

Chapter 1:

Introduction to Low Impact Development in Coastal South Carolina

1.1 Introduction to LID

What is LID?

Low Impact Development (LID) is an integrated, comprehensive approach to land development or redevelopment that works with nature to manage stormwater as close to its source as possible (US EPA, 2014). To achieve stormwater management, LID practices mimic the natural hydrologic regime through strategically integrated stormwater controls distributed throughout the landscape. The primary goal of LID is to recreate the predevelopment site hydrology through site design techniques that promote storage, infiltration, evaporation, and treatment of runoff. LID employs principles to create functional and appealing site drainage, such as preserving and recreating natural landscape features, that minimizes imperviousness and treats stormwater as a resource rather than a waste product (US EPA, 2014). These methods help reduce runoff and contribute to groundwater recharge and increase base flow.

The South Carolina Department of Health and Environmental Control's Bureau of Water (SCDH-EC-BOW) states that "LID is designed to mimic, as close as possible, the naturally occurring hydrologic conditions of a site thereby reducing the adverse impacts created by increased runoff that is typically associated with traditional development laden with impervious areas. The fundamental principle behind *Low Impact Development* is to both reduce the volume of runoff and to divert stormwater flows away from a common collection point. There are various practices that can be used in conjunction with one another to accomplish this goal. Some examples of these practices include open space preservation, infiltration basins/trenches, rain gardens, rain barrels/cisterns, eliminating curbs/gutters, bioretention, vegetated swales and converting turf areas to trees and shrubs."

A related, but not interchangeable, term is *green infrastructure* (GI). The United States Environmental Protection Agency (US EPA) notes that green infrastructure is a relatively new and flexible term that has been used differently in different contexts. It defines the term green infrastructure as, "systems or practices that use or mimic natural processes to infiltrate, evapotranspire, or reuse

stormwater or runoff on the site where it is generated (US EPA, 2014). Green infrastructure can be used at a wide range of landscape scales in place of, or in addition to, more traditional stormwater control elements to support the principles of LID.” In this manual, green infrastructure will refer to individual stormwater control elements that can be used to achieve low impact development goals.

More information can be found online at:

- ✧ <http://water.epa.gov/polwaste/green/>
- ✧ <http://www.scdhec.gov/HomeAndEnvironment/Water/Stormwater/LowImpact-Development/>

The Need for Coastal South Carolina LID Guidance

Since 2009, the Coastal Training Programs (CTPs) at the Ashepoo-Combahee-Edisto (ACE) Basin and North Inlet-Winyah Bay (NIWB) National Estuarine Research Reserves (NERRs) collaborated with partners at South Carolina Sea Grant and Clemson University along with engineers, researchers, developers, planners, and other coastal decision makers (CDMs) to identify barriers to LID implementation and the information that will help overcome these barriers. This feedback was generated using informal discussion with stakeholders and a formal needs assessment developed by the CTPs. Through workshops, facilitated meetings, and surveys, stakeholders identified the need for an LID guidance document that is specific to coastal South Carolina. Overwhelmingly, they requested an LID manual that addresses the needs of planners, landscape architects, developers, engineers, regulators, and home owners associations (Pollack and Szivak, 2007; Walker, 2011, Wood, 2012; Sutely, 2011). Furthermore, local research supports the need to use a comprehensive stormwater management approach that focuses on LID (Mallin, 2000; Mallin et al., 2001; Lewitus et al., 2003; Lewitus and Holland 2003; Brock, 2006; Drescher et al., 2007; Lewitus et al., 2008; Delorenzo and Fulton, 2009; Vandiver and Hernandez, 2009).

The need for a coastal LID manual for South Carolina is highlighted by a geographic gap in available resources. Neighboring states – Georgia and North Carolina – have coastal LID manuals that provide direction for improved stormwater management (CWP, 2009; NCCE, 2009). These two manuals, along with national guidance for coastal LID practices provided by research from UNH (2007), CWP (2010), and Schueler (2009), have helped develop the scope of information provided in this document, *Low Impact Development in Coastal South Carolina: A Planning and Design Guide*. In summary, the Coastal South Carolina LID manual need, research, policy, content, and application have been vetted over the years; research supports using LID to improve water quality and the need for a manual; and southeast and national LID resources and experts were used to support the manual.

This manual outlines the rationale for LID as a management tool to protect and restore coastal resources. LID is used collectively with planning, engineering, landscaping, education, and outreach strategies. The objectives of LID are accomplished using three basic principles (Prince Georges County, 1999):

1. Minimize stormwater impacts to the extent practicable. Highlighted techniques include reducing impervious cover, conserving natural resources and ecosystems, maintaining natural drainage courses, and minimizing clearing and grading.

2. Provide runoff storage measures placed throughout a site's landscape by using a variety of detention, retention, and infiltration practices.
3. Maintain predevelopment time of concentration by strategically routing flows to maintain travel time and control the discharge.

Low impact development can be part of the stormwater education and outreach programs in coastal South Carolina. While this manual focuses on better stormwater management for development, implementation of practices on public or private property, such as homeowner rain gardens or demonstration sites, is essential for a watershed-based approach to stormwater management and should also be considered. The public's involvement in LID implementation and maintenance is essential to support coastal water quality goals, and can be strengthened by education and outreach.

Manual Purpose and Application

The purpose of this manual is to remove barriers to Low Impact Development implementation by providing engineering tools, planning guidance, and case study examples that are relevant to the South Carolina coastal zone. The overall goal of this project is to provide local decision makers with the knowledge and resources to apply LID practices on the community, neighborhood, and site scale. The first chapter introduces LID terminology and coastal features pertinent to LID design. Chapter 2 provides a background on pertinent national, state, and local regulations and guidance related to stormwater and LID, in addition to strategies for how local governments can incorporate LID into ordinances. Chapter 3 focuses on the "big picture" of low impact development as a holistic process encompassing conservation, neighborhood site design, and landscaping practices. Chapter 4 provides specifications for stormwater best management practices that can be incorporated as part of a low impact design for a site. Chapter 5 includes additional LID case studies from the coastal region. Additional resources are provided in the Appendices, including strategies for climate change adaptations to LID stormwater designs, checklists for construction sequences and post-construction maintenance, and spreadsheet tools for runoff reduction crediting.

The information and references provided in this manual are the best available at the time of publication. Please be mindful that ordinances, regulations, and online references are subject to change after publication of this document.

The case studies included in this manual serve as general examples of successful low impact development projects in the South Carolina Coastal Plain. However, it is important to keep in mind that these examples were designed and built before this manual was written, so they may not align completely with the recommendations provided in the technical specifications or better site design guidance.

1.2 Benefits of LID

Overview

The benefits of LID can reach a wide spectrum of stakeholders, as summarized below (NCCE, 2009; US EPA, 2013):

- ✧ Developers
 - Reduces land clearing and grading costs
 - Reduces infrastructure costs (streets, curbs, gutters, sidewalks)
 - Reduces stormwater management costs
 - Increases lot yields and reduces impact fees
 - Increases lot and community marketability
- ✧ Municipalities
 - Protects native flora and fauna
 - Balances growth needs with environmental protection
 - Reduces municipal infrastructure (streets, curbs, gutters, sidewalks, storm sewers)
 - Reduces system-wide operations and maintenance costs of infrastructure
 - Reduces costs of combined sewer overflows (CSOs)
 - Increases groundwater recharge
 - Fosters public/private partnerships
- ✧ Home Buyers and Residents
 - Preserves and protects amenities that can translate into more salable homes and increased property values
 - Provides shading for homes, which decreases monthly energy bills for cooling
 - Reduces flooding
 - Saves money through water conservation
- ✧ Environment
 - Preserves integrity of ecological and biological systems
 - Reduces demands on water supply and encourages natural groundwater recharge
 - Protects site and regional water quality by reducing sediment, nutrient, and toxic loads to water bodies
 - Reduces impact on local terrestrial and aquatic plants and animals
 - Preserves trees and natural vegetation
 - Improves air quality through the addition of vegetation
 - Reduces urban heat stress
 - Lessens sewer overflows

◇ Social

- Enhances aesthetics
- Stimulates economic development
- Creates green jobs
- Encourages more urban greenways
- Educates the public on their role in stormwater management
- Reduces flooding

Environmental Benefits of LID

Coastal Plain communities face many environmental challenges when it comes to managing stormwater runoff. The unique resources affected include shellfish, nearshore fisheries, spawning grounds, and tourism revenue. The natural resources in South Carolina contribute roughly \$30 billion and 230,000 jobs to the state's economy according to a 2009 study conducted by the University of South Carolina's Moore School of Business Division of Research.

2008	Direct	Indirect	Induced	Total
Labor Income	\$4,700,082,548	\$1,620,135,670	\$1,460,706,160	\$7,780,924,382
Employment	\$150,531	\$40,677	\$44,885	\$236,110
Total Impact	\$18,472,375,564	\$5,806,770,994	\$4,803,232,321	\$29,082,378,867

Protecting coastal waters from pollution provides cleaner water that supports recreation, tourism, and economics. Clean water allows residents and tourists to fish, swim, and safely enjoy coastal South Carolina. The Watershed Planning Needs Survey of Coastal Plain Communities conducted by Law et al. (2008) captured a snapshot of what coastal communities are doing to protect or restore local watersheds. The survey included 12 responses from South Carolina (16% of the total), and 45 responses from other southeast states including North Carolina, Georgia, and Florida (comprising 62% of total). According to the results of the survey, the top three stormwater pollutants identified as priorities in coastal watersheds are: sediment (65%), nitrogen (60%), and trash/debris (46%). Also, bacteria (43%) and phosphorus (38%) were noted as pollutants of concern, but by fewer communities. Of the communities surveyed, 47% reported problems with harmful algal blooms due to excessive nutrient pollution and tidal flushing of stormwater ponds.

In South Carolina, sediment and bacterial water pollution of tidal creeks has been correlated to urbanization of coastal uplands at large spatial scales (Van Dolah et al., 2008). In addition, the sediment contaminant classes considered in the study (PAHs, PCBs, pesticides, metals) increased significantly in concentration with increasing urban land cover. Findings indicate that upland urbanization can result in an increased risk of biological degradation, as well as reduction in safety of human contact with South Carolina's coastal resources (Holland & Sanger, 2008; Van Dolah et al., 2008).

Although a relatively recent addition to the coastal landscape, stormwater detention ponds are the most common Best Management Practices (BMPs) applied in South Carolina urban environments

to treat stormwater runoff, with over 14,000 ponds exceeding 21,000 acres in total area identified along the SC coastal zone (Drescher et al., 2011; Smith, 2012). According to Vandiver and Hernandez (2009), this trend will continue in the future due to the ability of ponds to meet the regulatory requirements, enable development of low elevation flat property, and provide “fill” for low-lying areas within the development. However, recent studies have examined how they may affect nutrient and organic matter dynamics and the implications for managing and maintaining water quality in the coastal zone. Smith (2012) studied residential ponds located in Georgetown and Horry Counties and found that stormwater ponds have become the loci of nutrient-driven eutrophication; excess organic production from these ponds is exported to receiving coastal waters and promotes declines in dissolved oxygen conditions.

LID practices are promoted as a reasonable alternative to ponds and researchers (Vandiver and Hernandez, 2009 and Drescher et al., 2007) note that although the use of LID practices in the South Carolina coastal region is currently limited, with increased awareness, guidance, and training, increased LID implementation can be expected. Various studies have shown the benefits of different types of LID practices. Some, like green roofs, have well documented reduction in runoff. Bioretention, on the other hand, has documented reduction in both nutrients and metals (Ahiablame et al., 2012). In comparing traditional development methods to LID techniques, low impact developments retain significantly more stormwater on-site and have fewer pollutants exported from the site (Bedan and Clausen 2009). Traditional development practices like curb and gutter frequently produce stormwater discharge from the site, where low impact development techniques can produce little to no discharge for small rainfall events (Selbig and Bannerman, 2008). Compared to traditional development, LID reduces runoff depths and peak discharges, and produces a longer lag time to peak discharge. LID practices better mimic pre-development hydrology to help reduce stormwater pollution (Hood et al., 2007). Table 1.2-2 compares the annual estimates for pollutant removal for various LID and traditional stormwater management practices.

In addition, LID provides a host of “ecosystem services” that are typically not included in cost-benefit analysis. An *ecosystem* is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment interacting as a functional unit, and *ecosystem services* are defined as benefits people obtain from ecosystems (Millennium Ecosystem Assessment, 2005). The human population is dependent on the essential flow of ecosystem services, including:

- ◇ Provisioning services:
 - Food
 - Water
 - Timber
 - Fiber
- ◇ Regulating services:
 - Climate
 - Floods
 - Disease
 - Wastes
 - Water quality

- ✧ Cultural services:
 - Recreational
 - Aesthetic
 - Spiritual
- ✧ Supporting services:
 - Soil formation
 - Photosynthesis
 - Nutrient cycling

Table 1.2-2. Stormwater Management Practice Performance					
BMP	Pollutant Removal¹ (%)				
	Total Suspended Solids	Total Phosphorus	Total Nitrogen	Metals	Pathogens
Bioretention	80-90	55-90	65-90	N/A	55-90
Permeable Pavement	80	60-80	60-80	N/A	45-75
Infiltration	80-95	65-95	55-90	N/A	65-95
Green Roofs	80	45-60	45-60	N/A	45-60
Rain Water Harvesting	Varies				
Disconnection	80	25-50	25-50	25-50	N/A
Open Channels	40	40-45 ²	20-35 ³	30	N/A ⁴
Stormwater Filtering Systems	90	65	45	50	80
Dry Detention ⁵	N/A	N/A	N/A	N/A	N/A
Wet Ponds	85	75	40	40	70
Wetlands	80	50	30	50	70

¹ *expected annual pollutant load removal*
² *range, with best removal for the wet or dry swales*
³ *range, with best removal for grassed channels*
⁴ *no data available, but expected poor pollutant removal*
⁵ *available data suggest minimal pollutant removal*

Low impact development contributes to ecosystem services by reducing flooding, improving water quality, reducing ambient air temperatures, and improving air quality (ECONorthwest, 2007). LID also promotes infiltration with the benefit of sustaining stream baseflow; additionally, LID reduces runoff volumes and pollutant loadings to downstream waters and reduces incidences of combined sewer overflows. Current development practices can short circuit this process, and thus produce faster and larger volumes of stormwater runoff, which in turn leads to flashy stream flow conditions (Callahan et. al. 2011). Other LID benefits that are typically not considered include restoration of habitats and vegetation that are important to wildlife.

Economic Benefits of LID

Cost information is a key factor for LID implementation. The designer, engineer, developer, and construction teams need to know how much LID will cost because the price can drive decisions to use LID or to use conventional structural stormwater practices, such as stormwater ponds.

While expense is a very important consideration, the data is variable, is influenced by many factors, and changes over time and space. Additionally, there are few LID cost reports. Cost and value exist in many categories such as construction, maintenance, retrofits, do-nothing scenarios, property development opportunity lost, property value increase, and several others. Keeping this complexity in mind, the economics of LID are outlined here. This information should be used to inform stormwater professionals and builders as a general rule of thumb. The body of LID economic information will grow and will be refined as more LID practices are implemented on South Carolina's coast.

There are three major methods used to assess the economics of LID:

- ✧ Cost comparison – Includes initial construction costs only.
- ✧ Life-cycle cost analysis – Includes planning, design, installation, operation and maintenance, and decommissioning.
- ✧ Benefit-cost analysis – Includes a range of costs and benefits, encompassing long-term life cycle costs that contain the parameters in the life-cycle cost analysis method. The benefit-cost analysis incorporates the economic benefits of LID (Beggs and Perrin, 2008).

The US EPA found that developers, property owners, and communities save money and protect and restore water quality when well-chosen LID practices are implemented (US EPA, 2007). The following resources include case studies, research, recommendations, and site specific LID costs:

- ✧ “Case Studies Analyzing the Economic Benefits of Low Impact Development and Green Infrastructure Programs” (US EPA, 2013)
- ✧ “Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices” (US EPA, 2007)
- ✧ “The Economics of Low-Impact Development: A Literature Review (ECONorthwest, 2007);
- ✧ “Low Impact Development Versus Conventional Development” (Shaver, 2009)
- ✧ “Forging the Link: Linking the Economic Benefits of Low Impact Development and Community Decisions” - See Chapter 3 from the Economics of LID (UNH, 2011)
- ✧ Coastal LID Case Studies include site specific information and cost information when available. These are online at <http://www.cwp.org/case-studies-from-the-coastal-plain>

For example, in Boulder Hills, NH, a design firm developing a 24-unit condominium community compared two development options – conventional and LID – for the project, and the LID development option saved money in most line items (Table 1.2-3). The final cost savings for this LID development was \$49,000 and this represented a 6% savings in total cost of stormwater infrastructure for the zero stormwater discharge site. [See UNH (2011) for the entire case study].

Table 1.2-3. Comparison of unit costs for materials for Boulder Hills LID Subdivision (UNH, 2011). Note the road for this development was porous asphalt.

Item	Conventional	LID	Difference
Site Preparation	\$23,200.00	\$18,000.00	-\$5,200.00
Temp. Erosion Control	\$5,800.00	\$3,800.00	-\$2,000.00
Drainage	\$92,400.00	\$20,100.00	-\$72,300.00
Roadway	\$82,000.00	\$128,000.00	\$46,000.00
Driveways	\$19,700.00	\$30,100.00	\$10,400.00
Curbing	\$6,500.00	\$0.00	-\$6,500.00
Perm. Erosion Control	\$70,000.00	\$50,600.00	-\$19,400.00
Additional Items	\$489,700.00	\$489,700.00	\$0.00
Buildings	\$3,600,000.00	\$3,600,000.00	\$0.00
Project Total	\$4,389,300.00	\$4,340,300.00	-\$49,000.00

Regional LID cost examples include the following:

- ✧ There are several LID economic and general presentations on SCDHEC's website at <http://www.scdhec.gov/HomeAndEnvironment/Water/Stormwater/LowImpactDevelopment/Presentations/>
- ✧ Nicole Saladin (2008), from the North Inlet-Winyah Bay NERR's Coastal Training Program, gave a presentation "Stormwater & South Carolina: A Case for Low Impact Development" and cited the following reduced infrastructure costs:
 - \$150 per linear foot road reduced
 - \$25 to \$50 per linear foot road narrowed
 - \$10 per linear foot sidewalk eliminated
 - \$1,100 construction cost per parking space eliminated
- ✧ The Berkeley-Charleston-Dorchester Council of Governments (BCDCOG) compared LID versus conventional stormwater designs in coastal Cane Bay Plantation in South Carolina. The study reported that LID design costs for single family residential homes were about \$2,000 to \$11,000 per acre more expensive than conventional design. However, the LID design costs for multi-family residential development were similar to conventional design (Fisher et al., 2007).
- ✧ Charlotte, NC's Charlotte-Mecklenburg Storm Water Services used LID/GI to prevent more waterway degradation and protect the drinking water reservoir. This was a 526 square mile area with 890,000 people. The county conducted a cost-effectiveness analysis to determine the cost of sediment per pound removed using LID/GI. They found LID practices such as stream restoration cost far less than traditional, structural stormwater practices. Stream restoration cost \$0.60 to \$1.00 per pound of sediment removed compared to \$45 to \$69 per pound of sediment removed by a wet detention pond. See Exhibit A.8.1: Cost-effectiveness of program components in the McDowell Creek watershed for the suite of LID/GI cost comparisons (in \$ per lb. of sediment saved) (US EPA, 2013).

- ✧ The Poplar Street Apartments in Aberdeen, North Carolina used bioretention, grass channels, swales, and stormwater basins in an apartment complex during the development. Using LID not only reduced stormwater runoff volume at the site but also saved an estimated \$175,000 (US EPA, 2007).
- ✧ A case study from Brunswick, NC provided by NC State University demonstrated \$45,900 cost savings using LID versus a stormwater pond (Hunt et al., 2007).
- ✧ Homeowner's willingness to pay more for LID value was \$5,000 per home in the Shepards Vineyard housing development in Apex, NC (Beggs and Perrin, 2008).
- ✧ LID implementation in Lockwood Folly, NC, reduced the size of the required stormwater pond that allowed the addition of another home and increased the developer revenue by \$90,000 (Beggs and Perrin, 2008).

EPA (2007) reviewed 17 case studies of developments that included LID practices and concluded that applying LID techniques could reduce project costs and improve environmental performance. In most cases, LID practices were shown to be both fiscally and environmentally beneficial to communities. In a few cases, LID project costs were higher than those for conventional stormwater management practices. However, in the vast majority of cases, significant savings were realized due to reduced costs for site grading and preparation, stormwater infrastructure, site paving, and landscaping. Implementation of individual LID devices at limited locations within a mostly conventional development plan does not reduce expense. Rather, the EPA study found that cost savings were realized through a holistic LID site design and planning process. Total capital cost savings ranged from 15 to 80 percent when LID methods were used, with a few exceptions in which LID project costs were higher than conventional stormwater management costs.

In 2011, the US EPA funded a project by Greenville County, SC, in conjunction with Upstate Forever and economists from Clemson University, to present information about the average construction costs of traditional and LID BMPs. The costs were determined through a combination of data from installed BMPs in Greenville County, component costs from regional sources, and national average costs for components (where regional data was unavailable). The construction requirements and specifications for both the traditional and LID BMPs were determined using the guidance in the Greenville County *Storm Water Management Design Manual* (2013), the North Carolina Department of Environment and Natural Resources *Stormwater Best Management Practices Manual* (2007), and the Maryland Department of the Environment *Stormwater Design Manual* (2000). The costs are summarized in Table 1.2-4.

BMP Practice	Standard Size	Standardized Cost
Dry Pond	¼ Acre	\$12,629
Wet Pond	¼ Acre	\$16,271
Bioretention Cell	500 ft ²	\$3,122
Bioswale	100 ft ²	\$280
Buffer Strip	100 ft ²	\$7
Constructed Wetland	1,000 ft ²	\$8,016
Green Roof	100 ft ²	\$1,732
Infiltration Trench	100 ft ²	\$555
Porous Pavement	100 ft ²	\$810
Interlocking Pervious Pavers	1,000 ft ²	\$19,000
Rain Barrel (average)	55 gallons	\$193
Sand Filter	100 ft ²	\$3,490

**information excerpted from Greenville County Stormwater BMP Report*

Another study at NC State University (Wossink and Hunt, 2003), found that the size of the watershed, the soil type, the imperviousness of the watershed, the pollutant of main concern, and the amount and price of land for the structure all influence the selection of a BMP. Table 1.2-5 summarizes the cost information from this study and shows that a bioretention area would be the least expensive BMP if it could be installed in sandy soil. Both the cost per treated acre and cost per percent of total nitrogen (TN) removed are less for this practice than if a wet pond or wetland were used. However, if clay soils were prevalent, a stormwater wetland would be the least expensive solution (based on annualized cost per acre of watershed). The study also found that maintenance for stormwater wetlands and bioretention units was less expensive than for wet ponds.

Practice	Wet Pond	Wetland	Bioretention in clay soils	Bioretention in sandy soils
Construction cost	\$64,357	\$11,740	\$124,445	\$7,843
Annual maintenance cost	\$4,411	\$752	\$583	\$583
Opportunity cost of land (\$217,800/acre)	\$43,560	\$65,340	\$65,340	\$65,340
Present value of total cost	\$146,474	\$83,486	\$194,751	\$78,137
Annualized cost per acre watershed	\$1,721	\$981	\$2,288	\$918
Annualized cost per percent pollutant removed				
TSS	\$26	\$15	N/A	N/A
TN	\$61	\$45	\$51	\$20

**information excerpted from Wossink and Hunt (2003)*

LID Cost Case Study: Oak Terrace Preserve Cost Comparison

Oak Terrace Preserve (OTP) is a 55-acre sustainable redevelopment project located in Park Circle, North Charleston. In the construction of OTP, developers and engineers created a system of LID practices, including bioretention swales, pervious pavers, pocket parks, and a forebay, to restore pre-development hydrology and promote infiltration and retention of stormwater on site. In addition, the developers and engineers of OTP partnered with local scientists to evaluate the effectiveness of these systems, including a cost comparison of OTP's LID development to traditional stormwater pond developments.

Development costs and profits were compared between OTP (an LID development) and 3 traditional stormwater pond developments (Tupper, 2012). Both infrastructure costs (e.g., stormwater, engineering, roads, water and sewer lines) and indicators of potential profits (e.g., home sales price, sales minus infrastructure costs, lost potential profit from stormwater pond area) were used in the comparison of LID to stormwater pond developments. All values were standardized by either square footage of the homes and/or the number of lots within the development. Due to data limitations, the evaluations were not able to address potential variations in the cost of the land and/or home construction.

The study indicated that the infrastructure costs of the LID development, OTP, were over \$10,000 more per lot when compared to traditional development costs. In addition to using LID stormwater practices, OTP incurred costs associated with the re-development of the land. Furthermore, the development of OTP was provided through a public-private partnership with the City of North Charleston; therefore, the costs of the OTP development also included the costs to upgrade the roads and stormwater infrastructure of an adjacent public school on the property. Subsequently, the costs directly associated with the LID stormwater practices versus the costs of re-development were difficult to determine.

A comparison of indicators of potential profit, however, suggest that the LID development, OTP, may be more profitable than traditional stormwater pond developments. Sales price minus the costs of infrastructure suggested that the LID development lots were potentially \$32,000 more profitable than the lots in the traditional developments. In addition, the use of stormwater ponds in the traditional developments required additional area which resulted in an average loss of 19 lots per development. This lost land area equated to lost potential profit (or cost) of nearly \$21,000 per lot when compared to the LID development. In summary, although the LID development had greater initial upfront costs, the higher sales price and the prevention of 'lost profit' from stormwater pond area, made the lots in the LID development over \$42,000 more profitable than those in the traditional developments. In fact, an OTP homeowner, when discussing the appeal of the green features of Oak Terrace (e.g., LID), said "...that is why I spent a lot more money on this house than I expected or wanted to" (Vandiver and Hernandez, 2009). These study results support findings that the consumer plays an important role in providing financial incentives for LID in the immediate future (Vandiver, 2012).



Comparison of the cost and potential profit of Oak Terrace Preserve (an LID development) to 3 traditional stormwater pond developments. Based on these findings, infrastructure cost of LID was greater but potential profit was also greater; making the lots in Oak Terrace Preserve on average \$42,000 more profitable than the lots in the traditional developments.

Case Study provided by Lisa Vandiver, NOAA Restoration Institute

Economic Benefits Case Study: Rivertowne Harris Teeter, Mt. Pleasant, SC

Fox Capital Partners, in collaboration with Harris Teeter, made the initial decision to build a new shopping center with Leadership in Energy and Environmental Design (LEED) certification. Part of that certification process involved stormwater management. Tom Fox, partner-in-charge at Fox Capital Partners, said that the decision to use low impact development techniques on this property was “a no-brainer – it’s smart and saved us money on piping and grading.”

Drainage presented a challenge on this site, due to flat topography and aligning with a fixed discharge point to an existing pond in the adjacent Planters Point development. The flat topography in the Coastal Plain, combined with the high groundwater table, limits the amount of vertical distance that pipes can be sloped and still provide adequate drainage. Stormwater pipes are designed to flow using gravity where possible. If the designers and developer had decided to use the typical “curb and gutters” that consist of parking lot inlet and pipes, the invert elevations for each subsequent pipe needs to be lower. Eventually, this would create a vertical space limitation. Furthermore, if traditional stormwater inlets and pipe networks were used to drain the site, the pipes would need to be a modified elliptical shape. Elliptical pipes carry more capacity than the usual round pipes, but also are significantly more expensive.

A creative LID solution used a central bioretention swale in the main parking lot, which drains through a series of bioretention areas, a stormwater pond, and finally a vortex separator (KRISTAR). The engineers designed the parking lot to drain using sheet flow into the central swale, eliminating the need for piping. Minimizing the amount of piping saved the client money and gave the engineers more flexibility to design the pipe network that connected the Rivertowne shopping center BMPs to the neighboring stormwater pond in Planters Pointe. Additionally, the parking lot utilizes pervious pavers in overflow parking and along the perimeter of the parking lot. Fox emphasized that even in a wet year, such as 2013, the system functioned properly and was successful. He plans to use LID stormwater practices again on future projects. Part of the success was credited to regular maintenance that included sweeping the parking lot three to four times weekly; and picking up trash two to three times weekly per the typical Harris Teeter business trash maintenance.



The bioretention cell (left) and swale (right) in grocery store parking lot intercept and treat stormwater runoff.



Other Nutrient Reduction Practices

Although they are not typical LID practices, two of the top-ranked BMPs (CWP, 2013) for nutrient reduction are pet waste programs and illicit discharge elimination. The CWP study calculated preliminary cost and performance estimates for these practices. Based on limited data, these practices have a high potential for a role in local urban stormwater strategies.

Behavioral programs, such as pet waste programs, are part of a watershed-based approach to better stormwater management. Although these programs and practices are not detailed in this manual, they can be effective pollution reduction and prevention measures. For more information, please see Clemson University's information for pet owners: http://www.clemson.edu/public/carolinaclear/what_you_can_do/pet_owner.html

Illicit discharge detection and elimination (IDDE) is one of the six minimum measures required for the Municipal Separate Storm Sewer (MS4) permit. Often the MS4 permit requirement for IDDE can be enhanced and improved at the local level. Recent work by Lilly et al. (2012) identified dry weather sewer leaks (i.e., IDDE) in Baltimore City, MD that if fixed would result in 217 lb/yr TN and 1,897 lb/yr TP pollutant load reduction in the coastal watershed. For more information, please see the Clemson University fact sheet about Illicit Discharge: http://www.clemson.edu/public/carolinaclear/water_quality/idde/

In summary, the LID economics in coastal SC will be refined as more LID projects are implemented and these findings are reported to the developers, engineers, architects, landscapers, researchers, and other groups that are interested in this topic. National and regional case studies demonstrate that the developments that use LID realize cost savings and increased value of the goods and services to the community (i.e., non-market valuation). However, not all developments will realize cost savings using LID. Careful consideration of the market, value of LID to the developer and subsequent market, and the appropriate method to assess the economics of LID should be conducted on a case-by-case basis to ensure LID meets the goal.

Evaluating Cost Effectiveness of LID

CWP (2013) evaluated a suite of urban stormwater practices to determine which procedures provide the greatest nutrient and sediment reductions for the lowest investment to help localities more cost-effectively achieve the pollutant load reductions to accomplish water quality goals. Cost-effectiveness is defined in this paper as an annual unit cost per unit of pollutant removed, and is calculated based on annualized life cycle costs divided by the pounds of pollutants removed per year. This metric is intended to be used by Virginia localities to compare the relative costs and pollutant removal effectiveness of 33 strategies to treat urban stormwater runoff (CWP, 2013)

The goal of the cost analysis was to calculate 20-year life cycle costs associated with BMP implementation, including design, construction, land values, financing, and operation and maintenance. A review of the published literature on BMP costs (e.g., King and Hagan, 2011) was conducted to compile the existing data. The study's key conclusions include:

- ✧ In general, cost effectiveness decreases when practices are installed as retrofits (compared to new), have underdrains (compared to none), or have poorly drained soils (compared to A/B soils).
- ✧ Permeable pavement, dry detention ponds and hydrodynamic structures consistently rank in the least cost-effective

tive category, due to their low water quality benefit (dry detention ponds and hydrodynamic structures) or high cost (permeable pavement).

See Table 2 on page 13 in CWP (2013) for a full list of the urban stormwater BMPs and associated cost effectiveness (\$/lb) for total nitrogen (TN), total phosphorus (TP), and total suspended solid removal (TSS). This is available online at <http://www.jrva.org/what-we-do/cost-effective-stormwater-management>

While the initial costs of adopting and designing newer technologies may be higher, there is ample evidence which demonstrates the use of LID development strategies can be cost effective in the long term. Land conservation, another key aspect of LID, can also have economic benefits. Conservation subdivisions have been shown to provide higher profits to developers because lots in conservation subdivisions carry a price premium, are less expensive to build, and sell more quickly than lots in conventional subdivisions (Rayman, 2006). A recently conducted graduate study evaluated the costs and potential profits at Oak Terrace Preserve and three comparable traditional developments in Charleston and Beaufort Counties. The findings from this study show that even though the costs of conservation and LID stormwater practices at Oak Terrace Preserve were slightly more expensive, their potential profit margins were significantly higher than all three of the traditional developments (Vandiver, 2012). Furthermore, the homes in Oak Terrace Preserve have maintained sales in a less than favorable real estate market (Tupper, 2012). Sometimes, as in the preceding case studies, LID techniques are the most cost-effective solution to drainage problems.

1.3 Coastal Features and LID

Most stormwater management practices were originally developed in the Piedmont physiographic region and have not been adapted for the distinct conditions in the Coastal Plain. Consequently, much of the available stormwater design guidance is strongly oriented toward the rolling terrain of the Piedmont with its defined headwater streams, minimal shallow groundwater flow, low wetland density, and well-drained soils. By contrast, both conventional and LID stormwater design in the Coastal Plain is strongly influenced by unique physical constraints, pollutants of concern, and resource sensitivity of the coastal waters. The significance of these constraints is described in this section. Further, stormwater management regulations and policies are often founded on Piedmont-based estimates of the volume and rate of stormwater runoff and efficiencies of control technologies that often do not apply to the coastal zone. This can result in inadequate stormwater control practices. Recent studies by Epps et al. (2013a and 2013b) suggest guidance for land-use and water resource management decisions, specifically with respect to stormwater management requirements for residential and commercial development, that consider not only surface water, but also groundwater. Low gradient topography and shallow water table characteristics of lower Coastal Plain watersheds allow for unique hydrologic conditions that must be assessed and managed differently than higher gradient watersheds.

LID can be applied effectively in the Coastal Plain with careful planning and design. Improper application of LID design, with little consideration for physical constraints, will reduce LID performance and efficiency. Physical factors in the Coastal Plain include flat terrain, high water table, altered drainage areas, extensive groundwater interactions, poorly-drained soils, and extensive

Annual Precipitation, United States, 1961-1990

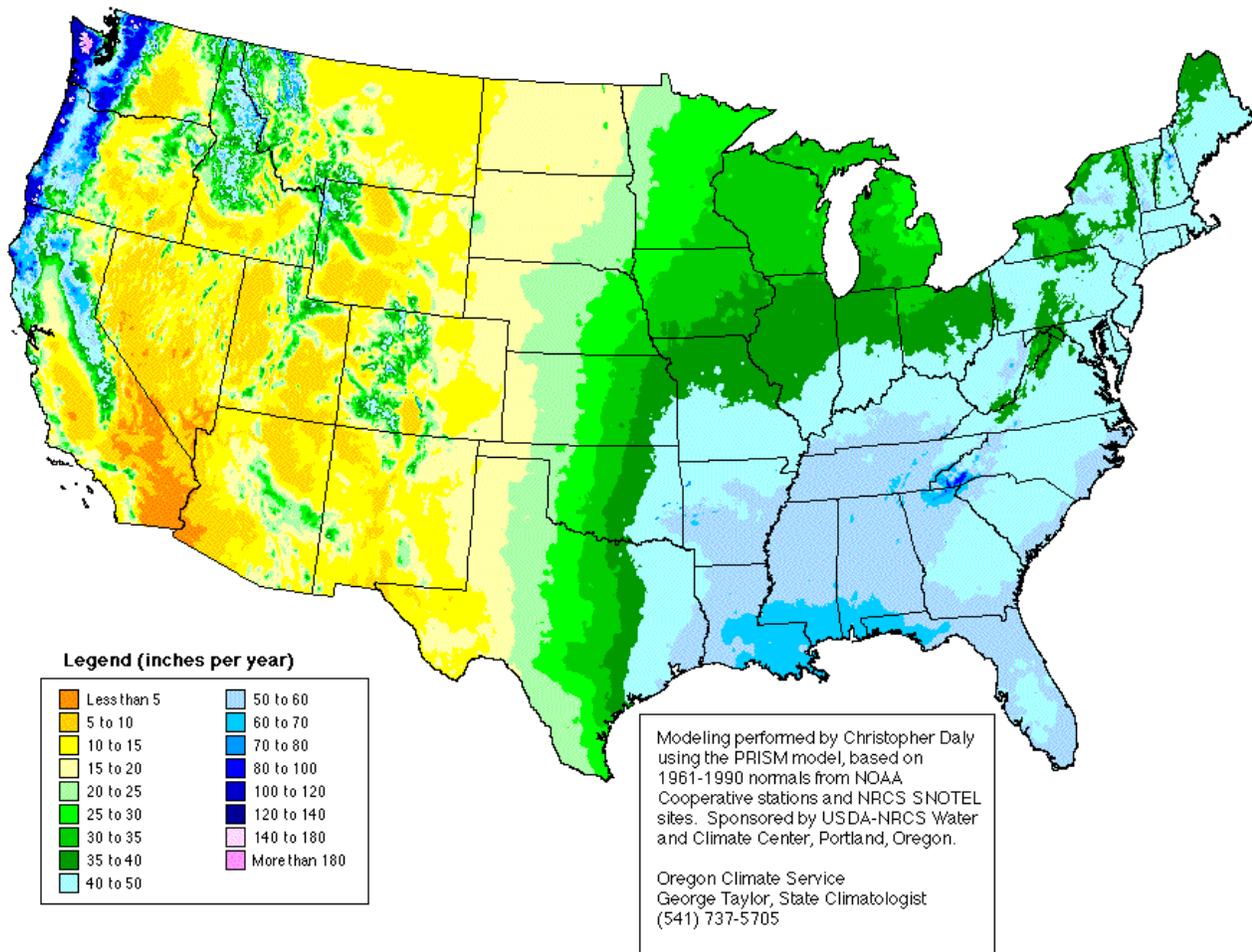


Figure 1.3-1. Annual Precipitation Map, United States, 1961-1990

(Source: http://hercules.gcsu.edu/~sdatta/home/teaching/hydro/slides/US_precip_map.gif)

wetland systems. The most notable feature of the Coastal Plain is its flat terrain, which in combination with its generally high and often tidally-influenced groundwater table, allows greater opportunity for non-point source (NPS) pollution to enter a coastal system when compared to inland systems. South Carolina's Coastal Plain has the highest average annual rainfall in the United States (see Figure 1.3-1), with the exception of the Pacific Northwest. The Coastal Plain in South Carolina averages 50 to 52 inches per year (SC State Climatology Office, accessed 2013). In addition, the region is subject to intense tropical storms and hurricanes, and generally has higher rainfall intensities than further inland. Recent studies related to the impacts of hurricanes on coastal forested wetlands have shown that Hurricane Hugo reduced carbon dioxide sequestration and significantly transformed the hydrology through two paired coastal watersheds (Dai et al., 2013; Jayakaran et al., 2013). The combination of high rainfall inputs, flat terrain, dense areas of impervious surfaces, and poorly drained soils (in some areas) can result in more frequent and even catastrophic flooding.

Flat Terrain

The most notable feature of the Coastal Plain is its uniformly flat terrain, which creates several watershed planning challenges. The low relief makes it possible to develop land without regard to topography. From a hydrologic standpoint, flat terrain increases surface water/groundwater interactions and reduces head available to treat the stormwater or move floodwaters through the watershed during the intense tropical storms and hurricanes. Work by Amatya et al. (2013) demonstrated a need for application of LIDAR-based digital elevation models together with field verification to improve the basis for assessments of hydrology, watershed drainage characteristics, and modeling in the flat lower Coastal Plain watersheds.

High Water Table

In much of the Coastal Plain, the water table exists within a few feet of the surface. This strong interaction increases the movement of pollutants through shallow groundwater and diminishes the feasibility or performance of many stormwater practices, including both LID and conventional BMPs. Additionally, the water table shows a strong relationship to tidal influences (Czwardacki, 2013), making it difficult to determine and design around the seasonal high water table. When the seasonally high water table is not accurately accounted for in design, it is not uncommon for LID and conventional best management practices to suffer performance deficiencies; for example, practices that were designed to infiltrate stormwater (e.g., bioretention) perform more similarly to stormwater wetlands.

Altered Drainage

The Coastal Plain stream network has been severely altered by 300 years of ditching, channelization, agricultural drainage, and mosquito control. The headwater stream network in many Coastal Plain watersheds no longer exists as a natural system because most first and second order streams have been replaced by ditches, canals, and road drainage networks (Van Dolah et al., 2008; O'Driscoll et al., 2010; Amatya et al., 2013; Jayakaran et al., 2013). These changes to the natural drainage patterns in the Coastal Plain are not reflected in existing LID models and regulations that may exist in other geographic regions, such as the Piedmont.

Poorly Drained Soils

Figure 1.3-2 depicts how portions of the Coastal Plain have soils that are poorly drained and frequently exhibit low permeability (Skaggs et al., 2011). As a result, the Coastal Plain watersheds contain extensive wetland complexes and have a greater density of wetlands than any other physiographic region in the country (see Figure 1.3-3). The South Atlantic Coastal Plain and Gulf Coastal Plain (excluding Texas) contained 29% of the total wetland acreage in the conterminous U.S. in 2004, while in many coastal watersheds, wetland cover alone often exceeds 25% of the total land cover, compared to the national average of 7% (Dahl, 2006). The prevalence of poorly-drained soils and wetlands may present certain challenges for implementing LID site design and practices which rely on infiltration.

Very Well-Drained Soils

In other parts of the Coastal Plain, particularly near the coast line, sandy soils with high permeability can have infiltration rates that exceed four inches per hour (Epps et al., 2013b). There is the possibility that runoff can move too rapidly through the soil profile without receiving full treatment.

Figure 1.3-2: Hydrologic Soil Group distribution, area, infiltration rates, and runoff potential for Coastal South Carolina

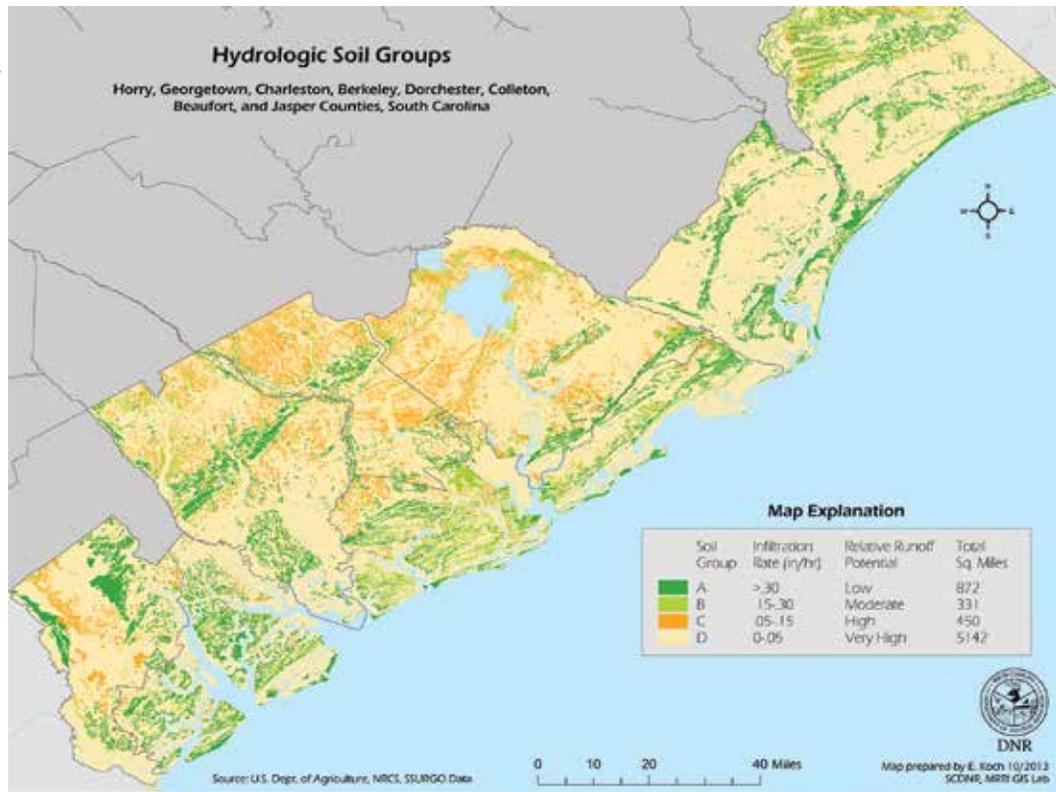
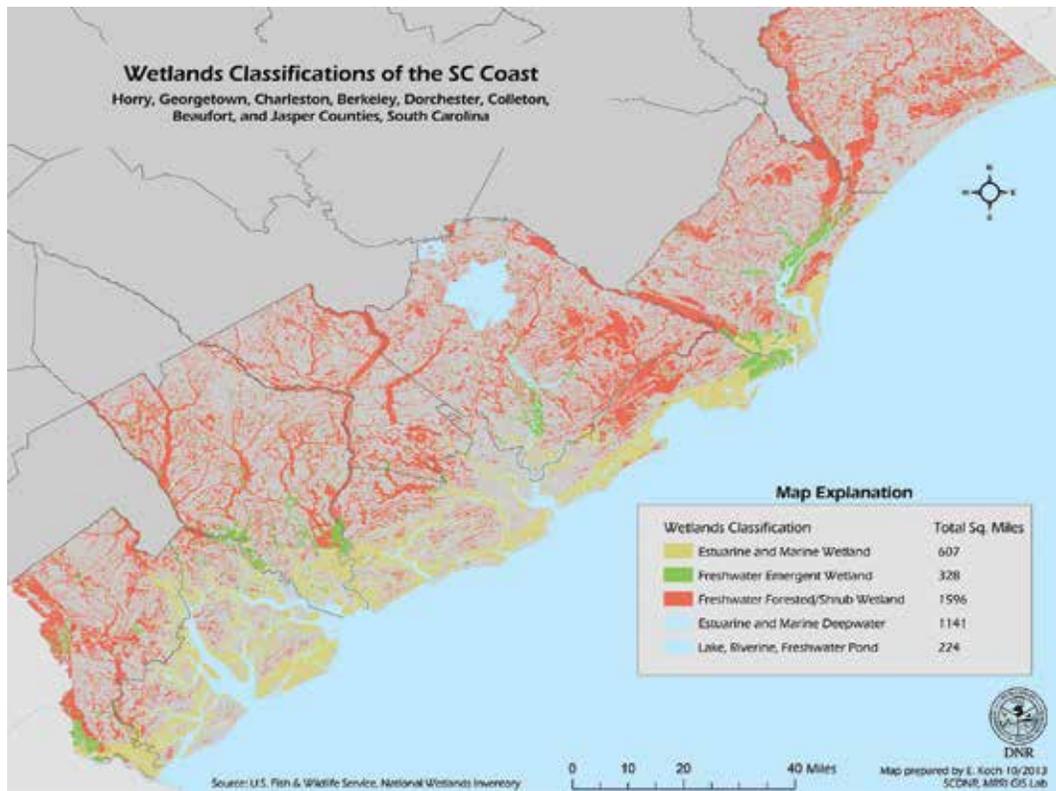


Figure 1.3-3: Extent and size of different types of wetlands along the South Carolina coast.



The risk is that these contaminated waters may be transported into nearby creeks and can pollute these waterbodies. At the same time, development in the Coastal Plain relies extensively on septic systems or land application to treat and dispose of domestic wastewater. Designers need to carefully consider how they design and locate stormwater so they do not impact adjacent septic systems.

Conversion of Croplands with Land Application

Land application of animal manure and domestic wastewater on croplands is a common practice across the Coastal Plain. When the land use of these areas changes (from agriculture to residential or commercial development), there may be concern that infiltration through these nutrient-enriched soils may actually increase nutrient export from the site. However, there are several regulations and permitting programs in place in South Carolina to prevent or limit these risks, including:

- ✧ SC R.61-43 *Standards for the Permitting of Agricultural Animal Facilities*;
- ✧ SC R.61-9.503 (Domestic Sewage Sludge) and SC R.61-9.504 (Industrial Sludge); and
- ✧ SC R.72-106 Erosion and Sediment Reduction and Stormwater Management.

Pollutants of Concern

Historically, watershed managers in the Piedmont have focused on phosphorus control, which is frequently a limiting nutrient for fresh waters but seldom for brackish coastal waters; however, given the naturally high phosphorus content in coastal soils and ubiquitous nature of freshwater stormwater ponds in the Coastal Plain, phosphorus is still considered a pollutant of concern. Phosphorus is a major indicator of algae in stormwater ponds and the presence of harmful algal blooms (HABs) in ponds has both human and ecosystem health impacts. The Ashley Cooper Stormwater Education Consortium identified phosphorus as a pollutant of concern to be addressed as part of a priority education strategy for both residential and commercial audiences in 2011 (Joyner and Counts, 2012).

Additional key pollutants of concern in Coastal Plain watersheds are sediment, nitrogen, bacteria, and metals. These pollutants have the ability to degrade the quality of unique Coastal Plain aquatic resources such as shellfish beds, swimming beaches, estuarine and coastal water quality, aquatic vegetation, migratory bird habitat, and tidal wetlands. The design and engineering of stormwater practices may need to be modified to achieve greater reductions in nitrogen, bacteria, and metals to improve coastal water quality.

Unique Development Patterns

The development patterns of Coastal Plain watersheds are also unique, with development concentrated around waterfronts, water features, and golf courses rather than an urban core. The demand for vacation rentals, second homes, and retirement properties also contributes to sprawling development.

The Highway as the Receiving System

The highway system represents an opportunity to treat stormwater runoff from these impervious surfaces in the Coastal Plain. The stormwater conveyance system for much of the Coastal Plain is frequently tied to the highway ditch system, which is often the low point in the Coastal Plain drainage network. New upland developments usually need approval from highway authorities to dis-

charge to their drainage system, which may already be at or over capacity with respect to handling additional stormwater runoff from larger events. The prominence of the highway drainage network in the Coastal Plain has several implications. For example, new and redevelopment projects should coordinate with the highway authorities to ensure that the site's stormwater runoff does not exceed the existing drainage system capacity. Also, when new development or redevelopment triggers stormwater treatment requirements, planners and designers should consider capturing and treating additional stormwater runoff from the highway with these new practices.

Hurricanes and Flooding

Communities face challenges when it comes to handling flooding events in the Coastal Plain (Amatya et al., 1998). First, their location on the coast subjects them to rainfall intensities that are 10 to 20% greater for the same design storm event compared to further inland. Second, the flat terrain lacks enough head to move water quickly out of the conveyance system (which may be further complicated by backwater effects due to tidal surges).

Future Conditions

Gradually, factors such as sea level rise and climate change will reshape the coastal features described in this section and potentially affect the ways stormwater will be generated and treated in the coastal region in the future, as described in Table 1.3-1. Climate change is anticipated to impact every aspect of the water cycle, and many of the underlying assumptions that stormwater managers use for runoff and storm system design might become outdated if these predictions become a reality. Changes in water elevation, storm intensity, and storm duration can impact the stormwater management program's LID placement, design hallmarks (such as the design storm, water quality volume, and stormwater conveyance), and other considerations needed to account for changing climate and associated impacts. Strategies to plan for these changes are provided in *Appendix G: Adapting Stormwater Management for Climate Change*.

Table 1.3-1. Climate Change Effects on Stormwater Design and Management

Climate Change Factors	Several Possible Effects on Stormwater Design & Management
<ul style="list-style-type: none"> ◆ Increase temperature of atmosphere ◆ Increase temperature of runoff ◆ Change in rainfall depth, intensity, and frequency ◆ Change in drought frequency and severity ◆ Decrease soil moisture (antecedent soil moisture between storms) ◆ Increase variability in winds and drying conditions ◆ Sea level rise ◆ In northern climates, more winter precipitation and creating rain on snow events ◆ Erratic climate patterns resulting in flash flooding, tornadoes, snow/ice precipitation, and severe drought 	<ul style="list-style-type: none"> ◆ Exceedances of storm system capacity and safety ◆ Increase in peak flows ◆ Number of properties and structures subject to flooding ◆ Decrease in annual infiltration volume due to higher evaporation and proportionally more runoff from more intense storms ◆ Decrease in stream baseflow ◆ Wider range of storm events to manage in order to achieve same level of pollutant load reduction ◆ Increased demand for water supply storage and reliability ◆ Broader application and geographic coverage of drought-tolerant plants for vegetated stormwater practices ◆ Impacts to sensitive waters, wetlands, and cold water fisheries ◆ Need for more land-use planning, such as floodplain management, “freeboard” requirements for storm systems, etc.
<p><i>Sources: Booth (2006), Hirschman et al. (2011), MWH (2009), Oberts (2007), and Shaw et al. (2005).</i></p>	

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