates	Intensely rely on state regulations (a very important factor)
	NGOs pressure	FOR: Direct influence	No direct influence	No direct influence
	Neighborhood locality pressure	No- we are the leader	Mixed influence	No - but it will be helpful to sway public opinion and BOS
	Local characteristics	Urban; Fairly high population density	Ultra urban; high population density	Suburban and rural; mixed population density (low to fairly high)
	LID model code	No -we don't need it	No- All localities have different system for LID adoption in codes and ordinances.	Helpful; less resistance (a successful case is always helpful)

Base on the final comparison of determinants within the same level of LID adoption, this study was able to conclude the most important factors for each level of LID adoption localities.

a. Influential factors for high level LID adoption
    - Strong champions in local government
        - Presence of staff experts, providing technical and political support
        - Members of the planning commissions and the BOS
        - Pressure from environmental NGOs (FOR)
    - Local LID education programs and training workshops; technical documents and manuals to assist LID use
b. Influential factors for moderate level LID adoption
    - High influence from federal/state mandates
    - Staff experts (champions) in local government
    - Green image of the locality
c. Influential factors for low level LID adoption
    - Strong dependence on federal/state mandates
    - Lack of strong champions in local government
    - Lack of clear LID definition
    - Limited resources in local government

These findings reveal two major determinants that influence level of LID adoption. One is strong champions and the other is regulatory mandates. A champion-driven LID adoption model is found in high level LID adoption localities. Usually, individuals from local governments, NGOs, and development communities have played a critical role in LID adoption process. The local government organizations in this group are usually self-motivated to adopt the innovation.

Especially, the presence of strong champions was identified as a key factor for the higher level of innovation adoption. Corbett and Hayden (1981) suggested that a strong political leader, a skilled local government technical staff member, and a community education person or grassroots group served as key figures for adoption of local solar ordinances. According to Corbett and Hayden, the role of local elected officials turned out to be crucial in local solar policy adoption. Several federal and state agencies even targeted city council members and county supervisors to encourage solar programs after they realized the importance of active involvement by local political leaders.

On the other hand, a regulation-driven LID adoption model is found in moderate to low level LID adoption localities. These localities are strongly influenced by state regulatory mandates. In these cases especially, external forces motivate local governments to adopt innovations.

Chapter 6. Recommendations and Discussions

6.1 Recommendations

This dissertation argues that crucial adoption factors vary across localities based on different levels of LID adoption. LID adoption was predominantly driven either by strong champions or regulatory mandates. First, a champion-driven LID adoption model was identified by which the LID adoption process was initiated by individuals from various groups such as local governments, NGOs, and the development community. This model was influenced by the internal characteristics of local governments. The second model was a regulation-driven LID adoption model in which the LID adoption process began with federal and state laws and regulations. This model profoundly depended upon external forces such as regulations and incentives from the EPA and DCR. Subsequently, various bundles or packages of strategies for promoting LID can be developed based on these two dominant adoption models.

Ultimately, to improve the local environment for LID adoption and to develop strategies to effectively promote LID use, this research emphasizes the following four recommendations to be considered: LID definition, education and collaboration, promotional plan development, and utilizing existing regulations and programs.

1) A clear definition of LID

A fundamental difference among localities with different levels of LID adoption was how LID was perceived. Localities with high level LID adoption considered LID as simple but moderate and low level LID adoption localities expressed that LID was complex. Therefore, the initial step to promote LID should be based on a simple and easy definition of LID. The general process of innovation adoption starts by learning new things. Then, adoption and implementation start to build from the ground up.

A unified definition of LID which is supported by federal and state level governments should be promoted nationwide by emphasizing both practices and site design strategies so that there will be no uncertainty about what LID is.

2) Fostering LID education programs and local collaboration

Most of the low level LID adoption localities have very limited information about LID effectiveness. Some localities still express uncertainty about hydrological effectiveness and maintenance issues with LID practices. There are many technical reports and publications from government agencies and research organizations which provide scientific evidence for LID effectiveness.

In terms of the maintenance, conventional facilities may require high costs to maintain them for the long term. However, many LID techniques are reported to be self-perpetuating, easily repairable, or can be left as natural areas at the end of their functional lifetime (LID center, 2003). Traditional stormwater management is required for development projects; on the other hand, LID can seek various new funding sources. Stormwater controls by LID can be integrated into the streetscape, landscape, or building. Therefore, the basic funding of LID can be included in the other projects to construct water quality improvements (Weinstein, 2002).

The question is how to familiarize local government staff and the development community with this information and how to facilitate the use of this information at a practical level. Gaining new information about LID takes time and may need a special channel of communication to make the use of this information effective. A resolution for this issue is developing and utilizing LID education programs. Moreover, stormwater is a complex topic to deal with, so many different departments in a local government (health department, fire department, public works, planning, and environmental engineering) should develop a consensus on local regulatory changes. Therefore, collaboration is the key to the success of LID local adoption.

Effective educational programs can involve environmental NGOs which promote regional collaboration. Local technical advisory and task forces are being used as tools for LID education. For example, the environmental quality advisory group (EQAC) in Fairfax County consists of committee members appointed by the BOS who are active advisors to the board on environmental matters. The members of EQAC have various backgrounds. One of the chairmen is with the National Wildlife Federation and works with the Center for Watershed Protection. This person became a champion of LID. As a result, people from different professional backgrounds with various agendas educate each other.

Another example of local task forces and advisory groups cooperating for educational and promotional purposes is the Green Ribbon Committee (GRC) in the City of Virginia Beach. According to a staff member, the GRC is made up of staff and people from the community, in particular, some representatives from development community and private and environmental organizations. The goal of GRC is to green the city code by revisiting the entire city code, not just the development ordinances. The case of GRC is unique because the "GRC was created not because the city wanted to do it but because the development community came to the city and said we like to look at these other options." Specifically, the combination of the development community and an environmental NGO, Lynn Heaven River Now, came to the city and they became a real force to encourage a more aggressive approach to make the city greener. The GRC supports LID incorporation in local codes and ordinances by providing recommendation reports to city council. In addition, the city's comprehensive plan also recommends incorporating LID designs into city projects for parking areas and major buildings.

In the case of Spotsylvania County, the county has semi-annual meetings with engineers and developers which provide a venue for teaching about LID. In addition, the engineer quarterly meeting brings everybody such as county engineers, local engineers, and local developers together, and all of them share the knowledge and information about LID practices.

Furthermore, environmental NGOs and federal and state agencies can provide education and training workshops for existing planning and environmental engineering staff. Due to budget issues, it is hard to hire a new person to only manage LID issues; therefore, it is more effective to educate existing staff members about LID. Moreover, to change the mindset of engineers is fundamentally important for the future of LID adoption. To do so, education about sustainable environmental measures such LID should begin with engineering schools. After students graduate, they might be better prepared to implement environmentally innovative techniques.

3) A comprehensive LID adoption approach

According to ten case studies, the majority of LID adoption cases adopted small scale LID practices such as bioretention, grass swales, green roofs, and biofilters which are in contrast to comprehensive site level strategies. A staff member from Spotsylvania County argued that "LID was taking two very distinctive tracks. One being the engineered hard-core design, and one being the basically landscape architect approach." He claimed that both approaches should come together. However, current trends of LID adoption show emphasis on the LID practice level only. Practices and site design strategies cannot be separated. For example, if the engineering approach takes a lead, then other methods will be disregarded. On the other hand, if the landscape- and site-focused design strategies take the lead, then the structural integrity of stormwater management facilities might be compromised. This separated approach will not deliver the completed level of LID adoption. Therefore, both approaches should be incorporated as the tool for stormwater management, and these approaches should not only employ the concept of hydrology, but also embrace smart land use planning.

4) Existing regulations and programs to promote LID: MS4 and LEED

National Research Council (2008) emphasizes the importance of local cooperation as a key factor for the survival of innovation solutions like CWA MS4 permits regardless of state or federal efforts. Local ordinances have been the source of many stormwater management approaches, including LID

requirements. Therefore, meeting multiple goals of federal and state level laws and regulations by implementing local stormwater management programs would benefit all parties.

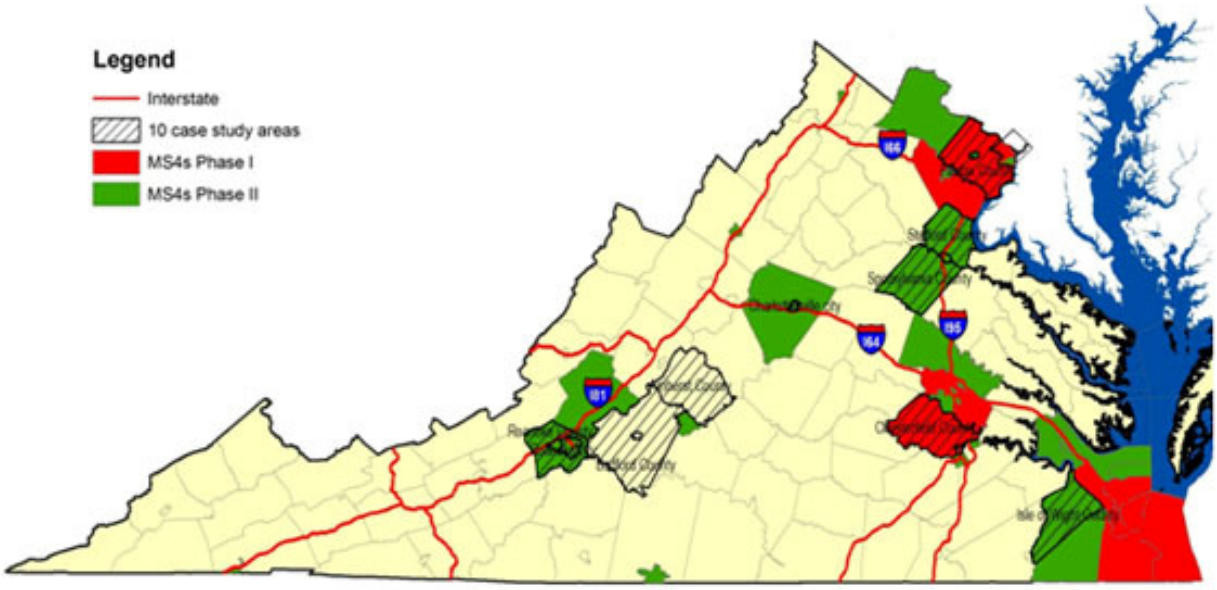

Figure 16 MS4 communities

GIS data source: National Transportation Atlas Database (2009) Retrieved from U.S. Department of Transportation (US DOT), http://www.bts.gov/publications/national_transportation_atlas_database/2009/
2009 TIGER/Line® Shapefiles for Virginia, Retrieved from U.S. Census Bureau http://www2.census.gov/cgi-bin/shapefiles2009/state-files?state=51

As shown in figure 16, 8 out of 10 localities are under MS4 permits. To discharge stormwater runoff into US waters, local governments have to receive a permit. Six minimum control measures must be incorporated into stormwater management programs. LID can be used as a tool to achieve MS4 requirements. Due to the flexibility of the six Minimum Control Measures (MCMs), local governments can address their unique characteristics of water pollution issues with these measures:

- Public education and outreach on stormwater impacts
- Public involvement and participation
- Illicit discharge detection and elimination
- Construction site stormwater runoff control

- Post-construction stormwater management in new development and redevelopment
- Pollution prevention/good housekeeping for municipal operations

Especially for post-construction runoff control, LID can be used as a tool for site planning to minimize polluted stormwater runoff (White, 2006). Six measures of MS4 show a clear implication of LID, and this aspect is critical to motivate localities to adopt LID.

An additional tool for LID implementation is Leadership in Energy and Environmental Design (LEED) which is a green building rating system. Seven localities (i.e., Amherst County, City of Charlottesville, Chesterfield County, Fairfax County, City of Roanoke, Roanoke County, and Stafford County) stated their engagement with LEED program. Even though LEED does not place as much emphasis on the exterior environment as it does buildings, LEED criteria such as water efficiency (i.e., water efficient landscaping) and sustainable sites (i.e., erosion and sediment control system, site selection, reduced site disturbance, stormwater management, and landscape and exterior design to reduced heat island) can be integrated with LID (U.S. Green Building Council, 2010).

5) Influence from new Virginia state stormwater regulations

Currently, the new Virginia stormwater regulations have undergone an administrative review and have gone to the governor for approval. By law, the regulations cannot take effect prior to July 1, 2010. The new Virginia stormwater management regulations are not favored by developers who are concerned about additional financial cost to meet the state regulations. Due to this ongoing controversy, the proposed regulations were delayed until July 1, 2011. (http://www.richmondsunlight.com/bill/2010/sb677/).

The impact of the new Virginia stormwater regulations will be enormous. According to the FOR director, the state stormwater management regulations present a tremendous opportunity to employ LID

practices. Many local governments are postponing their own stormwater management policies until the new state stormwater regulations are released. In particular, localities with low level LID adoption heavily rely on state level regulations. Even some low level LID adoption localities expressed that they will use LID more if it is mandated by new stormwater management regulations. Therefore, the new state stormwater management regulations which rely on infiltration and LID practices will provide a great opportunity to promote LID practices and principles.

6.2 Discussion

The focus of this study is local government LID adoption. Therefore, this study provides only a limited understanding of the diverse perspectives of stakeholder groups like builders, home owners, environmental NGOs, and state level staff. These groups' roles are critical in the LID adoption and diffusion process. Therefore, a topic for future research is an investigation of the dynamics of various stakeholder groups in LID adoption process.

In addition, this research limited the extent of components in the level of LID adoption to the activities that are usually implemented at the local government level: policy, education, incentives. And the process of determining the level of LID adoption was founded in subjective categorization based on researcher's observation and analysis. There is an opportunity for future research to further develop the framework for evaluating levels of LID adoption.

The quality of in-depth multiple case studies was proved to be valid internally and externally as research findings actually reflect reality, and triangulation based on multiples sources and methods has been used throughout entire data collection and analysis process. Rich and thick descriptions about multiple case studies provided a sound basis to generalize the findings from case studies. Moreover, the data collection protocol for selecting cases, interviewees, and case context which has been used for 10 cases can be replicated to other studies too.

There are also two scales of topics for future research. In broader scale, future research can focus on expanding the understanding of policy adoption innovation adoption theory. For example, the environmental innovations other than LID such as green infrastructure and better site design can be investigated to compare and analyze any similarities and differences with LID adoption process in innovation adoption process. In narrower scale, future research can be directed to develop more effective education tools for multiple groups of actors such as the board of supervisors, planning commissions, staff, and the public who are involved in the code change process. And even more, future research can be focused on LID promotional packages for different levels of local governments in the LID adoption stage.

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Appendix A. Interview Contact List

No.	Localities	Contact information
1	**Amherst County**	County Administrator Director, Department of Planning Director, Department of Public Utilities Watershed Coordinator (Robert E. Lee Soil & Water Conservation district)
2	**Bedford County**	County Administrator Director, Department of Planning Code Enforcement Officer, Department of Natural Resources
3	**Charlottesville city**	City Manager Director, Department of Planning Planning Manager , Neighborhood Development Services
4	**Chesterfield County**	County Administrator Director, Department of Planning Director, Environmental Engineering
5	**Fairfax County**	County Executive Director, Department of Planning & Zoning Director, Fairfax County Office of Public Affairs and Environmental Services Environmental Coordinator
6	**Isle of Wight County**	County Administrator Director, Department of Planning Engineering Division staffs, General Services Department/ Engineering Division
7	**Roanoke city**	City Manager Director, Department of Planning Building and Development City Engineers, Environmental Management
8	**Roanoke County**	County Administrator Director, Department of Planning County Engineers, Department of Community Development
9	**Spotsylvania County**	County Administrator Director, Department of Planning Director, Department of Environmental Engineering
10	**Stafford County**	County Administrator Director, Department of Planning and zoning Environmental Programs Coordinator, Department of Public Works Department Friends of Rappahannock (NGO)

Appendix B. Semi-structured interview questionnaire

1. What is your position in your local government? And what is your background (e.g. planning, engineering, administration, etc)?

2. Describe your community's LID policies and regulations.
    a. Are there any other LID programs or activities in the community?
        i. Local policies on LID
        ii. Demonstration projects; Probe, when and where?
        iii. Education program?
        iv. Task force, technical advisory group for LID?
        v. Financial/ procedural incentives(e.g. expedited review time, tax cut)

3. How many LID projects have been approved since these policies and regulations were adopted? Can I obtain a list of these projects?
    a. What types of development have adopted LID? For example, new construction (public-governmental, commercial, residential, mixed use); redevelopment (public-governmental, commercial, residential, mixed use)
    b. Can I get a description of the LID practices used in each of these projects?
    c. What types of LID practices and design strategies have been used mostly?

4. How important is the issue of stormwater management in your community? How severe are local environmental problems?
    a. Were there any problems with traditional stormwater management practices in the community? Did these problems influence the community's interest in LID
    b. Are there any other environmental or physical characteristics of COUNTY or CITY that influenced the community's interest in LID?

5. Describe how your LID policies and regulations were adopted, specifically the process involved and the agencies and people involved in the process?
    a. When did the community first become interested in LID policies and regulations? Can you describe a time-line for the LID activities that were adopted?
    b. Any "champions" and key stakeholders are involved in LID adoption process in your local government or community?
    c. Any organizations or agencies involved in the process?

i. What about environmental groups in the community? Were they involved in the community's adoption of LID policies and regulations?

d. About how many staff of the county (CITY) were involved in helping to adopt the community's policies and regulations?

e. Where there any other important local government resources that helped the community adopt LID policies and regulations, for example local funding or technical resources?

6. Would you describe LID as complex? (i.e. concept, definition, and process of LID)
    a. If yes, did this complexity influence the adoption of LID policies and regulations in your community? If so, can you provide any details?

7. What other characteristics of LID influenced the community to adopt its policies and regulations? For example, LID's environmental benefits? If not mentioned, follow for:
    a. Economic benefits
    b. Aesthetic benefits
    c. Hydrologic benefits
    d. Etc..please list any benefits that you think were important in the process

8. Did your community use a model LID code or other standard in adopting its LID policies and regulation?
    a. If so, record the model used, and ask how important was having this standard.
    b. If not, did the lack of a model make it more difficult to adopt LID policies and regulations? Elaborate.
    c. If not mentioned, did any neighboring communities have LID policies and regulations that influenced your community's interest in LID?
    d. If a nearby community was mentioned earlier as a model, ask—did having a neighboring community as a model influence your community's interest in LID? Did being near that community make a difference?

9. How important were federal or state laws and incentives in your community's interest in LID? Probe NPDES, CBPA, and MS4

Appendix C. LID in code and ordinances

Locality	LID in Code and ordinances	Details in local code
Amherst	Appendix A. zoning and subdivisions - Article IX. Special Provision	916. Short-term tourist rental of dwellings. The following regulations shall apply to all short-term rentals of residential dwelling units: 1…. In addition to the requirements thereof, site plans pursuant to this section shall include a maintenance schedule proposed by the developer or property owner, and shall incorporate **low impact development** techniques, such as those about which information is available from the Virginia Department of Environmental Quality.
Bedford	Ch7. Erosion and sediment control	Chapter 7 EROSION AND SEDIMENT CONTROL* Sec. 7-7. Standards to be used in preparation and consideration. (e) Stormwater management facilities shall be designed to hold a twenty-five-year storm of twenty-four-hour duration and release it at the pre-development rate, maintain structural integrity and shall include ultimate development of the project site. In the event stormwater quality measures or **Low Impact Design (LID)** techniques are incorporated in the overall stormwater proposal, the twenty-five-year-design storm event can be reduced as approved by the administrator. Incorporation of bioretention, infiltration and use of existing vegetation are highly recommended.
Charlottes-ville city	Ch 34. Zoning- Article I. - DIVISION 8. Special use permit	ARTICLE I. ADMINISTRATION Charlottesville, Virginia - Code of Ordinances…..that would mitigate any such impacts. The BAR or ERB, as applicable...shall provide a completed low-impact development ("LID") methods... (d) Environmental impact. The applicant for approval...development must mitigate the impact of increased density through implementation of a Low Impact Development (LID) strategy...
Chester-field	Ch19. Zoning- Only for Upper Swift Creek	ARTICLE 8C. WATERSHED MANAGEMENT DISTRICT (WMD) 8C-4. WMD development standards- If the proposed site development activities exceed sixty (60) percent impervious cover or seventy (70) percent site disturbance then **Low Impact Development (LID)** analysis and plan shall be prepared for review. The LID plan shall include site design checklist, LID calculation worksheets, and details of LID practices. The LID plan shall promote groundwater recharge, provide the required pollutant removal, and maintain the pre-development time of concentration, peak runoff rate and runoff volume.
Fairfax	Ch122. Tree Conservation Ordinance	ARTICLE 2. Tree Conservation During Land Development… Section 122-2-4. Tree Planting Requirements (b) Tree canopy credits shall be given to tree seedlings, shrubs and woody seed mix planted in large open spaces, low-density residential settings, or in **low-impact development projects.**
Isle of Wight	APPENDIX B. Zoning- overlay districts and parking (2005)	Article X. Vehicle Parking Facilities Sec. 10-1000. Purpose. The vehicle parking provisions below are intended to effectively manage traffic flows and provide for an adequate number of parking spaces for vehicles while creating and maintaining vehicle areas which are safe, attractive, and functional for both pedestrians and motorists. In addition, consistent with the objective to reduce impervious surfaces, these standards are intended to promote improved management of storm water in parking areas by limiting the number of spaces permitted and encouraging acceptable techniques of **low impact design** in the provision of essential parking areas. (7-7-05.)
Roanoke city	Ch11.4 SWM (2007) Ch36.2 Zoning (2005)	ARTICLE 6. DEVELOPMENT STANDARDS Roanoke, Virginia - Code of Ordinances ...required if the applicant incorporates low-impact stormwater design practices consistent...Environmental Protection Agency**, Low-Impact Development Design Strategies:** An...Integrated Design Approach (June 1999) and Low-Impact Development Hydrologic Low-Impact... ARTICLE IV. GENERAL CRITERIA FOR STORMWATER MANAGEMENT Roanoke, Virginia - Code of ..Determination of flooding and channel erosion impacts to receiving streams due to land-disturbing...Nonstructural stormwater practices and low impact development (LID) practices designed...facilities will not only help mitigate the impacts of new development, but may also provide...
Roanoke	Ch23. SWM APPENDIX A ZONING ORDINANCE	(n) Nonstructural stormwater practices and **low impact development (LID)** practices designed to reduce the volume of stormwater runoff are encouraged to reduce the amount of stormwater runoff that must be managed. This will help to minimize the reliance on structural practices which require ongoing maintenance in order to be effective. (2) Nonstructural site and LID development measures may include, but are not limited to, maintaining undisturbed naturally vegetated areas, minimization of impervious surfaces, stream buffer restoration, providing additional stream buffer areas, wetland restoration, water reuse and recycling, and development design that reduces the rate, time of concentration, and volume of stormwater runoff.
Spotsyl-vania	Ch19A. SWM Ch20. Subdivisions	Article 1. Sec. 19A-10. Definitions: **Low impact development (LID)** means an approach to site design and stormwater that seeks to maintain the site's predevelopment rates and volumes of runoff. LID accomplishes this through the minimization of impervious cover, strategic placement of buildings, pavement and landscaping, and the use of small-scale distributed management features collectively called "Integrated Management Practices" (IMPs). Low Impact Development Design Manuals (LIDM) means Low-Impact Development Design Strategies: An Integrated Approach (ref. EPA 841-B-00-003) and Low Impact Development Hydrologic Analysis (ref. EPA 841-B-00-002) (Ord. of 11-8-94; Ord. No. 19A-02, 5-13-03)
Stafford	Ch21.5 SWM Ch22. Subdivisions Ch28. Zoning	ARTICLE I. IN GENERAL, g) Incorporation by reference. For the purpose of this chapter, the following documents are incorporated by reference: 3) **Low-Impact Development Design Strategies**: An Integrated Design Approach, United States Environmental Protection Agency, Office of Water, EPA 841-B-00-003 dated June 1999 and subsequent modifications and updates thereof. Stafford County's Stormwater Management Ordinance (Chapter 21.5 of the County Code) establishes minimum stormwater management requirements. All land development projects must comply with the requirements of this ordinance. Both the Stormwater Management

Appendix D. IRB Approval Form

VirginiaTech

Office of Research Compliance
Institutional Review Board
2000 Kraft Drive, Suite 2000 (0497)
Blacksburg, Virginia 24061
540/231-4991 Fax 540/231-0959
e-mail moored@vt.edu
www.irb.vt.edu

FWA00000572(expires 1/20/2010)
IRB # is IRB00000667

DATE: August 13, 2009

MEMORANDUM

TO: Charles T. Koebel
Moonsun Jeong

Approval date: 8/13/2009
Continuing Review Due Date:7/29/2010
Expiration Date: 8/12/2010

FROM: David M. Moore

SUBJECT: **IRB Expedited Approval:** "The Adoption of Low Impact Development by Local Governments" , IRB # 09-651

This memo is regarding the above-mentioned protocol. The proposed research is eligible for expedited review according to the specifications authorized by 45 CFR 46.110 and 21 CFR 56.110. As Chair of the Virginia Tech Institutional Review Board, I have granted approval to the study for a period of 12 months, effective August 13, 2009.

As an investigator of human subjects, your responsibilities include the following:

1. Report promptly proposed changes in previously approved human subject research activities to the IRB, including changes to your study forms, procedures and investigators, regardless of how minor. The proposed changes must not be initiated without IRB review and approval, except where necessary to eliminate apparent immediate hazards to the subjects.
2. Report promptly to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.
3. Report promptly to the IRB of the study's closing (i.e., data collecting and data analysis complete at Virginia Tech). If the study is to continue past the expiration date (listed above), investigators must submit a request for continuing review prior to the continuing review due date (listed above). It is the researcher's responsibility to obtain re-approval from the IRB before the study's expiration date.
4. If re-approval is not obtained (unless the study has been reported to the IRB as closed) prior to the expiration date, all activities involving human subjects and data analysis must cease immediately, except where necessary to eliminate apparent immediate hazards to the subjects.

Important:
If you are conducting **federally funded non-exempt research**, please send the applicable OSP/grant proposal to the IRB office, once available. OSP funds may not be released until the IRB has compared and found consistent the proposal and related IRB applicaton.

cc: File

Appendix E. IRB Approval Form- Amendment 1

VirginiaTech

Office of Research Compliance
Institutional Review Board
2000 Kraft Drive, Suite 2000 (0497)
Blacksburg, Virginia 24061
540/231-4991 Fax 540/231-0959
e-mail moored@vt.edu
www.irb.vt.edu
FWA00000572(expires 1/20/2010)
IRB # is IRB00000667

DATE: September 17, 2009

MEMORANDUM

TO: Charles T. Koebel
Moonsun Jeong

Approval date: 8/13/2009
Continuing Review Due Date:7/29/2010
Expiration Date: 8/12/2010

FROM: David M. Moore

SUBJECT: **IRB Amendment 1 Approval:** "The Adoption of Low Impact Development by Local Governments" , IRB # 09-651

This memo is regarding the above referenced protocol which was previously granted approval by the IRB on August 13, 2009. You subsequently requested permission to amend your IRB application. Since the requested amendment is nonsubstantive in nature, I, as Chair of the Virginia Tech Institutional Review Board, have granted approval for requested protocol amendment, effective as of September 17, 2009. The anniversary date will remain the same as the original approval date.

As an investigator of human subjects, your responsibilities include the following:

1. Report promptly proposed changes in previously approved human subject research activities to the IRB, including changes to your study forms, procedures and investigators, regardless of how minor. The proposed changes must not be initiated without IRB review and approval, except where necessary to eliminate apparent immediate hazards to the subjects.
2. Report promptly to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.
3. Report promptly to the IRB of the study's closing (i.e., data collecting and data analysis complete at Virginia Tech). If the study is to continue past the expiration date (listed above), investigators must submit a request for continuing review prior to the continuing review due date (listed above). It is the researcher's responsibility to obtain re-approval from the IRB before the study's expiration date.
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cc: File