Guidance for Sustainable Stormwater Drainage on the Texas Coast

Neighborhood resident fishing in an enhanced detention wet pond, Chambers County, Texas (photo courtesy of Danica Adams)

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PREFACE

The purpose of this document is to provide guidance to small communities in the Texas Coastal Zone on the management of stormwater runoff from new development. New development may include a variety of projects such as residential, commercial, and office projects. The guidelines described are not intended to apply to redevelopment projects that do not result in a significant increase in the size of the existing development. Many of the chapters in this document are written for specific audiences, so the reader can focus primarily on those sections that are applicable to their situation.

The first chapter is intended to introduce the reader to the impacts of new development on the environment with a focus on aquatic impacts. It introduces the reader to the basics of stormwater runoff and discusses factors that impact the proper functioning of aquatic systems. The goal is to provide a basic understanding of the processes and provide motivation for adopting guidance to ensure that new developments include sustainable drainage systems. This chapter is written to highlight the importance of sustainable drainage systems whether you are a homeowner, elected official, business, drainage engineer or developer.

The second chapter is written specifically to describe practices that local residents can adopt to reduce the impact of stormwater runoff from their own properties. It includes a variety of topics including management of domesticated animal waste, use of herbicides and insecticides, maintenance of septic systems, and other topics. Like the first chapter, it is written to be accessible to a wide audience.

The third chapter transitions into a description of site design for new development. The primary audience for this section are developers, planners, and engineers, although the material should be of interest to a broad audience. Topics in this chapter include preservation of natural features, conservation design, and various practices to reduce the impacts of stormwater runoff from new development.

Chapter 4 is one of the more technical sections, with the intended audience primarily being civil engineers involved in the design of drainage systems for new development. It describes various types of drainage practices appropriate for different settings and provides detailed design guidelines. An important consideration in this chapter was to include only those design practices appropriate for the Texas Coastal Zone. Many new guidance documents (e.g., those adopted by Aransas and Harris Counties) are specifically focused on what has been termed Low Impact Development (LID). This manual, however, takes a broader approach and includes both LID practices and well as enhanced conventional practices to provide the designer with the widest range of options for the addressing the constraints of a particular site.

Chapter 5 is intended to provide examples of the implementation of the practices described in Chapter 4 in a variety of residential, commercial, and office developments. One of the most important points of this chapter is that much of the development now occurring in the Coastal Zone already includes a sustainable drainage system, although conveyance and flood control may have been the primary design considerations. This is especially apparent in residential developments that incorporate open channel drainage for stormwater conveyance.

In addition, many developments along the coast are required by drainage districts, counties, and other regulatory entities to provide stormwater detention for flood control. This manual describes how these detention facilities, with potentially only the slightest modification, can also improve water quality, while providing aesthetic benefits, recreational opportunities, and wildlife habitat.

The biggest change in current practice is likely to occur for commercial and office type projects, particularly those located close enough to the coast that detention is not required. Despite the additional effort required for compliance by these projects, the appropriate practices can include additional landscaping in parking areas, which, while improving stormwater quality, will also increase the attractiveness of these projects to both residents and visitors alike, potentially increasing tourism in the area.

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Chapter 1

INTRODUCTION TO WATER QUALITY IN THE TEXAS COASTAL ZONE

» *Stormwater Runoff Basics*

» *Importance and Status of Surface Water Quality in the Coastal Zone*

» *Why Stormwater Management Matters*

Citizens and communities of the Texas coast are proud of the diverse ecosystems, natural beauty, cultural bounty, and way of life they experience living along the Gulf of Mexico. The economy, cultural heritage, and environmental quality of the small communities and rural areas throughout the Texas coastal counties are inextricably linked to the health of tidal streams, bays, and estuaries along the Gulf Coast. Texas coastal waters sustain freshwater and marine water habitats that, in turn, support an abundance of fish and wildlife, tourism, and recreation. Threats to water quality, coastal habitats, and fish and wildlife populations are direct threats to the Gulf Coast economy.

While stormwater runoff from larger cities and metropolitan areas is regulated through a state permitting process, small cities remain unregulated. This document provides guidance for small cities in the coastal zone who would like to take the initiative in protecting their water quality.

1.1 STORMWATER RUNOFF BASICS

When a drop of rain falls during a storm, it may land on a tree and evaporate; it may land on a farm field and soak into the soil; or it may land on a rooftop, driveway, road or other hard, impermeable surface where it cannot soak in. Precipitation that does not evaporate or soak into the ground, but instead runs across the land and into the nearest waterway, is considered stormwater runoff. When stormwater travels across a surface, moving downhill towards rivers, resacas, and bays, it picks up pollutants along the way. These pollutants include bacteria, oil and grease, metals, organic material, or litter which eventually end up in the receiving water body.

Typically small coastal communities are faced with limited staff and funding resources for advancing environmental initiatives such as stormwater management. This document provides a pathway to improved water quality at minimal cost to the municipality.

Stormwater runoff from parking lots, roads and rooftops may flow to the street and into a storm drain, where it is conveyed through a pipe to a river or other body of water. Piping runoff in this way reduces the amount of water than can soak into the ground, and eliminates the pollutant removal that occurs in natural systems. Over time, this can reduce the water quality in the receiving waterbody.

Given the interconnectedness of ecosystem/water quality health and coastal community economies, it is critical to understand how land development directly affects watershed functions. This must be done at the regional scale, not a neighborhood or site scale. When development occurs in previously undeveloped areas, the resulting alterations to the land can dramatically change the conveyance and storage of stormwater runoff. Land development causes soil compaction and creates roadways, parking lots, buildings, and other surfaces that prevent infiltration of runoff into the ground. Any man-made surface which inhibits natural filtration of rain water through soil and increases surface runoff is typically called impervious cover.

As illustrated in Figure 1-1, new development, and the associated increase in hard, impervious surfaces often has the unintended consequence of increasing the volume as well as decreasing the quality of stormwater runoff that makes its way into rivers and bays. However, when new developments are designed using guidance in this document, it is possible to both reduce the amount of stormwater exiting a site, as well as improve its quality.

Sustainable development strategies are designed to reduce the impact of development on the environment and can be implemented at three scales: 1) the region or large watershed area, 2) the community or neighborhood, and 3) the site or block. Different stormwater approaches are used at different scales to afford the greatest degree of protection to waterbodies. At the regional or watershed scale, decisions about where and how to develop are the first, and perhaps most important, decisions related to water quality. At the site and block scale, combining multiple strategies to address stormwater volumes can have significant beneficial effects on both water quality and flood control. These issues are discussed in more detail in Chapter 3.

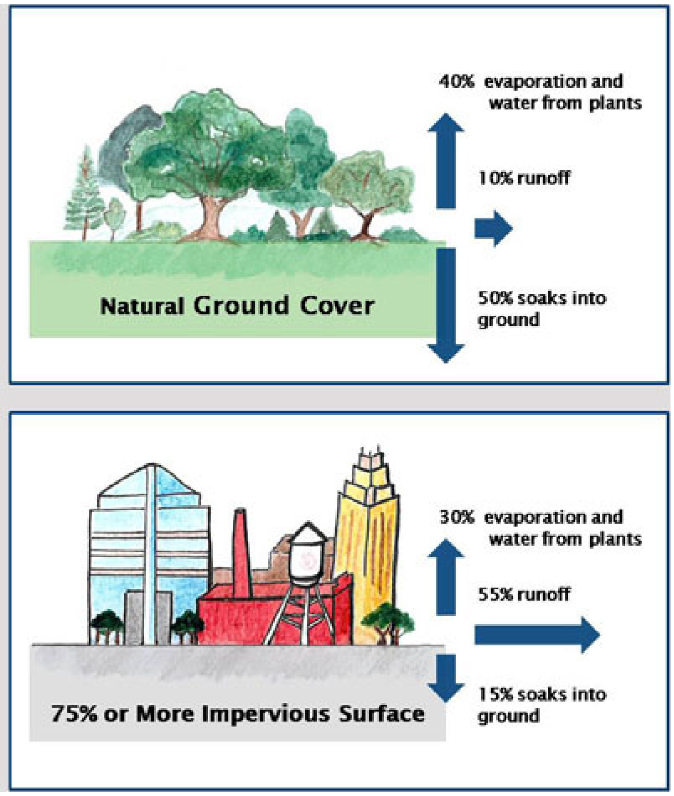


Figure 1-1: Influence of Impervious Cover on Infiltration. (Graphic courtesy of City of Durham, North Carolina)

Figure 1-2: Texas Coastal Wetlands. (Photo courtesy of TPWD)

1.2 IMPORTANCE AND STATUS OF SURFACE WATER QUALITY IN THE COASTAL ZONE

Water quality in Texas' tidal streams, bays, and estuaries is influenced by the quality and volume of freshwater inflow, which is critical for maintaining the fragile balance of water chemistry that marine species and coastal ecosystems depend on (TPWD 2014). Freshwater inflow to our coastal waters is provided by streams and rivers, groundwater, and stormwater runoff.

Water quality throughout the Texas coastal zone management boundary (CZMB) varies widely from high quality waters to those that are too polluted to meet water quality standards established by the Texas Commission on Environmental Quality (TCEQ). These water quality problems stem from a wide array of pollutants associated with "point sources" and "nonpoint sources" of pollution within coastal watersheds. Point sources of pollution originate from a single point or a discrete pipe such as a municipal wastewater treatment plant. Nonpoint sources of pollution originate from diffuse sources primarily associated with stormwater runoff. Protecting water quality will require ongoing commitments from developers; businesses; homeowners; landowners; drainage districts; and municipal, county, and regional governments. Nonpoint source pollution associated with stormwater runoff from new development is the sole focus of the recommendations and strategies described in this guidance document.

Texas has approximately 2,400 square miles of estuaries, and approximately 3,900 square miles of the Gulf of Mexico are within the jurisdiction of the state of Texas (TCEQ 2000). There are approximately 2,400 miles of tidally influenced

Table 1-1: 2012 §303(d) Listed Waterbodies near Non-MS4 Municipalities in Texas Coastal Zone

Municipality	County	Name of Water Body Segment	Impaired Use of the Water Body (2012)	2012 Pollutants of Concern
Anahuac	Chambers	Trinity Bay	Fish Oyster	Dioxin in edible tissue, PCBs in edible tissue
Aransas Pass	Aransas/Nueces/ San Patricio	Redfish Bay	Oyster	Bacteria
Bayview	Cameron	Laguna Madre	Aquatic Contact Oyster	Bacteria, depressed dissolved oxygen
Beach City	Chambers	Trinity Bay	Fish Oyster	Dioxin in edible tissue, PCBs in edible tissue
Brazoria	Brazoria	San Bernard River Tidal	Contact	Bacteria
Driscoll	Nueces	Petronila Creek Above Tidal	General	Chlorides, sulfate, TDS
Fulton	Aransas	Redfish Bay	Oyster	Bacteria
Ingleside	San Patricio	Redfish Bay	Oyster	Bacteria
Jamaica Beach	Galveston	West Bay	Fish Oyster	Dioxin in edible tissue, PCBs in edible tissue
Kingsville	Kleberg	San Fernando Creek	Contact	Bacteria
La Ward	Jackson	West Carancahua Creek Tidal	Aquatic	Depressed dissolved oxygen
Laguna Vista	Cameron	Laguna Madre	Aquatic Contact Oyster	Bacteria, depressed dissolved oxygen
Liverpool	Brazoria	Chocolate Bayou Tidal	Contact Fish	Bacteria, dioxin in edible tissue, PCBs in edible tissue
Palacios	Matagorda	Tres Palacios Bay/ Turtle Bay	Oyster	Bacteria
Port Aransas	Nueces	Gulf of Mexico	Contact Fish	Bacteria, mercury in edible tissue
Port Isabel	Cameron	Laguna Madre	Aquatic Contact Oyster	Bacteria, depressed dissolved oxygen
Port Lavaca	Calhoun	Lavaca Bay/ Chocolate Bay	Oyster	Bacteria
Raymondville	Willacy	Laguna Madre	Aquatic Contact Oyster	Bacteria, depressed dissolved oxygen
Rio Hondo	Cameron	Arroyo Colorado Tidal	Aquatic Contact Fish	Bacteria, DDE in edible tissue, depressed dissolved oxygen, mercury in edible tissue, PCBs in edible tissue
Robstown	Nueces	Oso Creek	Contact	Bacteria
Rockport	Aransas	Copano Bay/ Port Bay/ Mission Bay	Oyster	Bacteria
San Perlita	Willacy	Laguna Madre	Aquatic Contact Oyster	Bacteria, depressed dissolved oxygen
Seadrift	Calhoun	San Antonio Bay/ Hynes Bay/ Guadalupe Bay	Oyster	Bacteria
Sinton	San Patricio	Aransas River Tidal	Contact	Bacteria
South Padre Island	Cameron	Laguna Madre	Aquatic Contact Oyster	Bacteria, depressed dissolved oxygen
Sweeny	Brazoria	San Bernard River Tidal	Contact	Bacteria

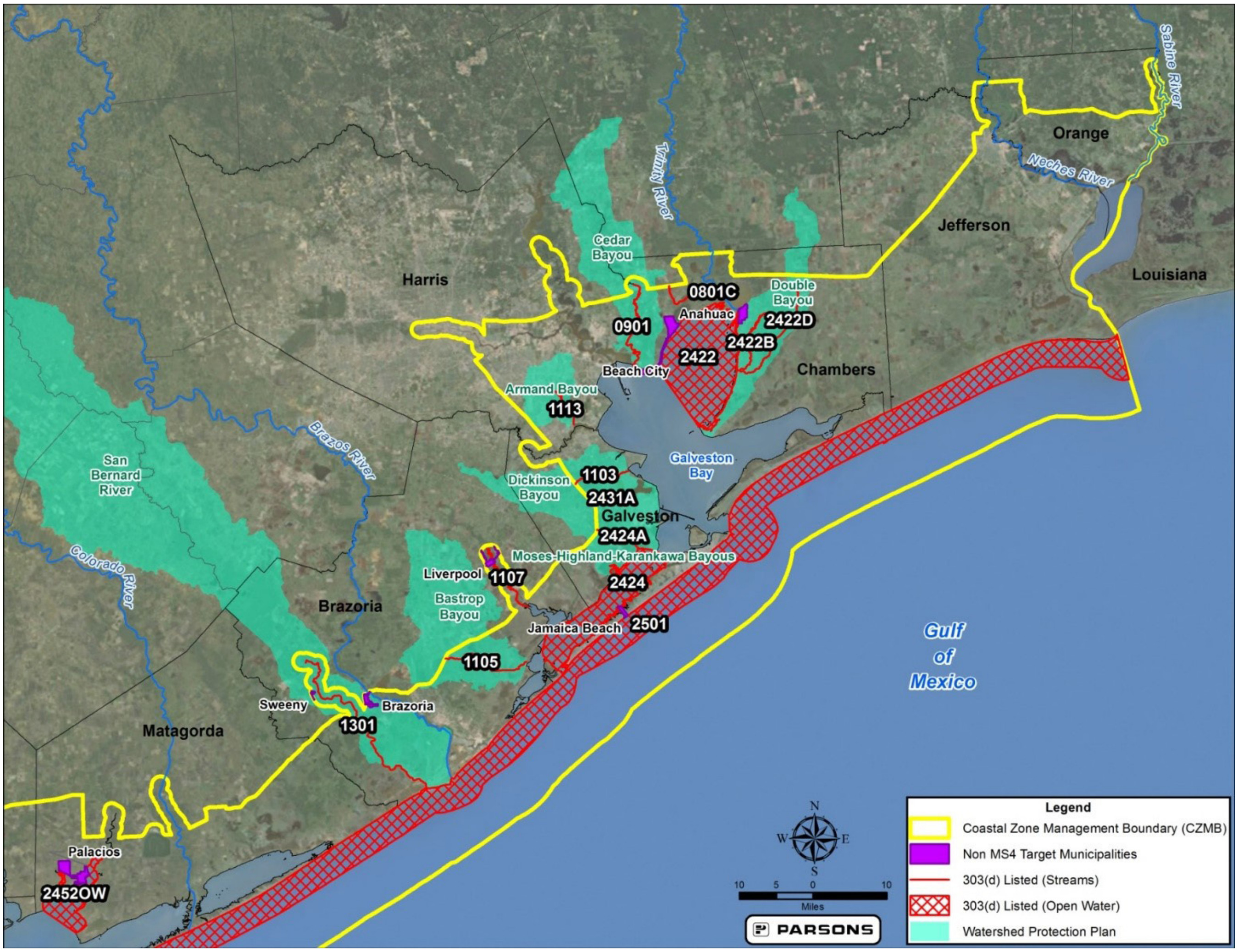


Figure 1-3: Waterbodies included on the 2012 Section 303(d) list of impaired waterbodies (Northern CZMB)

stream along the Texas coastline, which stretches 624 miles from the Sabine River to the Rio Grande.

Waterbodies in Texas have specific water quality standards, set by TCEQ and approved by the U.S. Environmental Protection Agency (USEPA), which must be met. These water quality standards serve as goals to protect water quality for a wide variety of uses, including drinking water, industrial use, agriculture irrigation, swimming, and protection of aquatic species. When these goals are not met, TCEQ requires local stakeholders to take steps to reduce sources of pollution that degrade water quality.

Waterbodies that do not meet water quality standards are included on a list of impaired waterbodies, in accordance with Section 303(d) of the Clean Water Act. This list is known as the "303(d) list". Waterbodies within the CZMB that are included on the 303(d) list are shown below in Table 1-1, and in Figure 1-3 through Figure 1-5. Table 1 1 lists several small cities in the Texas coastal zone that do not have state stormwater permits and their nearby impaired waterbodies. This table also identifies the uses of the waterbodies (such as fishing, oyster harvesting, aquatic contact, etc.) that have been impaired, and it lists the pollutants of concern. Typical pollutants transported in stormwater runoff from new development include metals, bacteria, sediment, organic matter, and nutrients. Design solutions used to mitigate pollutants and manage volumes of stormwater runoff are called best management practices (BMPs). Targeting BMPs to mitigate pollutants in stormwater runoff from new development is the focus of this guidance.

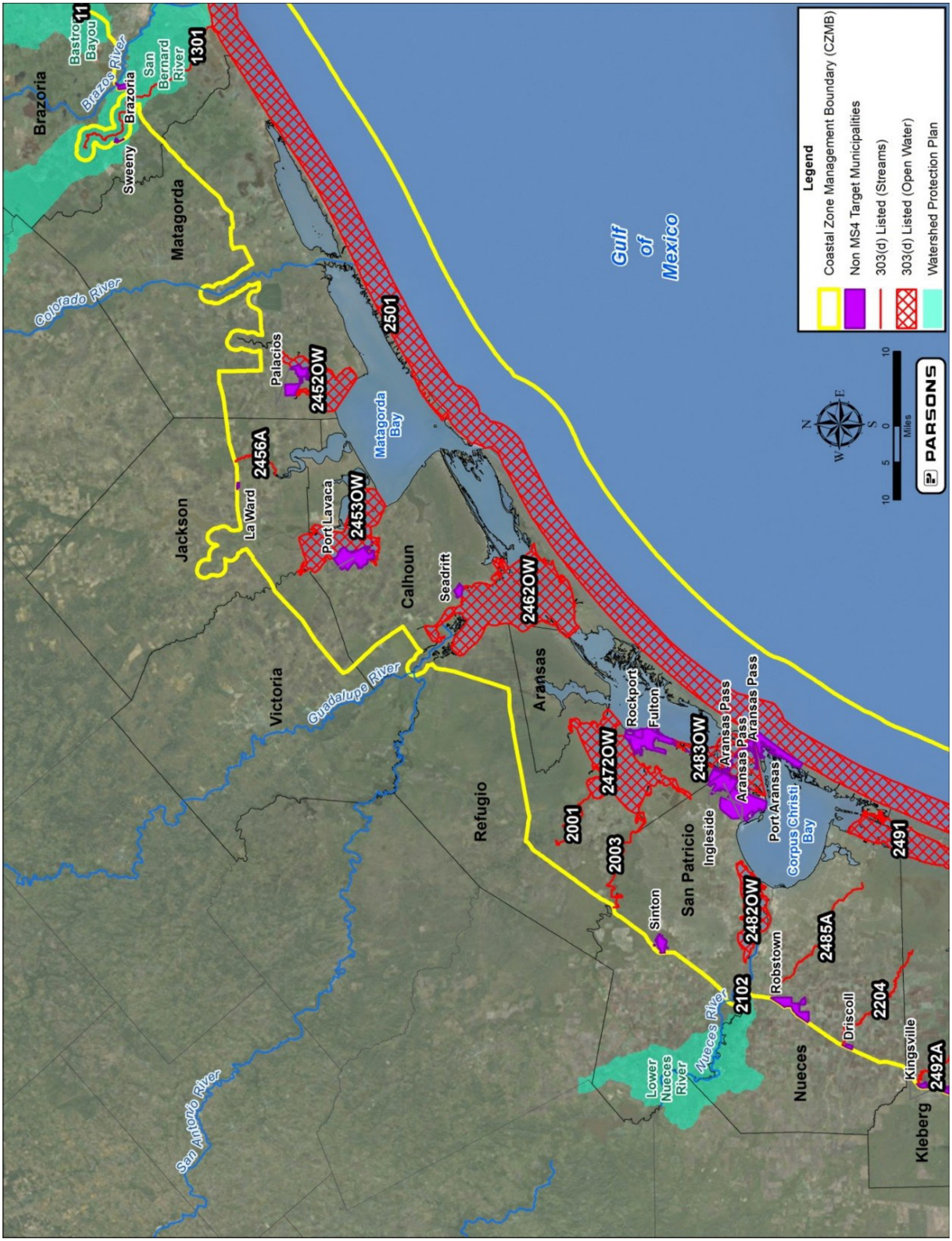


Figure 1-4: Waterbodies included on the 2012 Section 303(d) list of impaired waterbodies (Central CZMB)

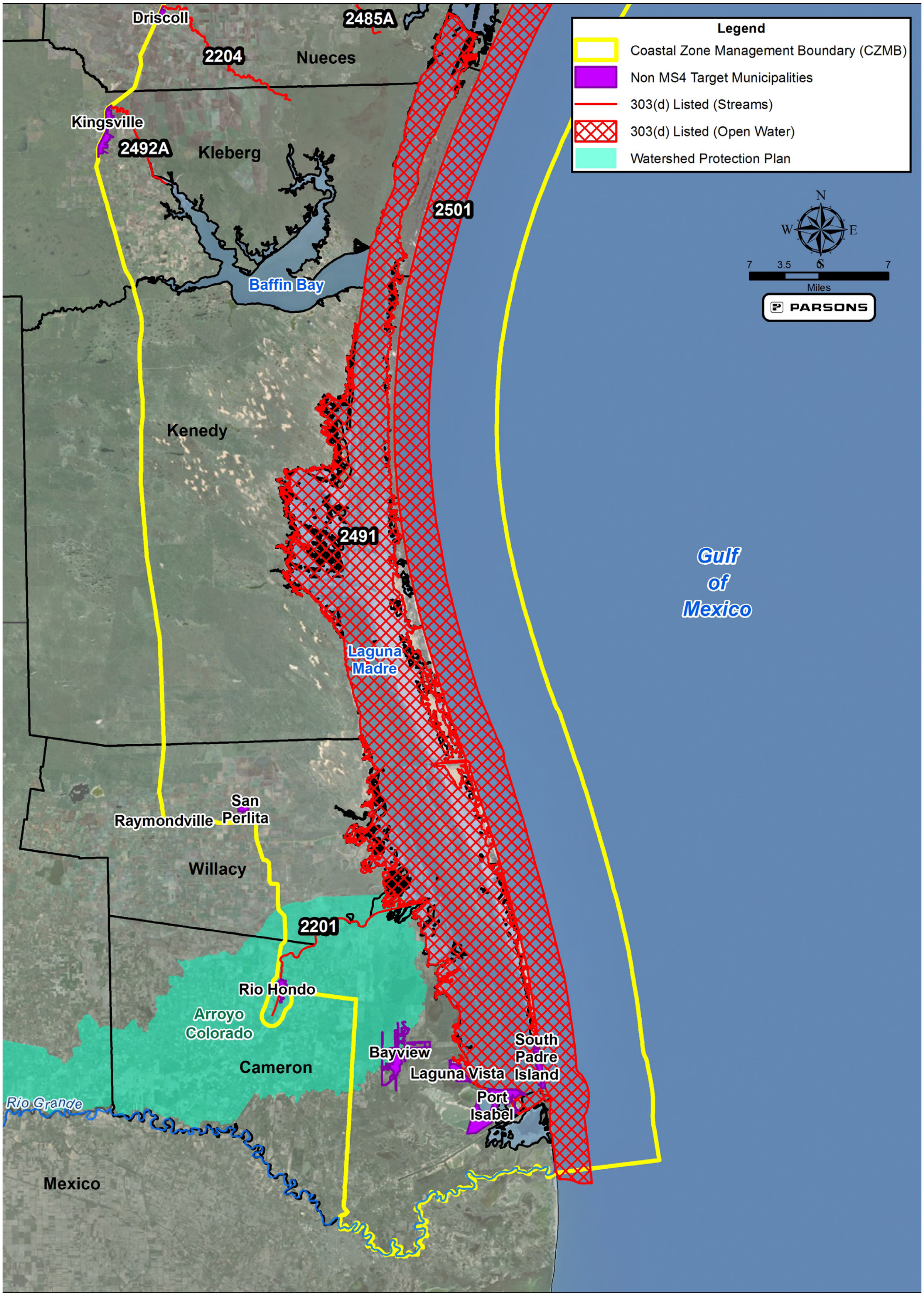


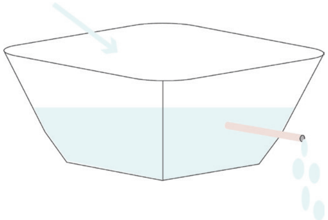
Figure 1-5: Waterbodies included on the 2012 Section 303(d) list of impaired waterbodies (Southern CZMB)

1.3 TERMINOLOGY

The following sections use several of the terms below as they define the practice and approaches to sustainable stormwater management strategies in more detail.

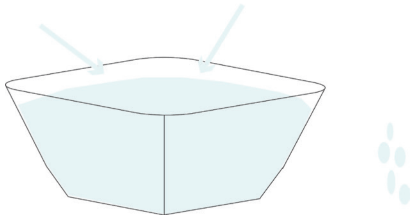
Detention

The temporary storage of stormwater runoff (in ponds, underground systems, or depressed areas) to allow for controlled discharge at a later time. The outlet structure restricts outflow to pre-development rates.



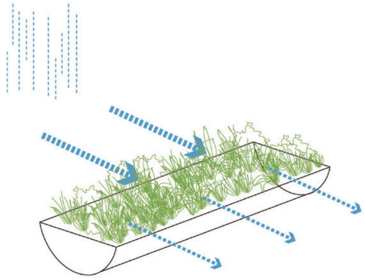
Retention

The storage of stormwater runoff on site and not released at a later time. There is no outlet structure, but retained runoff could be used for an additional purpose such as irrigation or a design amenity.



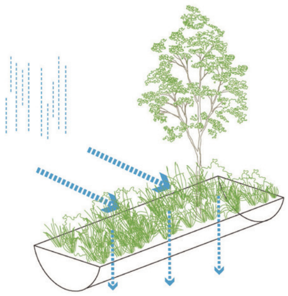
Filtration

The removal of sediment and other pollutants from stormwater runoff by the movement of runoff across a vegetated area and through media.



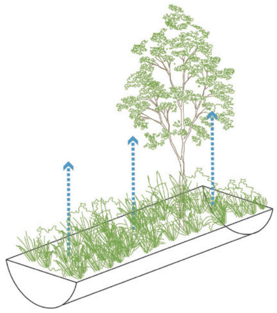
Infiltration

The vertical movement of stormwater through plants and soil; and in systems without an under drain or liner, recharging groundwater.



Evapotranspiration

The combined amount of evaporation and plant transpiration from the soil surface or the plant's vascular system to the atmosphere.



1.4 BENEFITS OF SUSTAINABLE DRAINAGE DESIGN

More than 6 million people live in the 18 Texas coastal counties; by 2050 the population in these counties is expected to reach 8.5 million (TWDB 2014a). Future land development in urbanized and rural areas will continue to create challenges for maintaining and restoring water quality in Texas' coastal watersheds. Sustainable stormwater management approaches can alleviate some of the challenges posed by development. The following section provides a brief discussion of some of the benefits of sustainable drainage practices.

1.4.1 Environmental Benefits

Pollution Abatement

The key to successful sustainable development practices is the reduction of both the volume of runoff and the amount of pollutants discharged into receiving waters. Sustainable development practices result in pollutant removal by using multiple strategies to mimic natural processes such as settling, filtration, adsorption, and biological uptake. The International BMP Database (www.bmpdatabase.org) is a good resource for examining pollutant removal data derived from multiple monitoring sites across the country. Reductions in stormwater pollutant discharges to receiving waters improve habitat for aquatic and terrestrial wildlife and enhance recreational uses.

Protection of Downstream Water Resources and Riparian Areas

Sustainable development practices can be used to protect water resources that are downstream. These practices can help to prevent or reduce hydrologic impacts on receiving waters, reduce stream channel degradation from erosion and sedimentation, improve water quality, increase water supply, and enhance the recreational and aesthetic value of the natural resources. Other potential benefits include reduced incidence of illness from contact recreation activities such as swimming and wading, more robust and safer seafood supplies, and reduced medical costs.

Ground Water Recharge

Sustainable development practices can be used to infiltrate runoff and recharge groundwater. Growing water shortages throughout Texas increasingly indicate the need for water resource management strategies designed to integrate stormwater, drinking water, and wastewater programs to maximize benefits and minimize costs. Development pressures typically result in increases in the amount of impervious surface and volume of runoff. Infiltration practices can be used to replenish groundwater and increase stream flow during dry periods. Adequate flow to streams during dry weather is important because low ground water levels can lead to greater fluctuations in stream depth, flows, and temperatures, all of which can be detrimental to aquatic life.

Habitat Improvements

Innovative stormwater management techniques like sustainable development or conservation design can be used to improve natural resources and wildlife habitat, or avoid expensive mitigation costs. Aquatic habitat improvements can be seen from sustainable development practices as the quality, volume, rate, and temperature of stormwater runoff entering receiving water bodies is more closely associated with pre-development conditions.

1.4.2 Land Value and Quality of Life Benefits

Many direct and indirect benefits of sustainable development derive from improved land value - through improved aesthetics, additional lot yield, or property protection – and quality of life benefits. These latter benefits are some of the most difficult to quantify, yet are also some of the most important for a community because sustainable development techniques can help enhance the quality of life in a community, provide multiple amenities, and provide an improved landscape and sense of place.

Reduced Downstream Flooding and Property Damage

Sustainable development practices can be used to reduce downstream flooding through the reduction of peak flows and the total amount or volume of runoff. Flood prevention reduces property damage and can reduce the initial capital costs and long-term operation and maintenance costs of stormwater infrastructure. Strategies designed to manage runoff on-site or as close as possible to its point of generation can reduce erosion and sediment transport as well as reduce flooding and downstream erosion. As a result, costs for cleanups and stream bank restoration can be reduced or avoided altogether. The use of sustainable development techniques at a regional and neighborhood scale can help protect or restore floodplains, which can be used as park space or wildlife habitat (Trust for Public Land 2007).

Real Estate Value/Property Tax Revenue

Homeowners and property owners are willing to pay a premium to be located next to or near aesthetically pleasing amenities like water features, open space, and trails. Some stormwater treatment systems can be beneficial to developers because they can serve as a "water" feature or other visual or recreational amenity that can be used to market the property. These designs should be visually attractive and safe for residents and should be considered an integral part of planning the development. Various sustainable development projects and smart growth studies show that people are willing to pay more for homes in a conservation development (a development strategy discussed in Chapter 3) than conventionally designed subdivisions. Further, many studies show examples where developers and, subsequently, homeowners, received premiums for proximity to attractive stormwater management practices (USEPA 1995).

Figure 1-6: Whooping Cranes in Aransas County. (Photo courtesy of TPWD)

Lot Yield

Strategies designed to manage runoff on-site can reduce the need for large detention areas and easements for stormwater infrastructure. In cases where sustainable development practices are incorporated on individual house lots and along roadsides as part of the landscaping, land that would normally be dedicated for a stormwater pond or other large structural control can be developed with additional housing lots. For more information on the cost-benefits of sustainable development, visit www.texassustainable development.org for a bibliography of cost-benefit resources and case studies.

Aesthetic Value

Sustainable development techniques can be attractive features when using landscaping as an integral part of the designs. Designs that enhance a property's aesthetics using trees, shrubs, and flowering plants that complement other landscaping features can be selected. The use of these designs may increase property values or result in faster sale of the property due to the perceived value of the "extra" landscaping.

Public Spaces/Quality of Life/Public Participation

Placing water quality practices on individual lots provides opportunities to involve homeowners in stormwater management and enhances public awareness of water quality issues. An American Lives, Inc. real estate study found that 77.7% of potential homeowners rated natural open space as "essential" or "very important" in planned communities (National Park Service 1995).

1.4.3 Other Economic Benefits

In addition to economic benefits from sustainable stormwater management such as erosion control, flood mitigation, or water quality improvements that reduce the cost of treating drinking water, there are a variety of economic benefits that are directly dependent on the quality and quantity of the water resources in the coastal zone. Examples of activities critical to the Texas economy and that are tied to the health of its bays and estuaries include:

» Coastal tourism provides $5.4 billion in Texas economic activity annually. Nature lovers from all over the world visit the Texas coast just to see rare species. Numerous activities contribute to making tourism the third largest industry in Texas, after oil and gas production and agriculture. Tourism for just the whooping crane alone results in over $6 million to Texas' coastal economy.

» Texas estuaries annually produce over 100 million pounds of seafood valued at $150-to-$250 million per year.

» Saltwater recreational fishing generates an estimated $2 billion (TPWD 2014). Sport fishing is popular among both residents and nonresidents in Texas, producing significant economic benefits for many individuals and businesses. Because fishing dollars are often spent in rural or sparsely populated areas, the economic contributions of these activities can be especially important to the rural economic base (Southwick Associates 2013).

Economic benefits are derived from preserving and restoring natural features and open space. Public and private investments in natural systems have a stimulating effect on economic output and employment. Restoration efforts offer localized benefits that can be attributed to the use of local labor and materials. Restoration investments have stimulus effects due to the ripple or multiplier effect on suppliers and related industries. These can be direct economic effects from the initial investment; indirect effects from increased demand in other industries for goods and services; and induced effects from changes in household spending by workers. One recent study found that restoration investments have beneficial effects on state or local economies comparable to those from investments in other industries (BenDor et al. 2014).

In addition, environmental conservation and sustainable development practices provide economic benefits by avoiding the costs of construction and maintenance associated with conventional infrastructure. Sustainable stormwater management can provide long-term benefits to property owners and businesses, increase tourism and recreation activity, increase yields for fisheries, and provide cost savings for local governments and state and federal agencies.

Chapter 2

HOW RESIDENTS CAN HELP PROTECT WATER QUALITY

» *Sustainable "Water-Smart" Landscape Maintenance*

» *Disposal of Household Hazardous Waste*

» *Septic System Maintenance*

» *Pet Waste Disposal*

» *Rainwater Harvesting and Use*

There are opportunities for everyone living along the Gulf Coast to help protect the quality of water resources. Even very simple changes in how landscaping is maintained, pet waste and ordinary household hazardous waste are disposed of, and how septic systems are maintained, make a difference downstream from a homeowner's property. Ideas presented in this chapter implemented at the neighborhood scale, such as installing rain barrels or a small cistern to capture rain water and using it to irrigate lawns or gardens, can have beneficial effects on managing stormwater volumes.

Figure 2-1: Garden featuring fall asters, a Texas native plant. (Photo courtesy of Lady Bird Johnson Wildflower Center at The University of Texas at Austin).

Making Landscape Part of the Solution

The proper design of landscapes to receive stormwater runoff from streets and other "impervious surfaces" can help reduce soil erosion and the natural processes in the soil will break down pollutants. Landscaping is recognized as the best form of erosion control; properly designed landscapes are shown to provide the most effective "treatment" in reducing stormwater volume and velocity and removing pollutants. However, there are also common landscape maintenance practices that can contribute to water quality problems, as described below.

Application of synthetic pesticides and herbicides can contribute to water quality problems. Many pesticides are toxic to aquatic life and may also enter the food chain.

Use of quick-release fertilizers can also be harmful to aquatic life. When entering receiving waters, the high levels of nutrients in synthetic fertilizers stimulate excessive growth of algae and other aquatic plants. This can create low oxygen conditions that adversely affect various aquatic species.

Excessive irrigation, in addition to contributing to water supply challenges, can contribute to water quality problems. Runoff from over-saturated landscapes and overspray from sprinklers onto sidewalks, streets, and parking lots can become dry-weather runoff. This flow of runoff can mobilize pollutants (such as oil and grease) on adjacent pavement, and carry the pollutants into creeks and other receiving waters.

Figure 2-2: Purple pleat leaf iris, a native plant of the Coastal Bend. (Photo courtesy of Dick Klopshinske, Native Plant Society of Texas, South Texas Chapter)

2.1 WATER-SMART LANDSCAPING

Getting started with water-smart landscaping can be as simple as applying mulch and compost. Using these readily available natural materials can help improve plant health, as well as the health of local creeks. The following tips can be helpful.

Water-Smart Landscaping Tip #1: Nurture the Soil

Developing and maintaining healthy soil is an important part of reducing or eliminating the need for quick release fertilizers and pesticides. The practices listed below help protect and improve the soil:

» Cover exposed soil with plants or mulch;

» Fertilize with compost; and

» Never mow more than one-third of the grass height.

Water Smart Landscaping Tip #2: Select the Right Plants

In addition to nurturing the soil, proper plant selection can reduce the need for synthetic pesticides and fertilizers. The following practices can help with successful plant selection:

» Landscape using native plants. Lists of plants suitable for local conditions, such as the following, should be consulted:

Plants for the entire Texas coastal area: http://aggie-horticulture.tamu.edu/southerngarden/coastplants.html

Lady Bird Johnson Wildflower Center Native Plant Recommended Species Collections, includes species recommended for South Texas: www.wildflower.org (click on Collections).

» Choose the right turf grass to reduce fertilizer and water needs:

Texas A&M Agrilife Extension, in its publication, Turf Grass Selection for Texas: Ecological Turf Tips, which may be downloaded at: http://galveston.agrilife.org/files/2011/05/L-5519-Turfgrass-Selection-for-Texas-6-2010.pdf.

» Plan for Growth - Newly planted shrubs and perennials will need room to grow.

Water Smart Landscaping Tip #3: Reduce Irrigation Use

Irrigation requirements can be reduced by selecting plants adapted to the local climate, as described above. The following additional tips can help reduce the use of potable water for irrigation, and avoid overwatering that can result in runoff flowing from saturated landscapes:

» Avoid water runoff from sprinklers and irrigation systems; and

» Use Efficient Irrigation to reduce overspray, evaporation, and runoff (Figure 2-3)

Water-Smart Landscaping Tip #4: Use Integrated Pest Management

Pest problems can be minimized by following the tips provided above for nurturing the soil, choosing the right plants, and providing sufficient irrigation to reduce stress on the plants and enhance their resiliency against pests and disease. When infestations occur, recommended integrated pest management (IPM) approaches described below should be followed. IPM is a common sense approach to managing pests.

» Encourage beneficial insects (Figure 2-4)

» Reduce or eliminate fertilizers, pesticides and fungicides

Figure 2-3: Irrigation overspray onto pavement can carry pollutants to creeks. (Photo courtesy of The Texas Coastal Watershed Program of Texas A&M University)

2.2 DISPOSAL OF HOUSEHOLD HAZARDOUS WASTE

Some consumer products contain chemicals that can present safety concerns if used or disposed of improperly. These materials are often called household hazardous waste and may include items such as:

» Corrosive cleaners (such as lye-based oven cleaner)

» Drain cleaner

» Fluorescent light bulbs (including CFLs)

» Fuels (gasoline, propane, diesel)

» Paints (oil-based or some anti-mildew latex)

» Pesticides

» Pool chlorine and acid

» Wood stains or varnishes

These materials should never be poured down the drain or disposed on the ground or in the storm drain system. If they are generated by a household, they are not required to be disposed as hazardous waste, and many can be placed in your regular trash. However, because these materials contain toxic, ignitable, or reactive ingredients, local governments may offer opportunities to dispose of these items in a more protective manner.

How to Dispose of Household Hazardous Waste

Many towns and cities in Texas have designated facilities where residents can drop off hazardous waste items and others may hold monthly or seasonal collection events. TCEQ maintains a list of ongoing household hazardous waste disposal facilities and programs, as well as individually scheduled events that are posted on the agency's Household Hazardous Waste web page (https://www.tceq.texas.gov/p2/hhw/contacts.html).

For the protection of homeowners and workers who collect hazardous waste, the following guidance and tips are provided regarding storage, transportation, and care:

» Products should be kept in their original container and labels should be readable. This ensures that household hazardous waste can be easily identified.

» Chemicals should be stored and transported in an upright position to avoid leaking – which could result in the mixing of incompatible chemicals.

» Products should never be mixed together, which can result in dangerous, even deadly, fumes.

» Chemicals should be kept in a cool, dry place out of the reach of children and pets.

Non-Hazardous Items that May Be Collected with Household Hazardous Waste

Many programs that collect household hazardous waste will also accept other common non-hazardous household material that can be recycled or offered to others in the community for reuse. These may include new or used:

» Antifreeze

» Motor oil or oil filters

» Non-hazardous latex paint

Items Exempt from Statewide Household Hazardous Waste Programs

Collections of any combination of batteries, used oil, latex paint, or antifreeze are exempt from requirements of the TCEQ's household hazardous waste program because these materials generally do not present substantial hazards.

2.3 SEPTIC SYSTEM MAINTENANCE

Septic systems are common along the Gulf Coast, where many residential properties are not served by centralized sewer systems. These underground wastewater treatment structures use a combination of nature and time-tested technology to treat wastewater from household plumbing, removing harmful bacteria, viruses, and nutrients in the wastewater. These systems require a regular program of maintenance to function properly.

Figure 2-4 shows how a typical septic system works. The system consists of a buried, water-tight septic tank and a drain field, or soil absorption field. Numbering included in the figure illustrates the following processes that occur in a system:

1. The septic tank receives wastewater from the house by way of a main drainage pipe.

2. The septic tank holds the wastewater long enough to allow solids to settle down to the bottom (forming sludge), while the oil and grease floats to the top (as scum). Compartments and a T-shaped outlet prevent the sludge and scum from leaving the tank and traveling into the drain field area.

3. After a period of settling, the liquid wastewater (effluent) exits the tank into the drain field. If the drain field is overloaded with too much liquid, it will flood, causing sewage to flow to the ground surface or create backups in toilets and sinks.

4. Finally, the wastewater percolates into the soil, naturally removing harmful coliform bacteria, viruses, and nutrients.

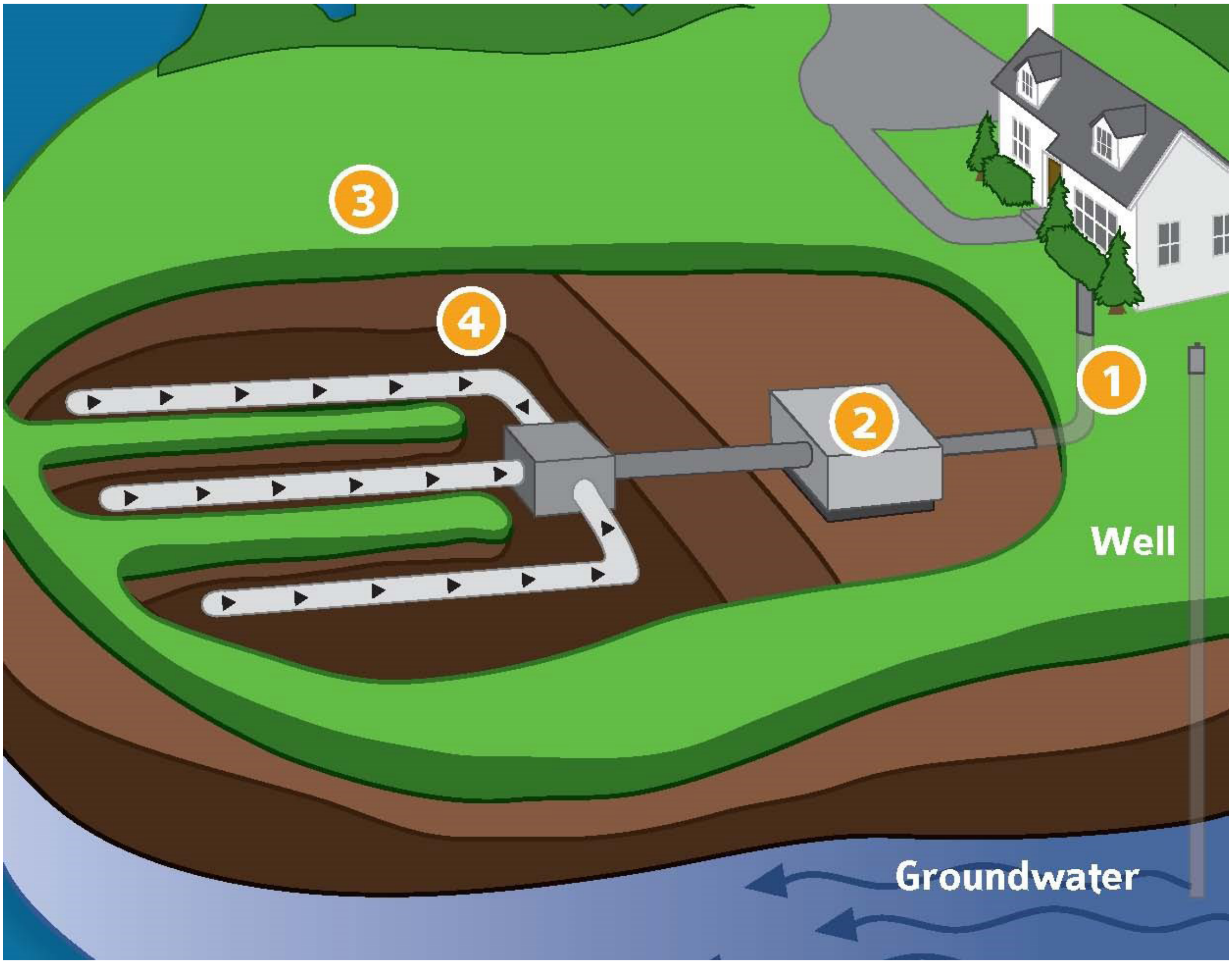


Figure 2-4: Schematic cut-away view of a typical septic system. (Photo courtesy of US EPA)

Why Maintain the Septic System?

Septic systems can be "out of sight, out of mind," but there are several reasons that maintaining a septic system is an important priority: cost savings, protecting property value, staying healthy, and protecting the environment. Regular maintenance is generally less expensive than the cost of repairing or replacing a malfunctioning system, and an unmaintained septic system will lower property value. Additionally, insufficiently treated sewage from septic systems can cause surface and groundwater contamination, affecting people and the surrounding environment.

How to Maintain a Septic System

To avoid costly system failures and establish a routine schedule of septic system maintenance, use a licensed maintenance provider for regular and standard inspections. TCEQ maintains an online listing, by county, of local government contacts for information regarding any local septic system requirements. Access to this list is at https://www6.tceq.texas.gov/oars/. Pumping is required if the bottom of the scum layer is within 6 inches of the bottom of the outlet, or if the top of the sludge layer is within 12 inches of the outlet. It is generally required every three to five years, but the need for pumping will be influenced by the size of the household, total wastewater generated, the volume of solids in water, and the size of the septic tank.

Signs of Septic System Failure

A foul odor isn't always the first sign of a malfunctioning septic system. A septic professional should be contacted if any of the following occur:

- Wastewater backing up into household drains.
- Bright green, spongy grass on the drain field, even during dry weather.
- Pooling water or muddy soil around the septic system or in the basement.
- A strong odor around the septic tank and drain field.

2.4 DISPOSAL OF ANIMAL WASTE

Pet waste is a water quality problem for creeks, rivers, lakes, and the Gulf. Microbial tracking studies performed on various watersheds in Texas found that domestic animals were the source contributor for 14 to 55% of the bacteria detected at sampling stations. Waste from domestic animals that is left on trails, sidewalks, streets, and grassy areas can be washed into the nearest waterway when it rains, which contributes to the following water quality problems:

» Bacteria and viruses: Like human waste, animal waste may contain harmful bacteria and viruses, making the water unfit for irrigation, recreation, or other uses.

» Excessive nutrients: Animal waste contains nutrients which, in excessive amounts, speed up the growth of nuisance weeds and algae in receiving water bodies. Overly fertile water becomes cloudy and green – unattractive for swimming, boating, and fishing.

» Low oxygen levels: When animal waste is washed into lakes or streams, the waste decays, using up the dissolved oxygen in the water, and sometimes releasing ammonia. Low oxygen levels and ammonia combined with warm temperatures can kill fish.

Safe Methods of Pet Waste Disposal

The most effective way for pet owners to limit their pet's contribution to water pollution is to simply clean up and dispose of pet waste. Remember the following safe methods for pet waste disposal:

» Flushing - As long as the droppings are not mixed with other materials, pet waste should be flushed down the toilet. This allows it to be properly treated by a community sewage plant or septic system. Pet owners should use plastic bags to pick up after their pet.

» Tossing - Pet waste can be sealed in a plastic bag and put into the garbage if local law allows it. This is good for water quality health, as well as the health of humans (especially children) and pets.

» Burying - Pet waste can be buried, if allowed by local law. Pet waste should be buried in a hole at least 1 foot deep, placing 3 to 4 inches of pet waste at the bottom. A shovel should be used to chop and mix the waste into the soil at the bottom, then covered with at least 8 inches of soil to keep away rodents and pets. Pet waste should only be buried around ornamental plants, and never in vegetable gardens or food-growing locations. Pet waste is not recommended for back yard compost piles because parasites carried in dog and cat feces can cause diseases in humans.

Other Water-Smart Pet Care Tips

The following practices will help pets be part of the solution to water pollution:

» Keep pets away from streams, ponds, or lakes.

» Keep pet waste off of sidewalks and streets.

» Use the "Long Grass Principle." Long grass (about 6 inches high or taller) helps filter pollutants so the waste can decompose naturally with minimal pollution of runoff.

Managing Waste from Larger Animals

Many of the practices listed above also apply to other domestic animals such as horses, cattle, swine, poultry, goats, or donkeys that may be kept on large residential or rural properties along the Gulf Coast. An animal waste management program to protect water quality would generally also include the following:

» *Correct Siting and Design.* Keep as much filtering vegetation as possible between livestock barns, corrals, etc., and any water body. High-use areas should be away from creeks/other water bodies.

» *Collection and Storage.* Manure and soiled bedding should be collected from stalls and paddocks daily and placed in temporary long-term storage protected from rainfall and runoff.

» *Disposal and Use.* Manure may be collected and applied to cropland or pasture as fertilizer. Two to three weeks should pass before allowing livestock on the pasture.

2.5 RAINWATER HARVESTING

Rain barrels and cisterns can be installed to capture stormwater runoff from rooftops and stored for later use. These are low-cost systems that allow homeowners to supplement the water supply with a sustainable source and help preserve local watersheds by detaining rainfall.

Collected rainwater may be used for landscape irrigation. Capturing even a small amount of roof runoff has environmental benefits because it reduces the quantity of stormwater runoff flowing to local creeks. Rain barrels typically store between 50 and 200 gallons (Figure 2-5). They require very little space and can be connected or "daisy chained" to increase total storage capacity.

Cisterns are larger storage containers that can store 200 to over 10,000 gallons. These come in many shapes, sizes, and materials, and can be installed underground to save space.

Figure 2-5: Residential rain barrel. (Photo courtesy of TCEQ)

Feasibility of Rain Barrels or Cisterns

Rain barrels and cisterns are appropriate for properties with the following characteristics:

- Roof areas that drain to downspouts.
- A level, firm surface to support a rain barrel(s) or cistern to prevent shifting or falling over. A full 55-gallon rain barrel will weigh over 400 lbs.
- A landscaped area where the captured water can be used (and where it can be drained by gravity flow) should be located within a reasonable distance from the rain barrel(s).
- A landscaped area or safe path to the storm drain system that can handle overflow.

Roofing Material Considerations

Surface materials on the area from which rainwater will be collected affect the quality of captured rainwater, which has implications for the recommended uses. If the roof has asphalt or wooden shingles, harvested rainwater should only be used for non-edible landscapes, unless the water is treated first. Petroleum or other chemicals from these roofing materials can leach into the rain water. Roofs with cement, clay, or metal surfaces are ideal for harvesting water for a wide variety of uses.

Gutter and Downspout Considerations

Properly sized and maintained gutters and downspouts are essential to a rainwater harvesting system. New downspouts should be strategically located in an area where the rain barrel or cistern will be most useful. A fine mesh gutter guard on gutters to keep leaves and other debris from entering and clogging the gutters should be installed, which will reduce the need for cleaning out accumulated sediment.

First Flush Diverters, Filters and Screens, and Downspout Consideration

Leaves, twigs, sediment, and animal waste are common in runoff, especially at the beginning of a storm ("first flush"). This debris can result in clogging, and encourages bacterial growth. A first flush diverter helps remove debris and contaminants by directing the first few gallons of runoff from the roof to landscaping, away from the rain barrel or cistern.

Rainwater Harvesting Design

There are a variety of available system designs that provide for water conservation as well as stormwater management. Sources for additional information include:

» Texas A&M AgriLife Extension: http://rainwaterharvesting.tamu.edu/

» American Rainwater Catchment Systems Association: http://www.arcsa.org/

Operation and Maintenance

After installing a rain barrel or cistern, these tips should be followed for long-term safety and functionality:

» Gutters and gutter guards should be regularly checked to make sure debris is not entering the rainwater harvesting system.

» Screens on the rain barrel or cistern should be inspected to make sure debris is not collecting on the surface and that there are no holes allowing mosquitoes to enter the rain barrel. Inspect screens more frequently if there are trees that drop debris on the roof.

» The inside of the rain barrel should be cleaned once a year to prevent buildup of debris. If debris cannot be removed by rinsing, vinegar or another nontoxic cleaner should be used.

» Clean out debris from cisterns once a year. Drain wash water to landscaping.

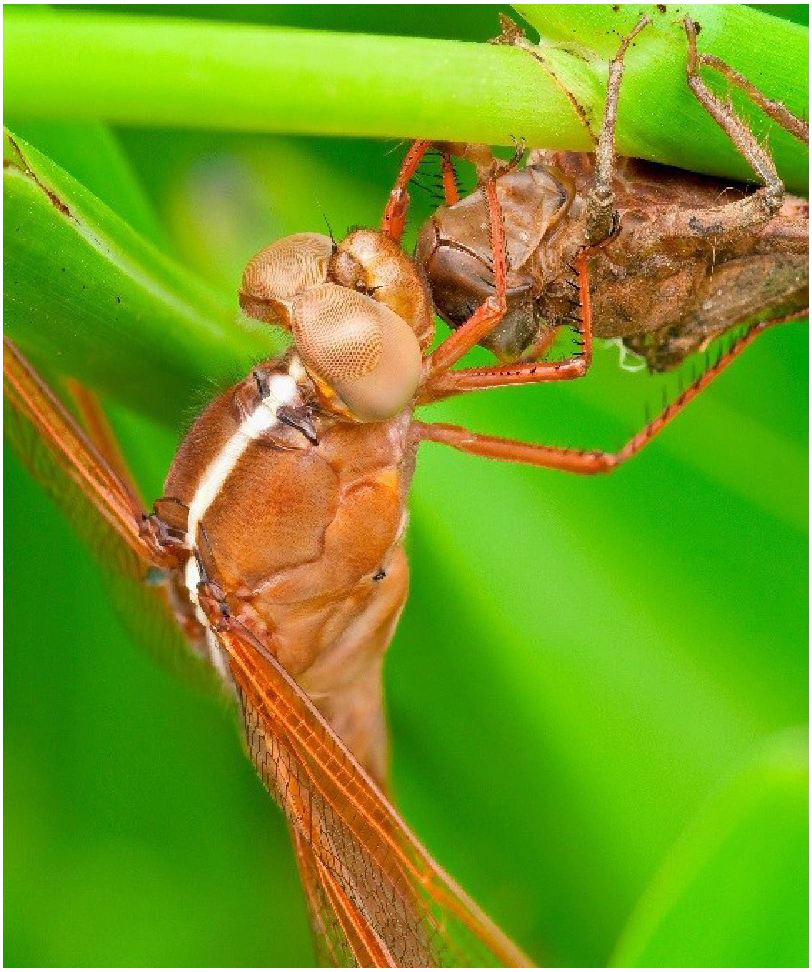


Figure 2-6: Dragonflies, a beneficial insect, eat mosquitoes, midges and other pests. (Photo courtesy of Lady Bird Johnson Wildflower Center at The University of Texas at Austin)

Chapter 3

GUIDANCE FOR SUSTAINABLE SITE DESIGN

» *Elements of Sustainable Site Design*

» *Preservation of Natural Features*

» *Conservation Design for Subdivisions*

» *Reduction and Disconnection of Impervious Cover*

Sustainable site design incorporates approaches to new and redevelopment projects which reduce impacts on watersheds by conserving natural areas and better integrating stormwater treatment.

3.1 INTRODUCTION

The aim of sustainable site design is to reduce the environmental "footprint" of the site while retaining and enhancing the owner/developer's purpose and vision for the site. Many of the sustainable site design concepts employ non-structural on-site treatment that can reduce the cost of infrastructure while maintaining or even increasing the value of the property relative to conventional designed developments. Non-structural treatment is the treatment of stormwater by maintaining a focus on preserving open space, protecting natural systems, and incorporating existing landscape features such as wetlands and stream corridors into a site plan to manage stormwater at its source. In other words, it is the treatment of stormwater without a structure.

The goals of sustainable site design include:

» Prevent stormwater impacts rather than having to mitigate for them;

» Manage stormwater (quantity and quality) as close to the source as possible and minimize the use of large or regional collection and conveyance;

» Preserve natural areas, native vegetation and reduce the impact on watershed hydrology;

» Use natural drainage pathways as a framework for site design;

» Reduce soil compaction during construction to maintain infiltration capacities of the soil;

» Minimize the amount of disturbance to existing, mature stands of vegetation;

» Utilize non-structural methods for stormwater management that are lower cost and lower maintenance than structural controls; and

» Create a multifunctional landscape.

The first series of stormwater site design practices and techniques can be grouped into Preservation of Natural Features and Conservation Design. Discussion of non-structural techniques on site and lot, such as reductions in impervious surface and disconnection, will follow.

3.2 PRESERVATION OF NATURAL FEATURES

Preservation of natural features includes techniques to foster the identification and protection of natural areas that can be used in the conservation of water resources. Whether a large contiguous area is set aside as a preservation zone or certain smaller areas have been identified as appropriate for preservation, protecting established vegetation (existing trees, shrubs, grasses, and other flora) can help reduce revegetation requirements, reduce long-term erosion, preserve habitat, protect water and land resources, and maintain a healthy ecosystem.

Other benefits include:

» An immediate finished "aesthetic" that does not require time to establish;

» Increased stormwater infiltration due to the ability of mature vegetation to process higher quantities of stormwater runoff than newly seeded areas;

» Reduced runoff velocity, quantity, (by intercepting rainfall, promoting infiltration, and lowering the water table through transpiration, among others);

» Provides a buffer against noise and visual disturbance during construction; and

» Usually requires less maintenance (e.g., irrigation, fertilizer), land clearing labor and costs than planting new vegetation.

Site Assessment

In order to reach these benefits, it is important to first identify and preserve sensitive areas on the site. A site assessment is the process whereby the design team conducts an in-depth evaluation of the overall environmental conditions of the proposed development or redevelopment prior to detailed site design. Natural conservation areas are typically identified using mapping and field reconnaissance assessments. Areas proposed for protection should be delineated early in the planning stage, long before any site design, clearing or construction begins.

Figure 3-1: Depression storage in Aransas County, Texas - larger than 1 acre in size and deeper than 2 feet.

The goal is to broadly identify and evaluate the ecological systems influencing the area to reduce cost and time impacts from a design, construction and maintenance perspective. Achieving cost reductions is a direct result of an understanding of environmental characteristics and integrating the most appropriate construction. The initial design and planning phase is the most appropriate time to conduct the site assessment. Items to examine during a site assessment should include:

» Soil types and infiltration rates;

» Health and types of existing vegetation (trees, grasses, shrubs and forbs);

» Riparian areas and significant waterways;

» Prominent landforms;

» Depression Storage;

» Wetlands;

» Flood plains.

Identifying these areas can help inform later development, as sites should be located to avoid sensitive resource areas such as floodplains, erodible soils, wetlands, mature forests and critical habitat areas. Buildings, roadways, and parking areas should be located to fit the terrain and in areas that will create the least impact.

Wetlands

Generally, wetlands are areas where regular or intermittent saturation with water determines soil type, flora and fauna. Non-tidal wetlands are most common in floodplains along rivers and streams, in isolated depressions surrounded by dry land, along the margins of lakes and ponds, and in other low-lying areas. While wetland plants and soils filter stormwater before it goes into groundwater or into rivers, a significant cause of loss for tidal and non-tidal wetlands is new development.

Wetlands are regulated under §404 of the Federal Clean Water Act. The U.S. Army Corps of Engineers, under provisions of the Clean Water Act and the Rivers and Harbors Act, must issue a federal permit for impacts to both tidal and non-tidal wetlands and shallow water habitat. It is illegal to drain or fill a wetland without a permit from the U.S. Army Corps of Engineers. The entire Texas coast is under the jurisdiction of the Corps' Galveston District Office. Before a permit can be granted, the requestor must show that the project has considered all viable alternatives and minimized impacts as much as possible. Any wetland loss must be compensated for by constructing new wetlands or by restoring or enhancing existing wetlands.

Depression Storage

Depression storage occurs when a particular area of land retains water in natural depressions, effectively storing stormwater and allowing it more time to infiltrate into the soil. Generally runoff occurs only after the depression storage capacity has been filled, which makes depression storage a natural, effective, and cost-free method of reducing the volume of stormwater runoff from a site. Standard design and construction practices remove these natural depressions in order to promote drainage, however these minor depressions in the landscape should be treated as sensitive resource areas and protected from construction activities. Depression Storage in Aransas County, Texas is shown in Figure 3-1.

Floodplains

Development in floodplain areas can reduce the ability of the floodplain to convey stormwater, potentially causing safety problems or significant damage to the site in question, as well as to both upstream and downstream properties. Ideally, the entire 100-year full build out floodplain should be avoided for clearing or building activities, and should be preserved in a natural undisturbed state. If development has already occurred in the floodplain, it should follow FEMA guidelines and, when possible, future development should stay out of these and other local floodplains.

Once identified, preservation areas should be incorporated into site development plans and clearly marked on all construction and grading plans. This will ensure that construction activities are kept out of these areas and that native vegetation is kept in an undisturbed state. The boundaries of each preservation area should be mapped by carefully determining the limit which should not be crossed by construction activity.

Soils

Areas of a site with permeable soils (hydrologic soil group A and B), such as sands and sandy loam soils, should be conserved as much as possible. These areas should ideally be incorporated into undisturbed natural or open space areas. Conversely, buildings and other impervious surfaces should be located on those portions of the site with the least permeable soils. Similarly, areas on a site with highly erodible or unstable soils should be avoided for land disturbing activities and buildings to prevent erosion and sedimentation problems, as well as potential future structural problems. These areas should be left in an undisturbed and vegetated condition.

Buffers

A riparian buffer is a special type of natural conservation area along a stream, wetland or shoreline where development is restricted or prohibited. The primary function of buffers is to protect and physically separate waterbodies from future disturbance or encroachment. If properly designed, a buffer can provide stormwater management functions, can act as a right-of-way during floods, and can sustain the integrity of water resource ecosystems and habitats. Ideally, all buffers should remain in their natural state.

In an effort to prevent stormwater from concentrating and flowing into the receiving water without first flowing through the buffer, riparian buffers should be continuous, at least 25 feet wide, and not interrupted by impervious areas.

In a forested ecosystem, existing forested riparian buffers should be maintained. Where no wooded buffer exists, reforestation should be encouraged. Proper restoration should include all layers of the forest plant community, including trees, understory, shrubs and groundcover.

Construction & Maintenance

Once a site is under construction, methods to minimize disturbance should be used to limit the amount of clearing and grading that takes place on a development site. This will help in preserving the undisturbed vegetation and natural hydrology of a site. A limit of disturbance (LOD) should be established based on the maximum disturbance zone. These maximum distances should reflect reasonable construction techniques and equipment needs together with the physical situation of the development site such as slopes or soils.

LOD may vary by type of development, size of lot or site, and by the specific development feature involved.

Not only should these natural conservation areas be protected during construction, but they should also be managed after occupancy by a responsible party able to maintain the areas in a natural state in perpetuity. Typically, conservation areas are protected by legally enforceable deed restrictions, conservation easements, and a maintenance agreement.

3.3 CONSERVATION DESIGN

Conservation design, also known as open space design or cluster development, includes laying out the elements of a development project in such a way that the site design takes advantage of a site's natural features, preserves the more sensitive areas, and identifies any site constraints and opportunities to prevent or reduce impacts. Techniques include:

» Preservation of undisturbed areas;

» Preservation of stream buffers;

» Reduction in clearing and grading;

» Locating projects in less sensitive areas;

» Clustering development;

» Reduced front and side yard setbacks;

» Aggregating shared open space rather than individual yards; and

» Clustering built features so as to minimize the amount of disturbed area.

As mentioned in Section 3.2, these natural conservation areas are typically identified through a site assessment. Depending on the site, an assessment can be performed by professionals on the project development team (engineers, landscape architects or planners for example). However, to fully examine a site and its ecological conditions which will influence drainage design, more in-depth site analysis should be done by hydrologists, ecologists, biologists or others professionals with site assessment experience. These professionals will be able to test infiltration rates, asses soil type and quality, and be able to properly identify existing vegetation. In many cases, a geotechnical report may also be required to assess depth to groundwater, among other factors. When done before the concept plan phase, the identification of sensitive features outlined above and the designation of conservation areas can be used to guide the layout of a project. For more guidance on conducting a site assessment, visit the Sustainable Sites Initiative™ guidelines, at www.sustainablesites.org/.

Conservation subdivisions typically incorporate smaller lot sizes to reduce overall impervious cover while providing more undisturbed open space and protection of water resources. This approach concentrates structures and impervious surfaces in a compact area in one portion of the development site in exchange for providing open space and natural areas elsewhere on the site. Typically smaller lots and/or nontraditional lot designs are used to cluster development and create more conservation areas on the site.

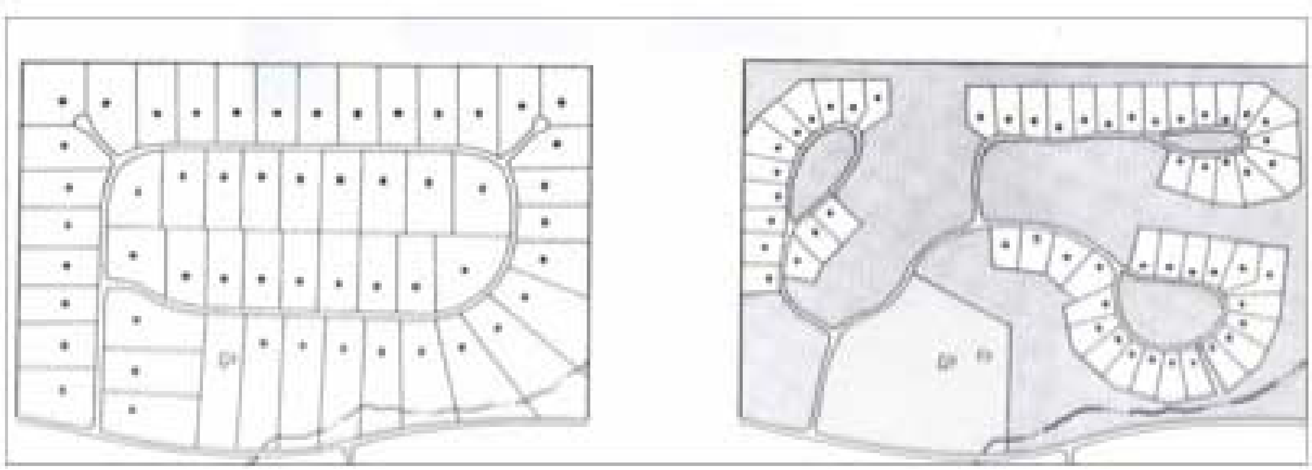


Figure 3-2: Conventional Design (Left) and Conservation Design (Right). (Graphic courtesy of Town of Pine Plains, NY)

Conservation developments have many benefits compared with conventional commercial developments or residential subdivisions. They can reduce:

» Reduce impervious cover and thus reduce runoff volume and rate;

» Reduce development and construction costs by reducing grading, landscaping, and the need for expensive stormwater conveyance infrastructure;

» Enhance the community experience;

» Enhance access to natural amenities;

» Enhance the sense of place and character; and

» Provide a safer pedestrian environment.

Along with reduced imperviousness and its associated benefits, conservation designs provide a host of other environmental benefits lacking in most conventional designs. They can prevent encroachment on conservation and buffer areas. They create community-wide interconnected network of protected meadows, fields and woodlands. They can help to provide larger areas of contiguous habitat, and protect farmland and other natural resources while allowing for the maximum number of residences under current community zoning. As less land is cleared during the construction process, alteration of the natural hydrology and the potential for soil erosion are also greatly diminished. Perhaps most importantly, open space design can preserve 25 to 50% of the development site in conservation areas that would not otherwise be protected.

Conservation developments can also be significantly less expensive to build than conventional projects. Most of the cost savings are due to reduced infrastructure cost for roads and stormwater management controls and conveyances. Further, developers find that these properties often command higher prices than those in more conventional developments because of the enhanced quality of life they provide. Several studies including one in Texas (Crompton 2007) estimate that residential properties in open space developments garner premiums that are higher than conventional subdivisions and moreover, sell or lease at increased rates.

Once established, common open space and natural conservation areas must be managed by a responsible party able to maintain the areas in a natural state in perpetuity. Typically, the conservation areas are protected by legally enforceable deed restrictions, conservation easements, and maintenance agreements.

Preservation of natural areas and conservation designs can help to preserve pre-development hydrology of the site and aid in reducing stormwater runoff and pollutant load. Undisturbed vegetated areas also promote soil stabilization and provide for filtering and infiltration of runoff. Maintaining existing vegetation can be particularly beneficial to sites with floodplains, wetlands, stream banks, steep slopes, critical environmental features, or where erosion controls are difficult to establish, install, or maintain.

3.4 REDUCTION OF IMPERVIOUS COVER

Once a development or redevelopment project has undergone a site assessment to identify all the features mentioned above, and the initial planning and design phase has begun, there are several additional non-structural sustainable development tools to implement. Two of these that will be discussed in this section are: reduce total impervious cover and disconnect impervious surfaces.

Methods of reducing total impervious cover include reducing the total square feet of rooftops, parking lots, roadways, sidewalks and other surfaces that do not allow rainfall to infiltrate into the soil. This will reduce the volume of stormwater runoff, increase groundwater recharge, and reduce pollutant loadings that are generated from a site.

Another non-structural sustainable development tool is disconnection of hard surfaces. Municipalities agree that an increase in impervious cover will increase runoff. However, the degree to which this is true is a function of several factors, such as soil type, rainfall intensity, flow path and the amount of connected impervious cover, among others. Thus, the effectiveness of disconnection practices – directing gutter downspouts into vegetated areas or disconnecting pavement – can be difficult to quantify. Therefore, many municipalities may not give any credit for these types of activities, even though there is obviously some benefit. The following section describes techniques to reduce overall impervious cover, and methods to disconnect existing or proposed impervious areas to maximize the benefit of sustainable development.

3.4.1 Streets

The first step in achieving a reduction in impervious cover for streets is by examining street lengths and widths. The use of alternative road layouts that reduce the total linear length of roadways can significantly reduce overall imperviousness of a development site. Site designers are encouraged to analyze different site and roadway layouts to see if they can reduce overall street length. Streets should be designed for the minimum required pavement width needed to support travel lanes, on-street parking, and emergency access. Several design options exist to reduce the total length and width of streets:

» One-way single-lane loop roads can reduce the width of lower traffic streets;

» On-street parking can be reduced to one lane or eliminated on local access roads with less than 200 average daily trips (ADT), and on short cul-de-sac streets;

» Reducing side yard setbacks and using narrower frontages can reduce total street length, which is especially important in Conservation Designs (Section 3.3);

» Emphasize grid patterns for roadways;

» Eliminate dead ends and cul-de-sacs;

» Design/build narrower, neighborhood-scale streets.

Another large opportunity to reduce impervious cover on streets is with alternative turnaround areas, such as cul-de-sac design. Many of these cul-de-sacs can have a radius of more than 40 feet. From a stormwater perspective, cul-de-sacs create a huge bulb of impervious cover, increasing the amount of runoff. For this reason, reducing the size of cul-de-sacs through the use of alternative turnarounds or eliminating them altogether can reduce the amount of impervious cover created at a site. Alternative design options include:

» Reducing cul-de-sacs to a 30-foot radius;

» Allowing hammerheads as an alternative cul-de-sac form;

» Creating uncurbed, below-grade pervious areas (rain gardens) in the center of the cul-de-sac to provide stormwater attenuation;

» Including sustainable development features in the center of the cul-de-sac such as bioretention areas to capture and treat runoff from the circular pavement; or

» Eliminating turnarounds altogether or building loop roads and pervious islands in the cul-de-sac center.

Figure 3-3: Example of Narrow Street and Disconnected Impervious Cover in a Residential Development in Chambers County, Texas (Google street view)

Sufficient turnaround area is a significant factor to consider in the design of these cul-de-sacs. For example, fire trucks, service vehicles and school buses are often cited as needing large turning radii. However, some fire trucks are designed for smaller turning radii. In addition, many newer large service vehicles are designed with a tri-axle (requiring a smaller turning radius) and many school buses usually do not enter individual cul-de-sacs.

Another option for designing cul-de-sacs involves the placement of a pervious island in the center. Vehicles only travel along the outside of the cul-de-sac when turning, leaving an unused "island" of pavement in the center. These islands can be attractively landscaped and designed as bioretention areas to treat stormwater.

3.4.2 Sidewalks

Most codes require that sidewalks be placed on both sides of residential streets (e.g. double sidewalks) and should be constructed of impervious concrete or asphalt. Many subdivision codes also require sidewalks to be 4 to 6 feet wide and 2 to 10 feet from the street. These codes are enforced to provide sidewalks as a safety measure. Alternative sidewalk designs include.

» Place sidewalks on only one side of the street.

» Place sidewalks further from the street. The added space in between the street and sidewalk is an ideal location to place sustainable development practices to capture runoff from the road.

» Grade sidewalks to drain to vegetated areas between the sidewalk and the street, rather than directly to the street.

» Use alternative surfaces for sidewalks and walkways, such as pervious pavements, to reduce total impervious cover.

» Reduce sidewalk requirements, as allowed under the Americans with Disabilities Act, if developers include alternative pedestrian networks, such as trails.

Providing a landscaped area between sidewalks and the streets will also provide substantial opportunity for stormwater infiltration.

3.4.3 Driveways & Setbacks

Typical residential driveways range from 12 feet wide for one car to 20 feet wide for two. There are several alternative driveway designs developers should be allowed to implement which help reduce impervious cover and these include:

» Shared driveways: can reduce impervious cover and should be encouraged with enforceable maintenance agreements and easements;

» Narrower driveway widths and lengths: When homes are positioned with a greater setback, the first portion of the driveway can be a single lane, which then expands to the full width of the garage;

» Alternative design such as double-tracks; or

» Alternative surfaces such as reinforced grass, or permeable paving materials.

Building and home setbacks should be shortened to reduce the amount of impervious cover from driveways and entry walks. A setback of 20 feet is more than sufficient to allow a car to park in a driveway without encroaching into the public right of way, and reduces driveway and walk pavement by more than 30% compared with a setback of 30 feet.

3.4.4 Parking

Many parking lots are built with more spaces than are actually used. In part, this is because minimum parking standards are often set to accommodate the highest hourly parking during the peak season or the highest hourly parking demand for the particular site and use. Since ordinance language provides flexibility for the designer and developer to provide additional parking spaces beyond the minimum, the result is often excess levels of parking. Setting parking standards as both a minimum and maximum can ensure that sufficient parking is established to meet the demand without creating excess spaces.

There are many options available to reduce the overall parking footprint and site imperviousness. First steps include determining average parking demand and the lot location. A lower maximum number of parking spaces can be set to accommodate most of the demand. The number of parking spaces needed may be reduced by a site's accessibility to public transportation. Additional design strategies include:

» Setting maximums for parking spaces rather than minimums;

» Minimizing stall dimensions (by reducing both the length and width of the parking stall);

» Requiring a certain number of spaces be sized for compact vehicles;

» Using structured parking (which can reduce the conversion of land to impervious cover);

» Incorporate efficient parking lanes such as utilizing one-way drive aisles with angled parking rather than the traditional two-way aisles;

» Encouraging shared parking, particularly in mixed-use areas and for non-competing parking lot users; and

» Using alternative porous surfaces.

Utilizing alternative surfaces such as porous pavers or porous concrete is an effective way to reduce the amount of runoff generated by parking lots. This can replace conventional asphalt or concrete in both new development and redevelopment projects.

Figure 3-4: Example of Sustainable Design in Medium Density Residential Development in Chambers County, Texas.

3.5 Disconnection

Disconnection of downspouts and impervious surfaces is encouraged to maximize the function of the sustainable development practices. Disconnection is a low-cost, effective non-structural control which can reduce total runoff volume, increase the time of concentration and promote infiltration. The first step in disconnection is to identify the source of runoff and understand how it will be managed once disconnection occurs. Well-conceived use of disconnection methods can reduce project costs by reducing or eliminating the need for more expensive structural practices.

By disconnecting impervious areas and directing the flow to infiltration basins or designated buffer areas, a portion of additional runoff that would contribute to stormwater runoff is infiltrated close to the source instead. Further, the runoff that would potentially carry pollutants from the site to surface water instead gets treated and helps recharge groundwater.

Disconnection methods should be incorporated at the planning and design level. However, the designer and reviewer should note that these methods must be used in concert with the design of other stormwater conveyance and treatment practices. The use of these disconnection methods does not relieve the designer or reviewer from following the standard engineering practices associated with safe conveyance of stormwater runoff and good drainage design.

Figure 3-5: Downspouts directed to permeable pavement on driveway. (Photo courtesy of Montgomery County, Maryland)

3.5.1 Downspout Disconnection

Rooftops with exterior drains for the gutter (the normal configuration for most residential structures) is one of the easiest disconnection practices to implement. Downspouts should be directed to landscaped portions of the site rather than driveways or sidewalks unless the driveway is constructed of pervious paving materials (Figure 3-4). It is not common, but driveways can be crowned so that a portion of the runoff is directed to vegetated areas, rather the street.

In addition to directing downspouts to vegetated areas, roof runoff may also be directed to cisterns and other rain barrels for later consumption, or even to depressed storage or other underground storage areas.

3.5.2 Disconnecting Urban Elements

Downtowns and commercial strip centers often promote an urban, "walkable" feel by putting buildings close to the sidewalk, and the sidewalk close to the street or parking area. While this practice promotes a fun street activity ambiance, there are some benefits to be had by disconnecting these impervious surfaces.

Site design should allow for a space of approximately 2-3′ between the street and the sidewalk, and the sidewalk and the building. These spaces between the street, sidewalk and building should be vegetated areas designed to intercept a portion of stormwater, and may also be fitted as a biofiltration area, vegetated swale, or vegetated filter strip. Disconnection can also be used when designing parking lots. Instead of a parking lot being sited directly adjacent to a roadway, the insertion of a grassy area between the road and the edge of the parking area can help reduce the velocity of water moving across the site and provides an opportunity for additional sustainable drainage techniques to be included.

These disconnected, vegetated areas alone will not be enough to filter all of the stormwater from the site; however, when used in tandem with other site design practices in this chapter and sustainable drainage techniques outlined in Chapter 4, they become part of an overall strategy for managing stormwater effectively

Chapter 4

STRUCTURAL PRACTICES FOR SUSTAINABLE DRAINAGE DESIGN

» *Minimum Requirements*

» *Submittal Requirements*

» *Vegetated Swales and Filter Strips*

» *Porous Pavement*

» *Enhanced Detention*

» *Bioretention*

» *Infiltration*

The purpose of this chapter is to describe the minimum requirements to achieve a sustainable drainage design and the design guidelines for these facilities. This manual focuses on practices that are most appropriate for the Texas coastal region. Guidance on the design of these systems is also available from several other regional sources including Aransas and Harris Counties. The following sections describe the minimum requirements, stormwater practices, selection criteria, design guidelines, and maintenance requirements.

4.1 MINIMUM REQUIREMENTS

These minimum requirements apply to all new development and redevelopment projects that disturb one acre or more of land, including projects less than one acre that are part of a larger common plan of development or sale that will result in disturbance of one acre or more. Projects whose final level of impervious cover is less than 20% are exempt, since the low level of development inherently results in little or no impact to water quality. Impervious cover includes but is not limited to:

» Pavement including streets, sidewalks, driveways, parking lots, etc.

» Rooftops if not part of a rainwater harvesting system

» Compacted road base, such as that used for parking areas

» Other surfaces that prevent the infiltration of water into the soil.

Bicycle and pedestrian paths separated from other impervious surfaces by a distance of at least 10 feet, except at intersections, are considered sustainable and do not require any special runoff management.

When the development project includes residential tracts that will be developed subsequently, and whose future impervious level is unknown, the assumptions presented in Table 4-1 should be used. The values in this table do not include the area of the streets in the development.

There are two options available to meet the sustainable drainage requirements: payment in lieu or use of at least one of the structural controls described below to manage stormwater runoff from the site.

Payment in Lieu

The payment in lieu option requires the developer to make a payment of $10,000 per impervious acre created (not total project size) into an account whose funds may only be used for drainage improvements that reduce the discharge of pollutants from the drainage system.

Structural Controls

Stormwater runoff generated on the site must be managed through the use of one or more of these structural practices:

» Vegetated Swale

» Vegetated Filter Strip

» Porous Pavement

» Enhanced Detention

» Bioretention/Rain gardens

» Infiltration Basins

For the structural practices that are sized based on runoff volume (bioretention, enhanced detention, infiltration basins), the capture volume must be sized to accommodate the runoff from a 1.0” rainfall event at a minimum. The runoff coefficient is a function of the impervious cover and is calculated as:

$Rv = 0.05 + 0.90IC$

Where:

Rv = Runoff Coefficient

IC = Fraction of impervious cover in the catchment of the structural practice

The minimum capture volume is then calculated as:

$V = P \times A \times Rv/12$

Where:

V = Minimum required capture volume

P = Rainfall depth (1.0 inches)

A = Catchment area of the practice (ft2)

Rv = Runoff Coefficient

Additionally, riparian buffers should be provided between any development and all natural bodies of water. The buffer width needed to perform properly will depend on the size of the stream and the surrounding conditions, but a minimum 25-foot undisturbed vegetative buffer is recommended for all waterbodies, even the smallest perennial streams. Where feasible, riparian buffers should be sized to include the 100-year floodplain.

This first 25 foot section should be a zero development zone. Buffer zones should generally remain free of construction, development, or other alterations. The number of roadways crossing through the buffer zones should be minimized and constructed only when necessary, such as when a significant portion of the site can only be reached by crossing a buffer zone. Other alterations within buffer zones beyond the 25 foot minimum could include utility crossings, but only when necessary, fences, low impact parks, and open space. Roadways and utilities crossings should be approximately perpendicular to the buffer zone. Low impact park development within the buffer zone should be limited to trails, picnic facilities, and similar construction that do not significantly alter the existing vegetation. Parking lots and roads significantly alter existing vegetation and are not considered low impact.

Table 4-1: Impervious Cover Assumptions for Residential Tracts

Lot Size	Assumed Impervious Cover (ft^2)
> 3 acres	10,000
Between 1 and 3 acres	7,000
Between 15,000 ft^2 and 1 acre	5,000
Between 10,000 and 15,000 ft^2	4,000
<10,000 ft^2	3,500

4.2 SUBMITTAL REQUIREMENTS

The following information must be submitted to the municipality for any new development where the impervious cover of the site is greater than 20% and the project disturbs one acre or more of land or is part of a larger common plan of development or sale that will result in disturbance of one acre or more. This material must be accompanied with a letter signed and sealed by a licensed engineer indicating that all drainage requirements in this guidance document have been met.

4.2.1 Site Analysis and Narrative

» Location map, size, and existing land use of the site;

» Description of existing land use of all adjacent properties;

» General description of existing site topography, natural and manmade features, County's watershed name, drainage patterns, flow paths, receiving waters, soil types and ground cover;

» Identify if the following exist on-site:

-Any body of water, including natural and manmade drainage paths, identifying each as natural or not.

-Any natural depressions or areas identified as probable areas of inundation for the 100- year storm event.

-A general description of the proposed uses and improvements, lot subdivision, roadways, and other pertinent improvements.

-Phasing and timing of project.

» A general description of proposed drainage, water quality, and erosion and sediment control facilities expected to be used on site and the methodology for choosing the facilities;

» Total Site Area and impervious cover planned for the development;

» Provide a description of the potential pollutant activities to be conducted at the site, if applicable. Such activities of interest include chemical storage and/or use, vehicle, equipment or boat repair and maintenance, on-site wastewater treatment, product fabrication or washing/cleaning activities.

» Confirmation that all applicable regulations and public health and safety requirements will be met by the developer/contractor/ builder.

» A simple drawing to depict the proposed layout, impervious cover areas, general hydrologic information, on-site and adjacent drainage conditions and improvements, and other pertinent information required for site stormwater assessment (a conceptual plan).

4.2.2 Site Layout and Drainage Design

» Legend, north arrow & scale;

» Existing property lines, ROWs, structures, impervious surfaces and improvements;

» Existing topography - contours;

-Location of FEMA 100-year Floodplain, Floodway, and Velocity Zone Boundaries that encroach on the site.

» Existing drainage patterns, flow paths, stormwater discharge locations, drainage easements;

» Limits of existing disturbed area;

» Proposed lots and/or building locations, ROWs, roadway locations and cross sections impervious surface areas and pavement types;

» Proposed grading (contours or elevations), drainage patterns and basins, discharge locations, and proposed easements; and

» Size and location and basis of design for all permanent drainage and stormwater quality improvements including: culverts, pipes, detention basins, swales, etc.

4.2.3 Drainage System Maintenance

» Contact information of end-user responsible for inspection, maintenance and repair of stormwater management system (i.e. property owner, Homeowners Association, etc...);

» If facilities are to be publicly maintained, municipal staff may benefit from establishing an inspection plan and maintenance plan.

» If facilities are to be privately maintained, include:

-Inspection Plan, which identifies the procedures that will be used to ensure the timely inspection of the control measures.

-A description of the maintenance plan for stormwater management devices and practices including operational and physical measures and a proposed schedule.

4.3 VEGETATED SWALES

4.3.1 Introduction

Grassy swales are vegetated channels that convey stormwater and remove pollutants by sedimentation and infiltration through soil. They require shallow slopes and soils that drain well. Pollutant removal capability is related to channel dimensions, longitudinal slope, and amount of vegetation. Optimum design of these components will increase contact time of runoff through the swale and improve pollutant removal rates.

Grassy swales are primarily stormwater conveyance systems. They can provide sufficient control under light to moderate runoff conditions, but their ability to control large storms is limited. Therefore, they are most applicable in low to moderate sloped areas or along highway medians as an alternative to curb and gutter drainage. Grassy swales can be used as a pretreatment measure for other downstream facilities, such as bioretention areas. Enhanced grassy swales utilize engineered soils and an underdrain to provide filtration of pollutants. A picture of a grassy swale is presented in Figure 4-1. They can also be included in the design of commercial parking areas as shown in Figure 4-2.

Grassy swales can be more aesthetically pleasing than concrete or rock-lined drainage systems and are generally less expensive to construct and maintain. Swales can slightly reduce impervious area and reduce the pollutant accumulation and delivery associated with curbs and gutters. The disadvantages of this technique include the possibility of erosion and channelization over time, and the need for more right-of-way as compared to a storm drain system.

The suitability of a swale at a site will depend on existing land use, size of the area serviced, soil type, slope, and dimensions and slope of the swale system. In general, swales can be used to serve areas of less than 2 acres. Irrigation is not required to maintain growth during dry periods, but may be necessary for vegetation establishment.

Selection Criteria

» Preferred method of conveyance in residential developments and islands in commercial parking lots.

» Pretreatment for other sustainable development practices.

» Limited to treating a few acres.

» Sufficient available land area.

Limitations

» Can be difficult to avoid channelization.

» Number of culverts required may make infeasible in higher density developments.

Figure 4-1: Picture of a Typical Swale in a Residential Neighborhood in Chambers County, Texas. (Photo courtesy of Google Earth)

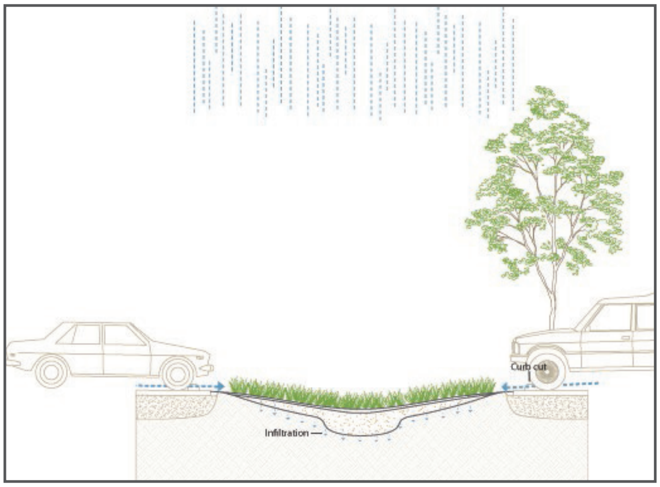


Figure 4-2: Swale in parking lot area showing the use of short grasses, low slopes, curb cuts from parking area and some infiltration.

4.3.2 Swale Design Guidelines

(1) The swale should be sized per local requirements for stormwater conveyance and be at least 50 feet long.

(2) The geometry of the channel is not critical as long as a broad, relatively flat bottom is provided. The side slopes should be no steeper than 6:1 (H:V).

(3) Roadside ditches should be regarded as significant potential swale/buffer strip sites and should be utilized for this purpose whenever possible.

(4) If flow is to be introduced through curb cuts, place pavement slightly above the elevation of the vegetated areas. Curb cuts should be at least 12 inches wide to prevent clogging. An apron of rip rap should be installed at the curb cut to slow the flow of the runoff and induce settling of sediment.

(5) Swales must have at least 80 percent grass cover in order to provide adequate stabilization. For general purposes, select fine, close-growing, water-resistant grasses. Climate-adapted plant species help reduce irrigation needs, vulnerability to pests, and the need for quick release fertilizers.

(6) Swales should be evaluated for the need to remove sediment and restore vegetation following construction.

(7) During the period of vegetation establishment, cover the graded and seeded areas with suitable erosion control materials.

4.3.3 Maintenance Requirements

Maintenance for grassy swales is minimal and is largely aimed at keeping the grass cover dense and vigorous. Maintenance practices and schedules should be developed and included as part of the original plans to alleviate maintenance problems in the future. Recommended practices include:

» Seasonal Mowing and Lawn Care. Lawn mowing should be performed routinely, as needed, throughout the growing season. Regular mowing should also include weed control practices; however, as noted in Herbicide use should be kept to a minimum. An Integrated Pest Management approach can help reduce chemical use. Healthy grass can be maintained without using fertilizers because runoff usually contains sufficient nutrients.

» Sediment Removal. Sediment accumulating near culverts and in channels needs to be removed when it results in a significant amount of standing water.

» Grass Reseeding. A healthy dense grass should be maintained in the channel and side slopes. Grass damaged during the sediment removal process should be promptly replaced using the same seed mix used during swale establishment.

» Public Education. Private homeowners are often responsible for roadside swale maintenance. Unfortunately, overzealous lawn care on the part of homeowners can present some problems. For example excessive application of fertilizer and pesticides will be detrimental to water quality. Pet waste can also be a problem in swales, and should be removed to avoid contamination. The delegation of maintenance responsibilities to individual landowners is a cost benefit to the locality. However, localities should provide an active educational program to encourage the recommended practices.

4.4 VEGETATED FILTER STRIPS

4.4.1 Introduction

Filter strips, also known as vegetated buffer strips, are vegetated sections of land similar to grassy swales, except they are essentially flat with low slopes, and are designed only to accept runoff as overland sheet flow. A diagrammatic photograph of a vegetated buffer strip is shown in Figure 4-2. The dense vegetative cover facilitates conventional pollutant removal through sedimentation and infiltration.

There are two primary applications for vegetative filter strips. First, roadways and small parking lots are ideal locations where runoff that would otherwise discharge directly to a piped conveyance system or receiving water passes through the filter strip. Properly designed roadway medians and shoulders make effective vegetated filter strips. The second is land in its natural condition located adjacent to perimeter lots in subdivisions that will not drain via gravity to other stormwater conveyance systems.

Successful performance of filter strips relies heavily on maintaining shallow dispersed flow. To avoid flow channelization and maintain performance, a filter strip should contain dense vegetation with a mix of erosion resistant, soil binding species. Filter strips can be used up-gradient from watercourses, wetlands, or other water bodies, along toes and tops of slopes, and at outlets of other stormwater management structures. The most important criteria for selection and use of this practice are space and slope.

Selection Criteria

- Soils and moisture are adequate to grow relatively dense vegetative stands
- Sufficient space is available
- Slope is less than 20% for engineered strips

Limitations

- Can be difficult to maintain sheet flow
- Area required may be infeasible on some sites

4.4.2 Filter Strip Design Guidance.

Filter strips may be natural or engineered. The use of natural filter strips is limited to perimeter lots and other areas that will not drain by gravity to other drainage facilities on the site.

Natural Filter Strips:

(1) The filter strip should extend along the entire length of the contributing area.

(2) The slope should not exceed 10% for natural filter strips.

(3) The minimum dimension (in the direction of flow) should be 25 feet.

(4) All of the filter strip should lie above the elevation of the 2-yr, 3-hr storm of any adjacent drainage.

(5) There is no requirement for vegetation density or type, but diverse native vegetation of varying physical types is preferred..

Engineered Filter Strips

Many of the general criteria applied to swale design apply equally well to engineered vegetated filter strips. Vegetated roadside shoulders provide one of the best opportunities for incorporating filter strips into roadway and highway design, as shown in Figure 4-2. The general design goal is to produce uniform, shallow overland flow across the entire filter strip.

(1) The filter strip should extend along the entire length of the contributing area and the slope should not exceed 20%. The minimum dimension of the filter strip (in the direction of flow) should be no less than 15 feet. The maximum width (in the direction of flow) of the contributing impervious area should not exceed 72 feet. For roadways with a vegetated strip along both sides the total width of the roadway should not exceed 144 feet (i.e., 72 feet draining to each side).

(2) The minimum vegetated cover for engineered strips is 80%.

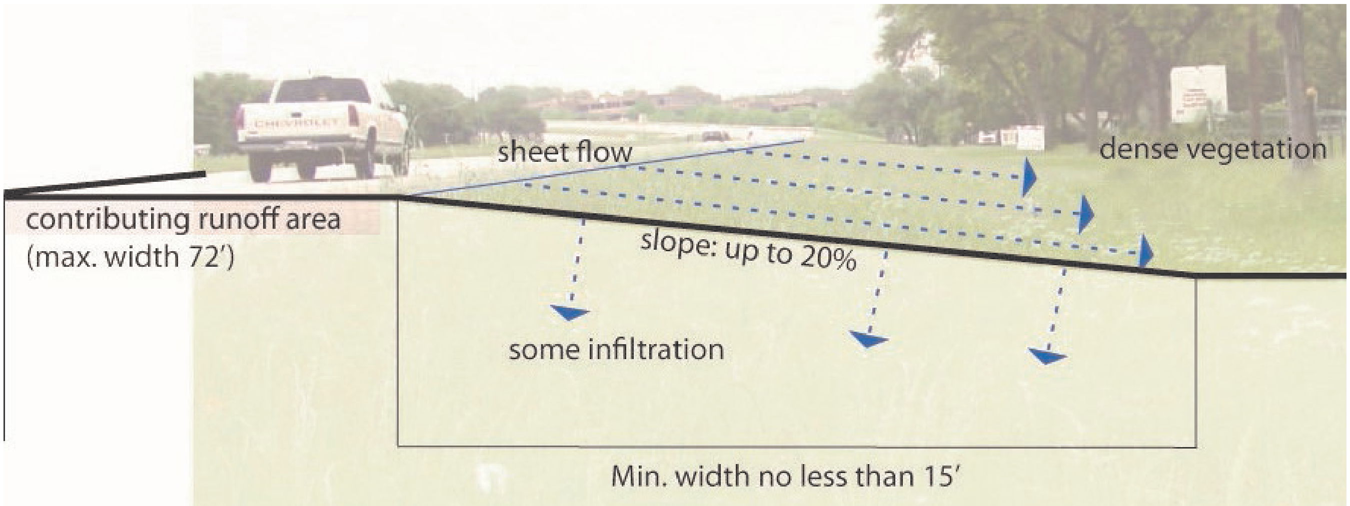


Figure 4-3: Filter Strip along side of Highway.

(3) The area contributing runoff to a filter strip should be relatively level so that the runoff is distributed evenly to the vegetated area without the use of a level spreader.

(4) The area to be used for the strip should be free of gullies or rills that can concentrate overland flow.

(5) The top edge of the filter strip along the pavement will be designed to avoid the situation where runoff would travel along the top of the filter strip, rather than through it.

(6) Top edge of the filter strip should be level, otherwise runoff will tend to form a channel in the low spot.

(7) Filter strips should be landscaped after other portions of the project are completed.

4.4.3 Maintenance Requirements

Once a vegetated area is well established, little additional maintenance is generally necessary. The key to establishing a viable vegetated feature is the care and maintenance it receives in the first few months after it is planted. Once established, all vegetated facilities require some basic maintenance to insure the health of the plants:

» *Seasonal Mowing and Lawn Care.* Grass height should be limited to 18 inches and mowed regularly. If native grasses are used, the filter may require less frequent mowing. While weeds should be removed, herbicide use should be kept to a minimum. Irrigation can help assure a dense and healthy vegetative cover.

» *Sediment Removal.* Sediment removal is not normally required in filter strips, since the vegetation grows through it and binds it to the soil. However, sediment may accumulate along the upstream boundary of the strip preventing uniform overland flow. Excess sediment should be removed by hand or with flat-bottomed shovels.

» *Grass Reseeding and Mulching.* A healthy dense grass should be maintained. Dense vegetation may require irrigation immediately after planting and during particularly dry periods.

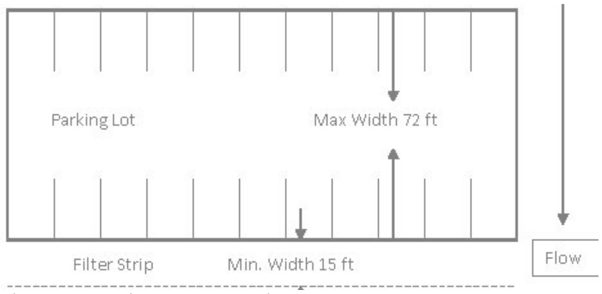


Figure 4-4: Example Configuration of Filter Strip adjacent to Parking Lot.

4.5 POROUS PAVEMENT

4.5.1 Introduction

Porous pavements are a special type of pavement that allows rain to pass through. They can be used on both permeable and impermeable soils and in the latter case are designed with an underdrain system. Where soils are sufficiently permeable, all the runoff will infiltrate and no discharge of stormwater or associated pollutants will occur. Systems designed with an underdrain provide substantial pollutant removal and increase the time of concentration, which are substantial benefits even when the volume of runoff is not substantially reduced.

There are several types of porous pavement, including porous asphalt, pervious concrete, pavers, and grid type systems. Porous asphalt pavement consists of an open-graded coarse aggregate, bonded together by asphalt cement, with sufficient interconnected voids to make it highly permeable to water. Pervious concrete differs from regular concrete in the proportion of coarse aggregate, in the absence of fine material, and in the reduced quantity of water in the mix. Pervious concrete has enough void space to allow rapid percolation of rainfall through the pavement. Pavers themselves are typically impermeable; however, infiltration occurs either in the gaps between the pavers or within openings cast as part of the geometry of the paver. The use of pavers in a portion of a parking lot in South Texas are presented in Figure 4-5.

The porous pavement surface is typically placed over a highly permeable layer of open-graded gravel and crushed stone as shown in Figure 4-6. The void spaces in the aggregate layers act as a storage reservoir for runoff. The liner and underdrain are optional features that might be required because of structural considerations and/or low soil permeability.

Figure 4-5: Permeable pavers in parking stall of Cascade Park parking lot in Cameron County, Texas. (Photo courtesy of Danica Adams)

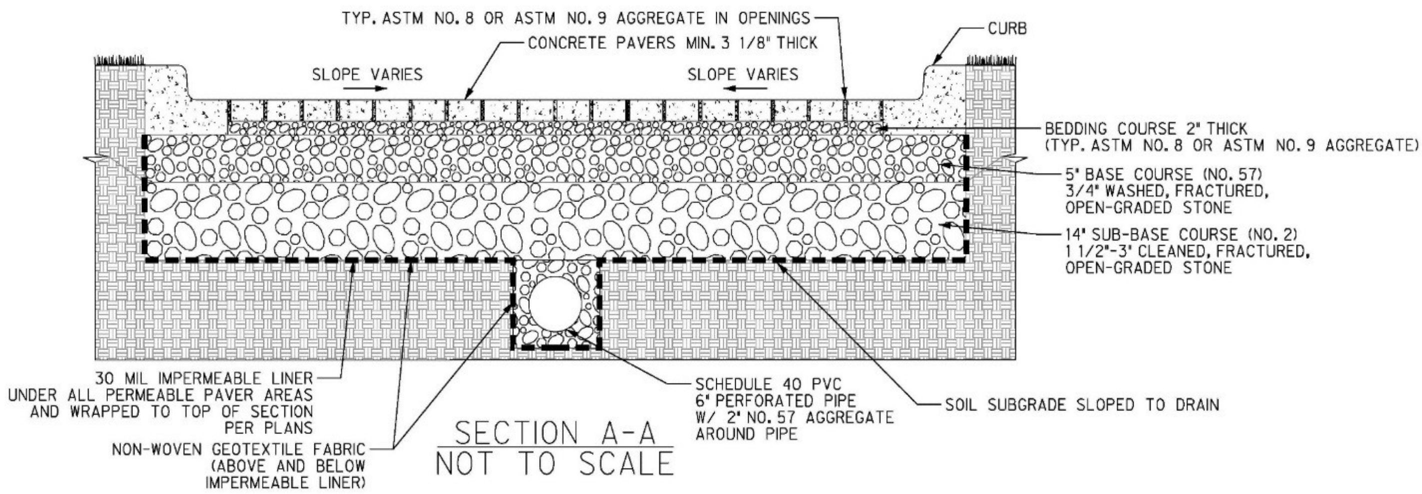


Figure 4-6: Representative Cross-Section of Porous Pavement.

Selection Criteria

Porous pavement may substitute for conventional pavement on parking areas, streets, sidewalks, and patios. Slopes should be flat or very gentle. Soils should have field-verified permeability rates of greater than 0.5 in/hour, and there should be a 4-foot minimum clearance from the bottom of the system to bedrock or the water table for systems installed without underdrains.

Advantages to using porous pavement include:

» Substantial pollutant reduction, even in systems with underdrains and surface discharge.

» Less need for curbing and storm sewers.

» Potential for groundwater recharge

Limitations

The use of porous pavement is constrained, requiring deep permeable soils (in systems without underdrains), and consideration of impacts to adjacent buildings. Some specific disadvantages of porous pavement include the following:

» Many pavement engineers and contractors lack expertise with this technology.

» Porous pavement has a tendency to become clogged if improperly installed.

» Pervious concrete and porous asphalt have a tendency to ravel in areas with a short turning radius.

4.5.2 Porous Pavement Design Guidelines

Most porous pavement installations are designed to infiltrate water into the soil, resulting in the requirements described below for minimum infiltration rate and separation from groundwater. If these requirements are not met, porous pavement can be installed with an underdrain, which still has significant benefits by increasing the time of concentration and reducing pollutants in runoff. Information on the structural requirements for various pavement types can be found at industry websites such as:

» Permeable pavers: http://www.icpi.org/

» Pervious concrete: http://www.perviouspavement.org/

» Porous asphalt: http://www.asphaltpavement.org/index.php?option=com_content&view=article&id=359&Itemid=863

Recommended design guidelines for porous pavement that does not incorporate an underdrain include the following elements:

(1) A minimum of 5 inches of reservoir rock must be provided below the pavement to store the 1.0 inch rainfall event.

(2) As part of the site evaluation, take soil boring to a depth of at least 4 feet below bottom of stone reservoir to check for soil permeability, porosity, depth of water table, and depth to bedrock.

(3) Minimum infiltration rate 3 feet below bottom of stone reservoir: 0.5 inch per hour or underdrain required.

(4) Minimum depth to bedrock and seasonally high water table: 4 feet.

(5) Minimum setback from water supply wells: 100 feet.

(6) Minimum setback from building foundations: 10 feet down-gradient.

(7) Use for, sidewalks, patios, parking areas and lightly used access roads.

(8) Excavate and grade with light equipment with tracks or oversized tires to prevent soil compaction.

(9) Divert stormwater runoff away from planned pavement area before and during construction.

4.5.3 Maintenance Requirements

Like all BMPs, porous pavements need to be maintained. Maintenance requirements will depend on the environmental context, intensity of use, etc. and may include periodic street sweeping, vacuum sweeping, and/or high pressure washing.. Potholes and cracks can be filled with patching mixes unless more than 10 percent of the surface area needs repair. Spot-clogging may be fixed by drilling half-inch holes through the porous pavement layer every few feet. The pavement should be inspected several times during the first few months following installation and annually thereafter. Annual inspections should take place after large storms, when puddles will make any clogging obvious.

4.6 ENHANCED DETENTION

Many regulatory agencies in the Coastal Zone require detention facilities for new development to manage the increased runoff volume associated with the increase in impervious cover. These facilities, sometimes with little or no modification to standard designs, can help create a sustainable stormwater drainage system. Excavation of detention ponds often brings the basin invert in contact with the water table. When this occurs, the basins with only a little additional excavation can take on the characteristics of either wetlands or wet ponds. The difference between the two is that wet ponds include substantially more open water. These two designs are described in detail below.

4.6.1 Enhanced Detention Wetland

Constructed wetlands are shallow pools with or without open water elements that create growing conditions suitable for marsh plants. Conventional stormwater wetlands are shallow manmade facilities supporting abundant vegetation and a robust microbial population. As constructed water quality facilities, stormwater wetlands should never be located within delineated natural wetlands areas. Significant potential exists for creative design and participation of an experienced wetland designer is highly recommended.

Constructed wetlands provide physical, chemical, and biological water quality treatment of stormwater runoff. Physical treatment occurs as a result of decreasing flow velocities in the wetland, and is present in the form of evaporation, sedimentation, adsorption, and/or filtration. Constructed wetlands offer natural aesthetic

Figure 4-7: Constructed Wetland in Aransas County, Texas. (Photo courtesy of Danica Adams)

qualities, wildlife habitat, erosion control, and pollutant removal. Natural wetlands should not be used for stormwater treatment. A picture of a wetland detention system is in Figure 4-6.

It is necessary to recognize that a fully functional wetland cannot be established spontaneously. Time is required for vegetation to establish and for nutrient retention and wildlife enhancement to function efficiently. Also, the wetland should approximate a natural situation as much as possible, and unnatural attributes, such as a rectangular shape or a rigid channel, should be avoided. Because the wetland must have a source of flow, it is desirable that the water table is at or near the surface.

Selection Criteria

» Ideal when water table is relatively close to the ground surface

» Multiple benefits of passive recreation (e.g., bird watching, wildlife habitat)

» Never use natural wetlands, or wetlands provided as mitigation for impacts to natural wetlands, as a treatment device

Limitations

» There is concern about mosquitoes; however, aeration and/or stocking the pond with gambusia may eliminate this problem

» May be infeasible to site or retrofit in dense urban areas

» Potential hazard (drowning when side slopes are too steep or are bulkheaded)

Detention Wetland Design Guidance

(1) Construction – The wet pond enhancement is created by over-excavating a portion of the detention basin. The material excavated, when suitable, can be used onsite to increase the finished floor elevations of any buildings constructed as part of the development. The surface water elevation should be equal to the invert of the detention basin outlet.

(2) Basin Inlets – Discharge to the facility should occur from as many inlets as possible to reduce concentrated flow. Energy dissipation should be provided at the inlet if the velocity of the flow is greater than 1 ft/s. Incorporation of low flow channels within the facility should be avoided as they concentrate runoff and reduce performance.

(3) Facility Sizing – The excavate volume of the wetland area should be no smaller than the volume of runoff produced by a 1.0 inch rainfall event.

(4) Pond Configuration - Stormwater constructed wetlands offer significant flexibility regarding pond configuration with the exception that short-circuiting of the facility must be avoided. Provision of irregular, multiple flow paths is desired. At least 25 percent of the basin should be an open water area at least 2-ft deep if the facility is exclusively designed as a shallow marsh. The open-water area will make the marsh area more aesthetically pleasing, and the combined water/wetland area will create a good habitat for waterfowl. The wetland zone should be 50 to 70 percent of the area, and should be 6- to 12-in deep.

(5) Vegetation - A diverse, locally appropriate selection of wetland plant species is vital for all constructed wetlands. Wetland vegetation elements should be placed along the aquatic bench or in the shallow portions of the permanent pool. The optimal elevation for planting of wetland vegetation is within 6 inches vertically of the normal pool elevation. Participation of a wetland designer or landscape architect familiar with local plants is highly recommended.

(6) Outflow Structure – The outflow structure should be designed as required by local regulations to achieve necessary detention requirements.


Figure 4-8: Enhanced Detention Wet Pond. (Photo courtesy of Houston Galveston Area Council)

4.6.2 Enhanced Detention Wet Ponds

The wet pond is a detention basin with a permanent volume of water incorporated into the design (Figure 4-8). Wet ponds are stormwater quality control facilities that maintain a permanent wet pool and a standing crop of emergent littoral vegetation. Wet ponds are often perceived as a positive aesthetic element in a community and offer significant opportunity for creative pond configuration and landscape design. Participation of an experienced designer is suggested.

Biological processes occurring in the permanent pool aid in reducing the amount of soluble nutrients present in the water. Because they are designed with permanent pools, wet basins can also have recreational and aesthetic benefits, as experienced in a Chambers County subdivision, Figure 4-8. During storm events, runoff inflows displace part or all of the existing basin volume and are retained in the facility until the next storm event. Wet basins also help provide erosion protection for the receiving channel by limiting peak flows during larger storm events. Wet ponds may be feasible for watershed areas greater than 10 acres and having a water table close to the land surface.

Selection Criteria

» Multiple benefits of passive recreation (e.g., bird watching, wildlife habitat)

» Ideal for large, regional tributary areas

» Site area greater than 10 acres

Limitations

» There is concern about mosquitoes; however, stocking the pond with gambusia may eliminate this problem

» May be infeasible to site or retrofit in dense urban areas

Detention/Wet Pond Design Guidance

(1) Construction – The wet pond enhancement is created by over-excavating a portion of the detention basin. The material excavated, when suitable, can be used onsite to increase the finished floor elevations of any buildings constructed as part of the development. The surface water elevation should be equal to the invert of the detention basin outlet.

(2) Basin Inlets – Discharge to the facility should occur from as many inlets as possible to reduce concentrated flow. Incorporation of low flow channels within the facility should be avoided as they concentrate runoff and reduce performance.

(3) Facility Sizing – The volume of the wet pond should be no smaller than the volume of runoff produced by a 1.0 inch rainfall event.

(4) Pond Configuration - The wet basin can be configured as a two stage facility with a sediment forebay and a main pool. The basins should be wedge-shaped, narrowest at the inlet and widest at the outlet if possible. The minimum length to width ratio should be 1.0. Higher ratios are recommended. A schematic of this is illustrated in Figure 4-9.

(5) Pond Side Slopes - Side slopes of the basin should be 3:1 (H:V) or flatter for grass stabilized slopes. Slopes steeper than 3:1 should be stabilized with an appropriate slope stabilization practice.

(6) Safety Considerations - Safety is provided either by fencing off the facility or by managing the contours of the pond to eliminate dropoffs and other hazards. Earthen side slopes should not exceed 3:1 (H:V). Landscaping can be used to impede access to the facility if desired. The primary spillway opening should not permit access by small children. Outfall pipes more than 48 inches in diameter should be fenced.

(7) Depth of the Permanent Pool - The permanent pool should be no deeper than 8 feet and should average 4-6 feet deep.

(8) Aeration – The performance and appearance of a wet pond may be improved by providing aeration of the permanent pool; however, this is not a requirement.

(9) Vegetation- Aquatic plants should be allowed to grow along banks s to enhance water quality treatment and habitat functions and to discourage inappropriate recreational activities (e.g. swimming,)

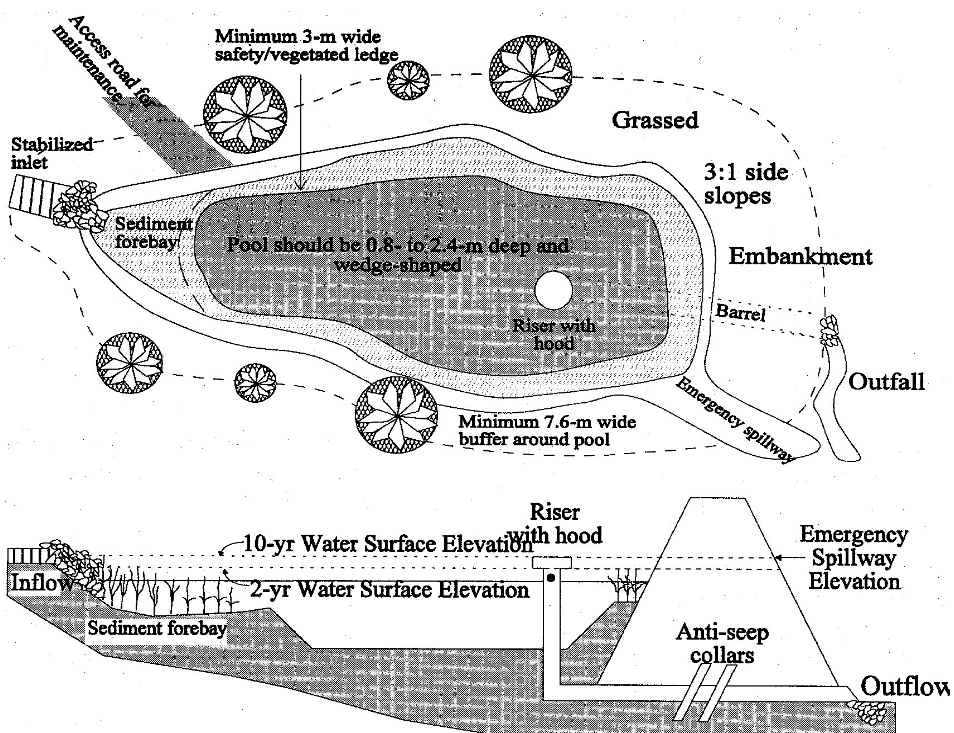


Figure 4-9: Schematic of a Wet Basin.

Chapter 4

4.6.3 Recommended Maintenance

Routine Maintenance:

Mowing. The side-slopes, embankment, and emergency spillway of the basin should be mowed at least twice a year to prevent woody growth and control weeds.

Inspections. Wet basins should be inspected at least twice a year to evaluate facility operation. When possible, inspections should be conducted during wet weather to determine if the basin is functioning properly. There are many functions and characteristics that should be inspected. The embankment should be checked for subsidence, erosion, leakage, cracking, and tree growth. The condition of the emergency spillway should be checked. The inlet, barrel, and outlet should be inspected for clogging. The adequacy of upstream and downstream channel erosion protection measures should be checked. Stability of the side slopes should be checked. Modifications to the basin structure and contributing watershed should be evaluated.

During semi-annual inspections prepare and update maintenance checklists, and replace any dead or displaced vegetation. Replanting of various species of wetland vegetation may be required at first, until a viable mix of species is established. Cracks, voids and undermining should be patched/filled to prevent additional structural damage. Trees and root systems should be removed to prevent growth in cracks and joints that can cause structural damage. The inspections should be carried out with as-built pond plans in hand.

Debris and Litter Removal. Debris and litter should be removed from the surface of the basin. Particular attention should be paid to floatable debris around the riser, and the outlet should be checked for possible clogging.

Erosion Control. The basin side slopes, emergency spillway, and embankment all may periodically suffer from slumping and erosion. Corrective measures such as regrading and revegetation may be necessary. Similarly, the riprap protecting the channel near the outlet may need to be repaired or replaced.

Nuisance Control. Most public agencies surveyed indicate that control of insects, weeds, odors, and algae may be needed in some ponds. If the ponds are properly sized and vegetated, these problems should be rare in wet ponds except under extremely dry weather conditions. Twice a year, the facility should be evaluated in terms of nuisance control (insects, weeds, odors, algae, etc.). Biological control of algae and mosquitoes using fish such as fathead minnows is preferable to chemical applications.

Non-routine maintenance:

Structural Repairs and Replacement. Eventually, the various inlet/outlet and riser works in the wet basin will deteriorate and must be replaced. Some public works experts have estimated that corrugated metal pipe (CMP) has a useful life of about 25 yr, while concrete barrels and risers may last from 50 to 75 yr. The actual life depends on the type of soil, pH of runoff, and other factors. Polyvinyl chloride (PVC) pipe is a corrosion resistant alternative to metal and concrete pipes. Local experience typically determines which materials are best suited to the site conditions. Leakage or seepage of water through the embankment can be avoided if the embankment has been constructed of impermeable material, has been compacted, and if anti-seep collars are used around the barrel. Correction of any of these design flaws is difficult.

Sediment Removal. Wet ponds will eventually accumulate enough sediment to significantly reduce storage capacity of the permanent pool. As might be expected, the accumulated sediment can reduce the performance of the pond. Sediment accumulated in the sediment forebay area should be removed from the facility every two years to prevent accumulation in the permanent pool. Dredging of the permanent pool should occur at least every 20 years, or when accumulation of sediment impairs functioning of the outlet structure.

Harvesting. If vegetation is present on the fringes or in the pond, it can be periodically harvested and the clippings removed to prevent the basin from filling with decaying organic matter. Clippings may be composted onsite, away from the wet pond, or at an off-site composting facility.

4.7 BIORETENTION

4.7.1 Introduction

Rain garden and bioretention best management practices function as a soil and plant-based filtration device that removes pollutants through a variety of physical, biological, and chemical treatment processes. These facilities normally consist of a filtration bed, ponding area, organic or mulch layer, and plants. Exfiltration of the stored water in the bioretention area planting soil into the underlying soils occurs over a period of days when installed as an unlined system. Figure 4-10 illustrates the basic components of the system and a picture of a bioretention system located in a parking lot island is presented in Figure 4-11.

Rain gardens and bioretention systems are very similar in their design and function. Both systems can be used in any land use type or for any site. For the purposes of this manual, the main difference between the two systems is that a bioretention system uses engineered soils. While rain gardens do not include engineered soils, they can include slightly modified soils. Both systems can be designed with or without underdrains.

Selection Criteria

» Good choice of an onsite system serving a relatively small drainage area, since it can be incorporated into the site landscaping.

» Bioretention provides stormwater treatment that enhances the quality of downstream water bodies by temporarily storing runoff and releasing it over a period of days to the receiving water.

» The vegetation provides shade and wind breaks, absorbs noise, and improves an area's landscape.

Limitations

» Bioretention is not recommended for areas with slopes greater than 20% or where mature tree removal would be required since clogging may result, particularly if the facility receives runoff with high sediment loads.

» Unlined bioretention systems are not suitable at locations where the water table is within 4 feet of the ground surface and where the surrounding soil stratum is unstable.

» Inclusion of substantial amounts of compost in the filter media can substantially increase nutrients in the discharge.

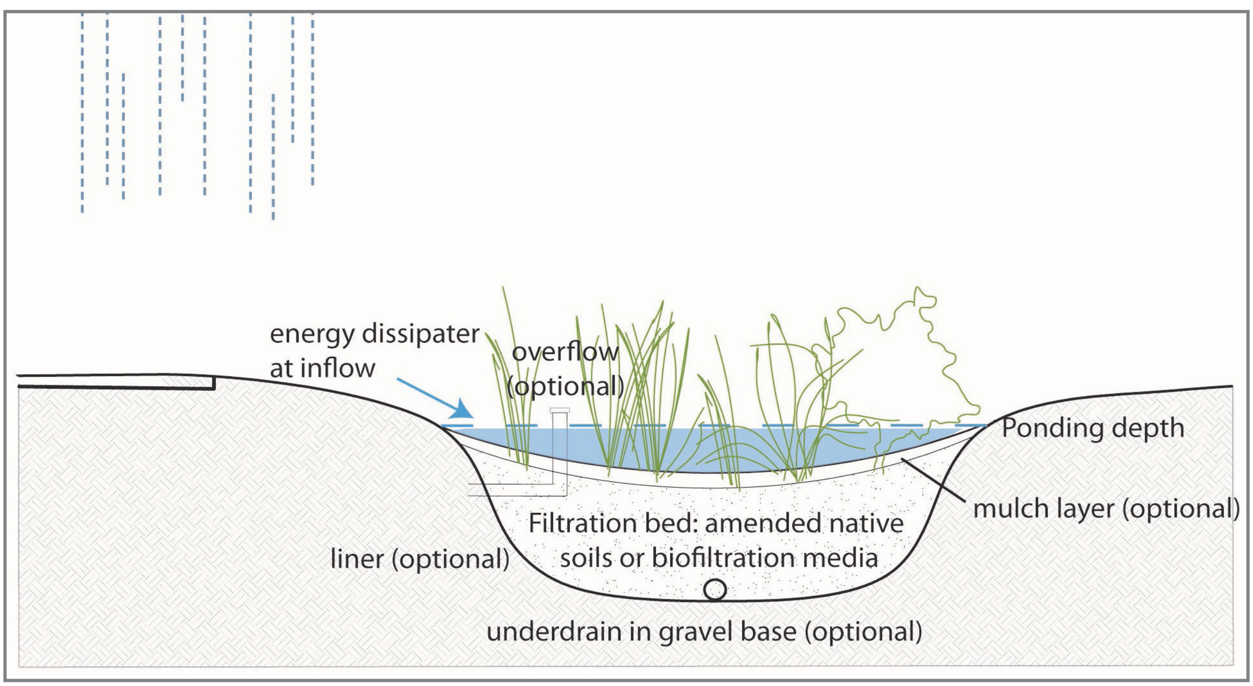


Figure 4-10: A diagram of the basic rain garden / bioretention system components, including optional components.

Figure 4-11: Picture of a Bioretention Facility. (Photo courtesy of David Dods)

4.7.2 Bioretention Design Guidance

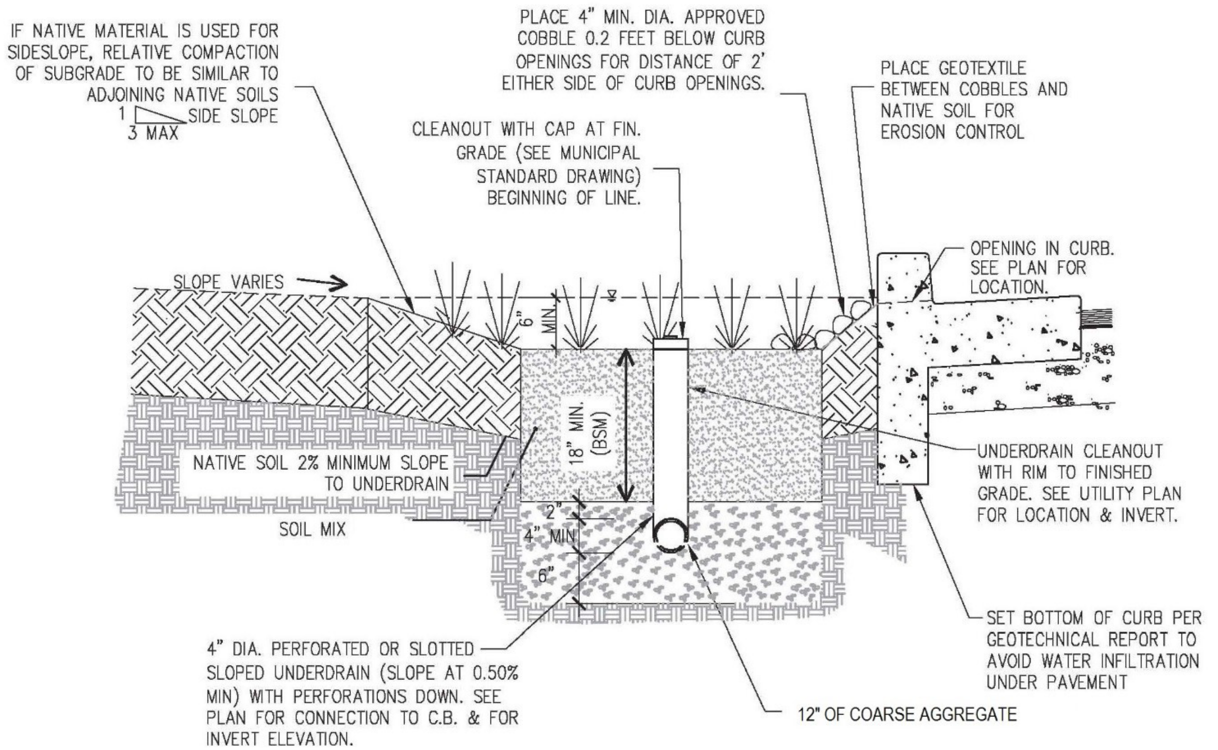
Bioretention facilities include organic and soil material in the filtration media to support vegetation. This allows these facilities to be integrated into the site landscaping where they can provide unobtrusive treatment of stormwater runoff. The following design guidelines are appropriate for conventional systems in the public domain. The reader should be aware that there are proprietary versions of bioretention systems commonly called "tree box filters", which will provide the same level of pollutant removal. Design of these systems should follow manufacturer's recommendations.

A schematic of a bioretention system is provided in Figure 4-12, which illustrates the design components. The figure includes a grass filter strip for pretreatment of the runoff to reduce sediment loading to the bioretention cell. This is a useful component, but is not required and may not be feasible depending on space constraints at the site. The "gravel curtain drain" and "optional sand filter layer" are not common or required.

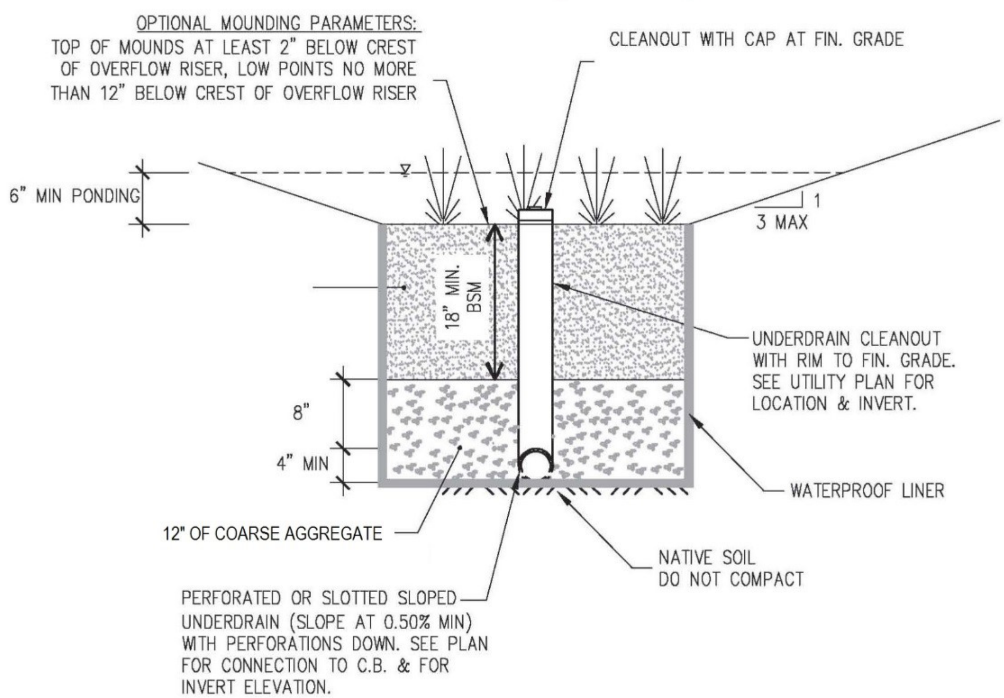
Underdrains are required if the system is installed in soils with infiltration rates of less than 0.5 in/hr. A bridging layer of pea gravel should be placed between the planting media and gravel layer to prevent the planting media from migrating into the gravel layer below.

1) Bioretention Sizing – The storage volume above the surface of the planting media should be sufficient to retain the volume of runoff from a 1.0 inch rainfall. The water depth over the media for the design storm should be between 6 and 12 inches.

2) Inlet Design - When siting bioretention facilities to intercept drainage, the designer should attempt to use the preferred "off-line" facility design. Off-line facilities are defined by the flow path through the facility. Any facility that utilizes the same entrance and exit flow path upon reaching pooling capacity is considered an off-line facility.



Cross-section of bioretention area showing inlet from pavement.



Cross section of lined bioretention area (Not to Scale)

Figure 4-12: Schematic Diagram of a Bioretention System.

3) Media Properties – The filtration media should have a minimum thickness of 18 inches and should have a maximum clay content of less than 5%. The soil mixture should be 75-90% sand; 0-4% organic matter; and 10-25% screened bulk topsoil. The soil should be a uniform mix, free of stones, stumps, roots, or other similar objects larger than two inches. No other materials or substances should be mixed or dumped within the bioretention that may be harmful to plant growth, or prove a hindrance to the planting or maintenance operations. Provide clean sand, free of deleterious materials. Sand may be composed of either ASTM C-33 (concrete sand) or ASTM C-144 (masonry sand). A good source of media is the material commonly used to construct golf course greens.

The organic matter listed above should be carefully selected. Traditional options for organic matter include peat moss or shredded bark mulch. There have been some issues with using compost and resulting water quality leaving the system. However, this is often due to compost that is high in nutrients or not mature compost. Compost can be an acceptable organic matter in bioretention systems but it must be used with caution. Only low-nutrient compost should be used, and preferably compost that is very mature (aged at least 6 months).

Installation of filter media must be done in a manner that will ensure adequate filtration. After scarifying the invert area of the proposed facility, place soil. Avoid over compaction by allowing time for natural compaction and settlement. No additional manual compaction of soil is necessary. Rake soil material as needed to level out. For facilities designed with a liner, no scarification of the invert area is required.

4) Underdrains – Underdrains should be incorporated in all designs unless installed where infiltration rates exceed 0.5 in/hr. The underdrain piping should consist of a main collector pipe and two or more lateral branch pipes, each with a minimum diameter of 4 inches. Underdrains should be perforated with ¼ - ½ inch openings, 6 inches center to center. The pipes should have a minimum slope of 1% (1/8 inch per foot) and the laterals should be spaced at intervals of no more than 10 feet. Each individual underdrain pipe should have a cleanout access location. Ideally the cleanout access will be located in the facility embankment to reduce the possibility of bypass if the cleanout is damaged (see Figure 4-13 for example). All piping is to be Schedule 40 PVC.

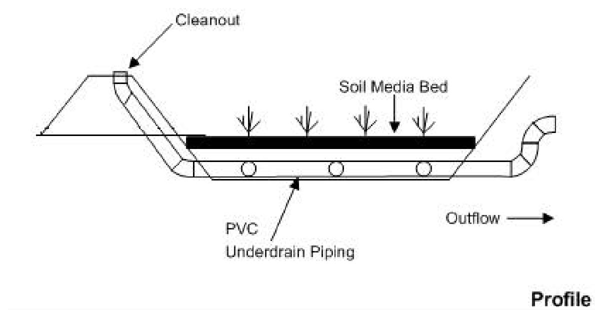


Figure 4-13: Detail of Cleanout Location.

5) Outlet – A raised outlet as illustrated in Figure 4 14 is optional. It has the potential advantage of reducing the headloss across the facility and providing a permanent pool that will provide additional water for the plants during long dry periods.

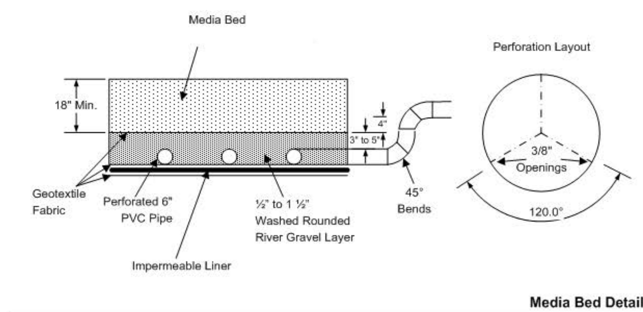


Figure 4-14: Illustration of Optional Outlet Design.

6) Setbacks - When siting bioretention facilities, a 50 foot setback from septic fields should be provided. Setback from a foundation or slab should be 5 feet or greater.

7) Vegetation – Vegetation selected for the bioretention system should be climate-adapted and tolerant of frequent inundation during extended periods of wet weather.

8) Curb Cut Inlet – There are several design options for curb cuts, where curbs are used or modified, to allow runoff to enter the bioretention or rain garden system. Several of these (non-

exclusive) options are diagramed below. The last option in the figure below demonstrates one type of inlet where a sediment / debris catchment area is included. These types of modifications can provide places to catch larger items such as soda cans or other floatables and can be designed with grates where water flows through the 'box' and into the rain garden or be designed to be level with the base of the bioretention system. In either method, they should be designed to be shovel-size for easy maintenance.

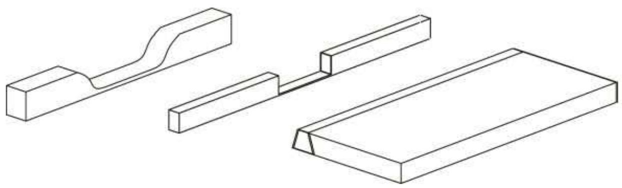


Figure 4-15: Curb cut options: smooth cut, hard cut and flush curb.

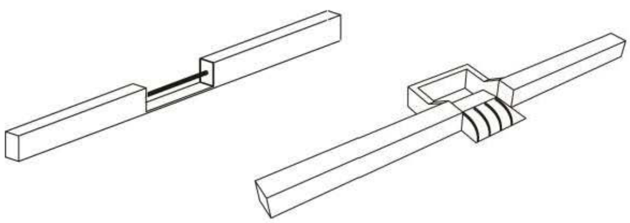


Figure 4-16: Curb cuts with optional sediment/trash screens.

9) Inlet Design – Where flows enter the treatment measure, allow change in elevation of 4 to 6 inches between the paved surface and the soil media elevation, so that vegetation growth or mulch build-up does not obstruct flow. Install cobbles, rocks or a small cement slab to dissipate flow energy where runoff enters the treatment measure.

10) Construction – During construction, minimize compaction of existing soils. Protect from construction traffic. Protect the area from construction site runoff. Runoff from unstabilized. Divert runoff from unstabilized areas away from the facility.

11) Mulch - Provide a 3-inch layer of mulch to cover exposed soil between plantings.

4.7.3 Recommended Maintenance

The primary maintenance requirement for bioretention areas is that of inspection and repair or replacement of the treatment area's components. Generally, this involves nothing more than the routine periodic maintenance that is required of any landscaped area. Plants that are appropriate for the site, climatic, and watering conditions should be selected for use in the bioretention cell. Appropriately selected plants will aide in reducing fertilizer, pesticide, water, and overall maintenance requirements. Bioretention system components should blend over time through plant and root growth, organic decomposition, and the development of a natural soil horizon. These biologic and physical processes over time will lengthen the facility's life span and reduce the need for extensive maintenance.

Routine maintenance should include a semi-annual health evaluation of the trees and shrubs and subsequent removal of any dead or diseased vegetation. Diseased vegetation should be treated as needed using preventative and low-toxic measures to the extent possible. Bioretention systems have the potential to create very attractive habitats for mosquitoes because of highly organic, often heavily vegetated areas mixed with shallow water. Routine inspections for areas of standing water within the facility and corrective measures to restore proper infiltration rates are necessary to prevent mosquito breeding.

In order to maintain the treatment area's appearance it may be necessary to prune and weed. Furthermore, mulch replacement is suggested when erosion is evident or when the site begins to look unattractive. Specifically, the entire area may require mulch replacement every year, although spot mulching may be sufficient when there are random void areas.

Other potential tasks include replacement of dead vegetation, erosion repair at inflow points, mulch replenishment, unclogging the underdrain, and repairing overflow structures.

Other recommended maintenance guidelines include:

» Inspections. Bioretention facilities should be inspected at least twice a year (once during or immediately following wet weather) to evaluate facility operation. During each inspection, erosion areas inside and downstream of the facility must be identified and repaired or revegetated immediately.

» Sediment Removal. Remove sediment from the facility when accumulated sediment hinders the flow of water into the facility.

» Drain Time. When the drain time exceeds 48 hours, the top few inches of filter media should be removed and replaced with material that meets the specifications of the original media.

» Vegetation. All dead and diseased vegetation considered beyond treatment should be removed and replaced. Re-mulch any bare areas by hand whenever needed. Replace mulch annually in the spring, or more frequently if needed, in landscaped areas of the basin where grass or groundcover is not planted. Grass areas in and around bioretention facilities should be mowed at least twice annually. More frequent mowing to maintain aesthetic appeal may be necessary in landscaped areas. Use Integrated Pest Management techniques to avoid or minimize the use of synthetic pesticides and fertilizers.

» Debris and Litter Removal. Debris and litter will accumulate in the facility and should be removed during regular mowing operations.

» Filter Underdrain. Clean underdrain piping network to remove any sediment buildup as needed to maintain design drawdown time.

4.8 INFILTRATION FACILITIES

4.8.1 Introduction

Infiltration basins are vegetated stormwater retention facilities designed to capture runoff and allow it to infiltrate directly to the soil profile rather than discharging to receiving waters. This practice is intended to mimic the natural rainfall retention and infiltration characteristics of undeveloped watersheds. Basins are typically excavated in native soils, constructed above grade using structural walls, or created with berms. Typical designs allow for complete infiltration of the capture volume within 2 to 3 days and provide a splitter structure to route surplus inflows around the facility when it is full. Infiltration basins are generally suitable for treatment of drainage areas from 5 to 15 acres. A schematic of an infiltration basin is presented in Figure 4-17.

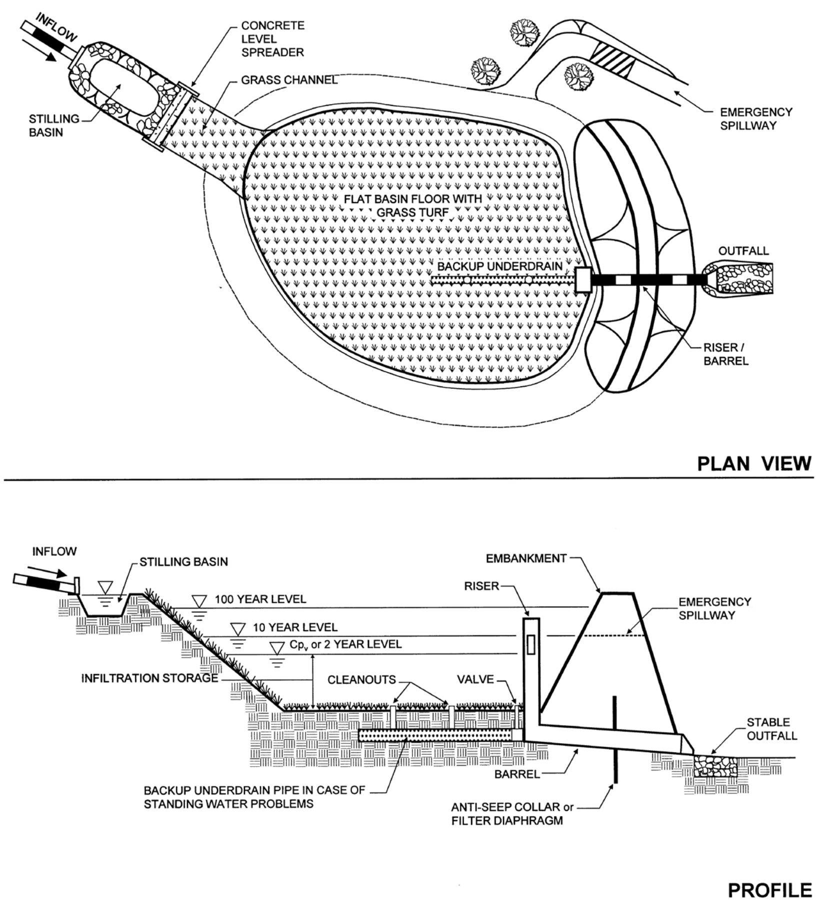


Figure 4-17: Infiltration Basin Schematic. (Photo courtesy of MDE, 2000)

Vegetation resistant to temporary inundation should be used in the facility. Root penetration and thatch formation maintains and often enhances infiltration capacity of the basin floor. In addition, vegetation can trap stormwater constituents by growing through accumulated sediments and preventing re-suspension. Vegetation also provides nutrient uptake in the shallow root zone and a substructure for microbial residence.

Advantages

» Provides 100% reduction in the volume discharged to surface waters, for frequent small storms.

» The principal benefit of infiltration basins is the approximation of pre-development hydrology during which a significant portion of the average annual rainfall runoff is infiltrated and evaporated rather than flushed directly to creeks.

» If the volume is adequately sized, infiltration basins can be useful for providing control of channel forming (erosion) and high frequency (generally less than the 2-year) flood events.

Limitations

» May not be appropriate for industrial sites or locations where spills may occur.

» Infiltration basins require a minimum soil infiltration rate of 0.5 inches/hour, not appropriate at sites with Hydrologic Soil Types C and D.

» Not suitable on fill sites or steep slopes.

» Upstream drainage area must be completely stabilized before construction.

» Difficult to restore functioning of infiltration basins once clogged.

4.8.2 Design and Sizing Guidelines

(1) Basin Sizing - The volume of the basin should be sized to retain at least the volume of runoff from a 1.0 inch rainfall event. The maximum water depth in the basin should not exceed 2.0 foot.

(2) Provide pretreatment if sediment loading is a maintenance concern for the basin.

(3) Include energy dissipation in the inlet design for the basins.

Siting

The key element in siting infiltration basins is identifying sites with appropriate soil properties, which is critical for long term performance.

» Determine soil type (consider RCS soil type ‘A or B only) from mapping and consult USDA soil survey tables to review other parameters such as the amount of silt and clay, presence of a restrictive layer or seasonal high water table, and estimated permeability.

» Groundwater separation should be at least 4 feet from the basin invert to the measured ground water elevation. There is concern at the state and regional levels of the impact on groundwater quality from infiltrated runoff, especially when the separation between groundwater and the surface is small.

» Location away from buildings, slopes and highway pavement (greater than 20 feet) and wells and bridge structures (greater than 100 feet).

» Ensure that adequate head is available to operate flow splitter structures (to allow the basin to be offline) without ponding in the splitter structure or creating backwater upstream of the splitter.

» Dry weather flow should not be present in the tributary watershed.

Before construction begins, stabilize the entire area draining to the facility. If impossible, place a diversion berm around the perimeter of the infiltration site to prevent sediment entrance during construction or remove the top 2 inches of soil after the site is stabilized. Stabilize the entire contributing drainage area, including the side slopes, before allowing any runoff to enter once construction is complete. Place excavated material such that it cannot be washed back into the basin if a storm occurs during construction of the facility.

Build the basin without driving heavy equipment over the infiltration surface. Any equipment driven on the surface should have extra-wide (“low pressure”) treads or tires. Prior to any construction, rope off the infiltration area to stop entrance by unwanted equipment. After final grading, till the infiltration surface deeply.

4.8.3 Recommended Maintenance

Regular maintenance is critical to the successful operation of infiltration basins. Recommended operation and maintenance guidelines include:

Observe drain time for the basin after completion or modification of the facility to confirm that the basin drains within 48 hours.

Schedule annual inspections to identify potential problems such as erosion of the basin side slopes and invert, standing water, trash and debris, and sediment accumulation.

Remove accumulated trash and debris annually.

Avoid reversing soil development: scarification or other disturbance should only be performed when there are actual signs of clogging, rather than on a routine basis. Always remove deposited sediments before scarification, and use a hand-guided rotary tiller, if possible, or a disc harrow pulled by a very light tractor.

Chapter 5

INCORPORATING STRUCTURAL PRACTICES INTO TYPICAL DEVELOPMENT PROJECTS

» *Projects with Detention Requirements*

» *Single Family Residential*

» *Multi Family Developments*

» *Commercial/Retail/Office*

» *Downtown Redevelopment*

The purpose of this chapter is to help visualize ways in which various structural practices can be employed, alone or in combination, to achieve more sustainable drainage site design. Some of the development now occurring in the Coastal Zone already includes a sustainable drainage system, although conveyance and flood control may have been the primary design considerations. This is especially apparent in residential developments that incorporate open channel drainage for stormwater conveyance.

In addition, many developments along the coast are required by drainage districts, counties, and other regulatory entities to provide stormwater detention for flood control. This manual describes how these detention facilities, with potentially only the slightest modification, can also improve the performance of the drainage system, while providing aesthetic benefits, recreational opportunities, and wildlife habitat.

Where detention is not desired or required, the biggest change in current practice is likely to occur for commercial and office type projects. Despite the additional effort required for compliance by these projects, the appropriate practices can include additional landscaping in parking areas, which then increase the attractiveness of these projects to both residents and visitors alike.

Opportunities for inclusion of stormwater practices generally fall into one of five categories: projects with detention requirements, single family residential developments, multi-family residential developments, commercial/retail/office establishments, and streetscape and downtown redevelopment projects.

5.1 PROJECTS WITH DETENTION REQUIREMENTS

Detention is a common flood prevention requirement for new developments in many areas of the Texas coastal zone. One example is the subdivision in Chambers County, shown in Figure 5-1, which has three detention areas. By tweaking the design of these detention basins to include wet pond or wetland characteristics, significant aesthetic and water quality improvements may be achieved.

Wet ponds can be designed as neighborhood amenities, attracting birds and allowing opportunities for fishing and canoeing. These visual elements and recreational opportunities, as shown in Figure 5-2 through Figure 5-4 enhance the value of the development. The first two figures illustrate detention incorporated in single family residential developments. In areas with dry detention basins, residents typically install privacy fences because the stormwater basin is viewed as an unsightly liability. On the other hand, residents that back up to a wet pond frequently chose fencing materials that provide a view of the facility, indicating that it is viewed positively, increasing the value of those lots. Figure 5-4 shows a wet pond located at an apartment complex. It is very clear that having an

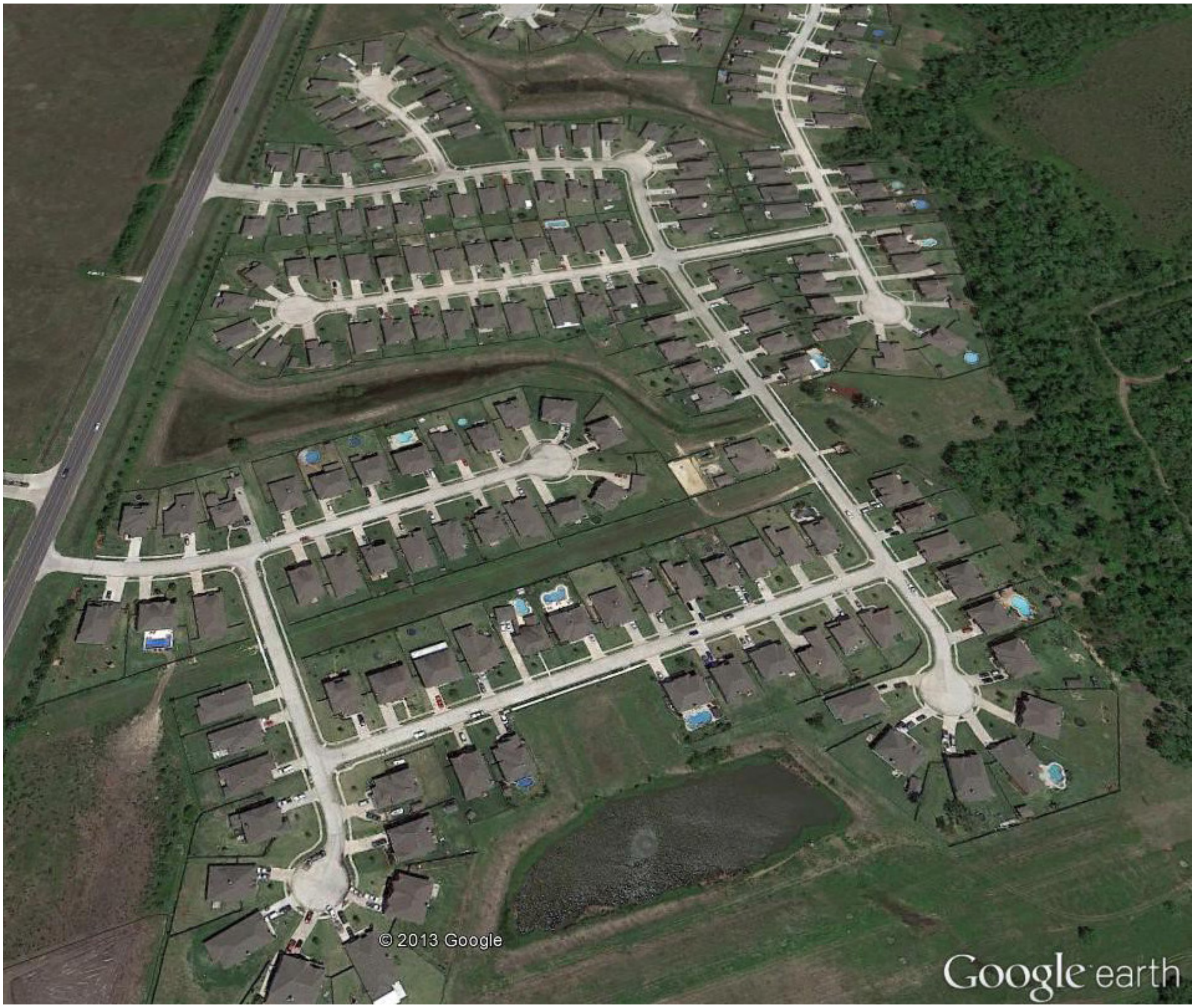


Figure 5-1: Layout of a high density single family residential development that includes three detention ponds.

Figure 5-2: Enhanced detention wet pond is an amenity in a subdivision in Chambers County, Texas.

open water component makes the detention basin an asset to the development, allowing higher rents to be charged for those apartments with a view of the pond.

If the use of the wet pond for recreational activities is not desired, the developer may choose to install a wetland detention area rather than a wet pond. Wet ponds include open water in the middle and vegetation around the edges while wetlands detention areas are generally shallow enough to have vegetation throughout. Both of these enhanced detention options are well suited to locations with a high water table.

Figure 5-3: Chambers County neighborhood uses wet pond with a fountain for water circulation as a prominent feature in the subdivision.

Figure 5-4: Constructed wet pond provides water quality benefits and an attractive place to recreate for nearby multi-family housing.

5.2 SINGLE FAMILY RESIDENTIAL

Structural stormwater controls that make sense in a medium or high density subdivision include bioretention, porous pavement, and vegetated swales and filter strips. Current construction practices for low density subdivisions usually include features that function as vegetated swales and filter strips. Additionally, because of their low levels of impervious cover, subdivisions with less than 20% impervious cover are exempt from stormwater requirements described in this document.

5.2.1 Medium and High Density Residential

When designing roadways in medium density areas, conveyance of stormwater in open channels (e.g., vegetated swales and filter strips) are a logical choice. While vegetated swales and filter strips may be difficult to employ in downtown, commercial, or very high density developments because of space constraints, they are well suited to receive stormwater in some lower density areas, such as the medium density subdivision pictured in Figure 5-5. As described in Chapter 2, the use of fertilizers and pesticides should be kept to an absolute minimum in order to realize the full benefits of vegetated swales or filter strips.

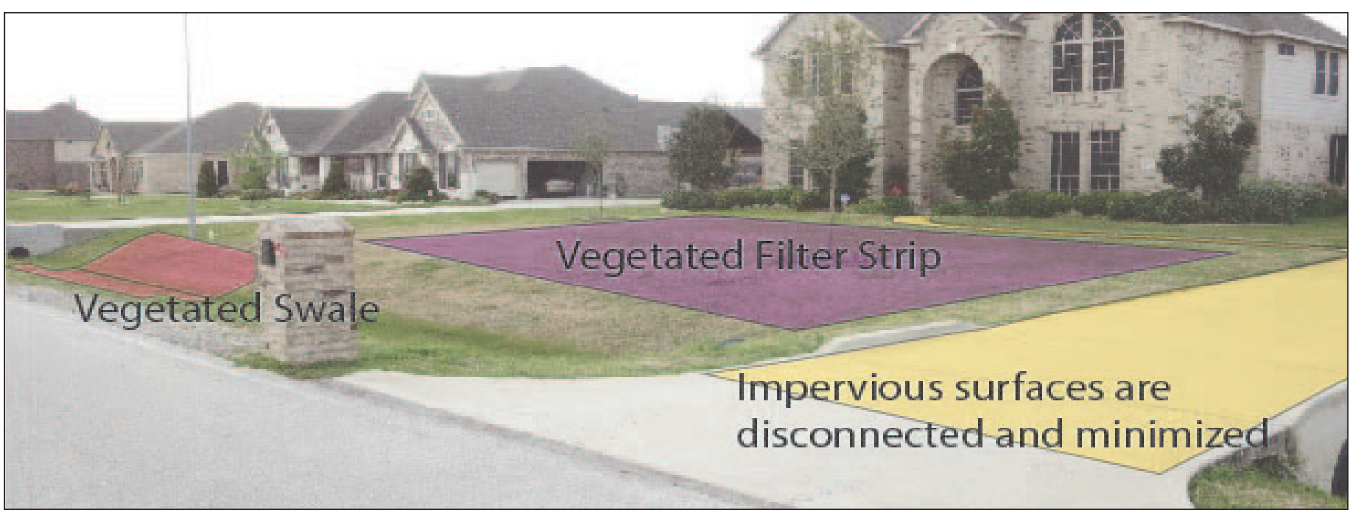


Figure 5-5: Medium density neighborhood uses vegetated swales for stormwater conveyance. These swales also provide water quality benefits.

Figure 5-6: Disconnected and minimized impervious cover in Chambers County, Texas.

Narrow sidewalks, roads and driveways, separated from each other by vegetation, help to minimize and disconnect impervious surfaces, as in Figure 5-6.

Driveways are also a common use of permeable pavers and can help reduce overall impervious cover on a residential site (see Figure 5-7), which reduces detention requirements. Lawns or bioretention areas on either side of the driveway can further improve the performance of the site. Tips for how to reduce lawn care and landscaping pollutants into the watershed can be found in the Watersmart Landscaping Practices in Chapter Two.

Figure 5 7: Driveway constructed of permeable pavers. (Photo courtesy of Mutual Materials)

5.2.2 Waterfront

Waterfront development, whether single family or multi-family, could include similar strategies for stormwater management as some higher density developments. Permeable pavement, bioretention areas or infiltration basins or vegetated filter strips and swales should be employed to collect and treat stormwater. Figure 5-8 illustrates how a variety of sustainable drainage practices can be incorporated into the site.

Waterfront development, whether residential or commercial, should always include an intact riparian zone buffer between the development and the waterway it is overlooking. As discussed in the beginning of this chapter, a riparian buffer should be at least 25 feet wide and should extend the entire length of the development along the waterway.

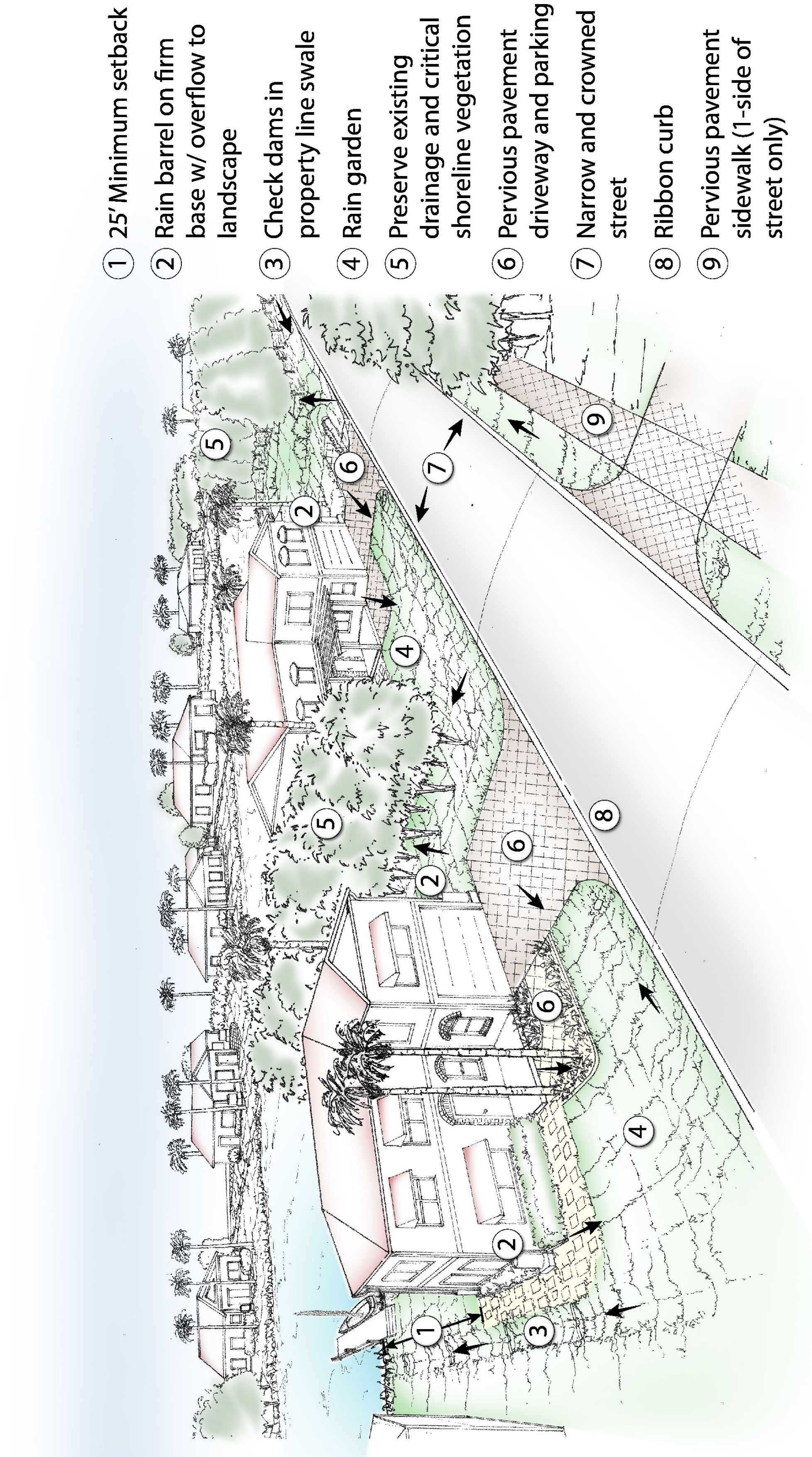


Figure 5-8: Example of waterfront development with sustainable drainage features.

5.3 MULTI-FAMILY DEVELOPMENTS

Figure 5-9: Multi-family with vegetated bioretention area (Photo courtesy of Michael Barrett)

Options for sustainable stormwater management in high impervious cover areas such as multi-family developments include pervious pavers, bioretention areas and infiltration facilities. In Figure 5-9, bioretention areas are integrated with conventional landscaping.

Parking lots in multi-family developments, Figure 5-10, can be outfitted with permeable pavement parking stalls. These permeable pavers serve to reduce the quantity of stormwater as well as improve the functional and aesthetic experience of the parking lot.

Multi-family developments on waterfront lots should include the same elements as other multi-family, including disconnection and minimization of impervious cover, pervious pavement, and bioretention or infiltration areas.

Figure 5-10: Multi-family units utilize permeable pavers to beautify their parking lot.

5.4 COMMERCIAL/ RETAIL/OFFICE

Commercial developments are frequently built with a high percentage of impervious cover. When detention is not required, feasible stormwater solutions include permeable pavement, bioretention, infiltration, and, depending on the land use and character of the surrounding land, vegetated filter strips. Figure 5-11 demonstrates how a variety of sustainable stormwater practices can be integrated into the site design. Parking lots can be outfitted with bioretention areas in the center medians, as shown in Figure 5-11, or vegetated filter strips on the edges. Trees in these center islands can provide welcome shade during hot Texas summers.

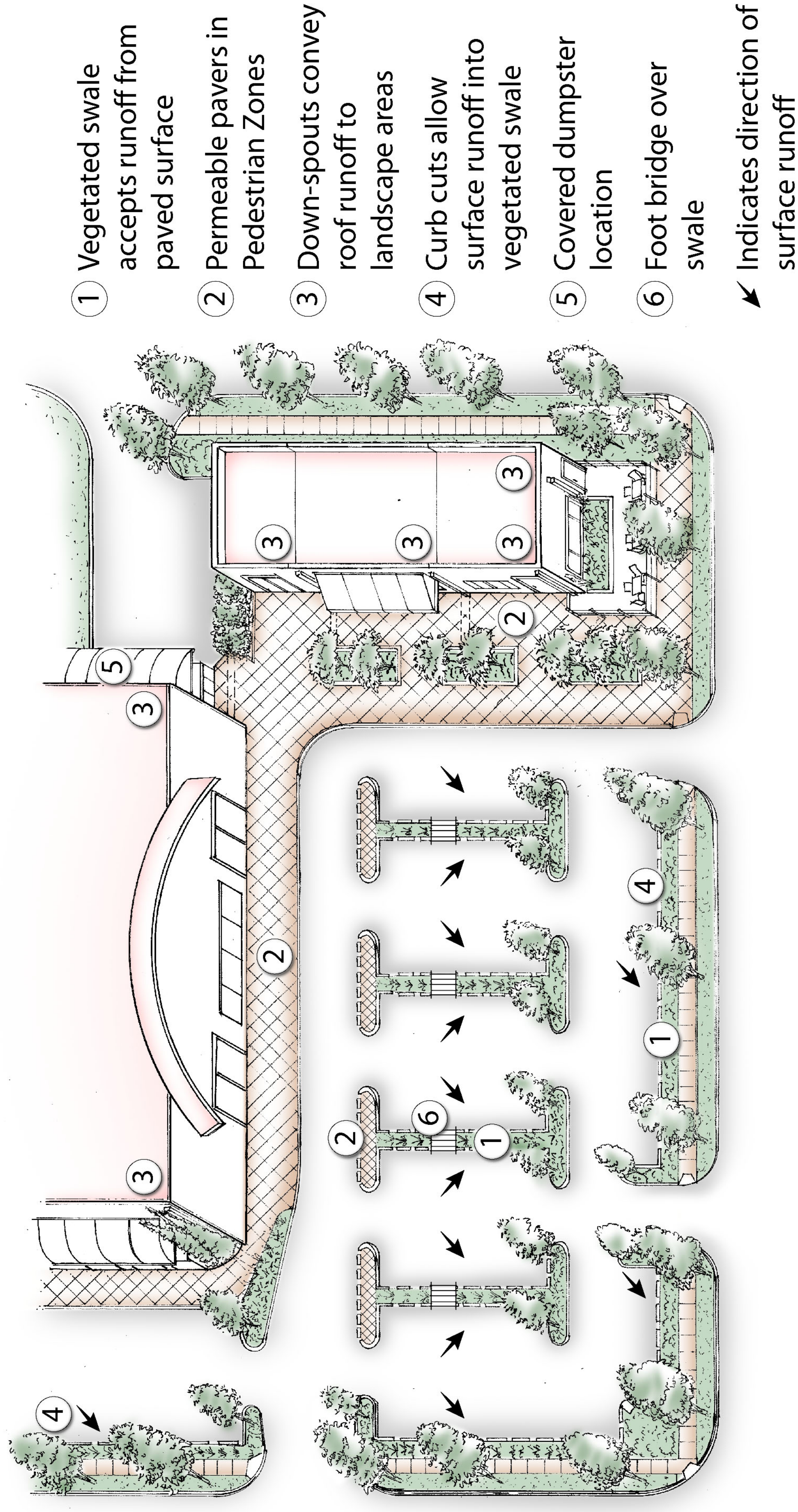


Figure 5-11: Commercial development incorporating sustainable drainage practices.

Figure 5-12: Parking lots can positively influence the customer experience at a commercial development.

Parking lots are a key part of commercial establishments and serve as the customer's initial introduction to the business. Parking lots can reflect the quality of the business, and a puddle-free lot with landscaped or shaded areas can improve the customer experience. Figure 5-12 shows two different parking lot designs, one with stormwater controls included in the design, and the other designed and built in a conventional manner.

To reduce standing water after a storm, parking lots can be fitted all or in part with permeable pavement. While one option is for the entire parking lot to be porous pavement, another common configuration includes standard pavement driving lanes which slope towards permeable parking stalls. This is illustrated below in Figure 5-13.

Figure 5-13: Permeable Interlocking Concrete Pavers with regular asphalt driving lane in Cascade Park parking lot, Cameron County, Texas.

5.5 DOWNTOWN REDEVELOPMENT

Retrofitting of existing development is not required by this document; however, grant funding is often available for projects that incorporate sustainable stormwater components as part of downtown renovation. High density and downtown areas frequently have space constraints that preclude the use of swales and filter strips. However, options such as bioretention and porous pavement are available, used either together or individually, to reduce the impacts of stormwater and improve the performance of the streetscape.

When designing a pedestrian walkway near a busy road, the use of swales or bioretention strips between the sidewalk and road can help the pedestrian feel insulated from nearby traffic and more comfortable walking in groups or with children and pets. As shown in Figure 5-14 and Figure 5-15, the stormwater benefits of these structures are integrated with the social and aesthetic benefits afforded by the landscaping and compliment the use of porous pavement.

Figure 5-14: Bioretention serves as a buffer between the sidewalk and street. (Photo courtesy of State of Washington Transportation Improvement Board)

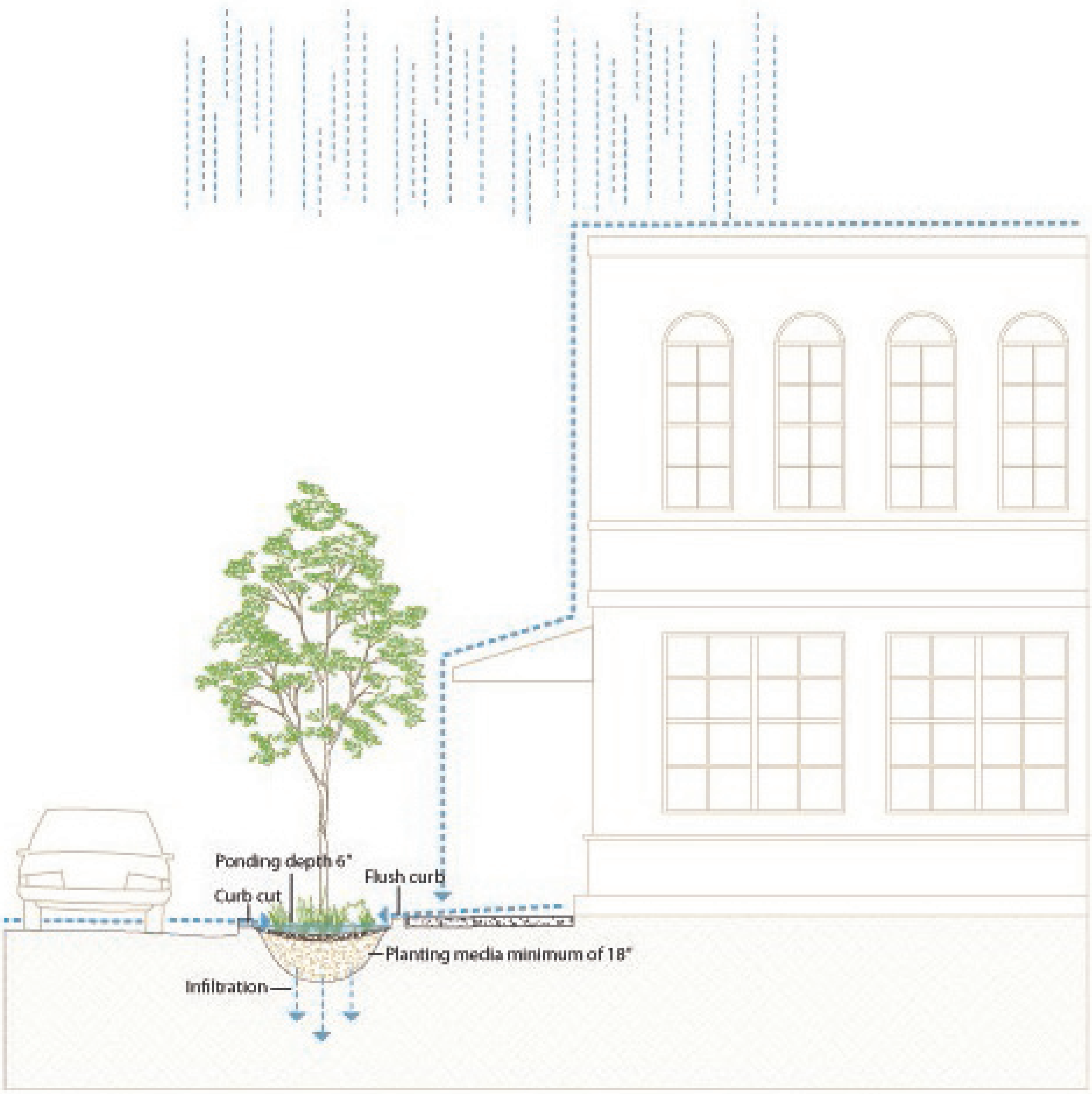


Figure 5-15: Schematic of a bioretention area with no underdrain creating a buffer between the pedestrian zone and the street; stormwater infiltrates into surrounding soils.

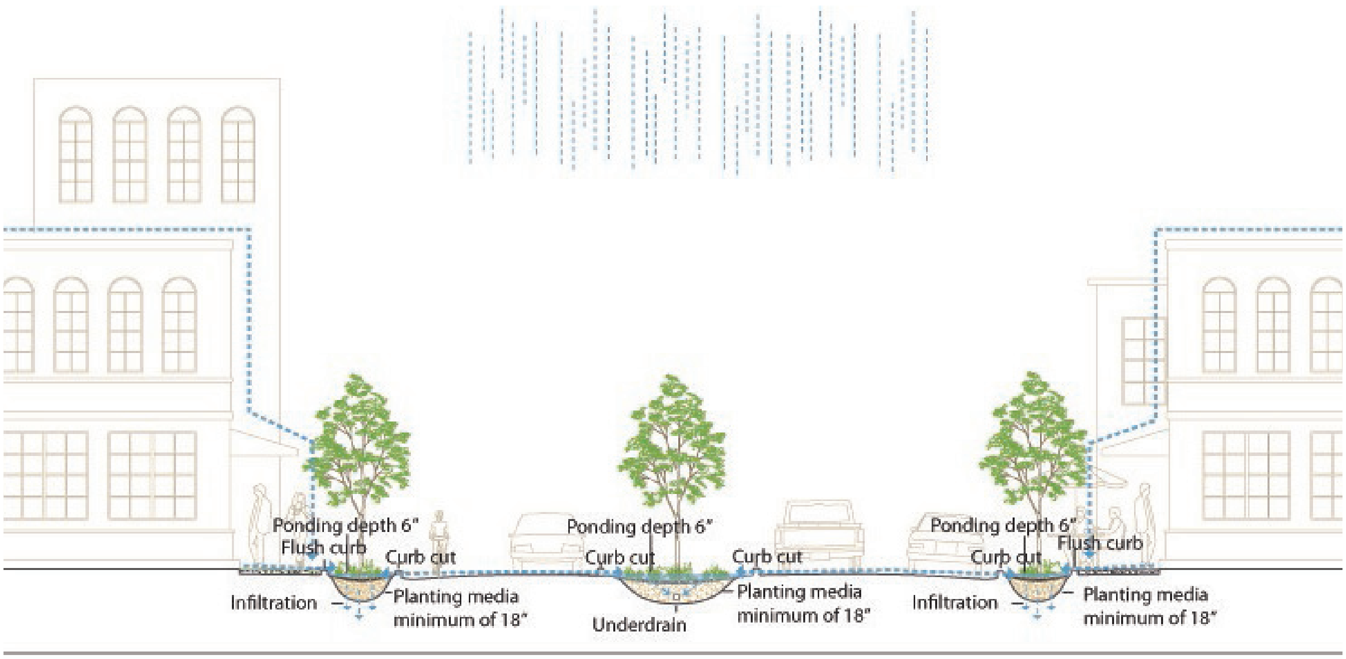


Figure 5-16: Bioretention along streets with a combination of infiltration and underdrain.

Medians and bike lanes afford additional opportunities for stormwater capture and filtration, as in Figure 5-16.

The use of alternate material for bike lanes and pedestrian crossings, such as that in Figure 5-17, can increase the safety of these biking and walking. Porous pavement can eliminate standing water on the surface of the area and reduce the opportunities for slipping or skidding. Alternate materials also serve to delineate the space, reducing the possibility of a vehicle crossing into the bike lane or failing to stop for a pedestrian.

Figure 5-17: Pedestrian crossing constructed with pervious pavers.

The following renderings (Figure 5-18 - Figure 5-20) illustrate possibilities for downtown redevelopment that incorporates stormwater controls while maintaining the local character of the place and improving the user experience. The renderings are set in Port Isabel, Texas, a small coastal community in the Lower Rio Grande Valley. Given that tourism in Port Isabel is the primary economic driver, the visitor experience can have an appreciable impact on economic growth in the area. The "before" photograph is shown in Figure 5-18.

Figure 5-19 shows pervious pavers on the sidewalks and bioretention areas between the sidewalk and the street that can easily be incorporated into redevelopment project. These features also serve to provide more shade for pedestrians and parked cars, and incorporate a buffer between the people and children on the sidewalk and the traffic on the street. Figure 5-19 demonstrates how these stormwater controls can be integrated seamlessly into the fabric of downtown life.

This type of redevelopment can be achieved with very little expense to the city. As redevelopment of private property occurs, stormwater controls can be incorporated into the new design, with no cost to the city. Additionally, as outlined in Chapter Four, the fee in lieu option requires the developer to make a payment of $10,000 per impervious acre created. These funds would be eligible for stormwater features in downtown redevelopment projects.

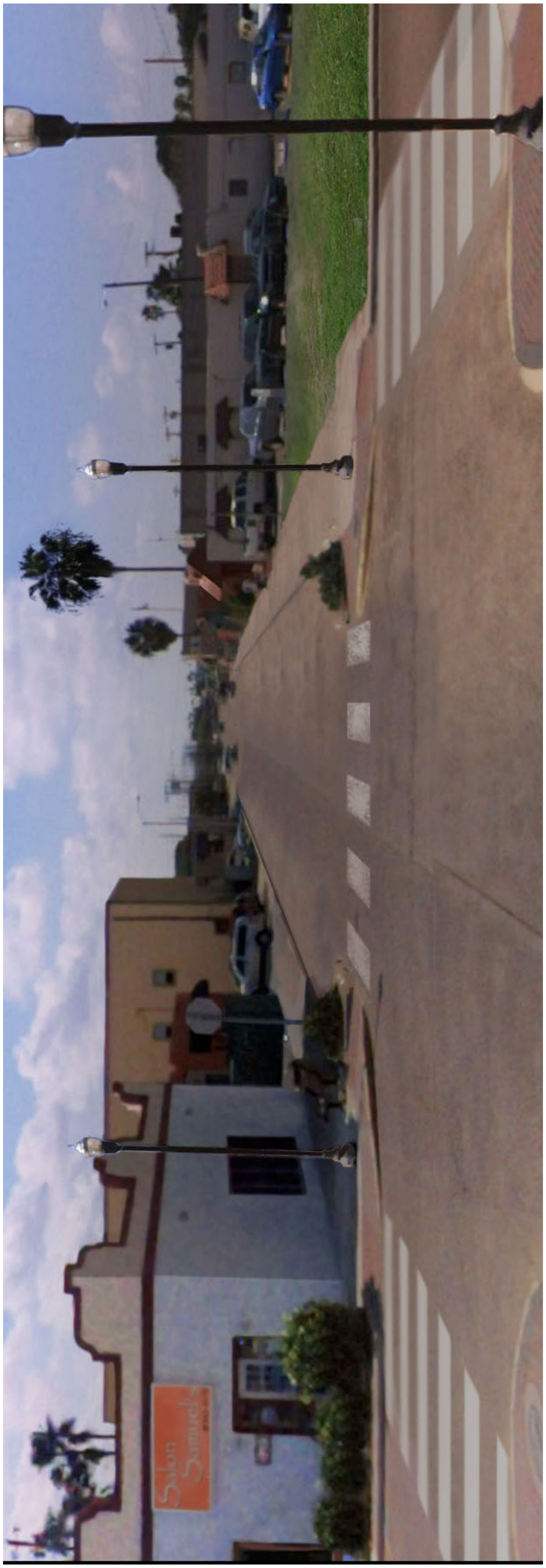
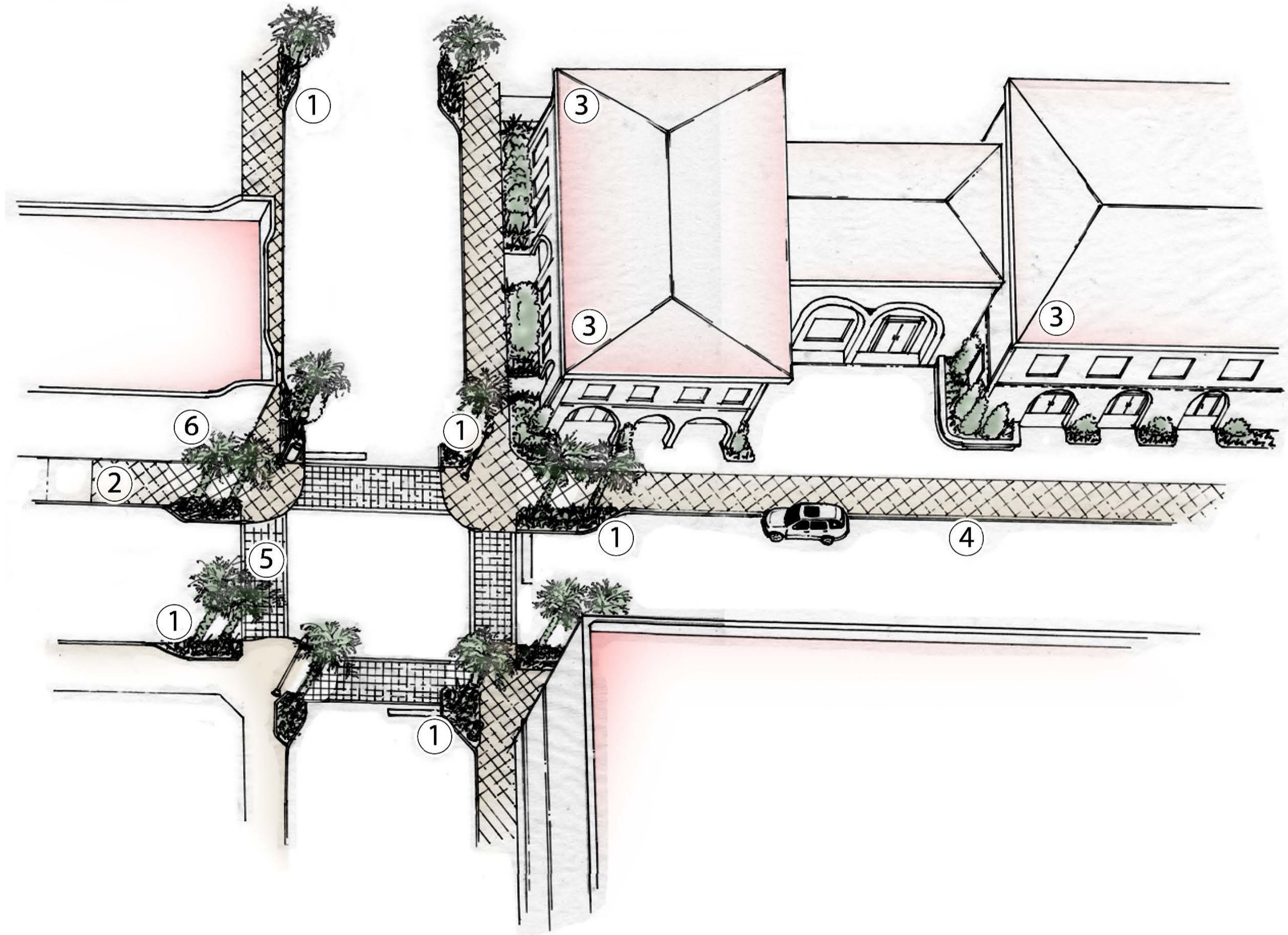


Figure 5-18: Downtown redevelopment. BEFORE stormwater controls.

Figure 5-19: Downtown redevelopment. Existing site including potential stormwater changes.



1 Bioretention curb extensions: Enhances pedestrian environment; accepts runoff from street and sidewalk. Runoff enters bioretention area via curb cuts; overflow enters storm drain.

2 Permeable pavers (interlocking concrete pavers separated by joints filled with small stones).

3 Roof runoff drains to lined bioretention areas with underdrains.

4 Parallel parking allows for narrower roadway than angled parking.

5 Permeable pavers in pedestrian crossings.

6 Trees intercept rainfall and contribute to the sense of place.

Figure 5-20: Downtown redevelopment. Birds-eye view of stormwater controls.

The Texas Coastal Zone is home to more than 6 million people, and is expected to grow to 8.5 million within 35 years. The urban and rural cities and towns along the Gulf Coast take pride in and depend on the rich, diverse ecosystems and natural bounty. The economy and character of these unique places is closely tied to the health of the waterbodies. However, as new land is developed to accommodate the expanding population, the Texas Gulf Coast will continue to experience challenges in maintaining and restoring water quality. Pollutants entering these waterbodies puts the natural landscape and ecosystems that Texas depends on at risk.

Stormwater runoff, or the rain water that falls to the ground but does not soak in or evaporate, can contribute to pollution entering waterbodies. While stormwater runoff from larger cities and metropolitan areas is regulated through a state permitting process, small cities remain unregulated. However, this presents an opportunity for small cities in the coastal zone to take the initiative in protecting their water quality in a cost-effective manner.

Individuals can help by implementing water smart landscaping, disposing of household hazardous waste properly, maintaining their septic system, disposing of pet waste, and harvesting rainwater from their roofs.

New development can positively impact both the economy and water quality, if executed with conservation and stormwater in mind. Developers can protect water quality by using conservation design for neighborhoods and preserving natural features during planning and construction. Reducing and disconnecting impervious cover will also positively impact water quality by allowing more permeable area for rain water to soak in.

Cities and developers can work together to integrate water quality features into the fabric of a neighborhood or shopping center, creating an integrated landscape that provides both aesthetic and water quality value. These features, or Best Management Practices, are techniques that will help prevent polluted stormwater from entering waterbodies. The simple conversion of a standard detention area to an enhanced detention can reduce suspended solids, allow certain pollutants to filter out, and create an attractive amenity for neighborhoods and communities.

As small towns grow and move forward, the inclusion of these Best Management Practices in new developments can improve the lives of thousands of Texans by protecting water quality and creating more attractive, vibrant communities.

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Photot courtesy of Laguna Atascosa National Wildlife Refuge | Texas © Lynn McBride/Nature Conservancy

Appendix A

MAPS

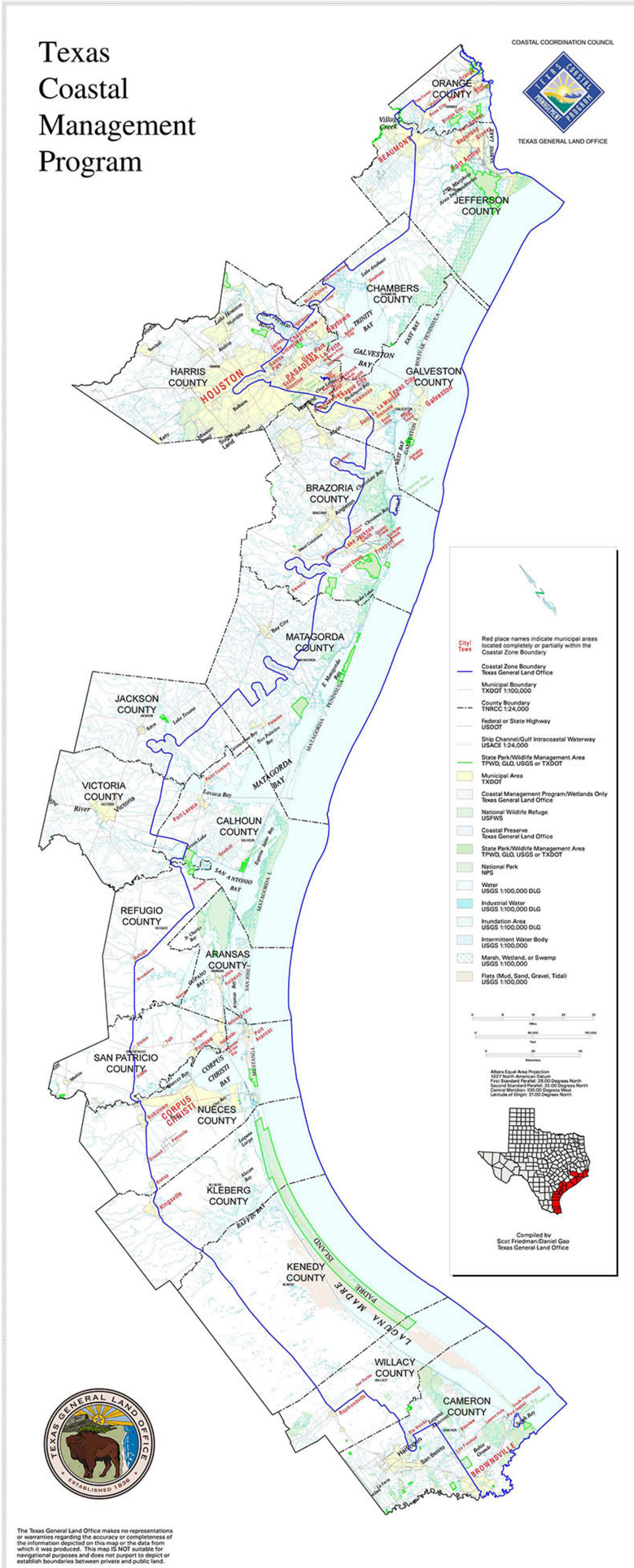
» *Map 1: Texas Coastal Program Boundary*

» *Map 2: Growth Rates of Non-MS4 Cities in the Coastal Zone Management Boundary*

» *Map 3: Natural Areas within the Coastal Zone Management Boundary*

» *Map 4: Ecoregions within the Coastal Zone Management Boundary*

» *Map 5: Landcover Type within the Coastal Zone Management Boundary*



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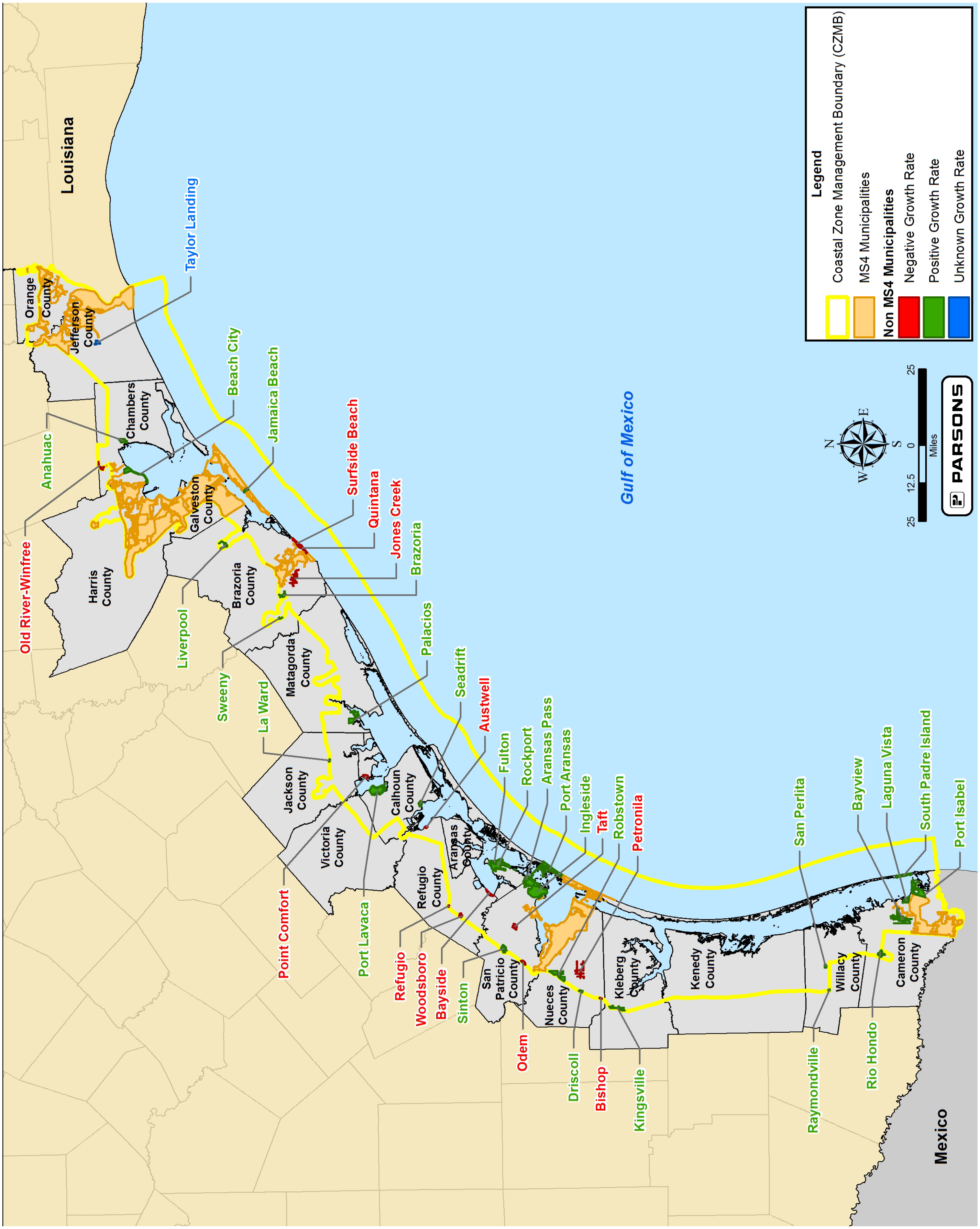

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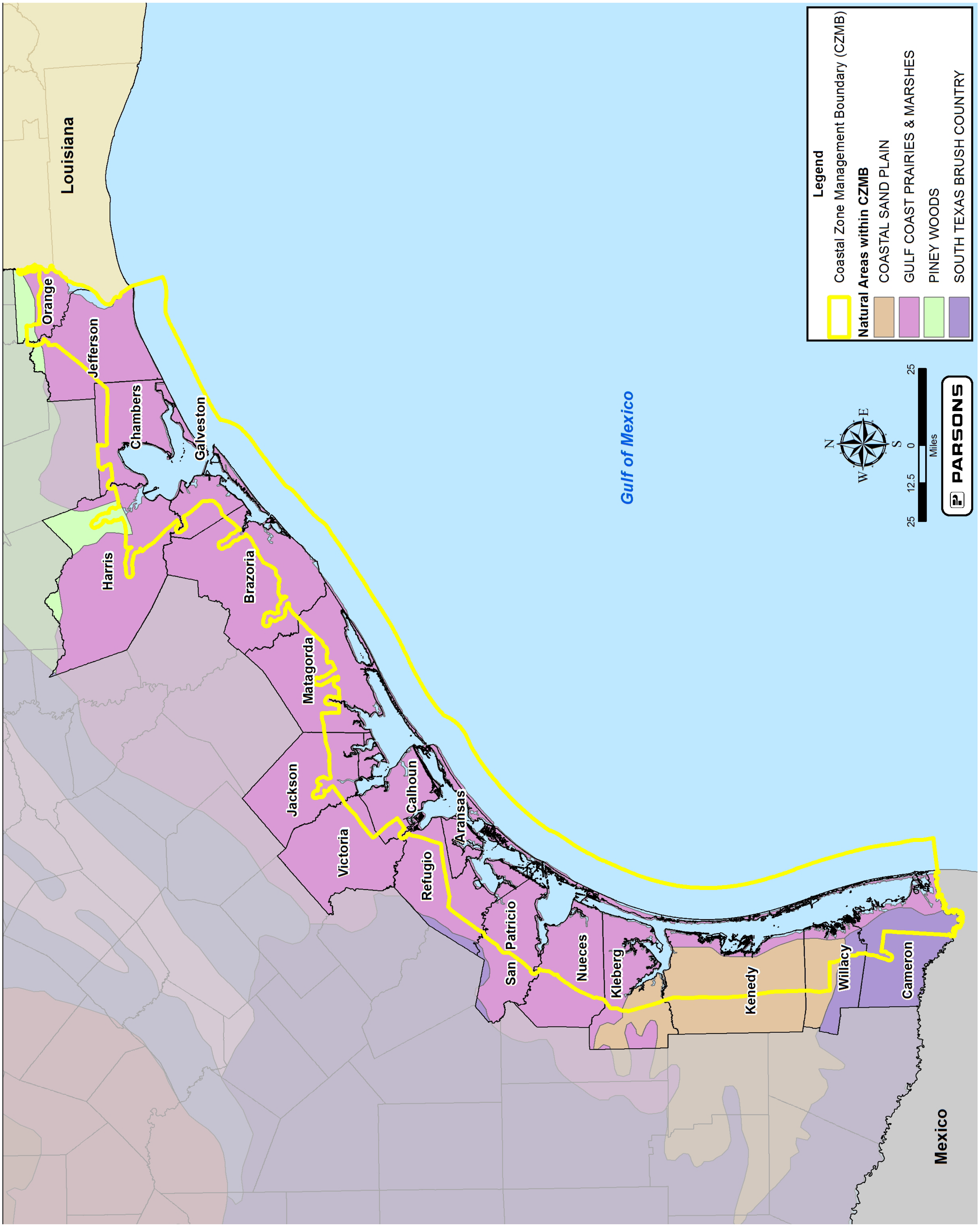
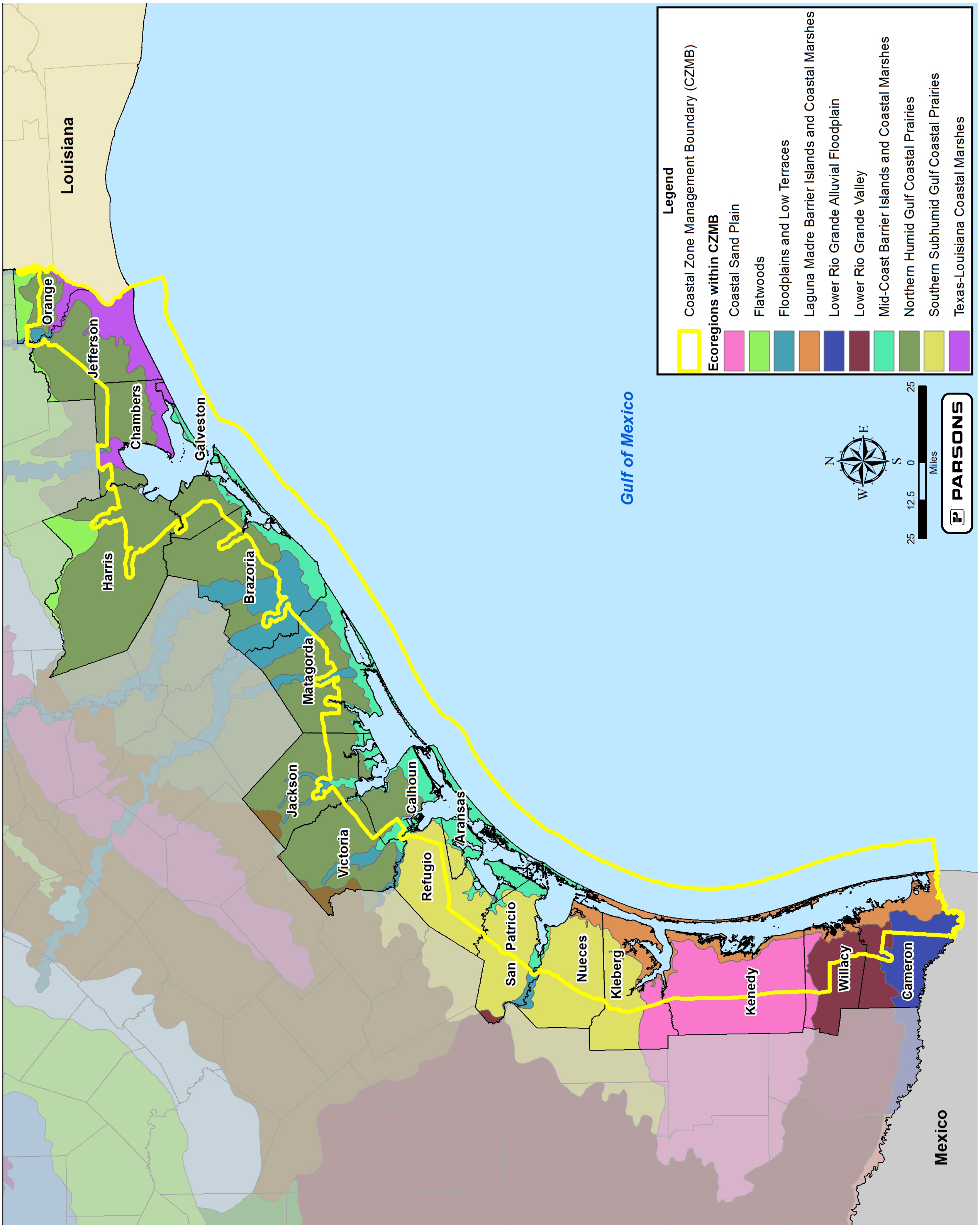
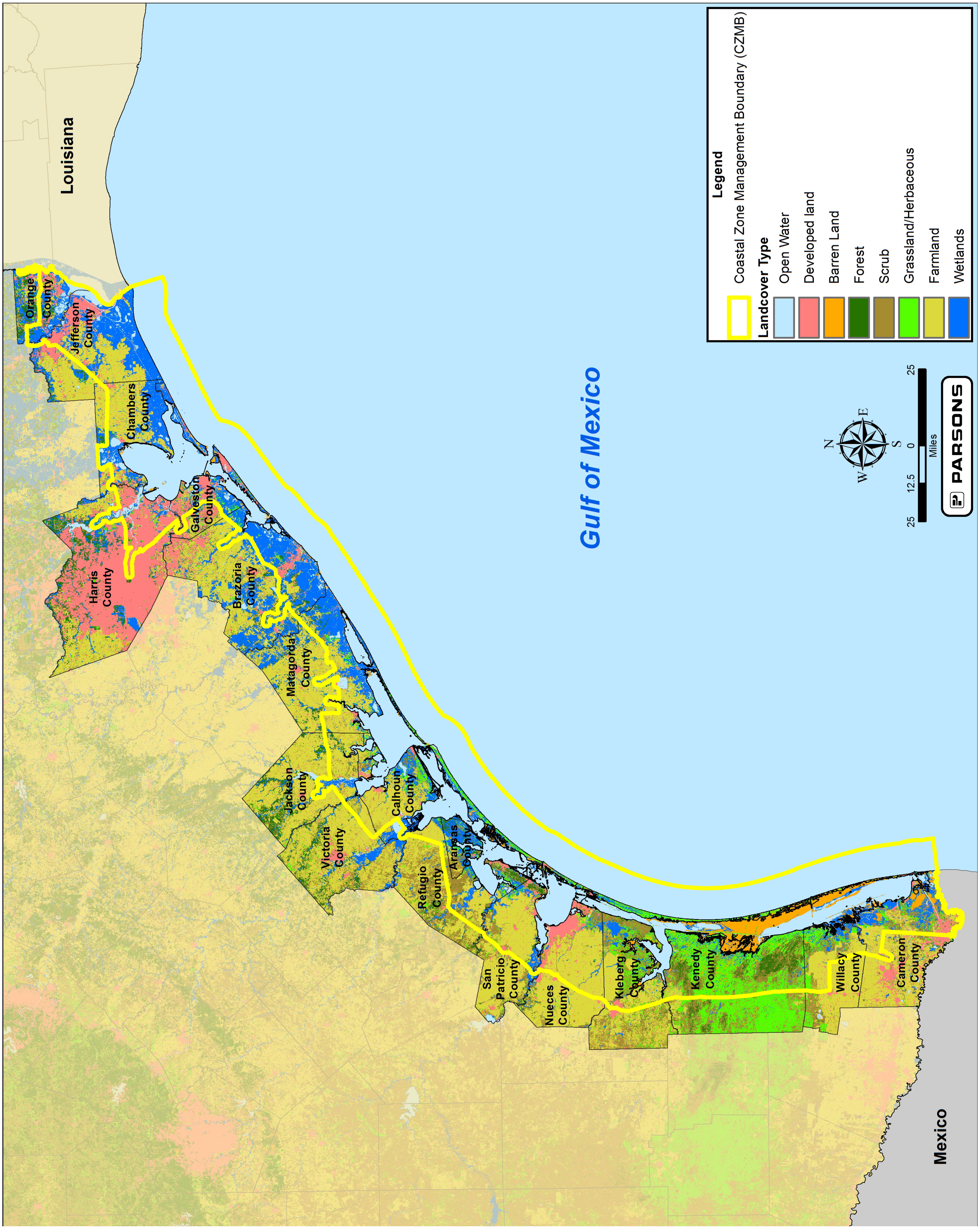


Map 3: Natural Areas within the Coastal Zone Management Boundary



Map 4: Ecoregions within the Coastal Zone Management Boundary



Map 5: Landcover Type within the Coastal Zone Management Boundary