GUIDANCE FOR SUSTAINABLE STORMWATER DRAINAGE ON THE TEXAS COAST

FOR NONPOINT SOURCE POLLUTION & FLOOD MANAGEMENT

3RD EDITION

TEXAS COASTAL MANAGEMENT PROGRAM

TEXAS GENERAL LAND OFFICE ESTABLISHED 1836

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INTRODUCTION

This guidance manual provides information that can be used by Texas coastal communities to improve stormwater management efforts. It provides decision makers with comprehensive guidance on conventional systems and an integrated green infrastructure-based approach to natural resource protection. Through implementation of these practices, communities can preserve the unique coastal resources from the negative impacts sometimes associated with land development and the resulting NPS pollution.

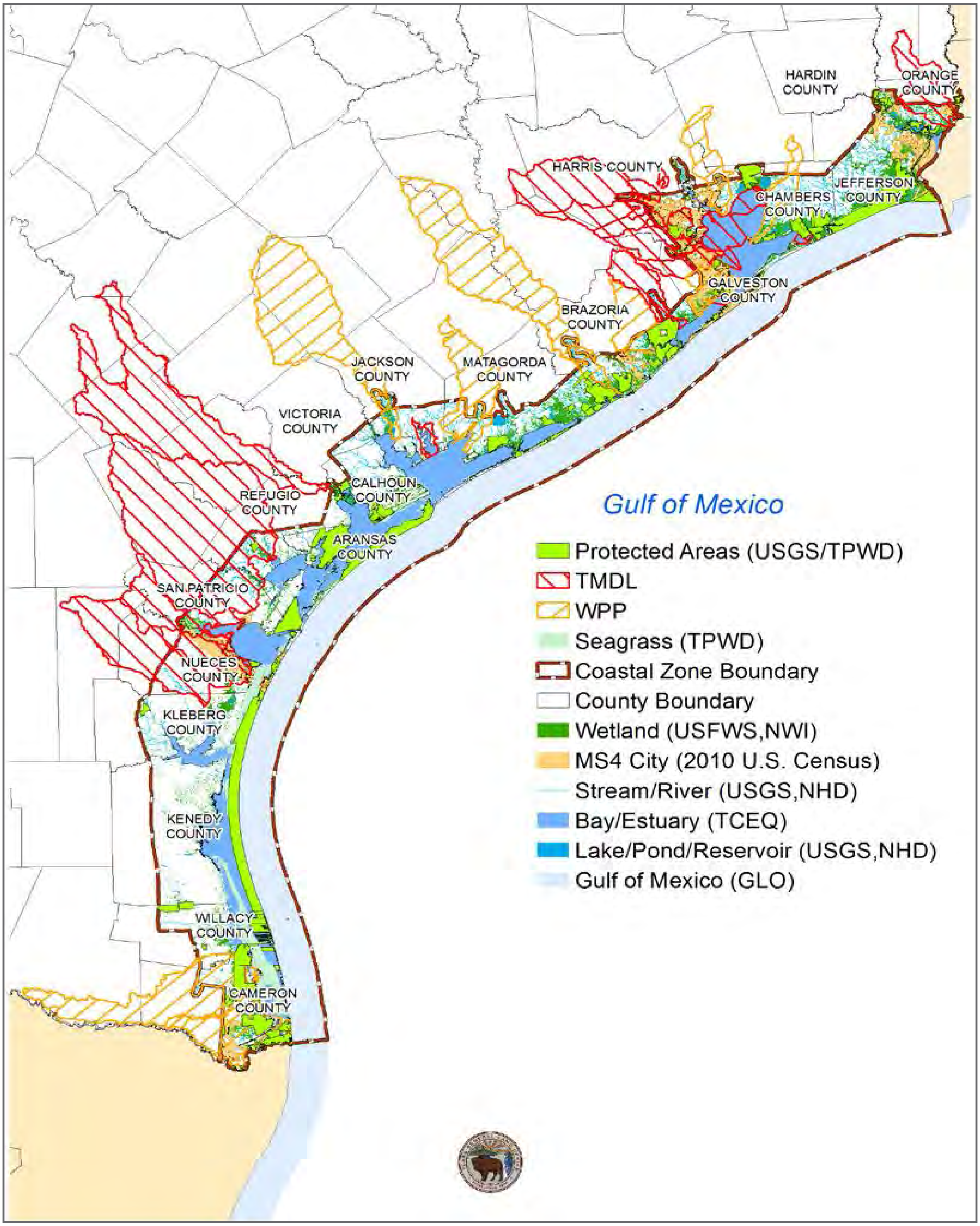
At the same time, recommended practices and design procedures will promote more resilient designs that can help manage long-term stormwater management costs and continue to promote tourism, recreation, and economic development.

PREFACE

The purpose of the guidance manual is to provide guidance to communities in the Texas Coastal Zone on the management of stormwater runoff from new development, existing development, and roads. Use of this guidance manual does not replace regulatory requirements. There are separate regulatory programs for MS4s and CWA Section 404. Federal, State, and local regulatory requirements would still apply.

Local communities can use sections of the guidance manual or use it as a wholesale approach. New development may include a variety of projects such as residential, commercial, and office projects. The guidelines described may also apply to redevelopment projects that add impervious cover.

Chapter	Title	Content	Management Measure
1	Introduction to Water Quality in the Texas Coastal Zone	Stormwater runoff basics that highlight the importance of sustainable drainage systems and minimizing hydromodification practices (channelization and filling of natural streams, shorelines, wetlands).	New Development Site Development
2	Guidance for Sustainable and Resilient Site Design	Site design for development including preservation of natural features, conservation design, and various practices.	New Development Site Development Watershed Protection
3	Erosion and Sediment Control Practices	Guidance on erosion and sediment controls during the construction phase.	Site Development Roads/Highways/ Bridges
4	Performance Standards and Design Approach	Performance criteria to manage stormwater runoff from development activity through the implementation of structural practices, low impact development, buffer zones.	New Development Site Development Watershed Protection
5	Structural Practices for Sustainable Drainage Design	Technical guidance for the design, construction, and maintenance of stormwater practices that are used to manage water quality and peak runoff rates.	New Development Site Development
6	Retrofitting Existing Development – Hydromodification Avoidance	Retrofit approach and implementation into a variety of development types. Techniques to manage erosion and implement natural channel design.	Existing Development New Development Site Development Watershed Protection
7	Floodplain Management	Guidance on the FEMA Flood Insurance Program, flood management planning and plan review guide.	New Development Existing Development


HARDIN COUNTY
ORANGE COUNTY
HARRIS COUNTY
JEFFERSON COUNTY
CHAMBERS COUNTY
GALVESTON COUNTY
BRAZORIA COUNTY
JACKSON COUNTY
MATAGORDA COUNTY
VICTORIA COUNTY
CALHOUN COUNTY
REFUGIO COUNTY
ARANSAS COUNTY
SAN PATRICIO COUNTY
NUECES COUNTY
KLEBERG COUNTY
KENEDY COUNTY
WILLACY COUNTY
CAMERON COUNTY
Gulf of Mexico
Protected Areas (USGS/TPWD)
TMDL
WPP
Seagrass (TPWD)
Coastal Zone Boundary
County Boundary
Wetland (USFWS,NWI)
MS4 City (2010 U.S. Census)
Stream/River (USGS,NHD)
Bay/Estuary (TCEQ)
Lake/Pond/Reservoir (USGS,NHD)
Gulf of Mexico (GLO)

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DEFINITIONS

Bioretention: Stormwater quality management facility that retains runoff in a shallow basin, usually less than 18 inches in depth and provides infiltration of runoff through designed soil media to filter pollutants. Bioretention basins can be landscaped to be an attractive site amenity. Rain gardens are a form of bioretention.

Depression storage: Natural features found in the landscape in the Texas coastal region that retains runoff, effectively storing stormwater and promoting infiltration.

Disconnection: Refers to vegetation, soil, and landscape areas that can disconnect impervious cover surfaces from one another. An example is the flow length across a single-family lawn that "disconnects" the downspout runoff from the street. Thus, runoff is slowed, spread out, and soaked into the ground to reduce runoff volume.

Extended detention: A stormwater management facility that can provide water quality and flood reduction benefits. The basin outlet is sized to release the design storm volume over a period of 24 to 72 hours, thus, promoting pollutant settling and slow runoff release to protect the receiving waterbody from scour and accelerated erosion as a result of development.

Hydromodification: The channelization or channel modification of existing drainage ways, creeks, and streams that negatively impact water quality and habitat. Includes dams and shoreline projects that adversely affect hydrology, natural flow patterns, and aquatic systems. The primary reasons for such alterations are agricultural activities and suburban and urban development. Examples of hydromodification include:

- Widening, deepening of channel (channelization, dredging) to increase capacity
- Stream relocating – moving streams to the property edge to maximize developable area
- Enclosing natural streams in pipes and box culverts
- Filling headwater streams and wetlands
- Straightening, steepening the gradient to increase flow velocity
- Decreasing channel length by cutting off natural stream meanders
- Bank stabilization using structures and hard engineering to manage bank erosion
- Bridge and culvert construction that change the flow patterns, vegetation, and slope

Vegetated filter strips: Vegetated sections of land that are relatively flat with low slopes to accept runoff as overland sheet flow and promote filtering and infiltration to improve runoff quality and slow runoff from impervious areas. Vegetated filter strips are a good choice to disconnect impervious areas.

Vegetated swales: Stormwater quality management channels that convey runoff and remove pollutants by filtering and infiltration through the soil. Pollutant management is related to the slope, vegetation density, and slope; thus, an optimum swale would have a shallow slope, dense vegetation, and porous soils to maximize water quality treatment benefits.

Wetland basins: Constructed shallow basin that creates growing conditions suitable for wetland and marsh plants while provide runoff storage to provide water quality and flood reduction benefits. Constructed wetlands provide physical, chemical, and biological water quality treatment of stormwater runoff.

Wet ponds: Stormwater quality control facilities that maintain a permanent wet pool, usually at least four feet in depth 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.

Municipal Separate Storm Sewer System (MS4) Summary

Municipal Separate Storm Sewer System (MS4): A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains):

(a) Owned or operated by the U.S., a State, city, town, borough, county, parish, district, association, or other public body (created by or pursuant to State law) having jurisdiction over the disposal of sewage, industrial wastes, stormwater, or other wastes, including special districts under State law such as a sewer district, flood control district or drainage district, or similar entity, or an Indian tribe or an authorized Indian tribal organization, or a designated and approved management agency under the CWA §208 that discharges to surface water in the State;

(b) That is designed or used for collecting or conveying stormwater;

(c) That is not a combined sewer; and

(d) That is not part of a publicly owned treatment works (POTW) as defined in 40 CFR §122.2.

Non-traditional Small MS4: A small MS4 that often cannot pass ordinances and may not have the enforcement authority like a traditional small MS4 would have to enforce the stormwater management program. Examples of non-traditional small MS4s include counties, transportation authorities (including the Texas Department of Transportation), municipal utility districts, drainage districts, military bases, prisons and universities.

Outfall: A point source at the point where a small MS4 discharges to waters of the U.S. and does not include open conveyances connecting two municipal separate storm sewers, or pipes, tunnels, or other conveyances that connect segments of the same stream or other waters of the U.S. and are used to convey waters of the U.S. For the purpose of this permit, sheet flow leaving a linear transportation system without channelization is not considered an outfall. Point sources such as curb cuts; traffic or right-or-way barriers with drainage slots that drain into open culverts, open swales or an adjacent property, or otherwise not actually discharging into waters of the U.S. are not considered an outfall.

Point Source: (from 40 CFR § 122.22) any discernible, confined, and discrete conveyance, including but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, landfill leachate collection system, vessel or other floating craft from which pollutants are or may be discharged. This term does not include return flows from irrigated agriculture or agricultural stormwater runoff.

Small Municipal Separate Storm Sewer System (MS4): A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, manmade channels, or storm drains):

(a) Owned or operated by the U.S., a State, city, town, borough, county, district, association, or other public body (created by or pursuant to State law) having jurisdiction over disposal of sewage, industrial wastes, stormwater, or other wastes, including special districts under State law such as a sewer district, flood control district or drainage district, or similar entity, or an Indian tribe or an authorized Indian tribal organization, or a designated and approved management agency under CWA § 208;

(b) Designed or used for collecting or conveying stormwater;

(c) Which is not a combined sewer;

(d) Which is not part of a publicly owned treatment works (POTW) as defined in 40 CFR § 122.2; and

(e) Which was not previously regulated under a National Pollutant Discharge Elimination System (NPDES) or a Texas Pollutant Discharge Elimination System (TPDES) individual permit as a medium or large municipal separate storm sewer system, as defined in 40 CFR §§122.26(b)(4) and (b)(7).

This term includes systems similar to separate storm sewer systems at military bases, large hospitals or prison complexes, and highways and other thoroughfares. This term does not include separate storm sewers in very discrete areas, such as individual buildings. For the purpose of this permit, a very discrete system also includes storm drains associated with certain municipal offices and education facilities serving a nonresidential population, where those storm drains do not function as a system, and where the buildings are not physically interconnected to a small MS4 that is also operated by that public entity.

Traditional Small MS4: A small MS4 that can pass ordinances and have the enforcement authority to enforce the stormwater management program. An example of traditional MS4s includes cities.

Urbanized Area (UA): An area of high population density that may include multiple small MS4s as defined and used by the U.S. Census Bureau in the 2000 and the 2010 Decennial Census.

CHAPTER 1

Introduction to Water Quality and Resiliency in the Texas Coastal Zone

- √ Stormwater Runoff Basics
- √ Importance and Status of Surface Water Quality in the Coastal Zone
- √ Sustainable and Resilient Site Design
- √ 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 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, fish and wildlife populations, and public safety are direct threats to the Gulf Coast economy.

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 be absorbed. 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, arroyos, and bays, it picks up pollutants along the way. These pollutants can include bacteria, oil, grease, metals, organic material, or litter and all eventually end up in the receiving water body.

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. When development occurs in previously undeveloped areas, the resulting alterations to the land can dramatically change the conveyance and storage of stormwater runoff and can generate downstream flooding. 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 rainwater 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 following guidance outlined in this document, it is possible to both reduce the amount of stormwater exiting a site and improve its quality.

Sustainable and resilient development strategies are designed to reduce the impact of development on the environment, are compatible with the coastal landscape, 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 and resiliency. 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 2.

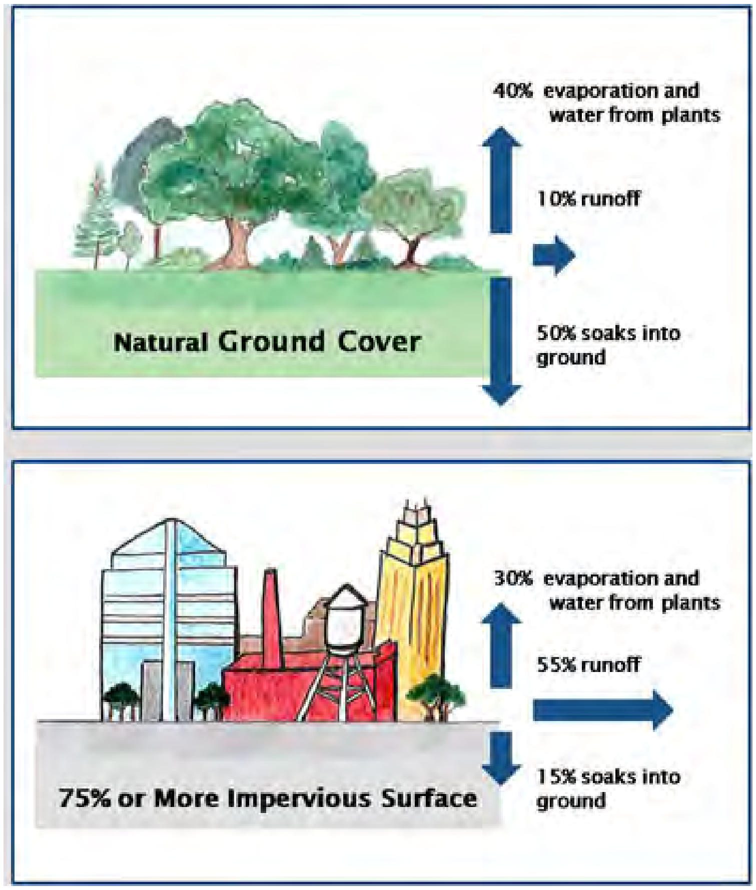


Figure 1-1: Influence of impervious cover on infiltration. (Graphic courtesy of City of Durham, North Carolina)

1.2 SURFACE WATER QUALITY IN THE COASTAL ZONE

Water quality in the State's 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, rivers, groundwater, and stormwater runoff.

Water quality throughout the Texas coastal zone management boundary (CZMB) varies widely from pristine, high quality waters to those that do not 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 (NPS) originate from diffuse sources primarily associated with stormwater runoff. Protecting water quality will require ongoing commitments from developers, businesses, homeowners, landowners, drainage districts, as well as municipal, county, and regional governments. NPS 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 streams 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 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.

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 provides information about management activities, such as total maximum daily load (TMDL), on that waterbody to address an impairment and lists the pollutant(s) 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). Best management practices are further described in Chapter 4.

Figure 1-2: Texas coastal wetlands. (Photo courtesy of TPWD)

1.3 STORMWATER CONTROLS AND TREATMENT FUNCTIONS

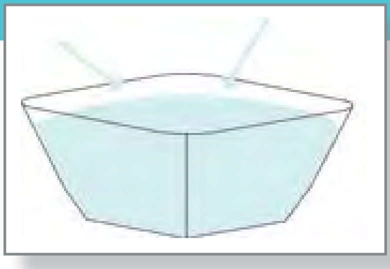
The following sections use several of the terms below as they define the practice and approaches to sustainable stormwater management strategies in more detail.

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.

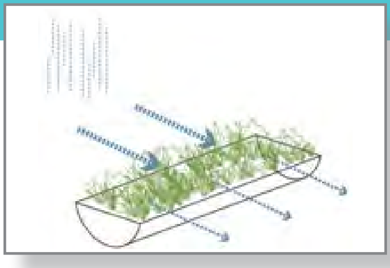
RETENTION

The storage of stormwater runoff on site and not released at a later time.



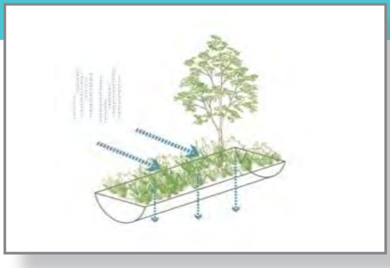
FILTRATION

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. In systems without an under drain or liner, infiltration recharges groundwater.



EVAPOTRANSPIRATION

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

1.4 BENEFITS OF SUSTAINABLE AND RESILIENT 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 AND HYDROMODIFICATION AVOIDANCE

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.

GROUNDWATER 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 groundwater 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.

HYDROMODIFICATION AVOIDANCE

Sustainable development practices such as stream and shoreline buffer zones that significantly limit disturbance of natural streams and wetlands protect water quality, slow and absorb flood flows, reduce stream velocities, and protect wildlife and aquatic habitats. Sustainable planning that encourages the design of development and roads beyond the floodplain and/or with limited stream crossings also preserves natural water body function and allows natural process to manage water quality and floods. At the same time, this preservation of natural resources to manage stormwater can reduce development costs and help mitigate long-term maintenance costs since infrastructure and other constructed measures are located outside of “harms way”.

1.4.2 LAND VALUE AND PUBLIC SAFETY 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. When used correctly, sustainable development techniques can enhance the quality of life within a community in many ways, from providing multiple amenities to creating improved landscapes with a strong 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, long-term operation and maintenance costs of stormwater infrastructure. 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 then be used as park space or wildlife habitat (Trust for Public Land 2007).

LOT YIELD

Strategies designed to manage runoff on-site or as close as possible to its point of generation can reduce the need for large detention areas and easements for stormwater conveyance 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. The BMPs listed in Chapter 4 illustrate the various measures that can be used to reduce the stormwater footprint as in the case of pervious pavement where runoff can be stored below the surface and negate the requirement for a stormwater basin.

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.

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 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 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—through environmental conservation and sustainable development actions—have a stimulating effect on economic output and employment. Restoration efforts offer localized benefits that can be attributed to the tendency for projects to employ local labor and materials. Restoration investments have economic and employment stimulus effects as a result of 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. While there is considerable variability, one 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.

Figure 1-3: Whooping cranes in Aransas County. (Photo courtesy of TPWD)

CHAPTER 2

Guidance for Sustainable and Resilient Development Design

- √ **Elements of Sustainable Site Design**
- √ **Preservation of Natural Features**
- √ **Resilient Design and Hazard Mitigation**
- √ **Conservation Design for Subdivisions**
- √ **Reduction and Disconnection of Impervious Cover**
- √ **Wetland and Stream Buffers**

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

2.1 INTRODUCTION TO SUSTAINABLE SITE DESIGN

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 simple, 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.

2.2 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.

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; and
- floodplains.

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 that are considered waters of the United States 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 to allow 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, restoring or enhancing existing wetlands, or purchasing credits from an approved wetland mitigation bank.

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 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.

CONSTRUCTION & MAINTENANCE CONSIDERATIONS

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.

2.2.1. BUFFER ZONES

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, act as a right-of-way during floods, and sustain the integrity of water resource ecosystems and habitats. Ideally, all buffers should remain in their natural state.

Buffer zones protect waterways, coastal marshes, and wetlands from the short- and long- term impacts of development activities. Buffer zones prevent conversion of sensitive lands to developed areas, which minimizes the potential for erosion and sediment loss into tidal waters. In addition, buffer zones preserve areas that provide important water quality benefits and maintain riparian and aquatic habitats.

TIDAL BUFFERS

Buffers serve as the protective zone between upland development and the salt marsh and open water beyond. Buffers reduce erosion and capture pollutants such as nitrogen, phosphorous, pesticides, fertilizers, and sediments before they reach the water or marsh. Buffers also serve as wildlife habitat corridors and increase the aesthetic appearance of the marsh. All of these functions ultimately help to protect the adjacent marsh from the effects of development.

FOREST BUFFERS

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.

CREEK AND RIVER BUFFERS

Natural buffer areas play an important role in maintaining pre-development water quality. Riparian vegetation stabilizes stream channels and floodplain areas, reducing the potential for creek erosion. Riparian buffers also provide filtration for overland flow from adjacent development projects. This filtering is beneficial during construction to retain sediment from up-gradient disturbed areas and also after construction to polish stormwater discharged from water quality measures. There are many benefits provided by buffer systems including:

- Minimizing activities that degrade, destroy, or negatively impact the value and function of coastal marshlands;
- Increasing pollutant removal including trapping sediment;
- Increasing distance of impervious areas from the drainage/creek/wetland/tidal waters;
- Moderating overland flow;
- Discouraging excessive storm drain systems;
- Increasing property values;
- May prevent severe rates of soil erosion;
- Minimizes disturbance to creek bank slopes;
- Improves water quality;
- Providing effective flood control;
- Helping protect nearby properties from the shifting and widening of the stream channel that occurs over time;
- Reducing small drainage problems and complaints by residents that are likely to experience backyard flooding;
- Enhancing the marshlands' scenic value and recreational opportunities;
- Protecting the terrestrial coastal habitat for nesting and feeding wildlife;
- Protecting important nursery areas for fisheries, which provide food and habitat to numerous species of fish, shellfish, including commercially important species; and
- Serving as the foundation for present or future greenways.

The purpose of the riparian buffer is to adequately protect waterways and aquatic resources from the short- and long-term impacts of development activities by providing a contiguous protection zone along the riparian corridor that is associated with natural drainage features. In many creeks, streams, and rivers, the floodplain is an integral part of the stream-riparian ecosystem. Due to natural topography and geomorphology, some streams are constrained to narrow valleys or ravines.

Many scientists and engineers have evaluated the effectiveness of riparian buffers and have found that riparian buffers can be an effective tool to reduce overland flow to streams, wetlands, and coastal marshes. Riparian buffer effectiveness has also been shown to be dependent on the condition of the watershed and should be used in concert with upslope watershed management.

LAND OR DEVELOPMENT RIGHTS ACQUISITION TO PROTECT SENSITIVE AREAS

An effective way to protect environmental integrity of an area is to preserve the land. The following practices can be used to protect beneficial uses:

- Fee Simple Acquisition/Conservation Easements
- Transfer of Development Rights
- Purchase of Development Rights
- Land Trusts
- Agricultural and Forest Districts

2.2.2. DEPRESSION STORAGE PRESERVATION

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, areas draining to depression generate no runoff until the storage has been filled, thus, making 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 minor depressions in the landscape should be treated as sensitive resource areas and should be protected from construction activities.

Due to the important role depressions play within drainage, water quality, and ecological components of the natural stormwater system, all attempts shall be made to incorporate depressions within localized stormwater management plans.

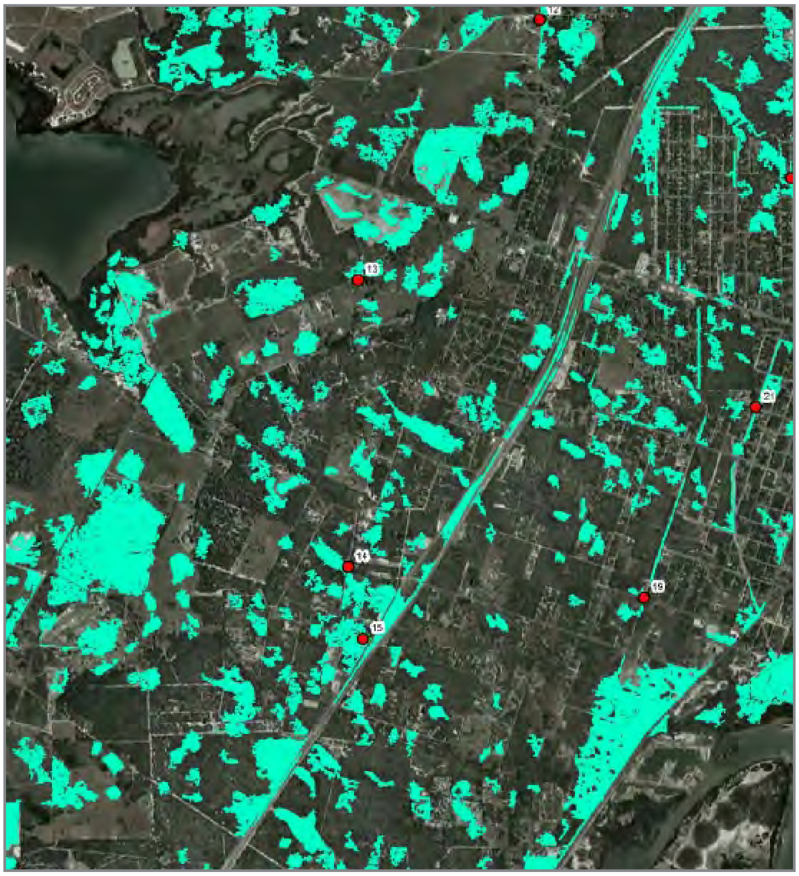


Figure 2-1: Depression storage in Aransas County, Texas (Larger than 1 acre in size and deeper than 2 feet).

2.3 RESILIENT DESIGN AND HAZARD MITIGATION

The Texas General Land Office (GLO) is leading the development and implementation of the Coastal Resiliency Master Plan (Plan) to protect communities and natural resources along the Texas Coast. The Plan will provide a framework for community, socio-economic, ecologic and infrastructure protection from coastal hazards, including short-term direct impact (e.g., flooding, storm surge) and long-term gradual impacts (e.g., erosion, habitat loss). The GLO is committed to protecting coastal resources and infrastructure by reducing vulnerability and protecting assets and the environment.

The Plan also provides a list of projects and strategies to address those problems – ensuring that the Texas coast is more resilient for generations to come. The initial screening process resulted in approximately 500 projects, programs, and land acquisitions warranting further evaluation. The Plan will continuously evolve along with the concerns and needs of the coast and its residents to ensure that recurrent and up-to-date coastal management is provided to coastal communities.

Key project types pertinent to stormwater management include:

- Restoration of beaches and dunes
- Bay shoreline stabilization and estuarine wetland restoration
- Freshwater wetlands and coastal uplands conservation
- Delta and lagoon restoration
- Water quality and restoration projects

While the Plan primarily focuses on existing development, this guidance manual also lends insight into creating new developments and communities that are resilient, strong and flexible. This can be accomplished by designing lifeline systems of roads, utilities, stormwater management, and water supply facilities that can continue functioning in the face of rising water, high winds, and subsiding ground. New development should be guided away from known hazard areas such as high tides, hurricane surges, and flood waters. Additionally, natural environmental protective systems should be conserved to maintain valuable hazard mitigation functions. The resiliency of an area is important to consider during the planning process for both new and existing developments. It is critical for community planners and engineers to attempt to mitigate future unknown hazards early on in the design process. This way, when disasters strike destruction to both people and property can be minimized. This sort of comprehensive approach to stormwater planning can protect every level of the community – from infrastructure and businesses to the lives and homes of citizens – during floods.

Hazard mitigation activities include planning to identify hazards and vulnerability, implementing smart growth and hazard mitigation plans before disasters occur, avoiding disaster areas (floodplains), and directing new development away from hazardous locations. Hazard mitigation also seeks to control identified hazards, using structural approaches such as flood works, slope stabilization, and shoreline hardening to attempt to reduce risks from potentially dangerous natural systems and to limit unwise public expenditures. Education is key in promoting development in this direction.

This guidance manual includes stormwater practices and development approaches that will function better when struck by disasters and enhance public safety. The guidance manual encourages low impact approaches for projects to obtain permit compliance while protecting water quality, managing runoff, minimizing long-term maintenance, and promoting public safety. Several of these development approaches are listed below with design guidance found in Chapter 4. In other words, this guidance manual connects low impact development practices to resilient design.

2.4 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:

- Preserving undisturbed areas;
- Preserving stream buffers;
- Reducing clearing and grading;
- Locating projects in less sensitive areas;
- Reducing 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 above, 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 other professionals with site assessment experience. These professionals will be able to test infiltration rates, assess 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 http://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.

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

- 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;
- Place development above flood levels and potential stormwater hazard areas;
- Protect floodplains, tidal waters, and wetlands;
- 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 networks of protected meadows, fields and woodlands. They can help provide larger areas of contiguous habitat in order to protect farmland and other natural resources while still allowing 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 development sites 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. Furthermore, 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 estimate that residential properties in open space developments garner premiums that are higher than conventional subdivisions and moreover, sell or lease at increased rates (Crompton 2007).

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, these conservation areas are protected by legally enforceable deed restrictions, conservation easements, and maintenance agreements.

Preservation of natural areas and the use of conservation designs can help preserve pre-development hydrology of sites 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.

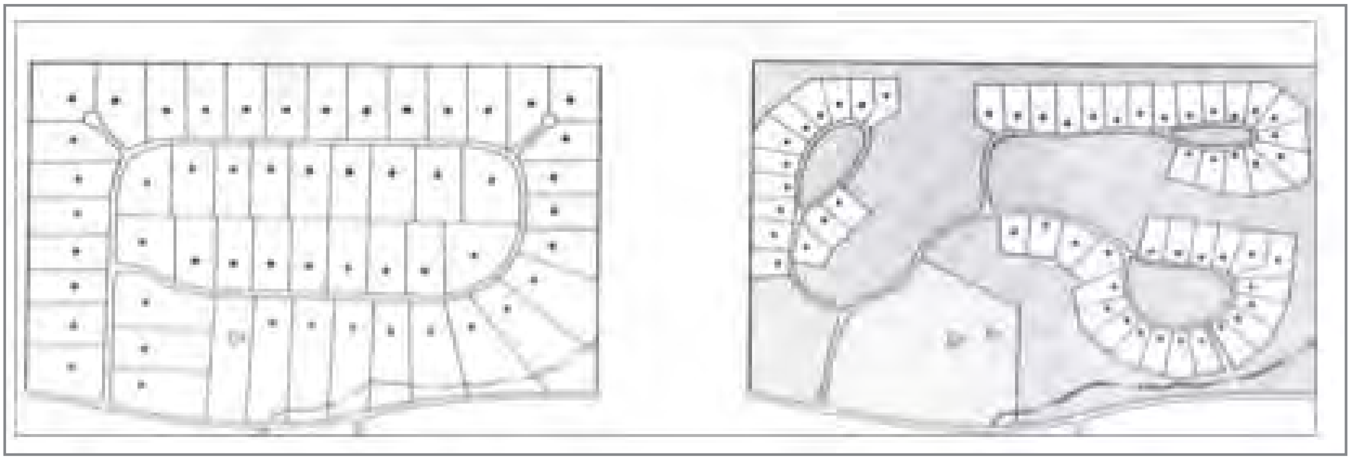


Figure 2-2: Conventional design (left) and conservation design (right). (Photo courtesy of Town of Pine Plains, NY)

2.5 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 reduces the volume of stormwater runoff, increases groundwater recharge, and reduces pollutant loadings generated from a site.

Another non-structural sustainable development tool is disconnection of hard surfaces. 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.

2.5.1. STREETS

The first step in achieving a reduction in impervious cover for streets is 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, including:

- 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);
- Emphasizing grid patterns for roadways;
- Eliminating dead ends and cul-de-sacs; and
- Designing/building 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;

- Incorporating 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.

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.

2.5.1. 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:

- Placing sidewalks on only one side of the street;
- Placing 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;
- Grading sidewalks to drain to vegetated areas between the sidewalk and the street, rather than directly to the street;
- Using alternative surfaces for sidewalks and walkways, such as pervious pavements, to reduce total impervious cover; and
- Reducing 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.

Figure 2-3: Example of Residential narrow street and disconnected impervious cover. (Picture courtesy of Google Earth)

2.5.3. 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:

- Share driveways, which 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. This allows the first portion of the driveway to be a single lane, while the second portion expands to the full width of the garage;
- Alternative design such as double-tracks; and
- 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.

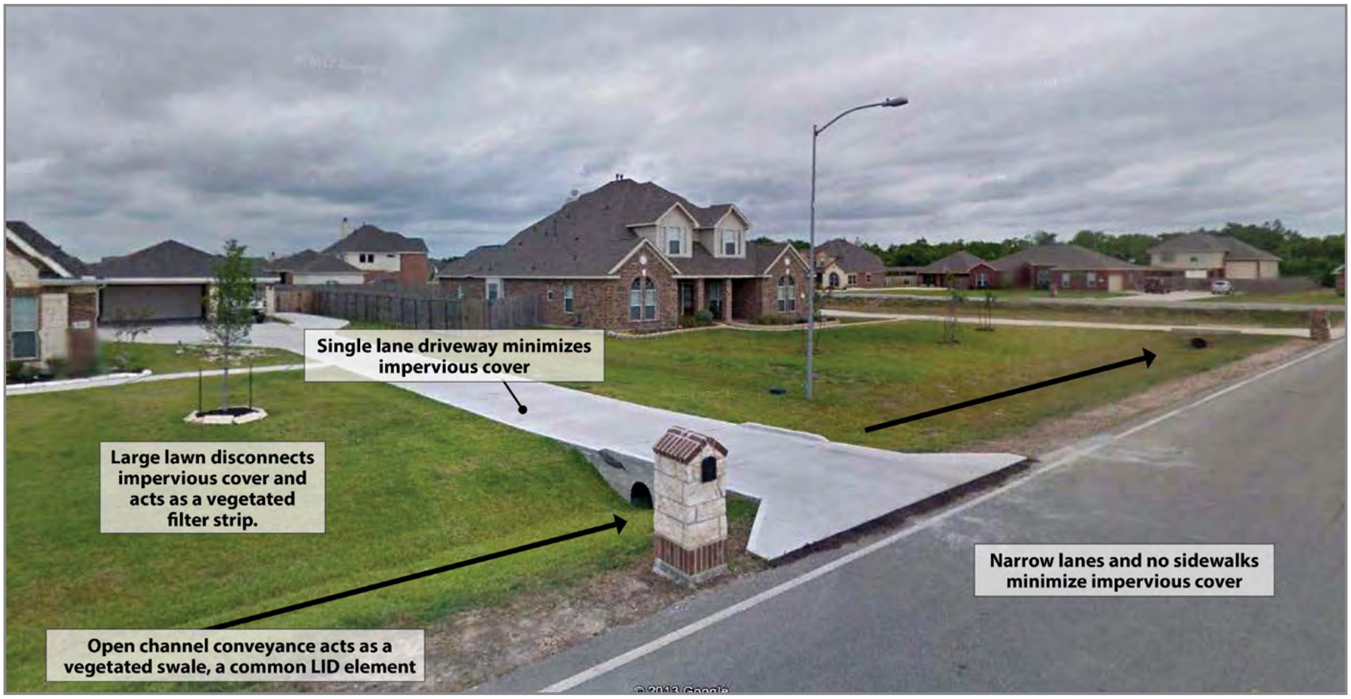


Figure 2-4: Sustainable design in medium density residential development. (Chambers County, Texas)

2.5.4. 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 excessive 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 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);
- Incorporating 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.

2.6 DISCONNECTION OF IMPERVIOUS COVER

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, 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.

2.6.1. DOWNSPOUT DISCONNECTION

Rooftops with exterior drains for the gutter (the normal configuration for most residential structures) are 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 2-5). While uncommon, driveways can be crowned so that a portion of the runoff is directed to vegetated areas rather than the street.

In addition to directing downspouts to vegetated areas, roof runoff may also be directed to cisterns and other rain barrels, or even to depressed storage or other underground storage areas for later consumption. Design details for impervious cover disconnection are found in Chapters 4 and 5 to add in preparing a low impact development plan.

Figure 2-5: Downspouts directed to permeable pavement on driveway. (Photo courtesy of Montgomery County, Maryland)

2.6.2. DISCONNECTING URBAN AREAS

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 reduces 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 3

Erosion and Sediment Control Practices

3.1 CONSTRUCTION PHASE EROSION AND SEDIMENT CONTROL PLANNING

The development of and adherence to a TCEQ Stormwater Pollution Prevention Plan (SWPPP) per the TXR150000 General Permit is an important first step in meeting the State requirements for erosion and sediment control. A SWPPP is required by the State when site disturbance exceeds one acre and notification to the TCEQ is necessary when the disturbance exceeds five acres.

There are three permit categories:

- **Construction Activities that Disturb Less than One Acre:** Not part of a larger common plan of development that would disturb less than 1 acre are not required to obtain coverage under the general permit.
- **Small Construction Activities:** Disturb at least 1 but less than 5 acres and is not part of a larger common plan of development
- **Large Construction Activities:** Disturb 5 or more acres or are part of a larger common plan of development that will disturb 5 or more acres

The most effective erosion control is the minimization of disturbed area. When this practice is combined with rapid re-vegetation of disturbed areas, receiving water bodies can be protected from sedimentation. Final stabilization of soil disturbing activities is considered complete when perennial vegetative cover reaches 70% density of the native background vegetative cover for the area. Permanent best management practices (BMPs) must achieve a density of 80% vegetative cover to be considered complete.

HOW TO CREATE AN EFFECTIVE EROSION AND SEDIMENT CONTROL PLAN

The following outlines the necessary steps for creating an effective erosion and sediment control plan. Details for individual erosion and sediment control BMPs can be found in this Chapter.

1. **Assess the drainage characteristics and construction phasing of a site. This process should identify:**
   - Patterns of stormwater flowing over the site including off-site sources, sub-drainage areas, sheet-flow areas, concentrated flow areas and exit points;
   - Location of proposed cuts and fills, grading, curbing, buildings, and impacts on drainage/sequence of construction relating to initial, interim and final drainage;
   - Necessary access points;
   - Limits of construction and non-disturbance area;
   - Construction equipment storage areas.

2. **Determine the location of the temporary erosion controls by:**
   - Locating controls as close to disturbed areas as possible allowing room for construction activities and maintenance of controls;
   - Assuring there are no breaks or points where runoff can bypass or short-circuit the temporary erosion controls;
   - Locating controls so as not to create off-site flooding of adjacent properties.

3. **Based on steps 1 and 2, the category or function of controls and their phasing should be determined to reflect construction sequence and changing drainage patterns.**

4. **The designer must now determine specific controls to be shown at the locations chosen in step 3.**

5. **Perform an adequacy check to determine compliance with the following items:**
   - Controls used are within the allowable drainage area limits;
   - Controls are located perpendicular to the runoff flow;
   - Detention controls are shaped to create adequate areas for ponding and sediment accumulation;
   - Detention/filtration controls are installed along contours to promote spreading of runoff;
   - Controls located in low traffic areas are easily accessible for maintenance;
   - Controls phased as necessary to reflect changes in drainage patterns to remain effective throughout the construction period;
   - Controls are located in areas that will not cause flooding of adjacent properties.

In order to recognize sites that have more erosion potential than others, the designer will rank the erosion potential based on the site characteristics in Table 3-1.

EROSION POTENTIAL – RANKING CATEGORIES

- **High Erosion Potential:** Key factors that impact erosion potential are steep slopes, soils conducive to erosion, construction disturbance covering a large area extending over a significant duration, and roadways planned to cross creeks.

- **Low Erosion Potential:** Minimal disturbance area, short construction period, relatively flat slopes, and non-erosion prone soils are common traits of sites that have a low potential for erosion problems.

If a development project is within different drainage areas or has more than one discharge point, then the above rating is applied to each drainage area/discharge point.

A project has a High Erosion Potential if four or more items are checked in Table 3-1.

Table 3-1: Site Characteristics for High Erosion Potential Checklist

____ Disturbed area > Five (5) acres
____ More than 25% of development area has slopes > 2 %
____ Soils – silts/clays from SCS Soil Surveys and field observation
____ Existing vegetative cover < 50 % coverage (groundcover)
____ Off-site drainage area > Five (5) acres (discharges to site)
____ Construction duration > Six (6) months
____ Utility and road crossing(s) of drainage ways/buffer zones
____ Distance of soil disturbance from creek centerline or tidal water is less than 100 feet

Sites that rank as having a high potential for erosion will require special attention in the design, implementation, and maintenance of construction activities and temporary erosion and sediment controls.

To aid in the proper selection of erosion control and stabilization techniques, Table 3-2 presents typical erosion site characteristics and the accompanying BMPs.

Table 3-2: Erosion Control Selection Guidance - Suggested Techniques to Minimize Soil Erosion

Site Characteristics	Management Approach	BMP Tools	Comments
Disturbed Area > 5 acres	Limit disturbance, control access to non-construction areas and buffers	Silt fence Rock berms Brush berms	Identify disturbed and protected areas on the construction plans
Slopes > 2%	Limit construction on steep slopes, stabilize immediately	Silt Fencing Rock berms Compost/mulch/seed	Seed and vegetate as soon as possible, use soil protection blankets or compost-seed mixes
Soils – Clay/Silt	Minimize excavation, cover/vegetate immediately	Silt Fence Blankets & Matting Compost/mulch/seed/ Sod	Difficult to settle soil particles, minimize disturbed area
Vegetative Cover < 50%	Minimize disturbance in this area, enhance vegetation	Seed Sod Compost/mulch/seed	Promote rapid vegetation growth
Off-site Drainage Area > 5 acres	By-pass runoff around site, or convey in stable manner	Diversion Dikes Interceptor Dikes Pipe/slope/Drain	Maintain diversion BMPs during construction to prevent sedimentation of devices
Construction Duration > 6 months	Phase construction disturbance, stabilize disturbed areas	Vegetation Blankets & Matting	Develop construction disturbance and re-vegetation plan as part of construction sequence
Road Crossings of Drainage Ways	Minimize crossings, stabilize road cuts as soon as possible	Temporary Sediment Basins that intercept runoff before reaching the drainageway	Basin size – 8,000 cubic feet per disturbed acre drainage to basin
Distance < 100 feet from Drainage	Relocate disturbed areas beyond the buffer zone limits	Silt Fence Rock Berms Sediment Basins	Identify buffer zones, use temporary fencing around buffer zones, perform work and maintain stockpiles outside of .this zone

Temporary Erosion Controls should be considered the first line of defense for the prevention of water pollution during construction activities. It is much simpler to maintain soil cover than to attempt to trap sediment once it has been mobilized. In addition, effective erosion prevention can result in cost savings, since repair of erosion damage can be minimized.

Permanent Erosion Controls are used to reduce the potential of erosion after construction activities are complete to ensure proper stabilization of areas disturbed by construction.

Primary erosion control strategies are to divert runoff away from unstable areas or to provide a stable surface that will resist the effects of rain and runoff. The Principle measures for diverting runoff during construction include building perimeter swales, dikes, and slope drains. Existing trees and vegetation should be protected to help maintain a stable ground surface and prevent loss of valuable topsoil. Forms of temporary vegetation, such as blankets, matting, and mulches, can stabilize an area until vegetation is established.

Final stabilization is achieved when all soil disturbing activities at site have been completed and a uniform vegetation cover with a density of 70% of the native background vegetative cover for the area has been established.

Contractors are encouraged to install and maintain practices carefully and minor adjustments should be anticipated to assure proper performance. Intensive maintenance and extensive use of vegetation, mulch, and other ground covers may be required to achieve optimum performance. The erosion and sediment control practices should be specified in the Stormwater Pollution Prevention Plan and in the general construction contract so that any unexpected expenses can be approved before they are incurred. When these controls are removed after final stabilization of the site, it is important to also remove or stabilize any accumulated sediment.

Periodic inspection and maintenance is vital to the performance of erosion and sedimentation control measures. It is recommended that all temporary erosion controls be inspected weekly and after every rainfall; however, daily inspections may be warranted when environmentally sensitive features are located on or immediately adjacent to the site. If not properly maintained, some practices may cause more damage than they prevent.

Always evaluate the consequences of a measure failing when considering which control measure to use, since failure of a practice may be hazardous or damaging to both people and property. For example, a large sediment basin failure can have disastrous results; low points in dikes can cause major gullies to form on a fill slope. It is essential to inspect all practices to determine that they are working properly and to ensure that problems are corrected as soon as they develop. The project owner should assign an individual to be responsible for routine checks of erosion and sedimentation control practices.

3.2 TEMPORARY EROSION AND SEDIMENT CONTROL DETAILS

The Texas Department of Transportation (TXDOT) provides design and construction details for many practices to manage construction erosion and sedimentation. This website, dated September 18, 2018, can be referenced for plan details that designers and engineers can include in their construction plans. Details from the website are found below:

- Silt fence and vertical tracking
- Rock filter dams
- Construction exits
- Dikes and earthwork
- Swales and earthwork
- Sediment basins and traps
- Temporary pipe slope drains
- Temporary paved flumes
- Erosion control log

3.3 SPILL PREVENTION AND CONTROL

The objective of this section is to describe measures to prevent or reduce the discharge of pollutants to drainage systems or watercourses from leaks and spills by reducing the chance for spills, stopping the source of spills, containing and cleaning up spills, properly disposing of spill materials, and training employees.

The following steps will help reduce the stormwater impacts of leaks and spills:

EDUCATION

1. Be aware that different materials pollute in different amounts. Make sure that each employee knows what a "significant spill" is for each material they use, and what is the appropriate response for "significant" and "insignificant" spills. Employees should also be aware of when spills must be reported to the TCEQ. Information available in 30 TAC 327.4 and 40 CFR 302.4.
2. Educate employees and subcontractors on potential dangers to humans and the environment from spills and leaks.
3. Hold regular meetings to discuss and reinforce appropriate disposal procedures (these may be incorporated into regular safety meetings).
4. Establish a continuing education program to instruct new employees.
5. Have contractor's superintendent or representative oversee and enforce proper spill prevention and control measures.

GENERAL MEASURES

1. To the extent that the work can be accomplished safely, spills of oil, petroleum products, substances listed under 40 CFR parts 110,117, and 302, and sanitary and septic wastes should be contained and cleaned up immediately.
2. Store hazardous materials and wastes in covered containers and protect from vandalism.
3. Place a stockpile of spill cleanup materials where it will be readily accessible.
4. Train employees in spill prevention and cleanup.
5. Designate responsible individuals to oversee and enforce control measures.
6. Spills should be covered and protected from stormwater run-on during rainfall to the extent that it does not compromise clean-up activities.
7. Do not bury or wash spills with water.
8. Store and dispose of used clean up materials, contaminated materials, and recovered spill material that is no longer suitable for the intended purpose in conformance with the provisions in applicable BMPs.
9. Do not allow water used for cleaning and decontamination to enter storm drains or watercourses. Collect and dispose of contaminated water in accordance with applicable regulations.
10. Contain water overflow or minor water spillage and do not allow it to discharge into drainage facilities or watercourses.
11. Place Material Safety Data Sheets (MSDS), as well as proper storage, cleanup, and spill reporting instructions for hazardous materials stored or used on the project site in an open, conspicuous, and accessible location.
12. Keep waste storage areas clean, well-organized, and equipped with ample cleanup supplies as appropriate for the materials being stored. Perimeter controls, containment structures, covers, and liners should be repaired or replaced as needed to maintain proper function.

CLEANUP

1. Clean up leaks and spills immediately.
2. Use a rag for small spills on paved surfaces, a damp mop for general cleanup, and absorbent material for larger spills. If the spilled material is hazardous, then the used cleanup materials are also hazardous and must be disposed of as hazardous waste.
3. Never hose down or bury dry material spills. Clean up as much of the material as possible and dispose of properly. See the waste management BMPs in this section for specific information.

MINOR SPILLS

1. Minor spills typically involve small quantities of oil, gasoline, paint, etc. which can be controlled by the first responder at the discovery of the spill.
2. Use absorbent materials on small spills rather than hosing down or burying the spill.
3. Absorbent materials should be promptly removed and disposed of properly.
4. Follow the practice below for a minor spill:
   - Contain the spread of the spill.
   - Recover spilled materials.
   - Clean the contaminated area and properly dispose of contaminated materials.

SEMI-SIGNIFICANT SPILLS

Semi-significant spills can be controlled by the first responder along with the aid of other personnel such as laborers and the foreman, etc. This response may require the cessation of all other activities.

Spills should be cleaned up immediately:

1. Contain spread of the spill.
2. Notify the project foreman immediately.
3. If the spill occurs on paved or impermeable surfaces, clean up using "dry" methods (absorbent materials, cat litter and/or rags). Contain the spill by encircling with absorbent materials and do not let the spill spread widely.
4. If the spill occurs in dirt areas, immediately contain the spill by constructing an earthen dike. Dig up and properly dispose of contaminated soil.
5. If the spill occurs during rain, cover spill with tarps or other material to prevent contaminating runoff.

SIGNIFICANT/HAZARDOUS SPILLS

For significant or hazardous spills that are in reportable quantities:

1. Notify the TCEQ by telephone as soon as possible and within 24 hours. It is the contractor's responsibility to have all emergency phone numbers at the construction site.
2. For spills of federal reportable quantities, in conformance with the requirements in 40 CFR parts 110,119, and 302, the contractor should notify the National Response Center at (800) 424-8802.
3. Notification should first be made by telephone and followed up with a written report.
4. The services of a spill management contractor or a Haz-Mat team should be obtained immediately.

Construction personnel should not attempt to clean up until the appropriate and qualified staffs have arrived at the job site.

5. Other agencies which may need to be notified/consulted include, but are not limited to, the City Police Department, County Sheriff Office, Fire Departments, etc.

VEHICLE AND EQUIPMENT MAINTENANCE

1. If maintenance must occur onsite, use a designated area and a secondary containment, located away from drainage courses, to prevent the run-on of stormwater and the runoff of spills.
2. Regularly inspect onsite vehicles and equipment for leaks and repair immediately
3. Check incoming vehicles and equipment (including delivery trucks, as well as employee and subcontractor vehicles) for leaking oil and fluids. Do not allow leaking vehicles or equipment onsite.
4. Always use secondary containment, such as a drain pan or drop cloth, to catch spills or leaks when removing or changing fluids.
5. Place drip pans or absorbent materials under paving equipment when not in use.
6. Use absorbent materials on small spills rather than hosing down or burying the spill. Remove the absorbent materials promptly and dispose of properly.
7. Promptly transfer used fluids to the proper waste or recycling drums. Don’t leave full drip pans or other open containers lying around.
8. Oil filters disposed of in trashcans or dumpsters can leak oil and pollute stormwater. Place the oil filter in a funnel over a waste oil-recycling drum to drain excess oil before disposal. Oil filters can also be recycled. Ask the oil supplier or recycler about recycling oil filters.
9. Store cracked batteries in a non-leaking secondary container. Do this with all cracked batteries even if you think all the acid has drained out. If you drop a battery, treat it as if it is cracked. Put it into the containment area until you are sure it is not leaking.

VEHICLE AND EQUIPMENT FUELING

1. If fueling must occur on site, use designated areas, located away from drainage courses, to prevent the run-on of stormwater and the runoff of spills.
2. Discourage “topping off” of fuel tanks.
3. Always use secondary containment, such as a drain pan, when fueling to catch spills/ leaks.

3.4 CREEK CROSSINGS

Creek crossings represent particularly important areas to employ effective erosion and sedimentation control. Creek crossings may require compliance with Section 404 of the Clean Water Act. The designer should verify the need for compliance. Guidance on Nationwide Permits should be reviewed as well as facilitate appropriate design and compliance. Underground utility construction across creeks requires special measures, as detailed below.

1. Unless prior approval is received from the jurisdictional stormwater authority, utility line creek crossings should be made perpendicular to the creek flowline.
2. Every effort should be made to keep the zone of immediate construction free of surface water. For construction in the creek channel, a pipe of adequate size to divert normal stream flow should be provided around the construction area. Diversion may be by pumping or gravity flow using temporary dams.
3. Where water must be pumped from the construction zone, discharges should be in a manner that will not cause scouring or erosion. All discharges shall be on the upstream or upslope side of emplaced erosion control structures. If discharges are necessary in easily erodible areas, a stabilized, energy-dissipating discharge apron shall be constructed of riprap with minimum stone diameter of 6 inches and minimum depth of 12 inches. Size of the apron in linear dimensions shall be approximately 10 times the diameter of the discharge pipe.
4. Before any trenching, install two high service rock berms at 100-ft spacing across the channel (perpendicular to the flowline) downstream of the proposed trench. These berms should be located between 100 and 300 feet downstream of the proposed trench. Lay pipe or other utility line and bury as soon as possible after trenching.
5. After installation is complete (or at the end of work day, if installation cannot be completed by end of day), install silt fencing along trench line on either side of creek at 25-ft intervals, as shown in Figure 3-1.
6. Material excavated from the trench in the creek channel should not be deposited on the channel banks. Excavation should be hauled out of the channel or used in backfill of open trench. No loose excavated material should be left in the channel at the end of a work day
7. A concrete cap should be placed over any buried pipe within the creek, and streambed should be restored to proper grade.
8. Revegetate disturbed areas using appropriate native or adapted grass species applied either with hydromulch at twice the normal application rate or incorporated with erosion protection matting.

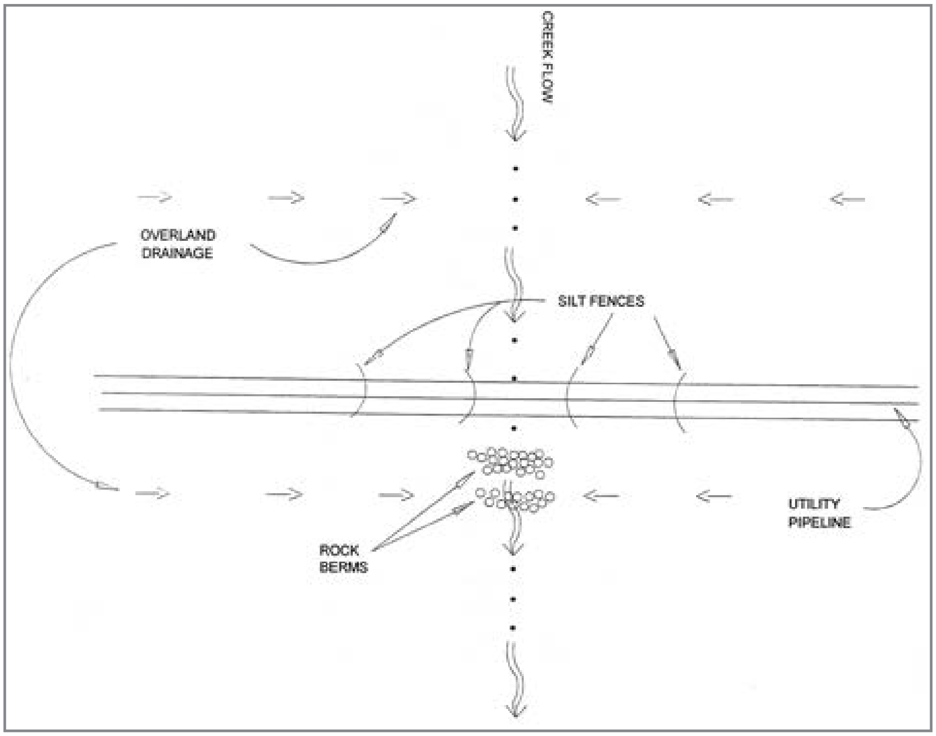


Figure 3-1: Utility Line Creek Crossing

CHAPTER 4

Recommended Performance Standards and Design Approach

This chapter describes recommended performance standards and design approaches to protect water quality through low impact development and conventional practices. These approaches can minimize project cost and long-term maintenance liability while also reducing water supply demand and promoting resilient practices.

4.1 PERFORMANCE STANDARDS

This guidance manual recommends the management of stormwater runoff from development activity through the implementation of performance standards identified in Table 4-1. This includes structural control measures and low-impact development design. The aim of these design standards and environmental incentives is to improve methods of stormwater management by relying less on individual BMPs and more on mimicking existing hydrology through total site design techniques. This approach can eliminate constructed stormwater control measures when impervious cover is limited or produce smaller facilities that are less costly.

Table 4-1: Performance Standards

Performance Standards	Purpose	Minimum Requirements
Pre-development Planning	Clarify stormwater requirements, encourage low impact development that costs less and facilitate permitting	Meeting with the jurisdictional stormwater authority staff and/or engineer
Water Quality and Drainage Management	Improve stormwater runoff water quality and manage runoff quantity. Eighty percent TSS management and peak rate management	Structural practice design, size, and define the low impact development design approach and compliance
Buffer Zones	Protect creeks, rivers, wetlands, and tidal waters from construction activities, manage flood risk	Delineate buffer widths on creeks, rivers, wetlands, and tidal waters
Construction – Phase Erosion and Sediment Control	Minimize construction sediment runoff, protect creeks, rivers, wetlands, and tidal waters	Construction phase erosion control plan per the TCEQ Construction Stormwater General Permit
Water Quality Education	Reduce the runoff of herbicides, pesticides, fertilizers, and trash to creeks, rivers, and tidal waters	Provide to residents and building/ site managers – GLO website
Maintenance of Structural Practices	Ensure long-term water quality and peak management performance, improve appearance and function	Prepare a maintenance plan and perform annual inspections and maintenance when necessary

These performance standards would apply to all new development and redevelopment projects per the criteria below:

Alternate BMP requirements employing low impervious cover levels with vegetative conveyance of stormwater runoff have been established. Compliance with the following specifications is assumed to meet the water quality management performance standards in this guidance manual. Development eligible for these Alternative Standards must meet the following design requirements:

- The gross development site impervious cover is 20% or less and the cluster development sections (individual drainage areas) have 25% or less gross impervious cover,
- Street and drainage network are designed to include the use of open-roadway sections, ribbon curb, and maintenance of sheet flow,
- Stormwater credits as defined in this guidance manual can be used to gain compliance with the impervious cover limits stated above.

- Commercial tracts with gross impervious cover less than 15% can obtain Alternate Standards compliance by providing vegetated filter strips per the guidance manual design criteria.

A cluster development section can be considered as an individual drainage area or discharge point containing development. The impervious cover is computed within this area and divided by the drainage area to determine the cluster development impervious cover percentage.

Development projects with less than 8,000 square feet of impervious cover and less than 1 acre of disturbance are exempt from providing permanent water quality measures. The landowner provides written notification to the regulating community and provides documentation that the planned activities meet these criteria.

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; and
- 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 4-2 should be used. The values in this table do not include the area of streets in the development.

Table 4-2: 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 acres	3,500

4.2 PRE-DEVELOPMENT PLANNING

Pre-development planning is an important first step in all projects.

A pre-development/concept plan meeting should occur for all single-family development projects greater than 20 acres in area and all commercial development greater than three (3) acres in area. The meeting should focus on land plan, slopes, floodplains, buffer zones, water quality management practices, and may include a site reconnaissance.

Sound land use planning is perhaps the most important step in managing construction and post development runoff problems. All new development plans (e.g., subdivisions, shopping centers, industrial parks, office centers, etc.) and redevelopment plans should be based upon accurate topographic data, up-to-date aerial photographs, field reconnaissance of the site, soils information, and knowledge of unique resources that serve amenities and add value to the project. Site planning may then proceed to minimize drainage impacts, avoid the concentration of flow to the maximum extent practical, and use natural topography and vegetation to manage stormwater runoff. Comprehensive site planning can reduce impervious cover and stormwater runoff volume, gain compliance with alternate standards, and avoid costly structural water quality basins.

Once a pre-development plan is prepared for the proposed development, the designer will need to coordinate with the local government to convene a pre-development planning meeting.

4.3 SUSTAINABLE DRAINAGE DESIGN

Sustainable drainage design is necessary for the protection of creek, river, and tidal waters in order to manage stormwater runoff rates and reduce channel erosion and flooding. This section presents the methodology to calculate the drainage design volume and low impact development options to satisfy performance standards. If a planned development cannot achieve compliance with the given low impact development standards, then the project shall provide the design volume in approved structural measures found in Chapter 5.

4.3.1 LOW IMPACT DEVELOPMENT

SINGLE-FAMILY DEVELOPMENT

Low impact development (LID) standards employing low impervious cover levels with vegetative conveyance of stormwater runoff allow developments to protect water quality while minimizing cost and long-term maintenance needs. Compliance with the following specifications is assumed to meet the 80% total suspended solids and peak flow rate management standards using a design storm rainfall depth of 1.5 inches. Development eligible for these low impact development standards must meet the following design requirements:

- The gross development site impervious cover is 20% or less and the cluster development sections (individual drainage areas) have 25% or less gross impervious cover;
- Street and drainage networks are designed to include the use of open-roadway sections, ribbon curb, and maintenance of sheet flow;
- Stormwater credits as defined in this guidance manual can be used to gain compliance with the impervious cover limits stated above; and
- Commercial tracts with gross impervious cover less than 20% can obtain compliance by providing vegetated filter strips per below and satisfying the above conditions.

A cluster development section can be considered as an individual drainage area or discharge point containing development. The impervious cover is computed within this area and divided by the drainage area to determine the cluster development impervious cover percentage.

COMMERCIAL DEVELOPMENT

For commercial projects less than three (3) acres in area, low impact development measures employing vegetated filter strips and grassy swales can be used to comply with performance standards. Commercial development eligible for these low impact development option must meet the following design requirements:

- Projects less than three (3) acres in area can achieve compliance with this section through the use of vegetated filter strips, vegetated swales, and flow spreading methodologies.
- The vegetated filter strip area is computed per the criteria found in this Chapter and designed and constructed per the guidance in Chapter 5.
- Vegetative filter strips must be located down-gradient of the developed areas.
- Runoff must discharge in a sheet flow manner from the impervious areas to the vegetated filter strips.

Projects gaining compliance with low impact development standards still must perform pre-development planning (if required), delineate buffers, prepare an erosion and sediment control plan, and incorporate water quality education materials.

4.3.2. STORMWATER CREDITS FOR LOW IMPACT DEVELOPMENT COMPLIANCE

The stormwater basin sizing criteria provides a strong incentive to reduce impervious cover at development sites, since significant reductions in impervious cover will result in smaller and less costly sustainable drainage measures.

The techniques presented below are considered options for use by designers to gain compliance with the low impact development approach or reduce the size of structural control measures. Due to local codes, soil conditions, and topography, some of these site design features may be restricted. In single-family subdivisions, stormwater credits will most likely be accrued on single-family lots. Since these activities will be constructed by homebuilders and not the developer, the stormwater credit will require easements, deed restrictions, or other articles approved by a regulating entity in the permitting process to ensure the proper installation, maintenance, and survivability. Additional details for each credit can be found in Chapter 5.

Table 4-3: Stormwater Credits for Low Impact Development

Stormwater Credits	Alternate Standard Application	Stormwater Volume Application	Comments
Porous Pavement or Pavers	Reduce paved area IC by 90%	Reduce paved area IC by %90	Product information shall support infiltration in excess of 10 inches per hour
Rainwater Harvesting (cisterns)	Reduce roof top IC up to 75%	Reduce roof top IC based on tank volume ratio to catchment area	Tank volume requirements related to catchment area
Soil Amendment	Reduce IC by 2%	Reduce drainage area IC by 2%	6-8” blended soil depth and appropriate turf
Conservation Landscaping	Reduce IC by 5%	Reduce drainage area IC by 5%	Limitations on turf area, use native plants/shrubs
Disconnection of Roof-Top Runoff	Deduction of rooftop IC based on flow length and rainwater storage	Deduction of rooftop IC based on flow length and rainwater storage	75’ flow length for full deduction with 90% grass
Natural Area Preservation	Include natural area in development cluster IC calculation	Natural area is subtracted from drainage basin area	Supports conservation development initiatives, yet connects to hydrology
Vegetated Filter Strips	Reduce IC by 50%	Reduce contributing drainage area IC by 50%	Natural filter strip minimum width of 25 feet or engineered filter strip minimum width of 15 feet and other criteria (slope, vegetation) are met
Vegetated Swale	Reduce IC by 20%	Reduce contributing drainage area IC by 20%	Vegetated channel with a slope of less than 0.5%, a minimum length of 50 feet and a maximum drainage area of 2 acres

IC = Impervious Cover
VFS = Vegetated Filter Strip

See next page for calculation procedures for each stormwater credit.

Porous pavement/pavers. Refers to porous asphalt, concrete, and paver surfaces through which stormwater runoff can infiltrate to the soil profile. Reduced impervious cover credit is computed per Equation 4.1.

Equation 4.1	**Ar = Ap * 0.90**
Where:	Ar = Allowable reduction in impervious cover
	Ap = Area of porous pavement or pavers

See Chapter 5 for details and specifications.

Rainwater Harvesting. Refers to the collection of stormwater runoff from roof-tops and its use for domestic or landscape purposes. Reduced impervious cover credit is computed per Equation 4.2. See Figure 4-1 below.

Equation 4.2	**Ar = ART * %IC REDUCTION FACTOR (Per Figure 4-1 below)**
Where:	Ar = Allowable reduction in impervious cover
	ART = Area of roof-top directed to rain barrel(s) (catchment area) (sq ft)
	% IC REDUCTION FACTOR = % Impervious area reduction
	RBV = Rain barrel volume (cubic feet)

See Chapter 5 for details and specifications.

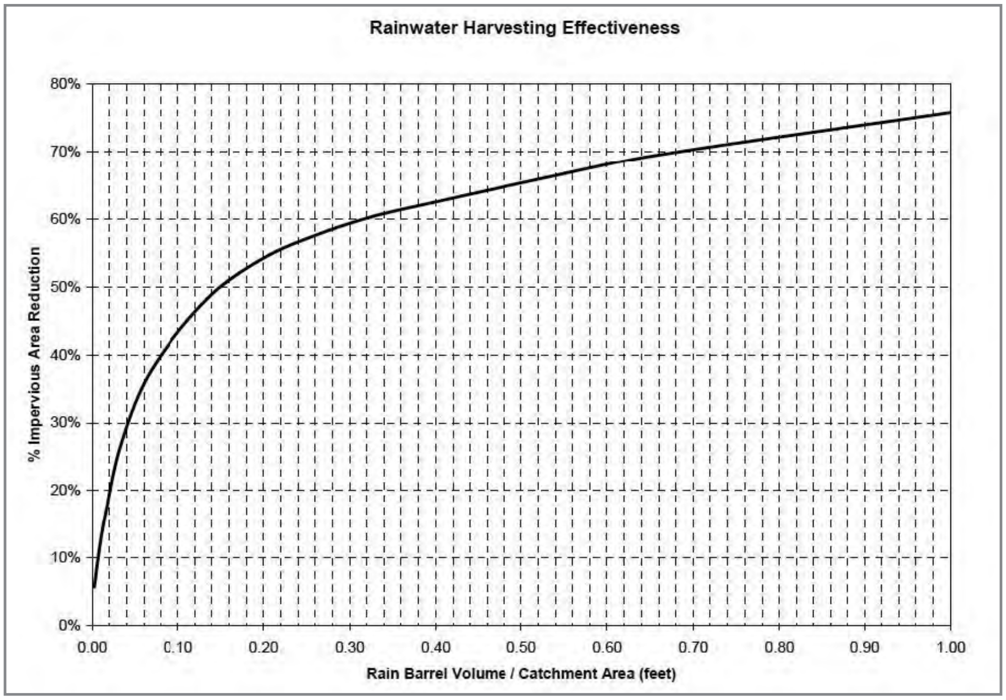


Figure 4-1: Rainwater Collection Credit (Photo courtesy of LCRA Highland Lakes Water Quality Technical Manual, 2007)

Soil Amendment. Refers to the placement of native or blended soils to a depth of six (6) to eight (8) inches to support appropriate turf grasses and landscaping. The soil amendment is applied to all lots within the development. Reduced impervious cover credit is computed by Equation 4.3.

Equation 4.3	**Ar = A * 0.02**
Where:	Ar = Allowable reduction in impervious cover
	AA = Amended area

Conservation Landscaping. Refers to the use of limited turf area, preservation of natural vegetation, and the planting of native trees, shrubs, and perennials to infiltrate stormwater runoff and minimize chemical use. Conservation landscaping should be applied to all lots within the development. Reduced impervious cover credit is computed by Equation 4.4.

Equation 4.4 **Ar = AA * 0.05**

Where: Ar = Allowable reduction in impervious cover

AA = Amended area

See Chapter 5 for details and specifications.

Roof-top Disconnection Credit. Using Table 4-4, the designer can deduct the disconnected impervious cover from the total impervious cover. The credit is based on distance of disconnection of roof top from conveyance system and/or use of localized water storage areas (rain gardens, bioretention, dry well, or cistern) in combination with the roof-top disconnection length. This credit applies only to single-family development with an average lawn slope of 5% or less.

Table 4-4: Rooftop Disconnection Impervious Cover Credit

Disconnection Length Provided	0 to 14 ft.	15 to 29 ft.	30 to 44 ft.	45 to 59 ft.	61 to 74 ft.	> 75 ft.
% Impervious Cover Credit	10%	20%	40%	60%	80%	100%
Dry Well, Rainwater Harvesting, Rain Garden, Storage Volume Required to achieve 100% Credit (in combination with flow length)	104 cu-ft.	83 cu-ft.	62 cu-ft.	42 cu-ft.	21 cu-ft.	0 cu-ft.

Source: LCRA Highland Lakes Water Quality Technical Manual, 2007.

Equation 4.5 **Ar = ART * %ICD**

Where: Ar = Allowable reduction in impervious cover

ART = Area of roof-top

%ICD = Impervious cover credit factor per Table 4-3

The reduction in impervious cover per the above techniques is summed and then subtracted from the total impervious cover to determine the effective impervious cover.

Equation 4.6 **ICeff = ICTOT - (Sum of individual Ar)**

Where: ICeff = Effective impervious cover

ICTOT = Total impervious cover

The effective impervious cover is used to determine Low impact development compliance or compute the structural measure volume.

Natural Area Preservation Credit. The credit for stormwater basin volume is computed by subtracting the preserved area from the area draining to individual stormwater control measures. This credit is granted for all preservation areas permanently protected under conservation easements or other locally acceptable means. The credit is computed by Equation 4.7.

Equation 4.7	**DAeff = DATOT - ANA**
Where:	DAeff = Effective drainage area
	ANA = Natural area preserved
	DATOT = Total drainage area

When computing stormwater volume for a measure using the natural area preservation credit, the designer will not need to adjust the effective impervious cover based on the reduced drainage area.

Vegetated Filter Strip Credit. The credit is applied when parking lots and roads drain via sheet flow to a natural or engineered filter strip per the criteria and specifications in Chapter 5.

Equation 4.8	**Ar = Ap * 0.50**
Where:	Ar = Allowable reduction in impervious cover
	Ap = Area of parking lot or street with a maximum flow length of 72 ft

Vegetated Swale. The credit is applied when parking lots, roads, and rooftops drain to a vegetated swale designed per the criteria and specifications in Chapter 5.

Equation 4.9	**Ar = Ap * 0.20**
Where:	Ar = Allowable reduction in impervious cover
	Ap = Area of parking lot or street within a 2-acre drainage area

Percent impervious cover. Use Equation 4.10 to find the percentage of impervious cover.

Equation 4.10	**IC = ICeff / DATOT**
Where:	IC = Percent impervious cover

4.3.3. STRUCTURAL PRACTICES SIZING CRITERIA

Structural practices are sized to accomplish water quality protection, creek erosion management, and runoff rate management.

Designers are encouraged to use the design spreadsheet model to compute stormwater volume requirements and determine the benefits of developing under the Low Impact Development approach. The model can be obtained from the GLO website at https://cleancoast.texas.gov/.

STRUCTURAL CONTROLS

Stormwater runoff generated on the site must be managed through the use of one or more of these structural practices if low impact development compliance is not achieved:

- Vegetated Swale
- Vegetated Filter Strip
- Porous Pavement/pavers
- Enhanced Detention
- Bioretention/Rain gardens
- Infiltration Basins

For the structural practices that are sized based on runoff volume (bioretention, enhanced detention, infiltration basins, porous pavement/pavers), the capture volume must be sized to accommodate the runoff from a 1.5" rainfall event at a minimum. The runoff coefficient is a function of the impervious cover and is calculated as:

Equation 4.9 $Rv = 0.05 + 0.90IC$

Where:
Rv = Runoff Coefficient
IC = Fraction of impervious cover in the catchment of the structural practice

The minimum capture volume is then calculated as:

Equation 4.10 $V = P \times A \times Rv/12$

Where:
V = Minimum required capture volume
P = Rainfall depth (1.5 inches)
A = Watershed area of the practice (ft^2)
Rv = Runoff Coefficient

Table 4-5: Runoff Volume 1.5 Inch Storm

Impervious Cover Percentage	Runoff Volume (in)
15%	0.28
20%	0.35
30%	0.48
40%	0.62
50%	0.75
60%	0.89
70%	1.02
80%	1.16
90%	1.29
100%	1.43

The 1.5-inch rainfall event runoff volume will be detained a minimum of 24-hours but not longer than 72 hours.

To provide sediment storage between structural practice maintenance, the structural practice capture volume is increased by 5%.

4.4 BUFFER ZONES AND HYDROMODIFICATION MANAGEMENT

Buffer zones protect waterways, tidal waters, and aquatic resources from the short- and long-term impacts of development activities. 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.

Buffer zones shall remain free of construction, development, or other alterations. By preventing hydromodification (channelization, stream straightening, filling of headwater, stream enclosure pipes/culverts, dams), natural drainage and aquatic systems are preserved, thus, enhancing water quality treatment and preserving natural floodplain characteristics that slow and store floodwaters when compared with channelized systems. This promotes natural management of storm events and helps to greatly reduce long-term maintenance costs. 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, when absolutely necessary, 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 projects that do not significantly alter the existing vegetation and are more resistant to flood damage. Parking lots and roads significantly alter existing vegetation and are not considered low impact.

No stormwater treatment facilities, golf courses, septic tanks, drain fields, or wastewater irrigation shall be located in the buffer zone. Manicured lawns and the application of herbicides shall not be allowed in the buffer. Stormwater discharge from development and water quality measures should be dispersed into overland sheet flow before reaching the buffer zone.

CREEK BUFFER ZONES

Creeks or swales draining less than 320 acres but more than 40 acres shall have a minimum buffer width of 25 feet from the top of bank on each side of the creek or swale or the buffer setback shall be the 100-year floodplain, whichever is greater.

Creeks or rivers draining 320 or more acres shall have a minimum buffer width of 50 feet from the top of bank on each side of the creek or river or the buffer setback shall be the 100-year floodplain, whichever is greater.

WETLAND/BAY/TIDAL WATERS/DEPRESSION STORAGE BUFFER ZONES

A buffer of 25 feet shall be maintained along all tidal waters/coastal marshlands, measured horizontally from the estuarine area.

A buffer of 25 feet shall be maintained along all wetlands as measured from the inland edge of the wetland.

A buffer of 25 feet shall be maintained along all depression storage basins as measured from the edge of the high-water mark. Additionally, the volume within the natural depressions deeper than 2’ and with a surface area larger than 1 acre shall be calculated and maintained so as to not adversely affect upstream/downstream properties. If there are no practical alternatives to maintain the depression storage volume at its existing location, the loss of volume shall be mitigated for on-site and within the same drainage basin. These depressions can be used toward the required detention storage.

4.5 WATER QUALITY EDUCATION

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 section implemented at the neighborhood scale can have beneficial effects on managing stormwater volumes and improving runoff quality.

The performance standards require that a recipient of a development permit participate in a water quality education program using Texas General Land Office, Texas Commission on Environmental Quality, and other recommended water quality education materials that focus on water quality protection and drainage management. The development project manager shall contact the approving entity as the permitted project nears construction completion to initiate the education process. The materials and/or website will be shared with the builders and real estate agents to promote the transfer of materials to the resident, homeowner, or building manager.

Water quality education will promote limited chemical use, proper storage of chemicals, disposal of animal waste, low water demand landscapes, septic system maintenance, and good housekeeping practices to minimize watershed residents' impact to the receiving waterbody. Education activities include:

- The jurisdictional stormwater authority will provide education materials to new residents at the time of occupying their home or establishment.
- Sharing the GLO NPS website with the developer and real estate sales staff to provide to homeowners, residents, and building operators.
- Education events sponsored by the GLO, TCEQ, and other agencies that promote creek and beach cleanups, roadside trash collection days, and adoption of creeks, beaches and highways.
- Household hazardous waste collection events.

The NPS website link can be found at https://cleancoast.texas.gov/.

4.6 STRUCTURAL PRACTICE MAINTENANCE

A maintenance plan developed by the design engineer and acceptable to the jurisdictional stormwater authority should be prepared prior to permit issuance.

Typical operation and maintenance activities for the stormwater structural practices include:

- Post construction inspection by the jurisdictional stormwater authority to verify that BMPs are installed as designed;
- Removal of trash and debris that accumulates in BMPs;
- Inspection of stormwater conveyance network serving the BMP and removal of debris and sediment;
- Evaluation of continuing ability for runoff to infiltrate into infiltration BMPs;
- Vegetation management;
- Inspection of vegetation and deposition of debris after significant storm events;
- Regular inspection of deposition of sediment for removal; and
- Replanting of vegetation, soil stabilization, and debris removal, as necessary.

4.6.1 MAINTENANCE PLAN

1. Specification of routine and non-routine maintenance activities to be performed;
2. A schedule for maintenance activities;
3. Provision for access to the tract by jurisdictional stormwater authority or other designated inspectors;
4. Name, qualifications and contact information for the party(ies) responsible for maintaining the BMP(s); and
5. The plan should be signed and dated by the party responsible for maintenance.

4.6.2. GENERAL GUIDELINES

Both the ability and the commitment to maintain stormwater management facilities are necessary for the proper operation of these facilities. The designer must consider the maintenance needs and the type of maintenance that will take place, in order to provide for adequate access to and within the facility site. Key design factors include:

- Maintainability;
- Accessibility;
- Durability;
- Basin de-watering; and
- Sediment disposal.

Specific maintenance guidance for each sustainable stormwater practice is included in Chapter 5.

4.7 SUBMITTAL REQUIREMENTS

The following information must be submitted to the municipality for any new development or redevelopment where more than 10,000 square feet of impervious cover is added 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.

4.7.1. SITE ANALYSIS AND NARRATIVE

The site analysis and narrative should include:

- 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;
- Identification 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 100-year storm events.
- 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; and
- 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).

4.7.2. SITE LAYOUT AND DRAINAGE DESIGN

The site layout and drainage design should include:

- Legend, north arrow, and 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;
- Buffer zones;
- 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.

4.7.3. DESIGN STEPS

1. Compute the impervious cover for the development. The applicant can use stormwater credits to reduce effective impervious cover and determine compliance with Low Impact Development.
2. Delineate drainage areas within development to define impervious cover percentage at each discharge point or structural control. When a site contains multiple drainage areas, the impervious cover shall be calculated for each area to determine the necessary water quality volume or compliance with the low impact development option in each drainage area.
3. Select the appropriate structural control(s) to meet the site constraints and manage stormwater runoff.
4. Compute the stormwater volume based on the runoff from the design storm in 4.3.3.
5. Design the stormwater controls per the guidance in Chapter 5 including discharge to the buffer zone in a sheet flow manner.

Table 4-6: Permanent BMP Summary

Permanent BMPs	Construction Cost	Recommended Drainage Area Size (acres)	Maintenance Requirement	Liability/ Safety Issues	Other Benefits
Vegetated Filter Strip	Low	< 3 acres or downstream of other measures	Low	None	Resilient
Vegetated Swale	Low	< 2 acres	Low	Low	Resilient
Extended Detention Pond	Moderate	Less than 128 acres	Low to Medium	Low, short term standing water	Promote baseflow enhancement
Bioretention/rain gardens	Moderate	< 10 acres	Medium to High	Low, shallow standing water depth	Promote baseflow enhancement
Infiltration	Moderate	Downstream of BMP	Medium to High	Moderate, standing water	Water supply
Wet Basins	Moderate to High	> 20 acres and less than 128	Medium to High	High, long term standing water	Habitat
Constructed Wetlands	Moderate to High	> 20 acres and less than 128	Medium to High	Moderate, long-term Standing water	Habitat
Stormwater Credits					

Table 4-6: Permanent BMP Summary Continued

Permanent BMPs	Construction Cost	Recommended Drainage Area Size (acres)	Maintenance Requirement	Liability/ Safety Issues	Other Benefits
Porous Pavement	Moderate	No off-site area drains to pavement	Moderate	Low, potential pavement issues	Water supply
Rainwater Harvesting	Moderate	House roof-top	Moderate	Low, rainwater stored in property owner tanks	Water supply
Soil amendment & conservation landscaping	Moderate	Lot size	Low	None	Water supply and resilient
Roof-top disconnection	Low	House roof-top	Low	None	Water supply and resilient
Natural Area Preservation	Low	NA	Low	None	Water supply and resilient
Buffers	Low	Creek, river, and tidal water boundaries	Very Low to none	None	Water supply and resilient

4.8 INCORPORATING PRACTICES INTO TYPICAL DEVELOPMENT PROJECTS

- √ Single Family Residential
- √ Multi Family Developments
- √ Commercial/Retail/Office
- √ Downtown Redevelopment

The purpose of this section 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 guidance manual describes in Chapter 6 how these detention facilities, with potentially only the slightest modification, can also improve the performance of drainage systems, while providing aesthetic benefits, recreational opportunities, and wildlife habitat.

4.8.1. 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.

4.8.2. 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 if lot widths are of sufficient length to include driveways and culverts. When lots are narrow in width, an alley to service the homes can be constructed in the backyards so that street drainage is not impeded by driveway culverts, thus, promoting sheet flow in a filter strip type method from the street to the vegetated swale. 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 4-2. 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 4-2: Medium density neighborhood uses vegetated swales for stormwater conveyance. These swales also provide water quality benefits.

Narrow sidewalks, roads and driveways, separated from each other by vegetation, help to minimize and disconnect impervious surfaces, as in Figure 4-3.

Figure 4-3: Disconnected and minimized impervious cover in Chambers County, Texas.

Driveways which use permeable pavers can help reduce overall impervious cover on a residential site (see Figure 4-4), which reduces detention requirements. Lawns or bioretention areas on either side of the driveway can further improve the performance of a site.

Figure 4-4: Driveway constructed of permeable pavers. (Photo courtesy of Mutual Materials)

4.8.3. 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, infiltration basins or vegetated filter strips and swales should be employed to collect and treat stormwater. Figure 4-5 illustrates how a variety of sustainable drainage practices can be incorporated into a 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.

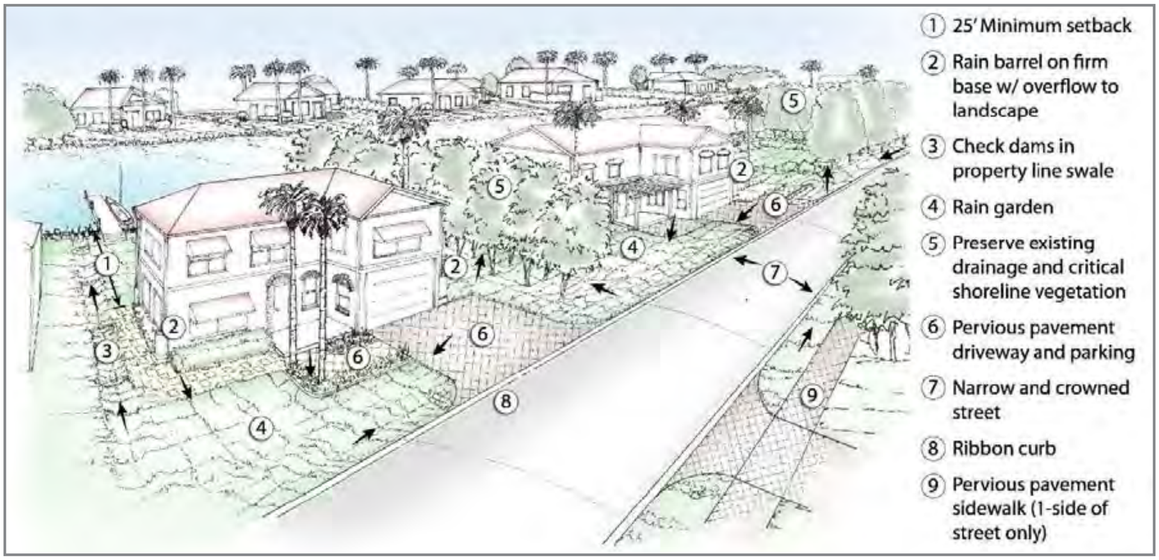


Figure 4-5: Example of waterfront development with sustainable drainage features.

4.8.4. MULTI-FAMILY DEVELOPMENTS

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 4-6, bioretention areas are integrated with conventional landscaping.

Figure 4-6: Multi-family with vegetated bioretention area. (Photo courtesy of Michael Barrett)

Parking lots in multi-family developments, Figure 4-7, 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.

Figure 4-7: Multi-family units utilize permeable pavers to beautify their parking lot

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

4.8.5. 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 4-8 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 4-8, or vegetated filter strips on the edges. Trees in these center islands can provide welcome shade during hot Texas summers.

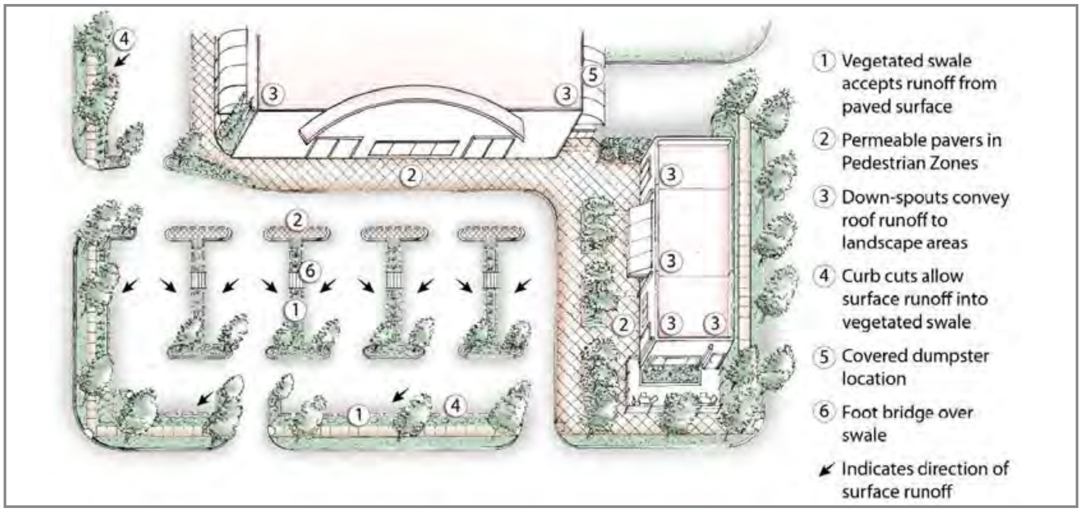


Figure 4-8: Commercial development incorporating sustainable drainage practices.

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 4-9 shows two different parking lot designs, one with stormwater controls included in the design, and the other designed and built in a conventional manner.

Figure 4-9: Parking lots can positively influence the customer experience at a commercial development.

To reduce standing water after a storm, parking lots can be fitted exclusively or in part with permeable pavement. While porous pavement is one option is for the entire parking lot, another common configuration includes standard pavement driving lanes which slope towards permeable parking stalls. This is illustrated below in Figure 4-10.

Figure 4-10: Permeable interlocking concrete pavers with regular asphalt driving lane in Cascade Park parking lot, Cameron County, Texas.

Example project designs can be found in the Appendices in the upcoming Manual edition, this will follow EPA and NOAA approval.

CHAPTER 5

Structural Practices for Sustainable Drainage Design

- √ Overview
- √ Vegetated Swales and Filter Strips
- √ Porous Pavement
- √ Enhanced Detention
- √ Bioretention
- √ Infiltration
- √ Rainwater harvesting
- √ Natural area preservation
- √ Disconnection of roof-top runoff
- √ Soil amendment and conservation landscaping

The purpose of this chapter is to describe the 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.

5.1 OVERVIEW

Structural practices for sustainable drainage design are those measures that are used to manage nonpoint source pollution (stormwater runoff quality) and peak flow rates from new development. This Chapter provides technical guidance for the design, construction, and maintenance of such measures. Sustainable practices designed per Chapter 4 and this Chapter will reduce total suspended solids (TSS) by at least 80% after the construction site has been permanently stabilized and maintain post-development peak runoff rates at pre-development levels for the 1.5" rainfall event. Sustainable drainage practices are required by all new development and redevelopment projects that disturb one acre or more of land, add 10,000 square feet of impervious cover, and 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% or use stormwater credits to create an effective impervious cover less than 20% are exempt from the implementation of structural practices.

5.1.1. GENERAL DESIGN GUIDELINES

The following general guidelines apply to all permanent BMPs in this section.

1. **SITING REQUIREMENTS:**
    - All water quality basins must lie outside the buffer zones; and
    - All permanent BMPs receiving off-site runoff or serving a single-family subdivision should be shown within a drainage easement or conservation easement. Vegetative filter strips may be shown within the building set back of a lot in lieu of being located in a drainage easement. The easement or building setback must include appropriate restrictions regarding the amount and type of improvements that may be constructed.

2. **SAFETY CONSIDERATIONS**
    - ***Embankment Safety:*** The design should direct grading to avoid drop-offs and other hazards. Side slopes of basins should be 3:1 (H:V) or flatter for grass stabilized slopes. Slopes steeper than 3:1 (H:V) must be stabilized with an appropriate slope stabilization practice;
    - ***Dam Safety:*** See Section 299 of the TCEQ rules on Dams and Reservoirs for dam safety requirements. These rules apply to any barriers, including one for flood detention or water quality management, designed to impound liquid volumes and which has a dam height greater than six feet;
    - ***Hazardous Materials:*** For developments that store or dispense hazardous materials a valve should be installed so that discharge from the BMP can be stopped in case runoff from a spill of hazardous material enters the basin. The control for the valve must be accessible at all times, including when the basin is full; and
    - ***Limit Access:*** Fencing, landscaping and curb stops can be used to impede access to a facility. The primary spillway opening must not permit access by small children. If the facility is fenced, gates must be provided to allow access for inspections and maintenance.

3. **STABILIZATION REQUIREMENT**

    A plan should be provided indicating how disturbed areas will be stabilized and re-vegetated. Revegetation must follow the guidelines in Chapter 3 and begin within 14 days of the end of construction activities. Erosion control must be provided to protect exposed soil on slopes greater than 3:1 and can be provided in the form of sod, matting, straw or other approved means.

4. **VEGETATION REQUIREMENTS**

    The vegetation density for all permanent BMPs must be greater than 80% with no large bare areas. The filter area should be densely vegetated with a mix of erosion-resistant plant species that effectively bind the soil. Native or adapted grasses, shrubs, and trees are appropriate because they generally require less fertilizer and are more drought resistant than exotic plants. Turf grass (vegetated filter strips) should be mowed to maintain a grass height of no more than 4-inches to keep the grass in an active growth phase. Permanent BMP areas should be managed to minimize or avoid the application of fertilizers, pesticides, or herbicides.

5. CONSTRUCTION-PHASE RUNOFF

Structural practices may be used as sediment basins during construction. Embankments and conveyances must be properly compacted with an emergency overflow outlet. Basins must have sediment accumulations removed, final grades restored, and stabilization achieved prior to completion. No portion of a basin using infiltration or filtration shall be used to collect or treat construction-phase runoff. No runoff shall be received by these facilities until site is completely stabilized.

6. MAINTENANCE REQUIREMENTS

Provide adequate maintenance access to all permanent BMP inlet and outlet structures, filtration and sedimentation areas. A fixed vertical sediment depth marker should be installed in the bottom of sedimentation areas to determine when sediment accumulation has exceeded limits set in the maintenance plan.

See Chapter 5 for Maintenance Plan requirements for all permanent BMPs.

5.2 VEGETATED SWALES

5.2.1. INTRODUCTION

Grassy swales are vegetated channels that convey stormwater and remove pollutants by sedimentation and infiltration through soil. They require well-draining shallow slopes and soils. 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.

A credit is given when impervious cover in a drainage area less than 2 acres is directed to a vegetated swale where it can either infiltrate into the soil or filter over it. The credit is obtained per the criteria in this section where 20% of the impervious area in that 2-acre contributing drainage area can be deducted from the total impervious cover (therefore, potentially gaining compliance with the Low Impact Development impervious cover levels or reducing BMP volume).

Grassy swales are primarily stormwater conveyance systems. They can provide sufficient control under light to moderate runoff conditions, but their ability to control large stormwater flows 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 photograph of a grassy swale is presented in Figure 5-1. They can also be included in the design of commercial parking areas as shown in Figure 5-2.

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. 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, as well as dimensions and slope of the swale system. 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 less than 2 acres.
- Sufficient available land area.

LIMITATIONS

- Can be difficult to avoid channelization.
- Number of culverts required may make infeasible in higher density developments.

Figure 5-1: Typical swale in a residential neighborhood in Chambers County, Texas. (Photo courtesy of Google Earth)

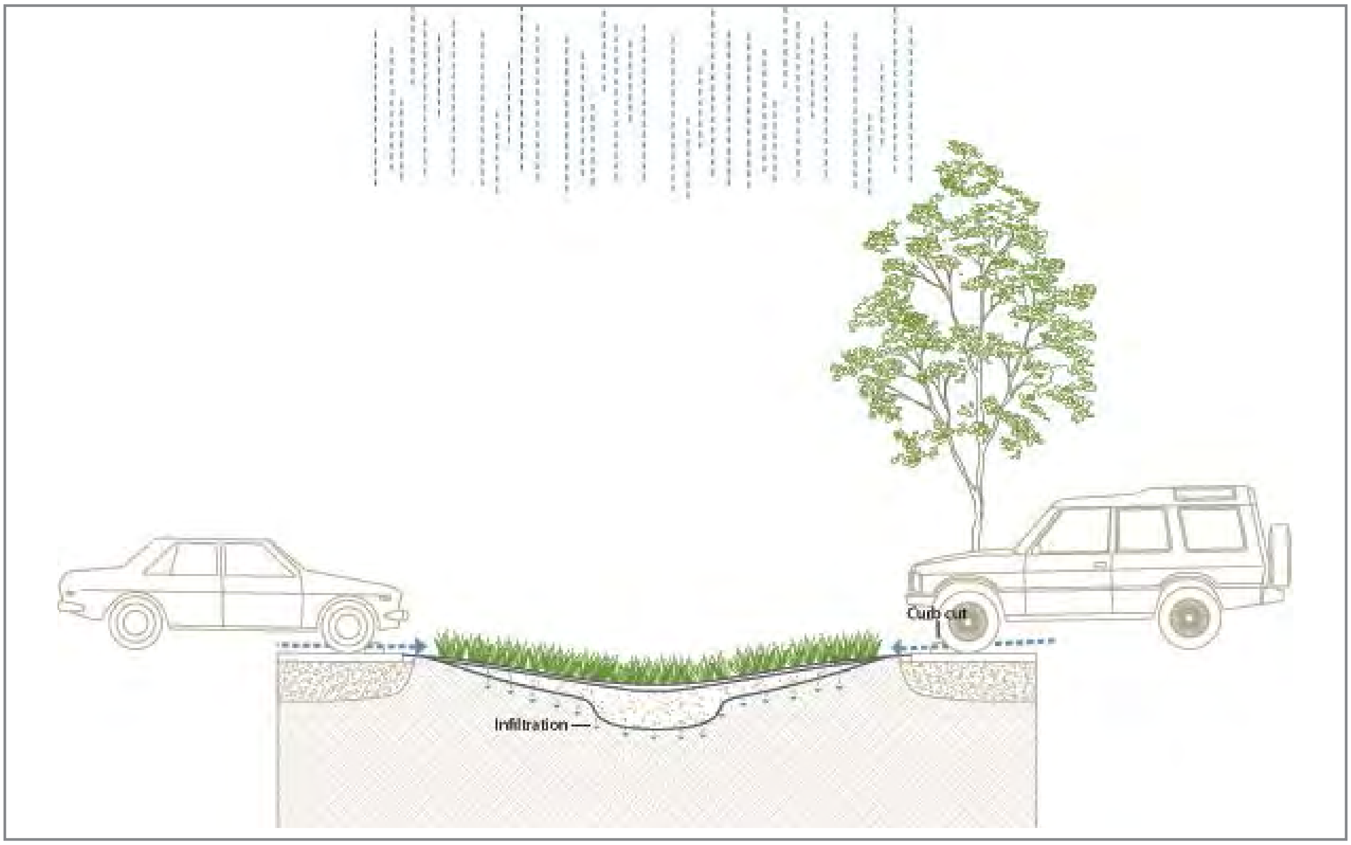


Figure 5-2: Swale in parking lot area. (Showing the use of short grasses, low slopes, curb cuts from parking area and some infiltration.

5.2.2. 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 with a longitudinal slope equal to or less than 0.5%. The side slopes should be no steeper than 6:1 (H:V).
3. Roadside ditches should be regarded as significant potential swale 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 riprap 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% 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.

5.2.3. 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 previously, 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 and is typically assisted by nutrient inflow from runoff.
- ***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 by homeowners can present numerous problems. For example, excessive application of fertilizer and pesticides is 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 these recommended practices.

5.3 VEGETATED FILTER STRIPS

5.3.1. INTRODUCTION

Filter strips, also known as vegetated buffer strips, are vegetated sections of land superficially similar to grassy swales. One important characteristic of filter strips is that they are essentially flat with low slopes and designed only to accept runoff as overland sheet flow. A diagrammatic photograph of a vegetated buffer strip is shown in Figure 5-3. 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 can pass through a filter strip, rather than discharge directly to a piped conveyance system. Properly designed roadway medians and shoulders can make effective vegetated filter strips. Another application for vegetative filter strips is simply leaving land located adjacent to perimeter lots in subdivisions that will not drain via gravity to other stormwater conveyance systems in its natural condition.

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.

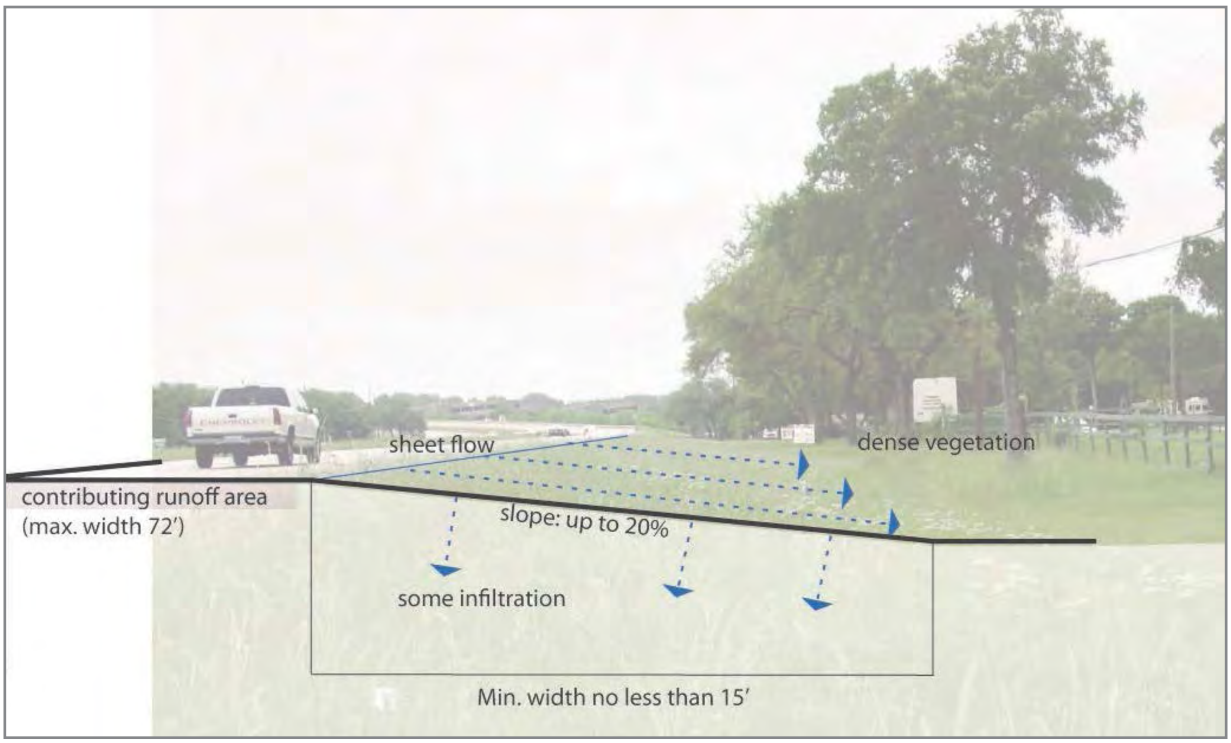


Figure 5-3: Filter strip along side of highway.

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 make infeasible on some sites.

5.3.2. FILTER STRIP DESIGN GUIDANCE

Filter strips may be natural or engineered. Natural filter strips can be applied to impervious areas as noted in Figure 5-3 and to perimeter lots and other areas that will not drain by gravity to other drainage facilities on the site.

A credit is given when parking lots and roads are disconnected from the drainage system and then directed to a vegetated filter strip where it can either infiltrate into the soil or filter over it. The credit is obtained in parking lot areas and roads with a maximum flow length of 72 feet. When meeting the criteria in this section, 50% of the impervious area contributing runoff to the vegetated filter strip can be deducted from the total impervious cover (therefore, potentially gaining compliance with the Low Impact Development impervious cover levels or reducing BMP volume).

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, 24-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 5-3. The general design goal is to produce uniform, shallow overland flow across the entire filter strip.The slope should not exceed 10% for natural filter strips.

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%.
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. The 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.

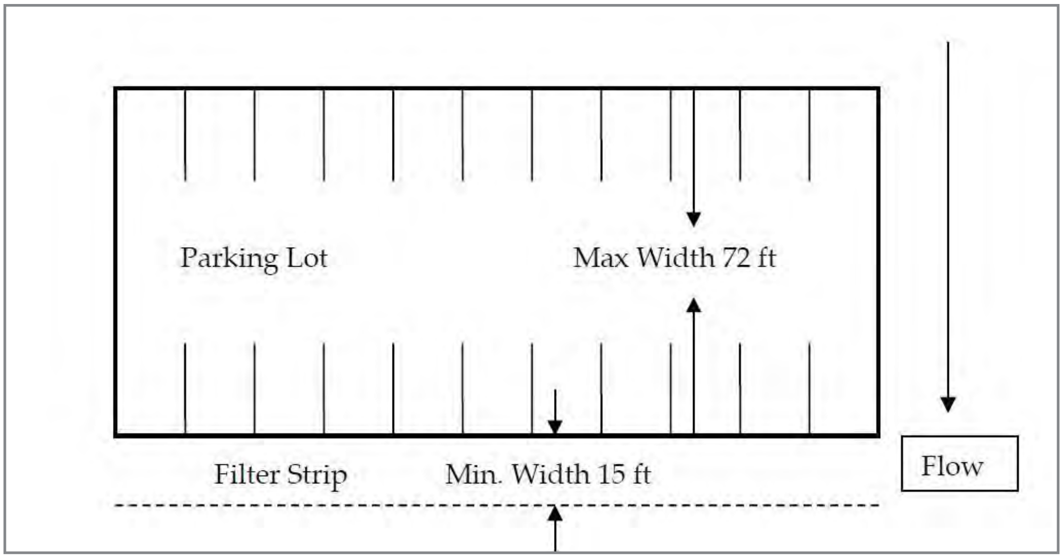


Figure 5-4: Example configuration of filter strip adjacent to a parking lot.

5.3.3. MAINTENANCE REQUIREMENTS

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

- ***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 vegetation grows through sediment and binds it to the soil. However, sediment may accumulate along the upstream boundary of the strip and prevent 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.

5.4 POROUS PAVEMENT

5.4.1. INTRODUCTION

Porous pavements allow rain to pass through and can be used on both permeable and impermeable soils. In the latter case, these porous pavements are designed with an underdrain system. Where soils are sufficiently permeable, runoff can infiltrate into the soil and the discharge of stormwater or associated pollutants can be avoided. 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 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, the absence of fine material, and 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 5-5.

Figure 5-5: Permeable pavers in parking stall of Cascade Park parking lot in Cameron County.

Porous pavement is typically placed over a highly permeable layer of open-graded gravel and crushed stone as shown in Figure 5-6. 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.

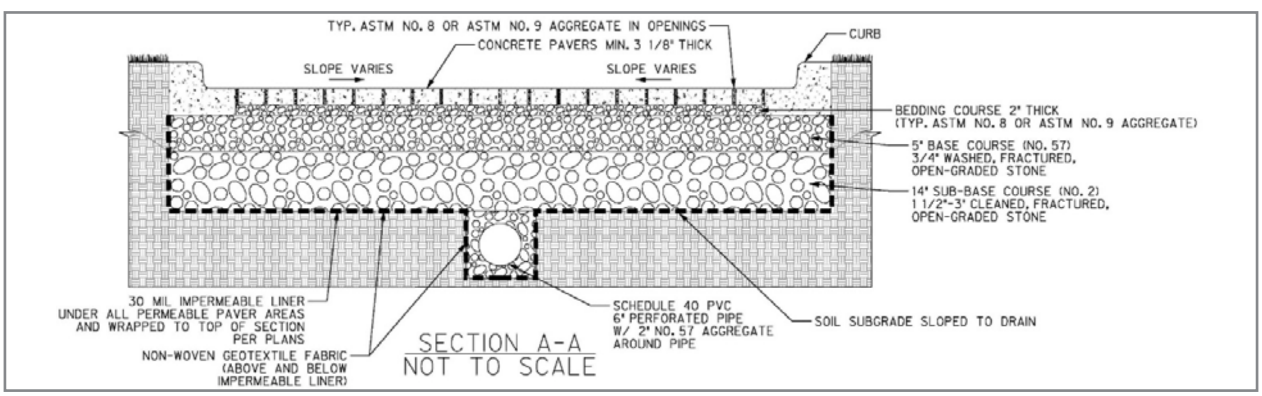


Figure 5-6: Representative cross-section of porous pavement.

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.

The advantages of 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:

- 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.

5.4.2. POROUS PAVEMENT DESIGN GUIDLINES

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 in order to increase concentration time and reduce 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 6 inches of reservoir rock must be provided below the pavement to store the 1.5-inch rainfall event.
2. As part of the site evaluation, obtain a 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 is 0.5 inch per hour or an underdrain is required.
4. Provide an under-drain system with perforated pipe in areas where infiltration rates do not meet the design requirements.
5. Minimum depth to the seasonally high-water table is 4 feet.
6. Minimum setback from water supply wells is 100 feet.
7. Minimum setback from building foundations is 10 feet down-gradient.

8. Porous pavement should be used for sidewalks, patios, parking areas and lightly used access roads.
9. Excavate and grade with light equipment with tracks or oversized tires to prevent soil compaction.
10. Divert stormwater runoff away from planned pavement area before and during construction.

5.4.3. 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% 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.

5.5 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.

5.5.1. 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 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 presented in Figure 5-7.

Figure 5-7: Constructed wetland in Aransas County, Texas. (Photo courtesy of Danica Adams)

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. Additionally, constructed wetlands should approximate natural situations as much as possible. Unnatural attributes, such as a rectangular shape or rigid channels, should be avoided. Because wetlands 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

- When located in an area of high visibility, constructed wetlands may not appear especially attractive to residents
- May be infeasible to site or retrofit in dense urban areas

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 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 excavated volume of the wetland area should be no smaller than the volume of runoff produced by a 1.5-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% of the basin should be an open water area at least 2-ft deep if the facility is exclusively designed as a shallow marsh. Added open-water area makes marsh space more aesthetically pleasing, and the combined water/wetland area creates a good habitat for waterfowl. The wetland zone should be 50 to 70% of the area and should be 6- to 12-inch 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 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.

5.5.2. ENHANCED DETENTION WET PONDS

The wet pond is a detention basin with a permanent volume of water incorporated into the design (Figure 5-8). 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.

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. 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 with a water table close to the land surface.

Figure 5-8: Picture of an enhanced detention wet pond. (Photo courtesy of Houston-Galveston Area Council)

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, 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 bulk-headed)

DETENTION/WET POND DESIGN GUIDANCE

1. ***Construction:*** 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 1.5-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. Basins should be wedge-shaped, narrowest at the inlet and widest at the outlet when possible. The minimum length to width ratio should be 1.0. Higher ratios are recommended. A schematic of this design is presented in Figure 5-9.

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 drop-offs 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).

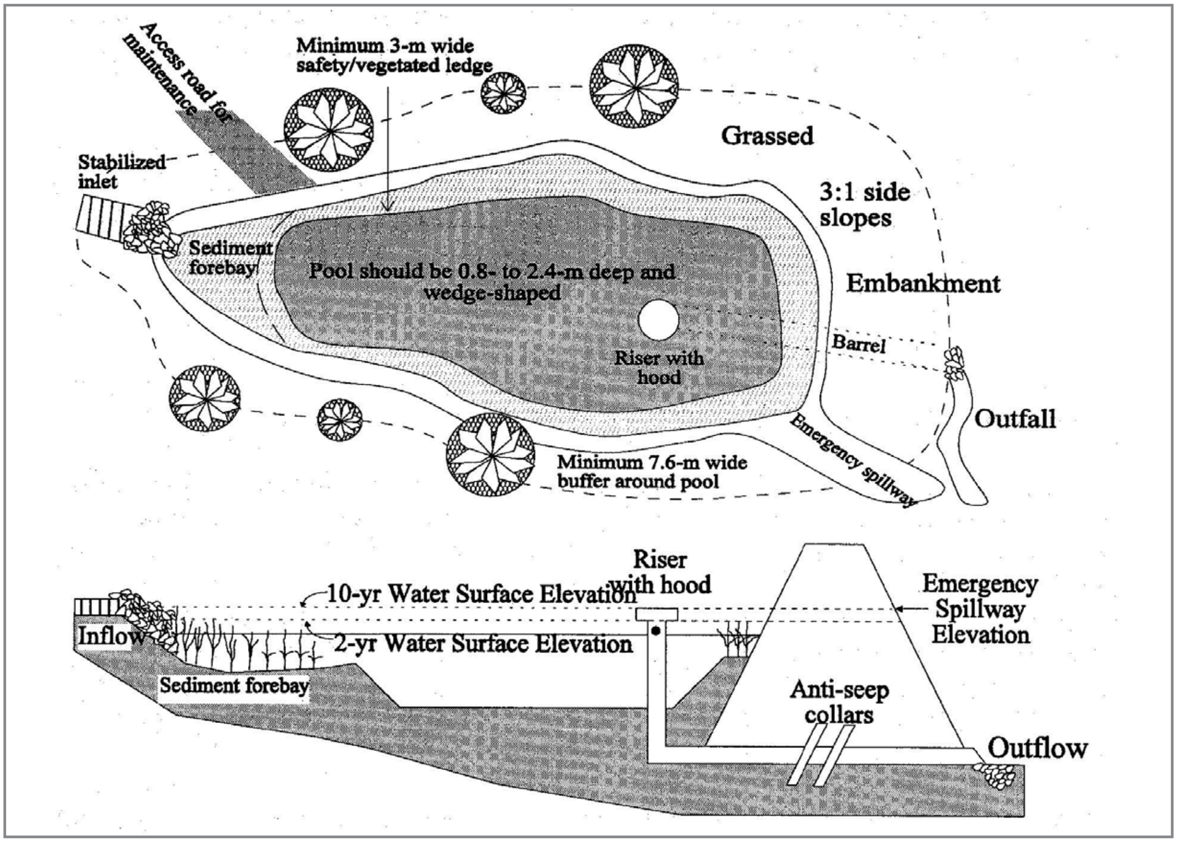


Figure 5-9: Schematic of a wet basin.

5.4.2. ENHANCED EXTENDED DETENTION

Extended detention basins capture and temporarily detain the water quality volume. They are intended to serve primarily as settling basins for the solids fraction, nutrients attached to solids, and as a means of limiting downstream erosion by managing stormwater.

- Extended detention basins may be constructed either online or offline.
- Extended detention basins are typically depressed basins that temporarily store stormwater runoff following a storm event and do not have a permanent water pool between storm events.

Water is controlled by means of a hydraulic control structure to restrict outlet discharge. Provided water quality benefits are the removal of sediment and buoyant materials. Furthermore, nutrients, heavy metals, toxic materials, and oxygen-demanding materials associated with these particles are also removed. Control of the maximum runoff rates serves to protect drainage channels below the device from erosion and to reduce downstream flooding. Refer to Figure 5-10 for a schematic of an extended detention basin.

One of the main advantages of extended detention basins is their adaptability; they can be used on areas with thin soils, high evaporation rates, low-soil infiltration rates, in limited space areas, and where groundwater is to be protected. Due to the simplicity of design, extended detention basins are relatively easy and inexpensive to construct and operate.

Extended detention basins are generally best suited to drainage areas greater than three acres, since the outlet orifice becomes prone to clogging for small water quality volumes. Extended detention basins can also be combined with flood control detention facilities by providing additional storage above the water quality volume.

DESIGN GUIDELINES

1. ***Contributing Drainage Area:*** These areas should be less than 128 acres with no minimum drainage area.
2. ***Pre-treatment:*** A sediment forebay is designed to retain the bulk of the sediment entering the facility. This will simplify sediment removal and reduce overall basin maintenance. Refer to the design guidelines for sediment forebays in General Guidelines Item No. 7, where the forebay volume is equal to 25% of the water quality volume to retain the first flush runoff volume. To promote advanced treatment of the first flush volume, the forebay design relies on a berm and/or gabion within the basin to promote pollutant settling. Non-woven filter fabric with a 0.15 mm (U.S. Sieve Size 100) opening shall be placed on the gabion to enhance detention and facilitate maintenance. Rock riprap shall be placed on the downstream side to prevent scouring in the event flow passes over the gabion. Use guidance found in 3.2.4 and 3.2.
3. ***Basin Sizing:*** The BMP Volume is calculated by applying a factor of 1.05 to the Water Quality Volume (WQV) calculated per Chapter 2.3. The WQV is increased by a factor of 5% to accommodate for reduction in the available storage volume due to deposition of solids in the time between full-scale maintenance activities.

   BMP Volume = WQV * 1.05

   WQV = Required Water Quality Volume as calculated in Chapter 2.3 (cubic feet)

4. ***Basin Configuration:*** The extended detention basin is optimally designed to have a gradual expansion from the inlet toward the middle of the facility and a gradual contraction toward the basin outfall. The ratio of flow-path length to width from the inlet to the outlet should be at least 2:1 (L:W). Flow-path length is defined as the distance from the inlet to the outlet as measured at the surface. Width is defined as the mean width of the basin. Higher length-to-width ratios are recommended. Outlets should be placed to maximize the flow-path through the facility. The basin should maintain a longitudinal slope between 1.0 – 5.0% with a lateral slope between 1.0 – 1.5%.
5. ***Basin Depth:*** The water depth in the basin when full should be no greater than 8 feet.
6. ***Basin Outlet:*** The facility's drawdown time should be regulated by an orifice plate located downstream of the primary outflow opening. The outflow structure should be sized to allow for complete drawdown of water quality volume within 48 to 72 hours. In addition, the outlet shall be configured to provide at least 12- hour detention for 0.5 inches of runoff from the total effective impervious cover. The minimum orifice diameter is 1-inch. Non woven filter fabric with a minimum opening of 0.15 mm (U.S. Sieve Size 100) shall be wrapped around the riser to enhance detention. Risers should be double-wrapped with filter fabric until the contributing drainage area is vegetated and stabilized. Outflow structures must have a trash rack or other acceptable means of preventing clogging at the entrance to the outflow pipes. The following equation can be used to determine the required orifice size:

$$A_O = \frac{0.001 BMP\_Vol.}{C\sqrt{2gH_{avg}}}$$

A_o = maximum orifice area (square inches)
BMP Vol. = required basin volume as calculated above (cubic feet)
C = orifice coefficient (Typical. 0.62)
g = acceleration of gravity (32.2 ft/s^2)
H_{avg} = $H_T/2$, average hydraulic head (ft)
H_T = total hydraulic head determined from difference between the WQ elev. and the center of orifice

7. ***Basin Soils:*** To enhance infiltration and water storage within the basin, topsoil must be placed on the basin floor after excavated bottom is scarified to a depth of 2 to 3 inches to improve drainage. Topsoil must be 6 to 8 inches deep with a soil mixture of 30-40% sand or granite sand, 60-70% topsoil, and 5-10% compost or peat to aid in water retention and promote vegetation growth. Soil blend must have clay content less than 20% and be free of stones, stumps, roots or other similar objects larger than one (1) inch. If on-site soils do not meet these specifications, topsoil per the above specs must be added. Sandy loam is not an approved soil and caliche is not considered a soil.

8. ***Vegetation:*** To enhance appearance and function, trees, shrubs, and additional forb vegetation are recommended along with Bermuda grass coverage (strongly recommend sod). Refer to bioretention basin vegetation requirements (4.2.2 (10)) for guidance. Muhly grass can be used to aid in spreading flow and concealing the riser pipe and mid-basin gabion. Trees and shrubs can effectively screen other structural aspects while also aiding in evapotranspiration and basin floor drying.

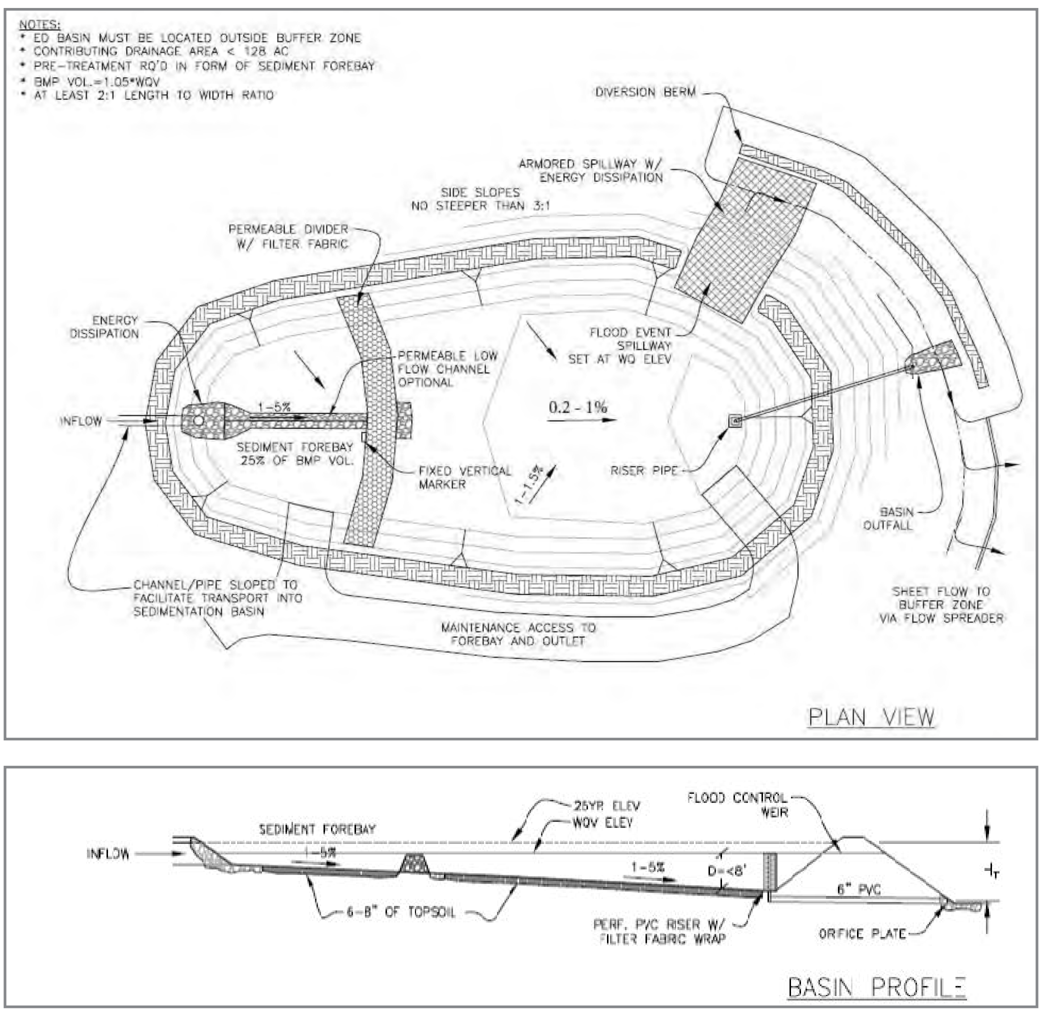


Figure 5-10: Schematic of an Enhanced Extended Detention Basin

5.5.4. RECOMMENDED MAINTENANCE

Extended detention basins capture and temporarily detain the water quality volume. They are intended to serve primarily as settling basins for the solids fraction, nutrients attached to solids, and as a means of limiting downstream erosion by managing stormwater.

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. The embankment should be checked for subsidence, erosion, leakage, cracking, and tree growth. The condition of the emergency spillway should also be evaluated. 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 tested. Any modifications to the basin structure and contributing watershed should also be evaluated.

  During semi-annual inspections, prepare and update maintenance checklists and replace any dead or displaced vegetation. Replanting various species of wetland vegetation may be required 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. 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, 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 is needed in some ponds. If the ponds are properly sized and vegetated, these problems should be rare in wet ponds with the exception of 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 years, while concrete barrels and risers may last 50 to 75 years. 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 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 both the appearance and pollutant removal 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 provide export of nutrients and 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.

5.6 BIORETENTION

5.6.1. INTRODUCTION

Rain garden and bioretention best management practices function as a soil and plant-based filtration device that remove 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 5-11 illustrates the basic components of the system and a picture of a bioretention system located in a parking lot island is presented in Figure 5-12. TSS removal efficiency = 89%.

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 guidance manual, the main difference between the two systems is that a bioretention system uses engineered soils while rain gardens do not. However, rain gardens can incorporate slightly modified soils. Both systems can be designed with or without underdrains.

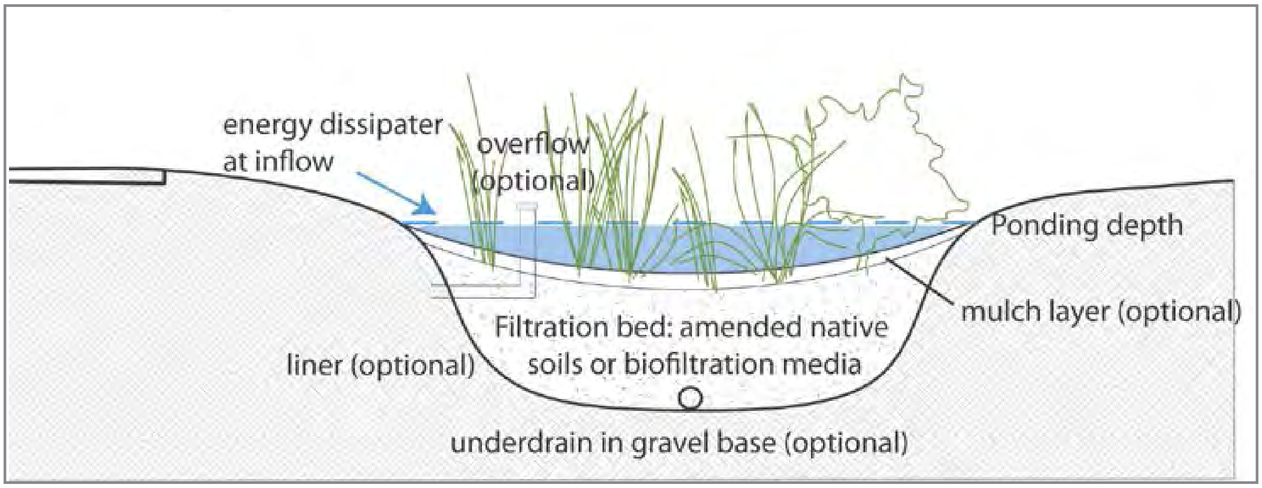


Figure 5-11: A diagram of the basic rain garden / bioretention system components including optional components.

Figure 5-12: Picture of a bioretention facility. (Photo courtesy of David Dods)

SELECTION CRITERIA

- Onsite systems serving a relatively small drainage areas are ideal since they 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.
- Vegetation provides shade and wind breaks, absorbs noise, and improves an area's landscape.

LIMITATIONS

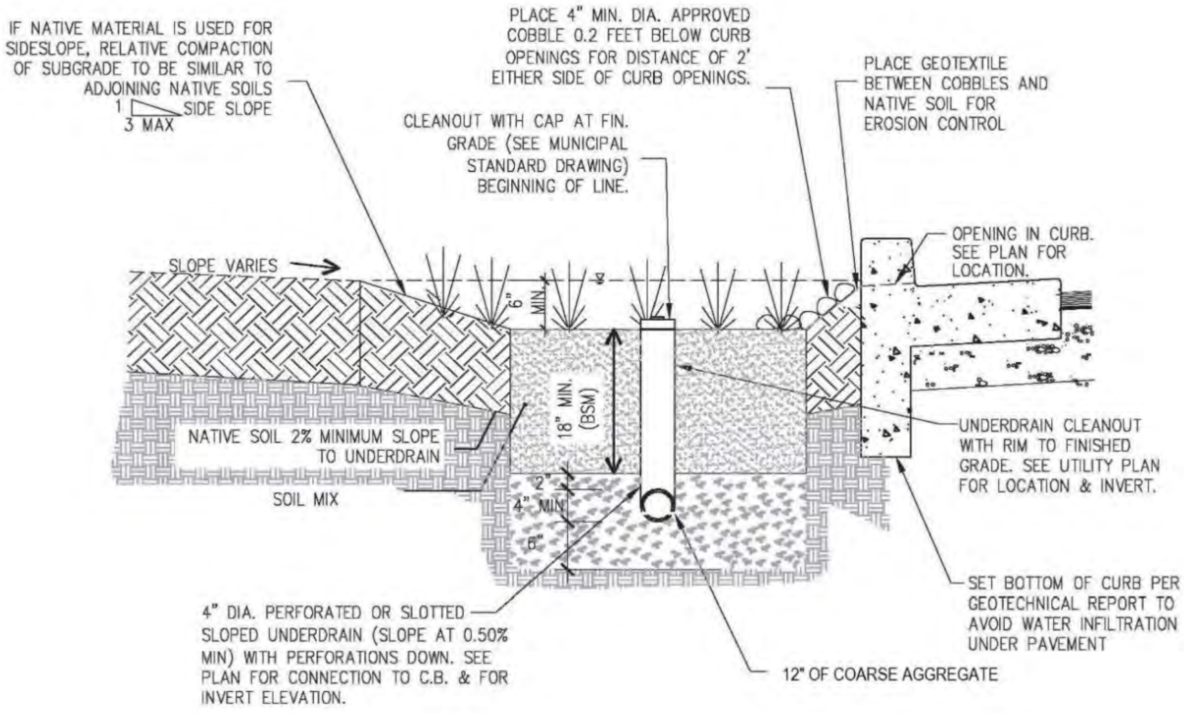
- Bioretention is not recommended for areas with slopes greater than 20% or where mature tree removal would be required since clogging may result, particularly if the facility receives runoff with high sediment loads.
- Unlined bioretention systems are not suitable at locations where the water table 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.

5.6.2. BIORETENTION DESIGN GUIDANCE

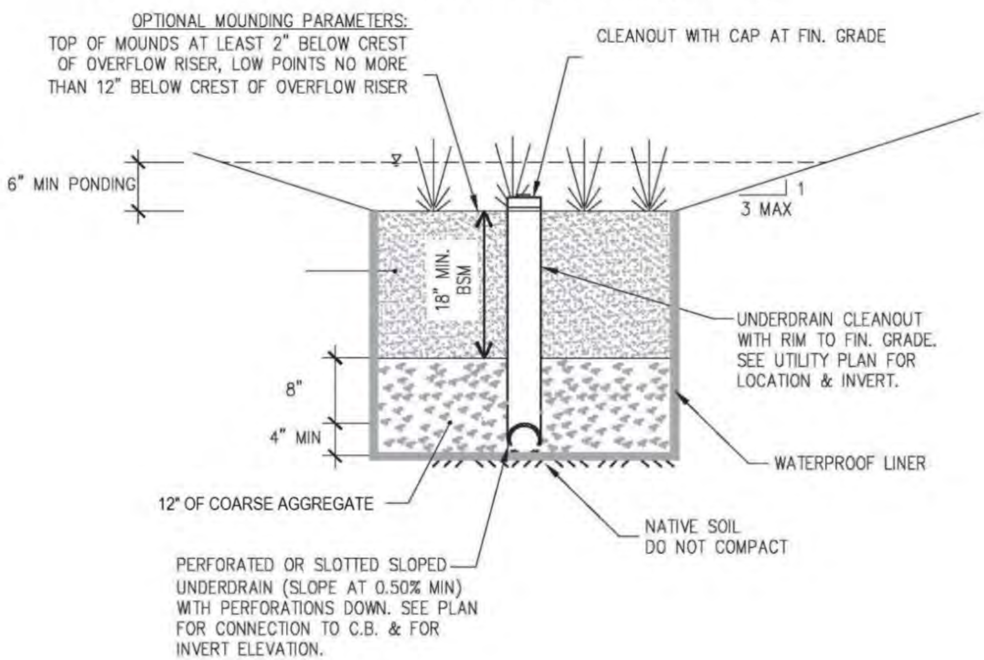
Bioretention facilities include inorganic and soil material in the filtration media to support vegetation. This allows these facilities to be integrated into site landscaping where they can provide unobtrusive treatment of stormwater runoff. The following design guidelines are appropriate for conventional 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 5-13, which illustrates recommended design components. The figure includes a grass filter strip for pretreatment of runoff to reduce sediment loading to the bioretention cell. While this is a useful component, it is not required and may not always 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.



Cross-section of bioretention area showing inlet from pavement.



Cross section of lined bioretention area (Not to Scale)

Figure 5-13: Schematic diagram of a bioretention system.

1. ***Bioretention Sizing:*** The storage volume above the surface of the planting media should be sufficient to retain the volume of runoff from a 1.5-inch rainfall. Water depth over the media for the design storm should not exceed 18 inches.

2. ***Inlet Design:*** When siting bioretention facilities to intercept drainage, the designer should attempt to use a 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.

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%. Soil mixtures should be 75-90% sand; 0-4% organic matter; and 10-25% screened bulk topsoil. 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 facility that may be harmful to plant growth or prove a hindrance to 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.

   A high-flow geotextile fabric or bridging stone is required to separate the soil media from the washed river gravel underdrain. A layer of pea gravel, a minimum of three inches thick will typically provide this bridge. This is an alternative to high-flow geotextile fabric.

   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. 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 5-14 for example). All piping is to be Schedule 40 PVC.

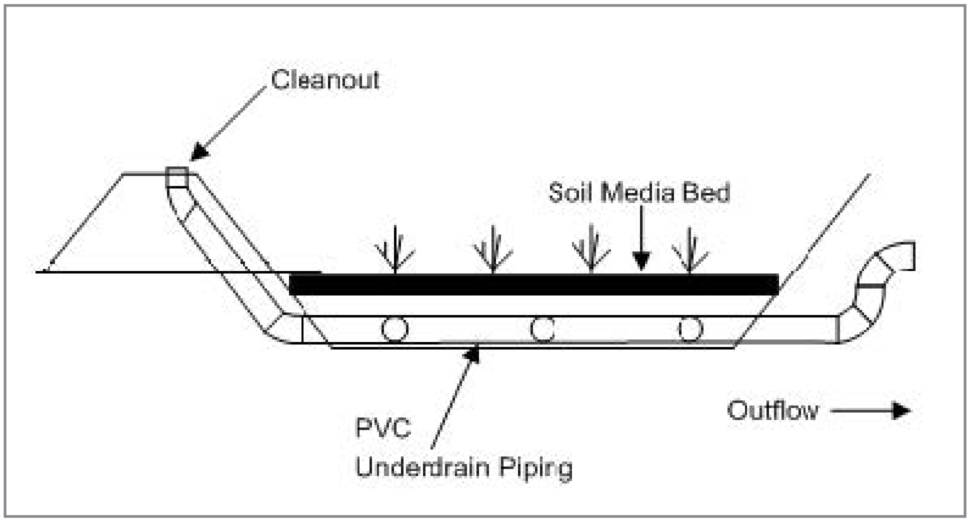


Figure 5-14: Detail of cleanout location.

5. ***Outlet:*** A raised outlet as illustrated in Figure 5-15 is optional. It has the potential advantage of reducing head-loss across the facility and providing a permanent pool that will supply additional water for plants during long dry periods.

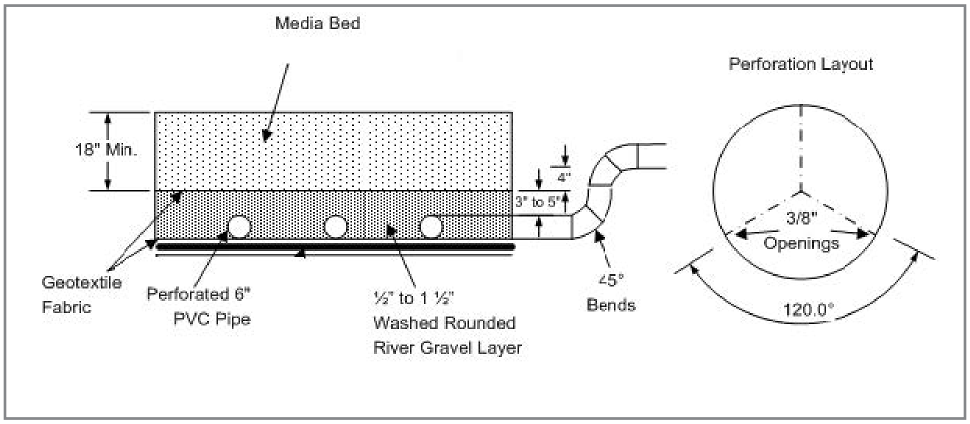


Figure 5-15: Illustration of optional outlet design.

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. If a low maintenance landscape is desired, Bermuda grass throughout the basin will function as an appropriate vegetative cover. No additional plants are necessary.

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

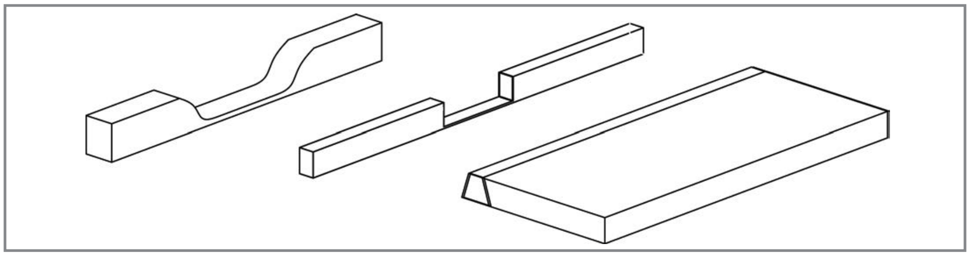


Figure 5-16: Curb cut options: smooth cut, hard cut and flush curb.

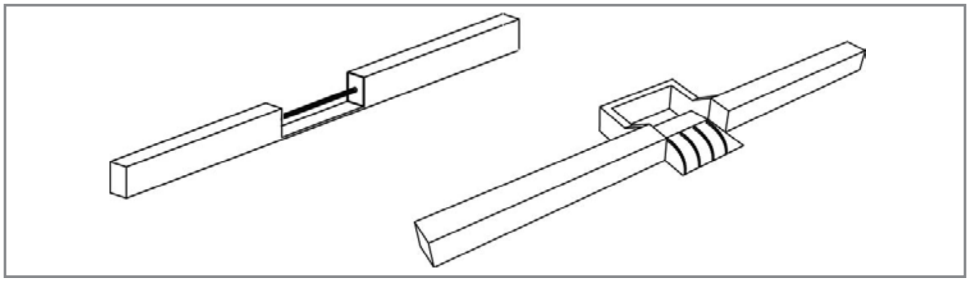


Figure 5-17: Curb cuts with optional sediment/trash screens.

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 the area from construction traffic and site runoff. Additionally, runoff from un-stabilized areas should be diverted away from the facility.

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

TREE BOX FILTERS – ROADSIDE BIORETENTION

Tree box filters are bioretention systems enclosed in concrete boxes or other sub-surface structures that drain runoff from paved areas via a standard storm drain inlet structure. They consist of a precast concrete (or other) container, a mulch layer, bioretention media mix, observation and cleanout pipes, under-drain pipes, a street tree or large shrub, and a grate cover.

DESIGN REQUIREMENTS

The ponding area in Tree Box Filters shall be designed with a maximum ponding depth of 24” and the capacity to drain ponded water within 24 hours. Other criteria include:

- Plants can also be selected from those that would be used in traditional bioretention systems (See Appendix A).
- An underdrain pipe is required to drain the feature.
- A maximum of 75% of the void space volume may be counted for detention.
- Pre-manufactured systems must be installed in accordance with the manufacturer’s instructions.

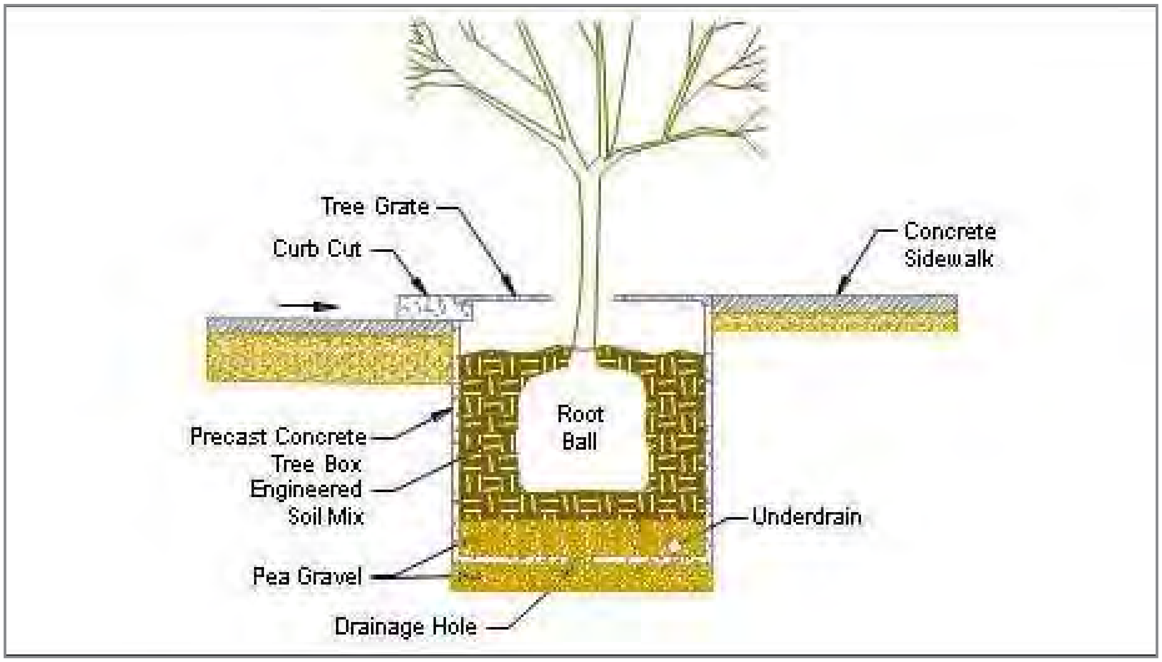


Figure 5-18: Tree Box Filters (Harris County LID Manual)

STORMWATER PLANTER BOXES – ROADSIDE AND BUILDING BIORETENTION

Storm Water Planters, also known as flow through planters, are bioretention systems enclosed in concrete structures. They can be designed to drain runoff from paved areas via curb inlet structures or pipes, or can be located under roof drain downspouts for treatment of roof runoff.

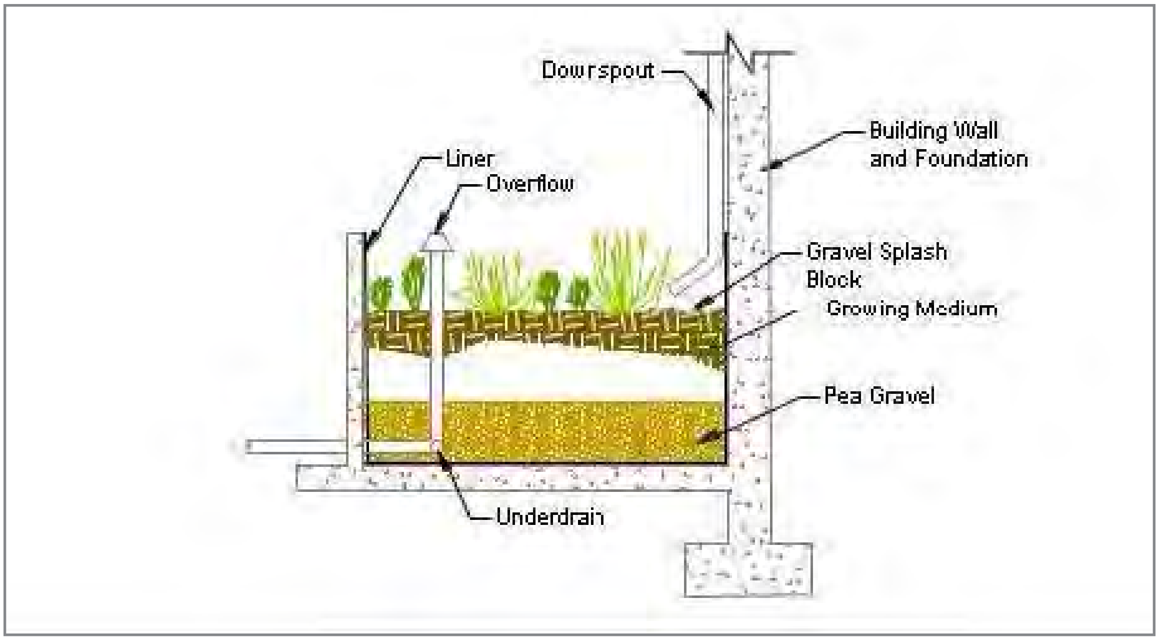


Figure 5-19: Stormwater Planter Box (Harris County LID Manual)

DESIGN REQUIREMENTS

- Waterproofing shall be incorporated into the designs of Storm Water Planters sited near buildings and other structures. An underdrain pipe is required.
- The ponding area in Storm Water Planters shall be designed with a maximum ponding depth of 24" and the capacity to drain ponded water within 24 hours.
- Plants can also be selected from those that would be used in traditional bioretention systems.
- Pre-manufactured systems must be installed in accordance with the manufacturer's instructions.

5.6.3. RECOMMENDED MAINTENANCE

The primary maintenance requirement for bioretention areas is routine inspection and repair or replacement of the treatment area's components. Generally, this involves nothing more than periodic maintenance that is required for landscaped area. Appropriate plants for the site, climate, and watering conditions should be selected for use in the bioretention cell. Properly selected or native 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 biological 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 trees and shrubs growing within the area and the subsequent removal of excessive dead or diseased vegetation. Diseased vegetation should be treated as needed using preventative and low-toxic measures to the highest 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. In some cases, the entire area may require mulch replacement every year, while in others spot mulching may be sufficient.

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

Other recommended maintenance guidelines include:

1. ***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.

2. ***Sediment Removal.*** Remove sediment when accumulated sediment hinders the flow of water into the facility.

3. ***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.

4. ***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.

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

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

5.7 INFILTRATION FACILITIES

5.7.1. INTORDUCTION

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 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 5-20.

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.

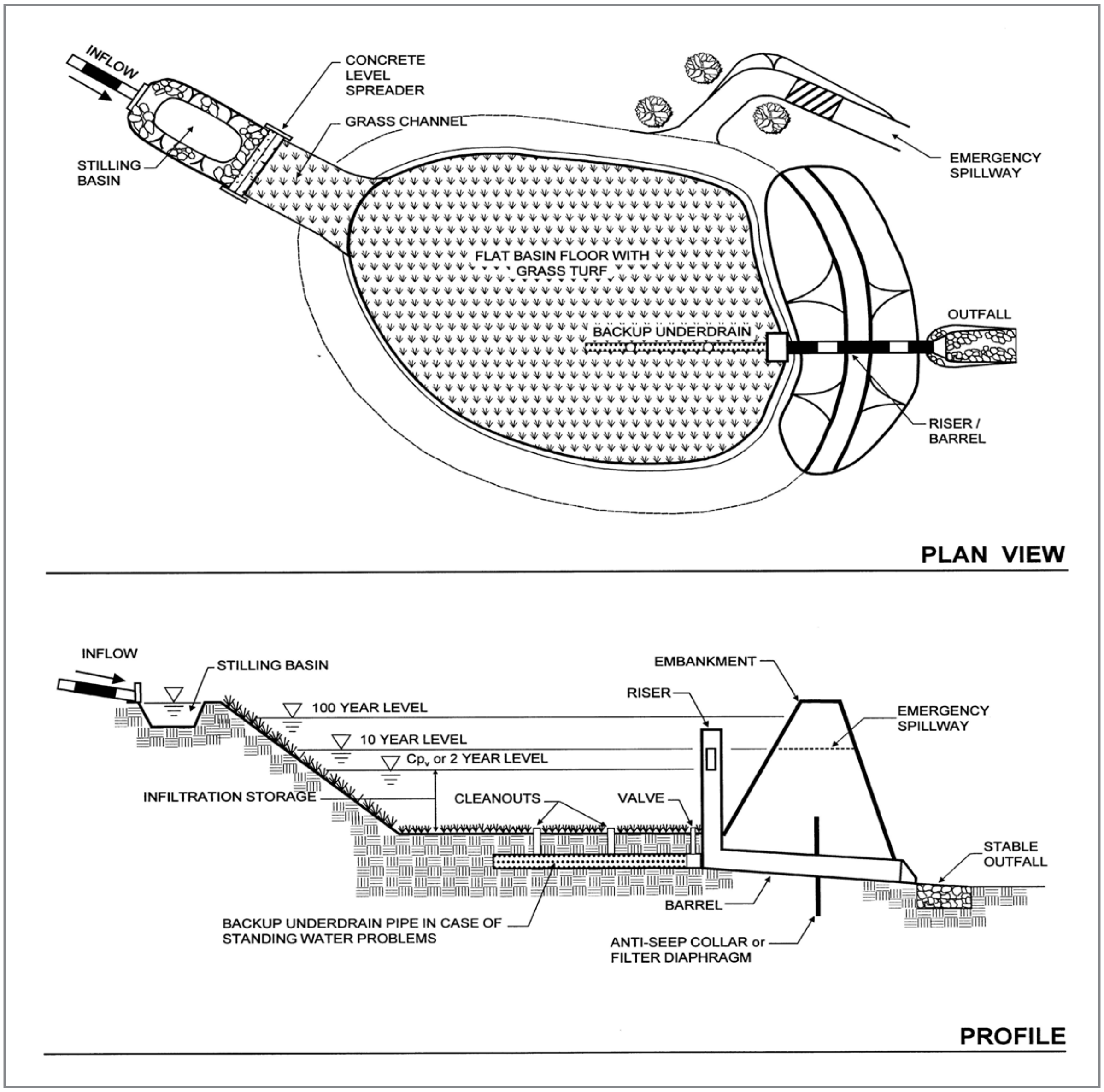


Figure 5-20: Infiltration Basin Schematic. (Photo courtesy of MDE, 2000)

ADVANTAGES

- This approach provides a 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

- Infiltration basins 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 which is not appropriate at sites with Hydrologic Soil Types C and D.
- Infiltration basins are not suitable on fill sites or steep slopes.
- Upstream drainage area must be completely stabilized before construction.
- Once clogged, it can be difficult to restore functioning of infiltration basins.
- Basin depth to groundwater should exceed 4 feet.

5.7.2. 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 1.5-inch rainfall event. Maximum water depth in the basin should not exceed 2.0 feet.
2. Provide pretreatment if sediment loading is a maintenance concern for the basin.
3. Include energy dissipation in the inlet design for the basins.
4. The bottom elevation shall be at least 4 feet above the seasonally high groundwater table.
5. Obtain soil borings to determine the soil infiltration rate.

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.
- Infiltration basins should be located away from buildings, slopes and highway pavement (by a distance greater than 20 feet) and away from wells and bridge structures (by a distance 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.

5.7.3. 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, the existence of standing water, and the accumulation trash debris, and sediment.
- 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 through the use of a hand-guided rotary tiller or a disc harrow pulled by a very light tractor.

5.8 RAINWATER HARVESTING

DEFINITION OF RAINWATER HARVESTING/CISTERN CREDIT

A credit is given when rainwater collection systems are used to retain roof runoff resulting in the reduction of the development impervious cover. Rainwater collection systems will generate an impervious cover reduction for the area that drains to the rainwater collection barrel(s) based on the ratio of the barrel volume to the roof (catchment) area. Rainwater collection can occur at single family residences, multi-family complexes, and commercial developments. This credit can be used to gain compliance with the Alternate Standards or reduce the water quality volume. The maximum impervious cover reduction is 75% to account for rainwater system maintenance and operation challenges that may occur over the system life.

Rainwater collection can also be used to satisfy the rooftop disconnection credit, but can not be counted as a credit for both rainwater harvesting and rooftop disconnection.

Reduced impervious cover credit is computed per the following equation and figure:

Ar = ART * %IC REDUCTION FACTOR (per Figure 5.21 below)

Where: Ar = Allowable reduction in impervious cover

ART = Area of roof-top directed to rain barrel(s) (catchment area) (sq ft)

% IC REDUCTION FACTOR = % Impervious area reduction

RBV = Rain barrel volume (cubic feet)

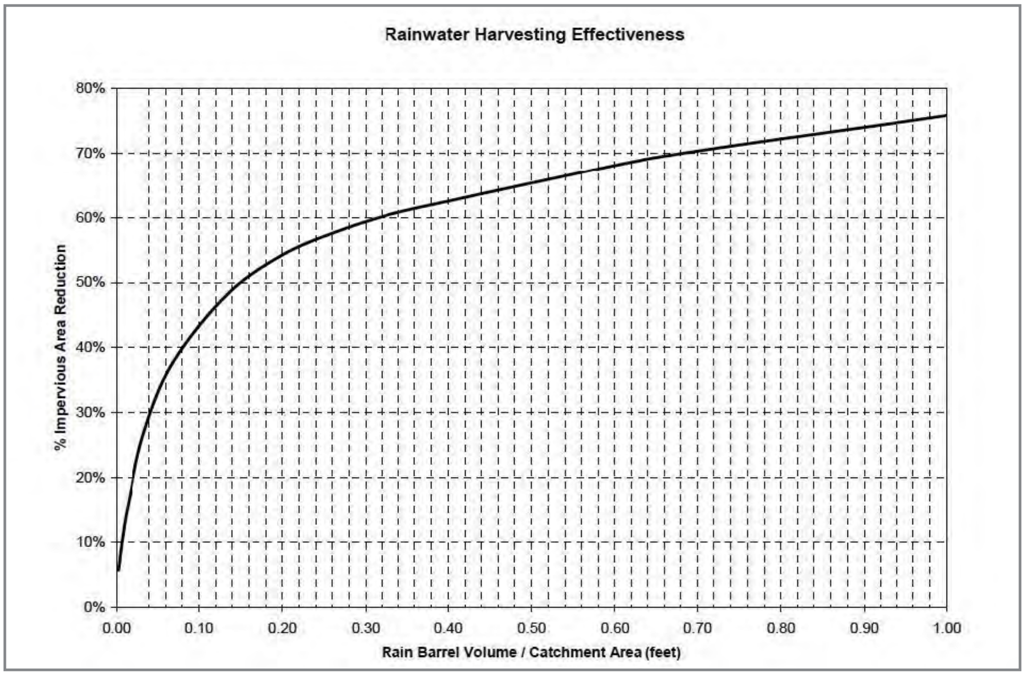


Figure 5-21: Rainwater Harvesting Effectiveness

RAINWATER COLLECTION CREDIT

Restrictions on the Credit: The rainwater harvesting credit is subject to the following restrictions:

- Rainwater collection and distribution systems must be designed and installed per the requirements in this Section.
- A rainwater collection system maintenance plan must be approved before issuance of a development permit. The maintenance plan will need to identify the responsible maintenance party and allow for periodic inspection.

- The development permit will include a condition that the contractor must contact the jurisdictional stormwater authority 48 hours prior to the final completion of the rainwater collection system.
- Storage shall be provided in cisterns, rain barrels, tanks, or other approved methods.
- Overflows from rainwater tanks should be diverted to grassy swales and/or lawns to promote infiltration of excess runoff volume.

Example calculation: The required water quality volume before the credit for a ten (10) acre site with 30 single family lots would be:

Impervious cover = 3 acres = 30%
1.5-inch storm runoff volume = 0.48 inches based on Equation 4.9
Water quality volume = (0.48 inches) * (10 acres) * (43,560/12) = 17,424 cubic- feet.

Applying the credit, each single-family lot will utilize a rainwater collection system per the criteria. Each house has a roof area of 2,000 square feet, however, individual roof design is not known at this phase, thus a factor of 0.75 is applied to the roof area, resulting in the assumption that 1,500 square feet can be drained to rainwater collection tanks. The home storage barrel(s) will provide 1,500 gallons of storage.

Roof area draining to collection barrels = 2,000 square feet * 0.75 = 1,500 square feet
Barrel volume = 1,500 gallons per plat note and deed restriction = 200 cubic feet
Barrel volume to catchment area = 200 / 1,500 = 0.13
Using the Rainwater Harvesting Effectiveness Figure, % IC Reduction = 43%
Ar = Allowable impervious cover reduction per house = (1,500) X (0.43) = 645 square feet
Impervious cover with credit = (3 acres) – ((30 lots) * (645 sq. ft)) = 2.56 acres
Effective impervious cover = 26%
1.5-inch storm runoff volume = 0.43 inches based on Equation 4.9
Water quality volume = (0.43 inches) * (10 acres) * (43,560/12) = 15,464 cubic-feet.

The BMP water quality volume is reduced by 11% in this example.

DESCRIPTION

Rainwater harvesting is a method of diverting and collecting rainfall that falls onto impervious surfaces, such as roofs. Harvested rainfall is typically used for indoor residential use, landscape irrigation, or both. By capturing and slowly releasing rooftop runoff over vegetated areas, rainwater harvesting can reduce stormwater volume and flow rates and the resultant erosion and pollutant discharges to surface waters. Schematics of a complex rainwater harvesting system are presented in Figures 5.22 and 5.23 below.

APPLICATION

In a rooftop rainwater harvesting system, runoff flows via gravity through gutters and downspouts into a storage tank where it is slowly released to landscaped areas or stored for later use. Rainwater harvesting systems are primarily designed for conservation— long-term storage and use—rather than to mitigate the impacts of impervious cover and increased runoff. If a tank is full or near-full (beneficial for conservation and long-term use) it will not provide stormwater benefits.

Rainwater harvesting systems can provide pretreatment for other BMPs and qualify for stormwater credit to reduce water quality basin size or gain compliance with the Alternate Standards. Collection systems are equally appropriate in large-scale landscapes, such as parks, schools, commercial sites, parking lots and apartment complexes and in small residential landscapes. Rainwater harvesting is a feasible alternative for intensively developed areas and is suitable for steep terrain and flat landscapes where collected water can be diverted to depressed landscaped areas or grassy swales.

Rooftop rainwater harvesting provides a lower-cost method of treating surface water runoff than other permanent water quality treatment structures. Costs include the storage tank, filtering system, and pressure pump. Routine maintenance is a minor expense but is essential for the system to properly function. In an effort to encourage water conservation, the State or local governments may provide financial incentives and tax exemptions to offset the equipment costs. Municipal incentives are also available in some areas.

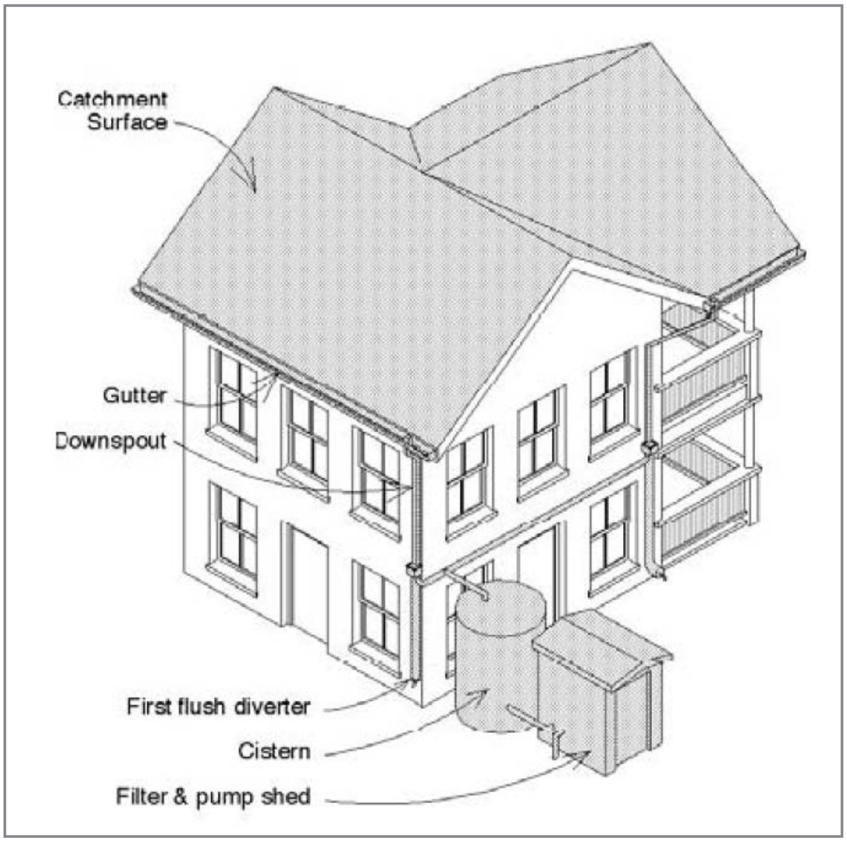


Figure 5-22: Complex water harvesting system (With roof catchment, gutter, downspout and storage tank City of Austin Energy's Green Building Fact Sheet, 1995).

Additional information can be found in the Texas Rainwater Harvesting Manual.

DESIGN GUIDELINES

Rainwater Harvesting is a system of collecting, conveying, and storing rainfall from impervious surfaces and directing water to where it is needed.

1. ***Catchment surface:*** The collection surface is the "footprint" of the roof. The effective collection surface is the length times the width of the roof from eave to eave and front to rear.

2. ***Conveyance systems:*** Gutters should be properly sized and located to maximize catchment efficiency and prevent overrunning. Overrunning can result from an inadequate number of downspouts, excessively long roof distances from ridge to eave, steep roof slopes, and inadequate gutter maintenance. Preventative strategies may include modifications to the size and configuration of gutters and addition of gutter boxes with downspouts and roof diverters near the eave edge. Gutters should slope towards the downspout with the outside face of the gutter lower than the inside face to encourage drainage away from the building wall. Downspouts should provide 1 square inch of downspout opening for every 100 square feet of roof area. The first flush runoff should outfall onto an adequately sized rock splash pad that will prevent erosion, channeling, or puddling.

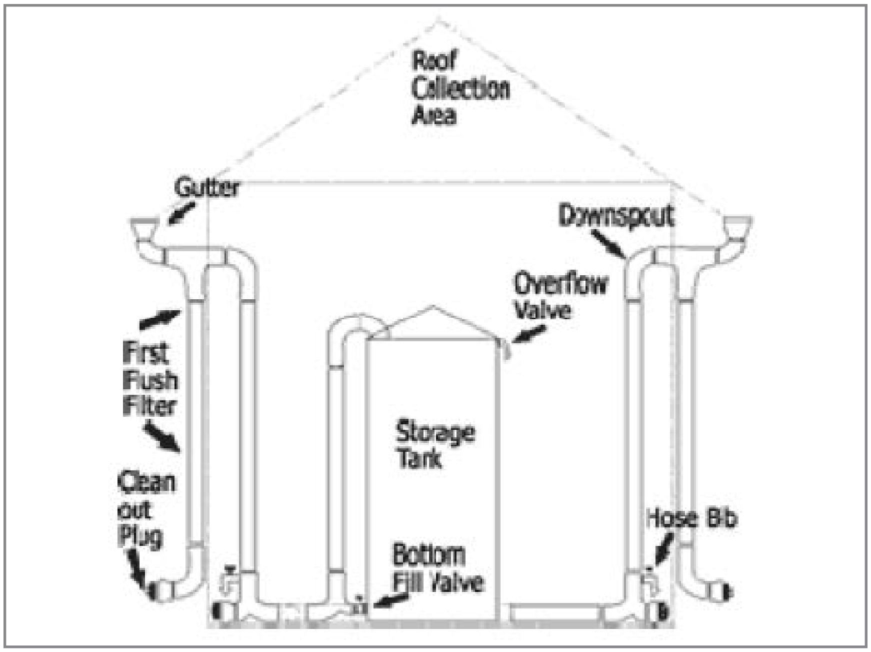


Figure 5-23: Complex water harvesting system (with roof catchment, gutter, downspout and storage tank. City of Austin Energy's Green Building Fact Sheet, 1995).

3. ***Storage - Filtration:*** Leaf screens, first-flush diverters, and roof washers should be installed on inflow lines to prevent trash and organics from entering the storage area. Permanent openings must be screened to prevent insect infestation in the piping and standpipe.

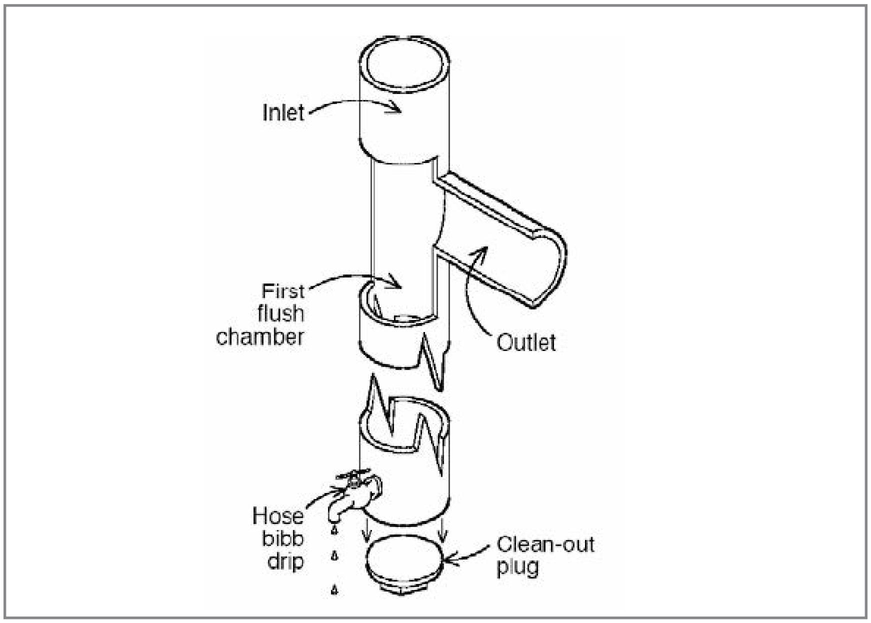


Figure 5-24: Standpipe first flush diverter. The recommended diversion of first flush ranges from one to two gallons of first-flush diversion for each 100 square feet of collection area. (TWDB, 2005)

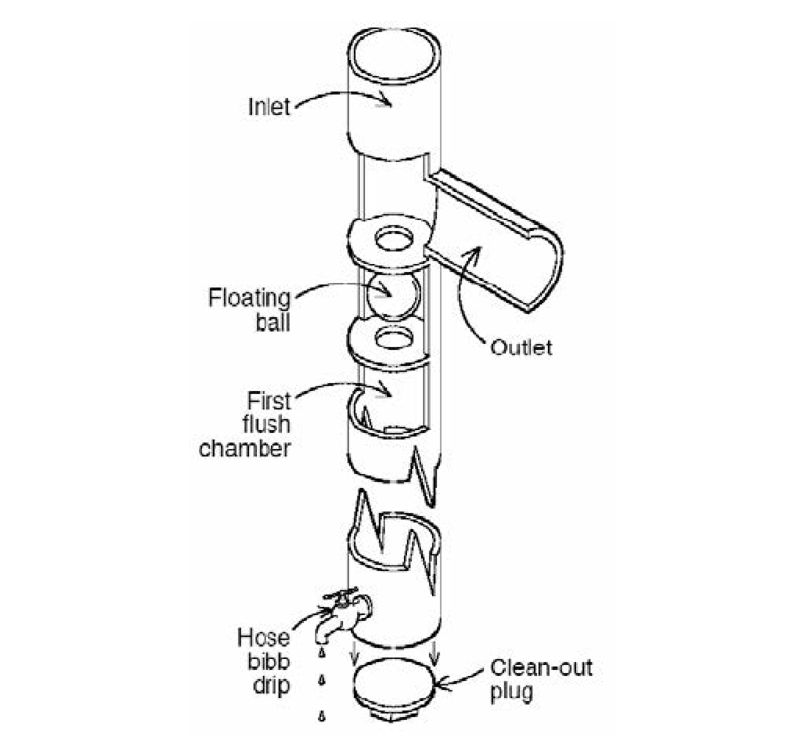


Figure 5-25: Standpipe with ball valve. The standpipe with ball valve is a variation of the standpipe filter. As the chamber fills, the ball floats up and seals on the seat, trapping first-flush water and routing the balance of the water to the tank. (TWDB, 2005)

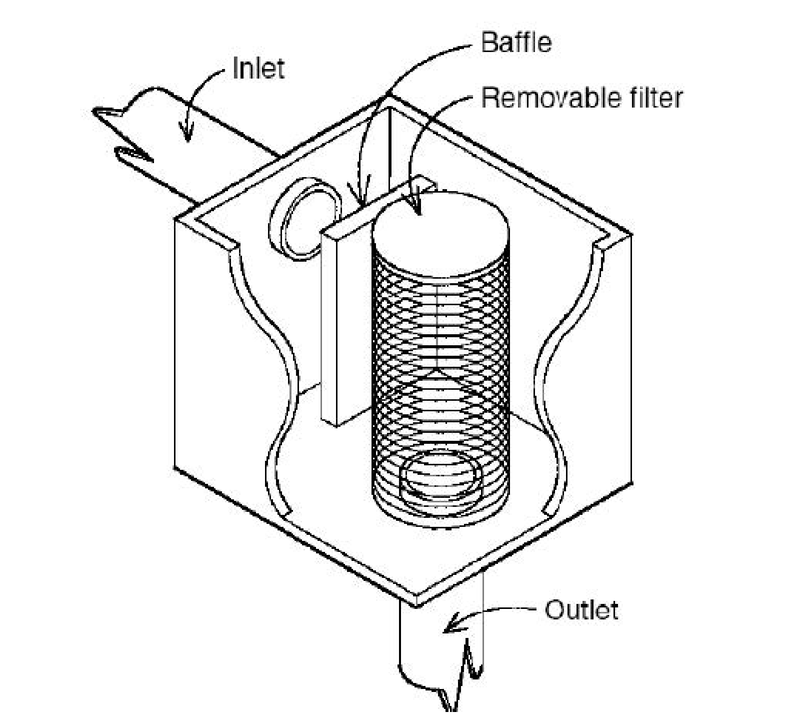


Figure 5-26: Box roof washer. Roof washers are recommended for drip irrigation systems. (TWDB, 2005)

4. ***Delivery system:*** The distribution directs water to plants from storage tanks to garden hoses, constructed (non-erosive) channels, or manual drip systems. Drip and other types of integrated distribution systems may require a small pressure pump to distribute the water. If a drip irrigation system is not used, water can gravity-flow to garden hoses. In addition, water harvested rainwater can be delivered to the house for domestic use.

5. ***Stormwater Credits:*** Stormwater credit is given when rooftop runoff is collected, stored per the volume requirements, and discharged through everyday consumption. The figure above illustrates the percentage of impervious cover reduction that can be obtained using the above listed criteria. The percentage of impervious cover reduction is based upon the percentage of rooftop runoff that is captured. A maximum reduction of 75% of rooftop impervious cover will be given. Credit is documented at the concept plan stage. Criteria for the rainwater harvesting system must be included in the deed restrictions to be eligible for stormwater credit

6. ***System Maintenance:*** The system should be checked annually and after every rainfall to ensure the system is operating optimally. The following maintenance should be conducted:

    - Keep debris out of holding areas;
    - Remove collected debris from the first-flush diversion standpipe after each rainfall event;
    - Control and prevent erosion;
    - Block and repair erosion trails;
    - Keep debris out of gutters and downspouts;
    - Flush debris from storage container bottoms;
    - Clean and maintain filters, especially those on drip irrigation systems;
    - Expand watering basins as plants grow; and
    - Roof washers must be readily accessible for regular maintenance.

5.9 NATURAL AREA PRESERVATION

DEFINITION OF NATURAL AREA PRESERVATION

A stormwater credit is given when natural areas are conserved at development sites, thereby retaining pre development hydrologic and water quality characteristics. For low impact development compliance, the preserved area is included in the impervious cover calculations to determine the gross development and cluster development impervious cover levels. The credit for stormwater basin volume is computed by subtracting the preserved area from the area draining to individual water quality basins. This credit is granted for all preservation areas permanently protected under conservation easements or other locally acceptable means. Examples of natural area conservation include:

- Wooded and meadow areas protected from disturbance
- Wetlands and associated buffers
- Creek buffers
- Other lands in protective easement (floodplains, open space, steep slopes)
- Stream systems

DAeff = DATOT - ANA

Where: DAeff = Effective drainage area

ANA = Natural area preserved

DATOT = Total drainage area

To receive the credit, the proposed preservation area:

- Must not be disturbed during project construction (e.g., cleared or graded) except for temporary impacts associated with selective management of invasive vegetation such as ashe juniper and incidental utility construction or mitigation projects (selective clearing of invasive vegetation shall be performed in a manner so as to not disturb the soil);
- Must be protected by having the limits of disturbance clearly shown on all construction drawings and be delineated in the field except as provided for above;
- Must be located within an acceptable conservation easement or other enforceable instrument that ensures perpetual protection of the proposed area. The easement must clearly specify how the natural area vegetation shall be managed and boundaries will be marked (Note: managed turf (playgrounds, regularly maintain open areas) is not an acceptable form of vegetation management); and
- Must be located on the development project.

Example calculation: The required water quality volume for a ten-acre site with three acres of impervious area and three acres of protected conservation area before the credit would be:

Impervious cover = 30%
1.5-inch storm runoff volume = 0.48 inches based on Equation 4-9
Water quality volume = (0.48 inches) * (10 acres) * (43,560/12) = 17,424 cubic- feet.

Applying the credit, three acres of conservation area is subtracted from total site area, which yields a smaller water quality basin volume. The impervious cover amount is not revised to reflect the smaller drainage area:

DAeff = (10 acres) – (3 acres) = 7 acres
Effective impervious cover = 30%
1-year runoff volume = 0.48 inches based on Equation 4-9
Water Quality Volume = (0.48 inches) * (7 acres) * (43,560/12) = 12,196 cubic-feet.

The BMP water quality storage volume is reduced by 30% in this example.

5.10 DISCONNECTION OF ROOFTOP RUNOFF

DEFINITION OF DISCONNECTION OF ROOFTOP RUNOFF CREDIT

A credit is given when rooftop runoff is disconnected and then directed to a pervious area where it can either infiltrate into the soil or filter over it. The credit is typically obtained by in areas with slopes less than 5% to promote overland filtering on single family residential lots.

If a rooftop is adequately disconnected, the disconnected impervious area can be deducted from total impervious cover (therefore potentially gaining compliance with the Low Impact Development impervious cover levels or reducing BMP volume). This credit is restricted to single family lots.

Table 5-1: Rooftop Disconnection Impervious Cover Credit

Disconnection Length Provided	0 to 14 ft.	15 to 29 ft.	30 to 44 ft.	45 to 59 ft.	61 to 74 ft.	> 75 ft.
% Impervious Cover Credit per By Disconnect (No Storage Volume)	10%	20%	40%	60%	80%	100%
Dry Well, Rainwater Collection, Rain Garden Storage Volume Required to achieve 100% Impervious Cover Credit in Combination with flow length	104 cu-ft.	83 cu-ft.	62 cu-ft.	42 cu-ft.	21 cu-ft.	0 cu-ft.

Source: LCRA Highland Lakes Water Quality Technical Manual.

Ar = ART * %ICD

Where: Ar = Allowable reduction in impervious cover

ART = Area of roof-top

%ICD = Impervious cover credit factor per the above Table

RESTRICTIONS ON THE CREDIT

The rooftop disconnection is restricted to single-family lots and subject to the following restrictions:

- The contributing area of rooftop to a disconnected discharge shall be 800 square feet or less;
- The length of "disconnection" shall be 75 feet or greater, or compensated using the above table;
- Disconnections will only be credited for lot sizes greater than 5,000 sq. ft;
- The length of "disconnection" shall be on an average slope of less than 5%;
- The entire vegetative "disconnection" shall have a minimum soil depth of 4 to 6 inches. Builders and owners will import soil if needed to achieve sufficient soil depth. Soil shall satisfy the import soil specifications found in the following Soil Amendment Credit
- The disconnection must drain continuously through a vegetated swale or across the vegetated landscape to the roadside curb, conveyance system, or BMP;
- The vegetated landscape should use appropriate turf grasses;
- Downspouts must be at least 10 feet away from the nearest impervious surface to discourage "re-connections;"
- Dry wells, French drains, rainwater collection tanks, or rain gardens (small bioretention areas) may be utilized to compensate for areas with disconnection lengths less than 75 feet. The volume shall be equal to the requirements found in the above table to receive 100% reduction in impervious cover. See Schematic of Dry Well in Figure 5.27;

- For those rooftops draining directly to a creek buffer, a rooftop disconnection credit can be used;
- Credit is documented during the development permit process and verified with the final grading plan as part of the development permit; and
- When more than one downspout drains in one direction, the shortest disconnection length will be used in the above table to determine the impervious cover deduction. For example, if the front and back downspout on one side of the house both drain towards the street (flow is combined), the distance from the front downspout to the street will be used as the disconnection length.

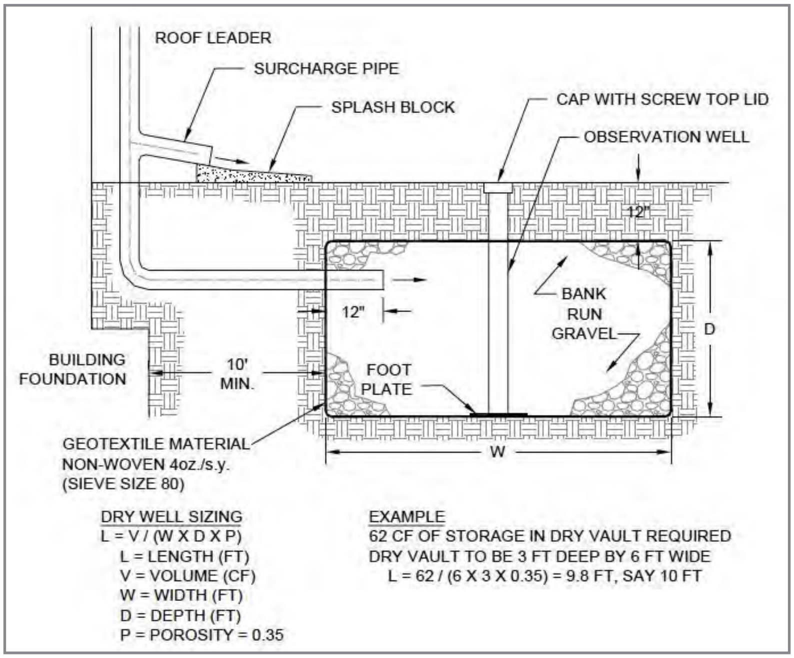


Figure 5-27: Schematic of Dry Well

Example calculation: the required water quality volume before the credit for a ten acre site with 30 single family lots would be:

Impervious cover = 3 acres = 30%
1.5-inch storm runoff volume = 0.48 inches based on Equation 2-9
Water quality volume = (0.48 inches) * (10 acres) * (43,560/12) = 17,424 cubic- feet.

Applying the credit, each single-family lot has a travel length of 35 feet from the house to the roadside curb and the lawns satisfy the vegetative cover requirement by using turf grasses. The designer chooses not to incorporate additional storage (dry wells, rain gardens, etc.) to increase credit. Thus, each house impervious cover is reduced by 40% per Table 5-1.

House roof area = 2000 square feet
40% impervious cover credit for roof from above table
Ar = Allowable impervious cover reduction per house = (2000) * (0.40) = 800 square feet
Impervious cover with credit = (3 acres) – ((30 lots) * (800 sq. ft)) = 2.45 acres
Effective impervious cover = 25%
1.5-inch storm runoff volume = 0.41 inches based on Equation 4-9
Water Quality Volume = (0.41 inches) * (10 acres) * (43,560/12) = 14,974 cubic-feet.

The BMP water quality storage volume is reduced by 14% in this example.

5.11 SOIL AMENDMENT

DEFINITION OF SOIL AMENDMENT AND CONSERVATION LANDSCAPING CREDITS

A credit is given when lawns and landscape areas within the development utilize the Soil Amendment or Conservation Landscaping guidance in this section. The benefit of these designs over more traditional lawns is the placement of sufficient soil depth and appropriate vegetation that promotes infiltration and less stormwater runoff.

The Soil Amendment Credit relies on native soils, appropriate soil depths, and low maintenance turf grasses to reduce the runoff volume. The stormwater credit for Soil Amendment is the reduction of project impervious cover by 2%.

The Conservation Landscaping Credit is based upon planting a reduced turf area and incorporating native plants, shrubs, trees and perennials to retain stormwater on site and require minimal chemicals to sustain a native and colorful landscape. The stormwater credit for Conservation Landscaping is the reduction of impervious cover by 5%.

These credits can be used to gain compliance with the Low Impact Development approach or reduce the stormwater basin water quality volume.

Ar = AD * 0.02

Where: Ar = Allowable reduction in impervious cover

AD = Area of development

RESTRICTIONS ON THE CREDIT

The soil amendment credit is subject to the following restrictions:

- Home-builders coordinate with the jurisdictional stormwater authority during soil placement. This coordination will be identified as a permit condition and will allow inspection of the soil depth and quality prior to grass placement.
- The soil amendment requirement shall be noted on the plat and included in the development deed restrictions.

Example calculation: the required water quality volume before the credit for a ten (10) acre site with 30 single family lots would be:

Impervious cover = 3 acres = 30%

1.5-inch storm runoff volume = 0.48 inches based on Equation 4.9

Water quality volume = (0.48 inches) * (10 acres) * (43,560/12) = 17,424 cubic- feet.

Applying the credit, the developer and home-builders agree to place grass and soil per the soil amendment specifications. Thus, the project impervious cover is reduced by 2%.

In this example, Ar = (10 acres) * (0.02) = 0.2 acres

Effective impervious cover = (3 acres) – (0.2 acres) = 2.8 acres = 2.8/10 = 28%

1-year Runoff Volume = 0.45 inches based on Equation 4.9

Water Quality Volume = (0.45 inches) * (10 acres) * (43,560/12) = 16,444 cubic-feet.

The BMP water quality volume is reduced by 5% in this example.

This option is intended to provide builders and homeowners with a well-designed and resource efficient landscape.

DESCRIPTION

Naturally occurring undisturbed soil and vegetation provide important stormwater functions including: water infiltration; nutrient, sediment, and pollutant adsorption; sediment and pollutant biofiltration; water interflow, storage and transmission; and pollutant decomposition. These functions are largely lost when development strips away native soil and vegetation and replaces it with minimal topsoil and sod. Not only are these important stormwater functions lost, but such landscapes themselves become pollution- generating pervious surfaces due to the increased use of pesticides, fertilizers and other landscaping and household/ industrial chemicals, the concentration of pet wastes, and added pollutants that accompany roadside litter.

Establishing soil quality and depth regains greater stormwater functions in the post development landscape, provides increased treatment of pollutants and sediments that result from development and habitation, and minimizes landscaping chemical need. As a result, these preventative measures effectively reduce pollution. Soil amendment and the usage of appropriate turf provide a practical and cost-effective mechanism to mitigate stormwater runoff pollution and treatment.

Establishing a minimum soil quality and depth will provide improved on-site management of stormwater flow and water quality. Soil organic matter can be attained through materials such as composted herbaceous and woody material, biosolids, and forest product residuals. It is important that the materials used to meet the soil quality and depth requirements are appropriate and beneficial to the establishment of plant cover. Likewise, imported topsoil should improve conditions and avoid excessive percentages of clay fines.

DESIGN GUIDELINES

The soil amendment credit is subject to the following guidelines and restrictions:

1. ***Stockpile Topsoil:*** Salvaged topsoil from the site should be used whenever possible. In any areas requiring grading, remove and stockpile topsoil on site in a designated controlled area to be reapplied to other portions of the site where feasible. Stockpiled soils must be protected from erosion with appropriate temporary erosion controls and cannot be placed adjacent to surface waters, within the buffer zones or in areas with concentrated flow.

2. ***Soil Depth:*** All newly planted turf areas will have a minimum soil depth of 6 to 8 inches. Builders and owners will import soil if needed to achieve sufficient soil depth. Soil in these areas may be either native soil from the site or imported, improved soil.

3. ***Import Soil:*** Topsoil must be weed free, contain a minimum of 20% compost by volume, contain less than 20% clay, and be free of stones, stumps, roots or other similar objects larger than one (1) inch. If on-site soils do not meet these specifications, topsoil per the above specs must be added. Sandy loam is not an approved soil and caliche is not considered a soil.

4. ***Import Soil Application:*** Topsoil that is added to the site shall be incorporated in a 2 to 3- inch scarified transition layer to improve drainage. Do not scarify within a drip line of existing trees to be retained.

5. ***Soil Inspection:*** Home-builders should coordinate with the jurisdictional stormwater authority after topsoil has been spread on the site immediately prior to laying sod.

6. ***Turf:*** Turf is required and shall be Bermuda, buffalo, or zoysia sod.

7. ***Slope Limitation:*** The soil amendment cannot be used on slopes greater than 20%, in areas subject to concentrated flows or any sensitive areas to minimize potential discharge of soil to waterways.

8. ***Roadside Revegetation:*** Utilizing native seed in revegetation of roadsides and other areas helps preserve ecosystem integrity. Native grasses and wildflowers are well adapted to the environment and provide a low maintenance, resilient long-term landscape. A recent study conducted by the Landscape Restoration Program at the Lady Bird Johnson Wildflower Center demonstrated that commercial grass mixes consisting of native plant species seeds performed as well or better than mixes containing Bermuda grass, a popular and widely used invasive grass species.

Conservation Landscaping

Ar = AD * 0.05

Where: Ar = Allowable reduction in impervious cover

AD = Area of development

RESTRICTIONS ON THE CREDIT

The conservation landscaping credit is subject to the following restrictions:

- Home-builders coordinate with the jurisdictional stormwater authority during landscape installation. This coordination will be identified as a permit condition and will allow inspection of soil depth and quality prior to grass placement.
- The soil amendment requirement shall be noted on the plat and included in the development deed restrictions.

Example calculation: the required water quality volume before the credit for a ten (10) acre site with 30 single family lots would be:

Impervious cover = 3 acres = 30%
1-year runoff volume = 0.48 inches based on Equation 4.9
Water quality volume = (0.48 inches) * (10 acres) * (43,560/12) = 17,424 cubic- feet.

Applying the credit, the developer and home-builders agree to install conservation landscaping per the specifications. Thus, the project impervious cover is reduced by 5%.

In this example, Ar = (10 acres) * (0.05) = 0.5 acres
Effective impervious cover = (3 acres) – (0.5 acres) = 2.5 acres = 2.5/10 = 25%
1-year Runoff Volume = 0.41 inches based on Equation 4.9
Water Quality Volume = (0.41 inches) * (10 acres) * (43,560/12) = 14,974 cubic-feet.

The BMP water quality volume is reduced by 14% in this example.

DESCRIPTION

Native vegetation is best suited to local climate and soils. Existing native vegetation should be conserved and protected where possible. Where new planting is required, the use of native plants will increase plant survival and decrease the cost of subsequent plant replacement. Reapplication of organic compost or mulch every few years may be necessary to maintain positive soil infiltration characteristics. The initial costs of native plants, trees, shrubs, and soil amendments are recouped through significant reductions in water, fertilizer and pesticide use, as well as increased plant survival within the first few years after planting.

Conservation landscaping and native vegetation are equally appropriate in large-scale landscapes, such as parks, schools, commercial sites, parking lots, apartment complexes and in small residential landscapes.

Four major components that increase landscape sustainability are: adequate quantity of high- quality soil, implementation of efficient irrigation, appropriate turf and plant choice, and installation. Along with obtaining a stormwater credit and protecting water quality, this landscape option will save the homeowner time and money through reduced lawn watering requirements and mowing needs. Below is a sample design comparison between a conservation landscape design and a conventional landscape design for a lot with a front yard measuring 70 feet wide and 50 feet deep. The conservation option is composed of shrubs, perennials and ground covers that are watered every 14 days and turf that is watered once a week. The conventional lot front yard is comprised mainly of turf and a few shrubs watered three times a week.

Figure 5-28: Sample Costs Over 10 years (Actual Costs Will Vary)

	Soil Amendment Landscape	Conventional Landscape
Installation Cost	$3,293	$2,440
Yard Care Time	425 hours	615 hours
Water Cost	$360	$1,440
Treatment Cost	$50	$500
Total Time and Cost	**$3,703**	**$4,380**

As shown above, the conservation option costs $677 less and requires 190 hours less yard care and maintenance.

Source: LCRA, Texas Hill Country Landscape Option, 2005

DESIGN GUIDELINES

The soil amendment credit is subject to the following guidelines and restrictions:

1. ***Stockpile Topsoil:*** Salvaged topsoil from the site should be used whenever possible. In any areas requiring grading, remove and stockpile topsoil on site in a designated controlled area to be reapplied to other portions of the site where feasible. Stockpiled soils must be protected from erosion with appropriate temporary erosion controls and cannot be placed adjacent to surface waters, within the buffer zones or in areas with concentrated flow.

2. ***Soil Depth:*** All newly planted turf areas will have a minimum soil depth of 6 to 8 inches. Builders and owners will import soil if needed to achieve sufficient soil depth. Soil in these areas may be either native soil from the site or imported, improved soil.

3. ***Import Soil:*** Topsoil for turf areas must be weed free, contain a minimum of 20% compost by volume, contain less than 20% clay, and be free of stones, stumps, roots or other similar objects larger than one (1) inch. If on-site soils do not meet these specifications, topsoil per the above specs must be added. Sandy loam is not an approved soil and caliche is not considered a soil.

4. ***Import Soil Application:*** Topsoil that is added to the site shall be incorporated in a 2 to 3- inch scarified transition layer to improve drainage. Do not scarify within a drip line of existing trees to be retained.

5. ***Soil Inspection:*** Home-builders should coordinate with jurisdictional stormwater authority after topsoil has been spread on the site immediately prior to laying sod.

6. ***Turf:*** Turf shall be Bermuda, buffalo, or zoysia sod. A maximum 30% of the lot can be covered in turf. The remainder of the lot will follow the Hill Country Landscape Option that relies on native trees, shrubs, and perennials.

7. ***Irrigation:*** Spray irrigation shall be limited to 2.5 times the foundation footprint with a maximum of 12,000 square feet. The footprint may include the house and garage but not the driveway or patio.

8. ***Undisturbed Area Requirement:*** For lots greater than 15,000 square feet, no less than 25% of the lot shall remain in a natural condition (no grading, planting sod, etc.). Removal of scrub brush and other invasive species can be performed by hand clearing methods to restore native vegetation and grasses. This area shall not be irrigated. Deed restrictions and plat notes will be necessary to ensure natural area preservation.

5.12 DEALING WITH MULTIPLE STORM WATER CREDITS

Site designers are encouraged to perform a development design that works with natural topography, soils, and vegetation to utilize as many credits as possible. Greater reductions in stormwater storage volumes can be achieved when credits are combined (e.g., disconnecting rooftops and protecting natural conservation areas). The use of multiple credits can gain compliance with the Low Impact Development (LID) approach or significantly reduce water quality basin size and cost.

Example: Combined Use of Multiple Stormwater Credits to Achieve Alternate Standards Compliance

Development area = 10 acres
40 single-family lots
Lot sizes average 9,500 square feet (70 feet by 135 feet)
Lot impervious cover = 2,500 square feet/lot per Table 4-2
Use roadside swales, not curb and gutter to gain Alternate Standards Compliance
Proposed impervious cover = 3.4 acres = 34%
Maximum allowed impervious cover for Low Impact Development = 20%
Need to use Stormwater Credits to achieve 20% effective impervious cover

Use pervious pavement credit for driveways; receive 90% I.C. credit for pervious pavement area
Driveway Area = 800 square feet (50 feet long by 16 feet wide)
Ar = Allowable impervious cover reduction = (40 lots) * (800 sq ft) * (0.90) = 0.66 acres

Use roof-top disconnection credit for lots with slopes less than 5%

Flow length from home to street = 50 feet, however only 30 lots meet 5% slope limitation
Designer chooses not to include rainwater gardens or dry wells to gain additional credit
Impervious cover reduction = 60% per Table 5-1
Roof Area = 2500 – 800 (driveway area) = 1,700 square feet
Ar = Allow. Imp. Cover Reduction. = (30 lots) * (1,700 sq ft) * (0.60) / 43,560 = 0.70 ac
ICeff = (IC TOT) – (Sum of Ar) = (3.4 acres) - (0.70 + 0.66) = 2.0 acres
ICeff = Effective Impervious Cover = 2.0 / 10 = 20 %

Combining pervious driveways and disconnected impervious cover create a development project where the Low Impact Development approach is met and the project does not need to construct stormwater basins.

No water quality design for permanent BMPs is necessary. The designer may proceed to the preparation of an erosion and sedimentation control plan and coordinate with the jurisdictional stormwater authority to develop appropriate water quality education programs for residents.

CHAPTER 6

Incorporating Practices into Existing Development - Retrofits / Hydromodification Avoidance

6.1 RETROFIT PLANNING

While new development may be required to manage stormwater on-site, older developments may have been constructed before stormwater management was required or modern criteria were established. Retrofits include new installations or upgrades to existing BMPs in developed areas where there is a lack of adequate stormwater treatment. Stormwater retrofit goals may include, among other things, correcting prior design or performance deficiencies, mitigating flood impacts, disconnecting impervious areas, improving recharge and infiltration performance, addressing pollutants of concern, demonstrating new technologies, and supporting stream restoration activities. Retrofits can be designed to target trash, sediment, nutrients, or other concerns. Common retrofit locations include public open spaces and large parking lots. Often, retrofits can be completed in tandem with other capital projects including roads and parks to achieve multiple benefits and manage cost.

Many grant opportunities for funding retrofit projects exist. Please see Appendix F in this guidance manual for a list of potential grant partners.

While all retrofit sites are unique and no single solution fits all, preferred practices generally provide for increased infiltration, evapotranspiration and rainwater harvesting. Practices such as these reduce stormwater runoff volume while also providing water quality and supply benefits. Retrofits that provide for infiltration (e.g., infiltration basins and trenches, bioretention systems, rain gardens, and swales) where little or no infiltration currently exists are likely to improve site hydrology. Infiltration practices also help to recharge groundwater aquifers, although practices located near public drinking water sources should carefully consider the impact of infiltrating stormwater discharges on drinking water sources. In many cases, retrofits provide an opportunity to remedy past design and/or performance deficiencies.

Depending on the water quality goals for the watershed, communities should also consider retrofitting existing BMPs to maximize pollutant removal. The retrofitting of dry detention ponds, for instance, may provide the most cost-effective approach to capture and treat large drainage areas.

Most of the content in this section is from the EPA Retrofit Guidance.

Table 6-1: Purpose of the Eight Steps in the Stormwater Retrofitting Process

Step and Purpose	Key Tasks
Step 1: Retrofit Scoping Refine the retrofit strategy to meet local restoration objectives.	• Screen for subwatershed retrofit potential • Review past, current and future stormwater • Define core retrofitting objectives • Translate into minimum performance criteria • Define preferred retrofit treatment options • Scope out retrofit effort needed
Step 2: Desktop Retrofit Analysis Search for potential retrofit sites across the subwatershed	• Secure GIS and other mapping • Conduct desktop search for retrofit sites • Prepare base maps for RRI
Step 3 : Retrofit Reconnaissance Investigate feasibility of retrofit sites in the field	• Advanced preparation • Evaluate individual sites during RRI • Finalize RRI sheets back in office
Step 4: Compile Retrofit Inventory Develop initial concepts for best retrofit sites	• Complete storage retrofit concept designs • Finalize on-site retrofit delivery methods • Assemble retrofit inventory
Step 5: Retrofit Evaluation and Ranking Choose the most feasible and cost-effective sites	• Neighborhood consultation • Develop retrofit screening criteria • Create retrofit project priority list
Step 6: Subwatershed Treatment Analysis Determine if retrofits can achieve subwatershed restoration objective	• Compute pollutant removal by storage retrofit • Compute pollutant removal by on-site retrofits • Compare against restoration objective
Step 7: Final Design and Construction Assemble design package to lead to successful retrofit construction	• Secure environmental permits • Obtain landowner approval and easements • Perform special engineering, studies • Put together final design package • Contract and project management
Step 8: Inspection, Maintenance & Evaluation Ensure retrofits are working property and achieving subwatershed objectives	• Construction inspection • Retrofit maintenance • Project tracking and monitoring

Figure 6-1: Adding a Bioretention basin (rain garden) in a municipal park

Figure 6-2: Adding a bioswale at edge of a parking lot

Figure 6-3: Adding a sand filter to treat parking lot runoff

THE STORMWATER RETROFIT PROCESS

1. Evaluate the need and capacity for retrofitting in your community. Determine if your jurisdiction falls within an ongoing or planned Watershed Protection Plan or other Total Maximum Daily Load (TMDL) watersheds and identify your pollutant reduction requirements. If there are redevelopment projects in the planning stage, identify any local requirements for improving on-site stormwater management and assess grant opportunities to support the inclusion of water quality treatment into the project. See Appendix E for a list of potential grant resources.

2. Using Geographic Information System (GIS) software, institutional knowledge, and construction plans as appropriate, identify potential retrofit locations at publicly-owned properties (e.g., parks, schools, and municipal maintenance yards), street rights-of-way, culverts/outfalls, and existing detention practices. Target large parking lots, rooftops, or other impervious areas (public or privately-owned) that lack stormwater management and are considered directly connected to creeks and tidal waters. Identify sites that are prone to flooding, chronic contamination, and/or have a high maintenance burden.

3. Conduct a retrofit investigation by visiting each location to verify current conditions and identify potential retrofit treatment options and constraints. Use this opportunity to verify if impervious cover on site is directly-connected to the streams or tidal waters. Eliminate sites where retrofitting is infeasible or impractical due to existing constraints (e.g., land use, environmental conditions, presence of utilities, or other limitations).

4. Develop an inventory of potential retrofit candidates, with illustrative concept sketches, site photos, and basic drainage calculations. Concept sketches can be done by hand. Once priorities have been identified, concepts can be further advanced to engineering design and construction plans.

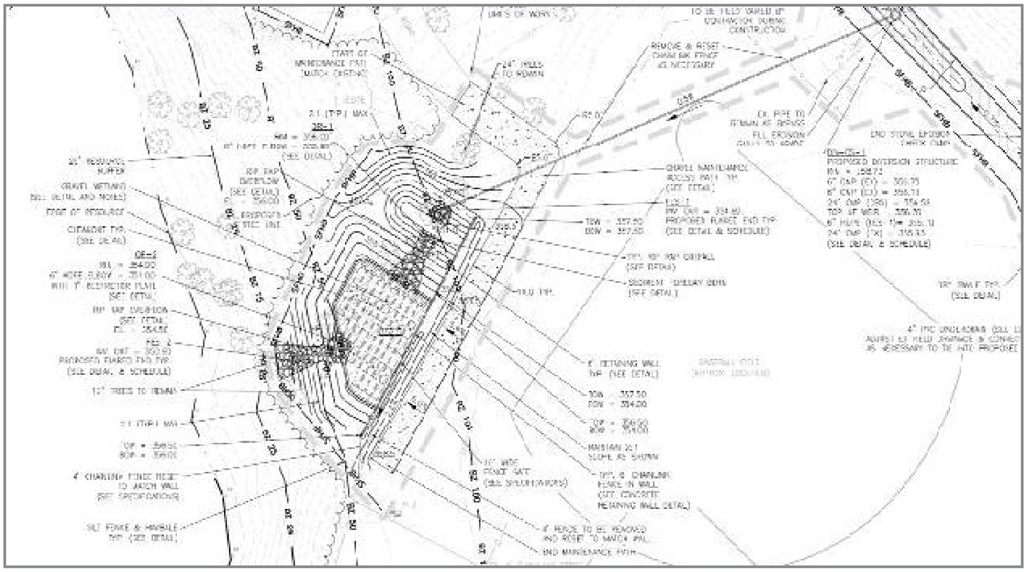


Figure 6-4: Retrofit Concept Sketch

5. Evaluate and rank retrofit concepts based on predetermined factors such as pollutant reduction requirements, BMP feasibility and performance, impervious cover disconnection, cost, visibility, property ownership, and community support. Structural control measures include practices that reduce or disconnect impervious cover, enhance infiltration, or otherwise treat stormwater. Non-structural measures include pollution prevention and source control activities (e.g., street sweeping). Retrofits should also be viewed as demonstration projects to highlight water quality management in your community.

6. Model watershed treatment benefits for various implementation scenarios to help determine the most cost-effective approaches to implementation to maximize pollution management per dollar spent. There are a number of existing public models that could be used to assist in the evaluation of implementation

scenarios including the design guidance found in Chapter 4 in this guidance manual. Other resources include the Harris County LID Manual, the San Antonio River Authority LID Manual, and the Aransas County Storm water Management Design Criteria. **At this point in time, it is appropriate to seek grant funding and/or public private partnerships to help fund the project.**

7. Take the top projects to final design and construction stages. Allow additional time to complete site surveys, necessary State and local permitting, contractor bidding and specifications, and, in some cases, generate public support. The time required to secure implementation funding will likely vary depending on the primary source of funds (i.e., stormwater utility, general or capital budgets, or grants).

8. Provide frequent and detailed construction inspection to ensure that the project is built per the design plans. Also, maintenance inspection services are necessary for the life of the retrofit to verify performance and identify maintenance issues as needed so that maintenance (mowing, sediment removal, trash collection, etc.) takes place to maximize function and appearance. The community should establish a BMP tracking system to ensure long-term maintenance of existing and retrofitted facilities.

CASE STUDY

TULE CREEK WEST: SEDIMENT TRAP POND, BANK STABILIZATION, AND HABITAT ENHANCEMENT

- Aransas County, 2015.
- Grant funded: 60% federal funds and 40% local match.
- Total Project Cost = $740,000

The Tule Creek watershed drains areas of the City of Rockport and the Town of Fulton. The area population and impervious cover are expected to increase in the next two decades, causing an associated increase in stormwater runoff. Scientists have identified polluted stormwater runoff as a principal cause of declining water quality and loss of wildlife habitat within Little Bay, which Tule Creek joins. Little Bay provides water-based recreational activities for local residents along with important habitat for local wildlife.

Aransas County, working with local communities, developed a stormwater management plan. A range of stormwater BMPs were identified for use in the area.

This project implemented several stormwater BMPs along West Tule Creek. The first project built a sediment trap pond below the confluence of the Upper Tule Creek West with North Tule Creek. Invasive vegetation was selectively removed from riparian areas to allow natural colonization of deep-rooted species for shoreline stabilization, improved wetland functions, reduced erosion, and improved water quality. Two additional projects widened a section of creek bank, stabilized it with riparian vegetation, and monitored water quality after the sediment trap was installed, as well as before and after the bank stabilization. Using this monitoring data to conduct continuous simulation modeling, they documented the effectiveness of the sediment trap and bank stabilization in reducing sediment loading to Little Bay.

6.2 RETROFITTING EXISTING DETENTION BASINS

Modifying existing detention basins may be one of the most cost-effective approaches to enhance water quality treatment. 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 6-5, which has three detention areas. By modifying the design of these detention basins to include wet pond or wetland characteristics, significant aesthetic and water quality improvements may be achieved.

Figure 6-5: Layout of a high-density single-family residential development. Includes three detention ponds.

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 6-6 through Figure 6-8 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 stormwater basins are viewed as unsightly liabilities. 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, and increases the value of those lots. Figure 6-8 shows a wet pond located at an apartment complex. It is evident that having an open water component makes the detention basin an asset to the development, allowing for higher rents to be charged to apartments that have a view of the pond.

If the use of a wet pond for recreational activities is not desired, the developer may choose to install a wetland detention area instead. 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 and high average annual rainfall.

Figure 6-6: Enhanced detention wet pond is an amenity (in a subdivision in Chambers County, Texas).

Figure 6-7: Chambers County neighborhood uses wet pond with a fountain for water circulation as a prominent feature in the subdivision.

Figure 6-8: Constructed wet pond provides water quality benefits and an attractive place to recreate for nearby multi-family housing.

6.3 DOWNTOWN REDEVELOPMENT - RETROFITS

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 therefore more comfortable walking in groups or with children and pets. As shown in Figure 6-9 and Figure 6-10, the stormwater benefits of these structures are complimented by the use of porous pavement and can be, integrated with the social and aesthetic benefits afforded by the landscaping.

Figure 6-9: Bioretention serves as a buffer between the sidewalk and street. (Photo courtesy of State of Washington Transportation Improvement Board)

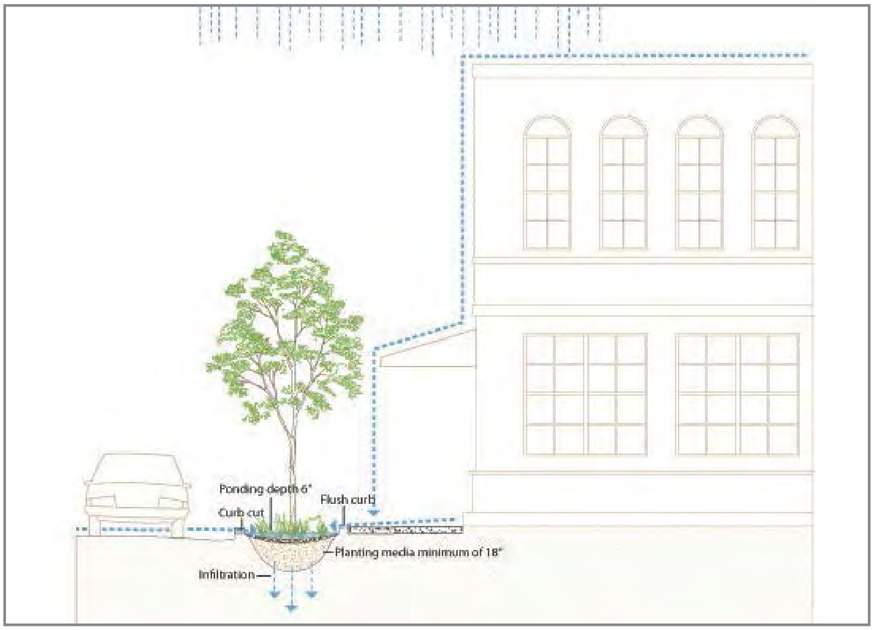


Figure 6-10: Schematic of a bioretention area with no underdrain creating a buffer between the pedestrian zone and the street; stormwater infiltrates into surrounding soils.

Medians and bike lanes afford additional opportunities for stormwater capture and filtration, as in Figure 6-11.

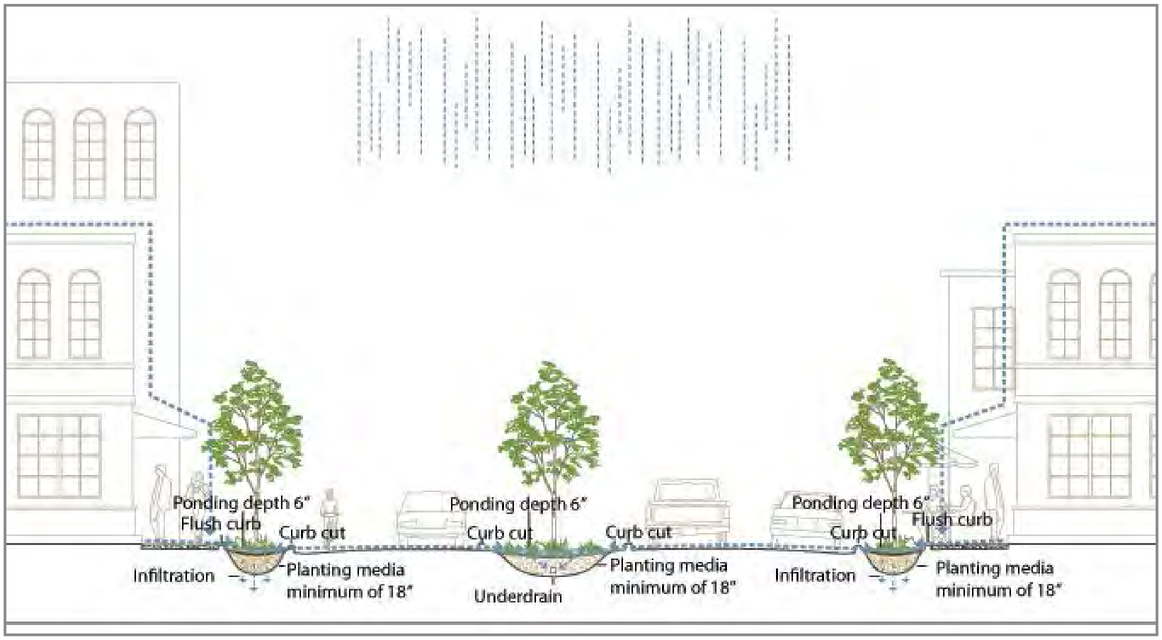


Figure 6-11: Bioretention along streets with a combination of infiltration and underdrain.

The use of alternate material for bike lanes and pedestrian crossings, such as that in Figure 6-12, can increase the safety of those biking or walking. Porous pavement can eliminate standing water on the surface of the area and reduce 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 6-12: Pedestrian crossing constructed with pervious pavers.

The following renderings (Figure 6-13 through Figure 6-15) 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. 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 6-13.

Figure 6-14 shows pervious pavers on the sidewalks and bioretention areas between the sidewalk and the street that can easily be incorporated into a redevelopment project. These features also provide more shade for pedestrians and parked cars and create a stronger buffer between people on the sidewalk and traffic on the street. Figure 6-15 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.

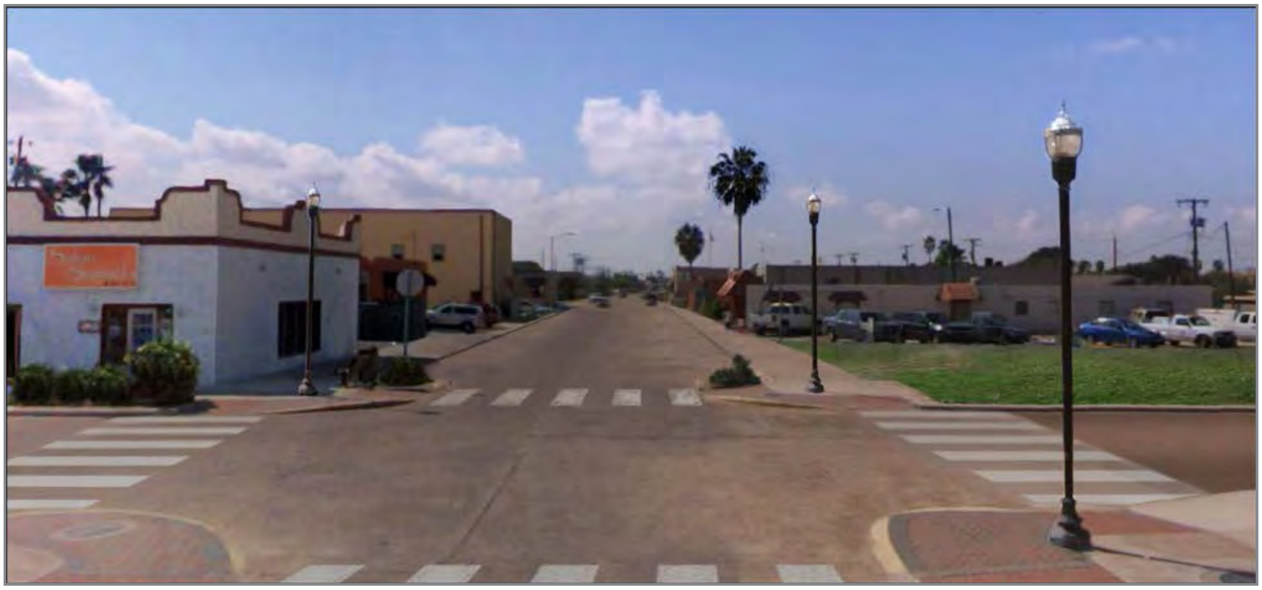


Figure 6-13: Downtown redevelopment BEFORE stormwater controls.

Figure 6-14: Downtown redevelopment. Existing site WITH potential stormwater changes.

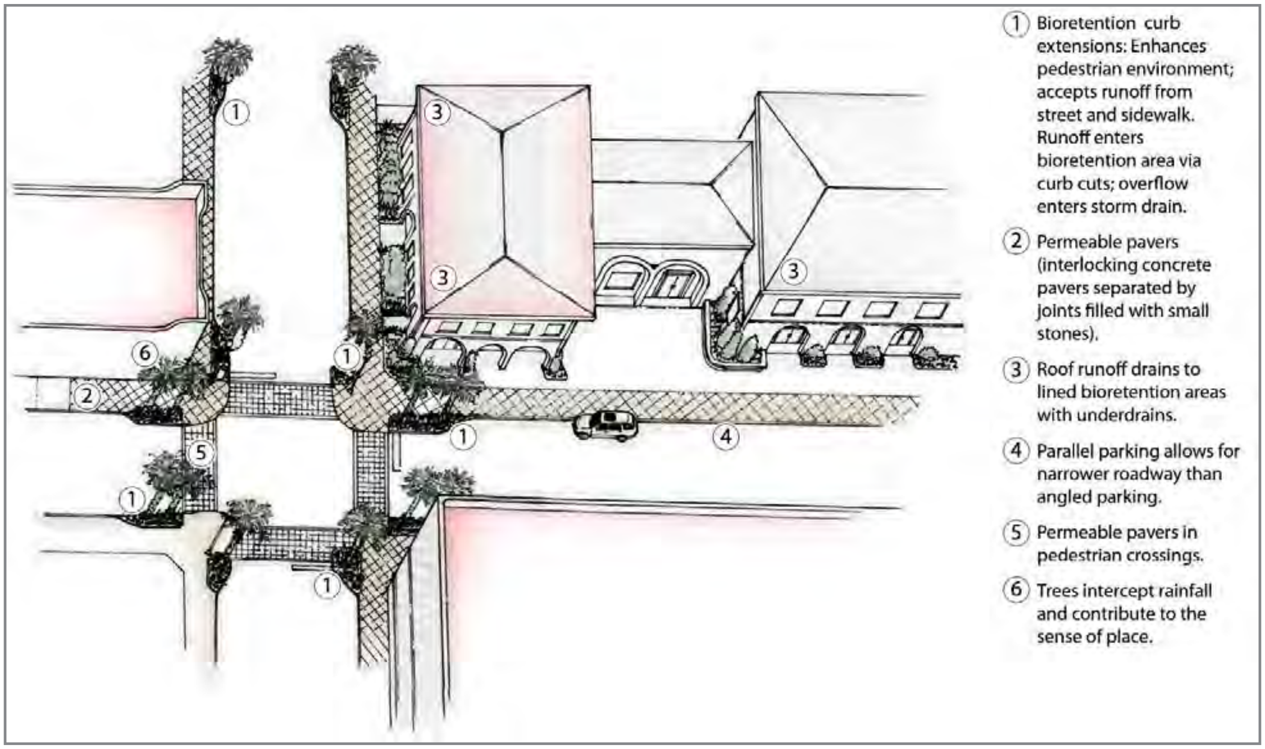


Figure 6-15: Downtown redevelopment. Birds-eye view of stormwater controls.

6.4 HYDROMODIFICATION MANAGEMENT

In some conditions, streams, rivers, and shorelines have been impacted by severe erosion, constructed channels, floodplain encroachment, fill, excavation and removal of native vegetation. In addition, dams have affected the natural flow, habitat, and fluvial processes, thus impacting aquatic habitat, sediment movement, and the natural hydrology, adversely affecting water quality. In the following sections, guidance and references are provided to assist local, state, federal, as well as developers/engineers to restore water resources that have been affected by hydromodification. Please refer to the links in this section, references, and the Texas Hydromodification Best Management Practices Manual, 2008, for additional guidance.

6.4.1 CHANNEL RESTORATION AND NATURAL CHANNEL DESIGN

Streams impacted by natural and un-natural causes can in some cases be restored. Healthy streams enhance habitat, water quality, and provide essential flood mitigation benefits. This section provides excerpts from the San Antonio River Authority, *Natural Channel Design Protocol*, that outlines design considerations, processes, methods, and construction techniques.

While natural channel design is often used in stream restoration projects, it can also be implemented in projects where restoration of ecosystem habitat is not the primary goal, such as flood control projects. Projects that implement restoration and natural channel design techniques are typically part of a holistic, multi-objective plan to improve water quality, restore riparian communities, provide recreation opportunities, and address flooding concerns. Stormwater best management practices (BMPs), Low Impact Development (LID) measures, habitat creation, re-vegetation of stream banks, preservation of natural communities, and trail systems are often incorporated into the project design to meet these multiple objectives. Often, projects implementing natural channel design techniques will do so to address USACE permitting requirements and minimize impacts. Additionally, not all projects may be suitable for a natural channel design approach. Project constraints may preclude a pure natural channel design approach, particularly in urban settings. However, natural channel design elements may still potentially be incorporated into designs. Project goals and constraints must be carefully considered when using the approaches presented in this document.

Goals presented in this manual for incorporating natural channel design into projects include:

- Creating geomorphically stable conditions for appropriate stream reaches;
- Improving and restoring hydrologic connections between the streams and their floodplains;
- Improving aquatic and terrestrial habitat;
- Improving water quality by establishing buffers for nutrient removal from runoff, and by stabilizing stream banks to reduce bank erosion and sediment contribution to stream flows;
- Improving in-stream habitat by providing a more diverse bedform with riffles and pools, creating deeper pools and areas of water re-aeration, providing woody debris for habitat and, reducing bank erosion; and
- Providing storage within a floodplain to retain and attenuate flood flows.

The San Antonio River Authority, Natural Channel Design Protocol, provides detailed guidance to planners, engineers, public works, and maintenance operations staff in the planning, design, permitting, construction, and operations of restored streams. This manual should be used to guide stream restoration and natural channel design in the coastal region and includes the information on the following:

- Watershed assessments;
- Regional flow curves to define hydrologic conditions and design flows;
- Field investigation and base map surveys;
- Geomorphic assessments including bankfull discharge determination, stability, and bedform diversity,

channel evolution, and restoration potential;

- Natural channel design methods including sediment transport analysis;
- Natural channel design within flood control channels;
- In-stream structures and bioengineering;
- Construction plan preparation;
- Technical specifications;
- Permits;
- Construction observation;
- Maintenance; and
- Monitoring and evaluation.

6.4.1.1 CHANNEL OPERATIONS AND MAINTENANCE GUIDANCE

Each project will have site specific maintenance considerations. A maintenance plan will be prepared as part of the natural channel design report for each project site, and will address both short-term and long-term maintenance items. Maintenance plans should include such aspects as inspections, repairs, replacement, mowing, and vegetation management. In constructed projects, the contractor is typically responsible for coordinating maintenance activities for a specific project area for one year following installation of the project (the warranty period). Example tasks to be considered in the first year following installation for the successful establishment of a project site include:

- Initial inspections including photographs for the first 6-months following construction. The site should be inspected at least twice after storm events that exceed 0.5 inch of rainfall.
- Bare or eroding areas in the project area should be re-seeded to ensure they are immediately stabilized with grass cover.
- Proper fertilization based on soil and vegetation nutrient demands.
- Watering may be needed once per week during the first 2 months and then as needed during the first growing season, depending on rainfall. Under drought or unusual site conditions, watering may be needed for longer periods of time to ensure proper vegetation establishment. Minimum quantities of water should coincide with plant specific needs.
- Since plant stock may die off in the first year, construction contracts should include a care and replacement warranty to ensure that vegetation is properly established and survives during the first growing season following construction. The typical thresholds below which replacement is required are 75% survival of plant material and 90% of planted trees during the first growing season. In later years, the project's defined success criteria for vegetation will dictate whether replanting is necessary.
- Control of invasive and/or exotic vegetation.

Long-term maintenance considerations may include items such as those listed below:

- Allowing for site access in the future to address maintenance needs
- Inspection schedules
- Addressing severe storm damage
- Control of invasive and/or exotic vegetation

- Control of animal activity that may damage planted vegetation or site stability (i.e. beavers, hogs, etc.)
- Vandalism and/or unauthorized site access

Monitoring and evaluation of restoration and natural channel design projects is a useful method to evaluate project performance. A monitoring plan should be developed to determine whether these goals and objectives have been achieved, in order to validate the effectiveness of the project and identify trends, or necessary corrective actions, through the adaptive management process. A common goal when monitoring a natural channel design project is to demonstrate that the restoration activities create a stable functioning stream channel. To ensure that channel stability has been achieved, physical inspections are conducted using a variety of qualitative and quantitative measures. Inspections data are then compared to data and photographs collected prior to restoration and/or during the monitoring previous years.

A qualified or knowledgeable field inspector should walk the entire length of the project with the as-built plans noting any areas of concern. Using a monitoring data sheet, the inspector should describe, in detail, the problem area(s) and take adequate photographs to document the concern and if necessary, provide a recommendation for corrective action. Specific metrics and resolution alternatives should be tabulated in the Monitoring Report. Inspections should be conducted at least once per year. More frequent inspections may be necessary if stability concerns have previously been noted, or there have been frequent/intense storm events. An inspection may be necessary immediately following a significant storm event (bankfull or higher) if it occurs soon after completion of the project and, before bank vegetation has been established in accordance with the plans and specifications. The inspection should evaluate the following:

- Vertical instability
- Lateral instability
- Structural integrity
- Vegetation viability

In the event that the site or a specific component of the site fails to achieve the defined success criteria or project goals, the designer or mitigation provider should work with the owner to develop necessary adaptive management plans and/or implement appropriate corrective actions for the site in coordination with the appropriate agencies and other stakeholders. Corrective action required should be implemented to achieve the success criteria specified in the project design and monitoring plan. The plan should also include a work schedule and monitoring criteria that consider physical (exotic vegetation, beaver dams) and climatic conditions (droughts/floods, long-term hydrology), as well as documenting any significant changes within the watershed.

6.4.2 DAM REMOVAL GUIDELINES AND HABITAT PROTECTION

As an owner of a dam, you may want to remove the dam due to factors such as deterioration and risk of failure, or to return a waterway to its original condition. By performing a dam removal operation, habitat can be restored and natural aquatic functions can return to enhance biological activity. Based on the State of Texas Dam Removal Guidelines, TCEQ, the question of whether to remove a dam is primarily up to the owners and stakeholders of the structure. The Dam Safety Program of TCEQ is not opposed to the removal of dams; however, the Dam Safety Program does want to ensure that the process is conducted safely and in accordance with all the applicable state and federal rules. The guidelines presented here cover the major items that you should consider before beginning the removal process. For the purposes of this document, these items are organized into six general categories:

- Safety Issues
- Erosion Prevention and Sediment Control
- Ecological Issues

- Floodplain Management
- Stakeholder Issues
- Ownership Issues

The safety of downstream residents and the personnel working on the dam are of primary importance. Before engaging in a dam removal, the owner should acquire an approved dam removal plan from the TCEQ Dam Safety Program. This plan should contain the following items:

- Schedule and plan for conducting the phases of the work.
- Description of the method to be used to dewater the reservoir.
- Drawings that illustrate the location and size of the breach.
- Rationale for the sizing and placement of the breach.
- Plan for preventing erosion and sediment loss from the work site, lake bottom, and breach during and after removal.
- Emergency Action Plan that addresses the risks associated with the removal process.

Plans for addressing any relevant items that are noted in these guidelines. There are several important safety issues that must be considered in developing a dam removal plan.

- Construction activity will occur in the vicinity of water.
- Staging and operations will take place on steep inclined slopes.
- Water can flow uncontrollably through a breach, quickly eroding the side walls.
- Removal of material on the downstream slope can cause an increase in the hydraulic gradient within the embankment, which may lead to quickening of the soil.
- Rapid drawdown (lowering of the water level) of the reservoir can create slope instabilities upstream.
- Severe or extreme rainfall events can occur during the removal process.
- Outlet valves may be corroded or inoperable.
- Outlet conduits may be corroded, damaged, or incapable of containing hydraulic pressures or flows associated with drawdown operations.
- Inform the downstream county sheriff before draining, so that emergency management personnel know why a change in stream level is taking place.

By performing the above steps in compliance with the TCEQ Dam Removal Guidelines, minimal water quality impacts can occur and habitat can be protected.

Existing dams and their accompanying reservoirs/water bodies that will not be removed also have the need to practice riparian habitat restoration and maintenance in areas around the impounded water body and in the water body downstream from a dam. Reservoir shorelines are important riparian areas and they need to be managed or restored to realize their habitat and water quality benefits. This management plan must consider fluctuating water levels due to floods and droughts and implement resilient vegetation that can withstand the hot, dry summers but also survive long-periods of inundation. Examples of downstream aquatic habitat improvements include maintaining minimum instream flows, providing scouring flows when needed, providing alternative spawning areas if appropriate for the water body in consideration, protecting streambanks from erosion, and maintaining wetlands and riparian areas.

6.4.3 OPERATION AND MAINTENANCE OF DAMS

Dams are defined as constructed impoundments that are either (1) 25 feet or more in height and greater than 15 acre-feet in capacity, or (2) 6 feet or more in height and greater than 50 acre-feet in capacity. The siting and construction of a dam can be undertaken for many purposes, including flood control, power generation, irrigation, livestock watering, fish farming, navigation, and municipal water supply. Some reservoir impoundments are also used for recreation and water sports, for fish and wildlife propagation, and for augmentation of low flows. Dams can adversely impact the hydraulic regime, the quality of the surface waters, and habitat in the stream or river where they are located. A variety of impacts can result from the siting, construction, and operation of these facilities.

The siting of dams can result in the inundation of wetlands, riparian areas, and land in upstream areas of the waterway. Dams either reduce or eliminate the downstream flooding needed by some wetlands and riparian areas. Dams can also impede or block healthy spawning, migration routes of fish, and any threatened or endangered species. Construction activities from dams can cause increased turbidity and sedimentation in the waterway resulting from vegetation removal, soil disturbance, and soil rutting. Fuel and chemical spills and the cleaning of construction equipment (particularly concrete washout) have the potential for creating nonpoint source pollution. The proximity of dams to streambeds and floodplains increases the need for sensitivity to pollution prevention at the project site in planning and design, as well as during construction.

The operation of dams can also generate a variety of types of nonpoint source pollution in surface waters. Controlled releases from dams can change the timing and quantity of freshwater inputs into coastal waters. Dam operations may lead to reduced downstream flushing, which, in tum, may lead to increased loads of BOD, phosphorus, and nitrogen; changes in pH; and the potential for increased algal growth. Lower instream flows, and lower peak flows associated with controlled releases from dams, can result in sediment deposition in the channel several miles downstream of the dam. The tendency of dam releases to be clear water, or water without sediment, can result in erosion of the streambed and scouring of the channel below the dam, especially the smaller-sized sediments. One result is the siltation of gravel bars and riffle pool complexes, which are valuable spawning and nursery habitat for fish. Dams also limit downstream recruitment of suitably-sized substrate required for the anchoring and growth of aquatic plants. Finally, reservoir releases can alter the water temperature and lower the dissolved oxygen levels in downstream portions of the waterway.

To guide the safe and effective operation and maintenance of dams, this document references the TCEQ "Guidelines for Operations and Maintenance of Dams in Texas." All dam owners and operators should follow this guidance to ensure safe operations and high-water quality management in the daily operations and maintenance of their dams. Some key items noted in the document include:
Establish a schedule for both day-today tasks and tasks performed less frequently throughout the year. The schedule should formalize inspection and maintenance procedures so that even an inexperienced person can determine when a task is to be done.

- Operation Plan Guidelines
- Establishing an operation procedure or plan calls for detailed
- Data on the physical characteristics of dam and reservoir
- Descriptions of dam components
- Operating instructions for operable mechanisms
- Instructions for inspections
- Instrumentation and monitoring guidelines
- Guidelines for maintenance
- Guidelines for emergency operations

MAINTENANCE GUIDELINES

A sound maintenance program will protect a dam against deterioration and prolong its life. A poorly maintained dam will deteriorate and may fail. Nearly all the components of a dam and the materials used for its construction are susceptible to damaging deterioration if not properly maintained. A well-prepared maintenance program protects not only the dam owner, but the general public as well while considering and providing good habitat preservation and enhancement. The cost of a proper maintenance program is small compared to the cost of major repairs or the loss of life and property and resultant litigation. A basic maintenance program based primarily on systematic and frequent inspections is necessary. Inspections, as noted in Chapter 5 of the Guidance, should be carried out monthly and after major floods or earthquakes. During each inspection, fill out a checklist of items requiring maintenance and ensuring that the dam operators are aware of the latest reports and findings to enhance operations and water quality protection.

Preventing erosion and soil loss within the impoundment and dam failures protects water quality and lives. When dams fail, extensive amounts of soil and debris are released into the receiving stream. Further, the large volume of water and sediment washes away streamside trees and vegetation and generates additional erosion and scour, significantly altering habitat and the natural aquatic and nearby terrestrial areas. Additionally, streamside homes and businesses can be swept away. Thus, the proper operations and maintenance of dams is essential in protecting lives, property, habitat, and water quality.

6.4.4 STREAMBANK AND SHORELINE EROSION GUIDANCE

Streambank erosion is used in this guidance to refer to the loss of land along nontidal streams and rivers. Shoreline erosion is used in this guidance to refer to the loss of beach or land in tidal portions of coastal bays or estuaries. Erosion of ocean coastlines is not regarded as a substantial contributor of NPS pollution in coastal waterbodies and will not be considered in this guidance.

The force of water flowing in a river or stream can be regarded as the most important process causing erosion of a streambank. All of the eroded material is carried downstream and deposited in the channel bottom or in point bars located along bends in the waterway. The process is very different in coastal bays and estuaries, where waves and currents can sort the coarser-grained sands and gravels from eroded bank materials and move them in both directions along the shore, through a process called littoral drift, away from the area undergoing erosion. Thus, the materials in beaches of coastal bays and estuaries are derived from shore erosion somewhere else along the shore. Solving the erosion of the source area may merely create new problems with beach erosion over a much wider area of the shore.

The erosion of shorelines and streambanks is a natural process that can have either beneficial or adverse impacts on the creation and maintenance of riparian habitat. Sands and gravels eroded from streambanks are deposited in the channel and are used as instream habitat during the life stages of many benthic organisms and fish. The same materials eroded from the shores of coastal bays and estuaries maintain the beach as a natural barrier between the open water and coastal wetlands and forest buffers. Beaches are dynamic, ephemeral landforms that move back and forth onshore, offshore, and along shore with changing wave conditions. The finer-grained silts and clays derived from the erosion of shorelines and streambanks are sorted and carried as far as the quiet waters of wetlands or tidal flats, where benefits are derived from addition of the new material. There are also adverse impacts from shoreline and streambank erosion. Excessively high sediment loads can smother submerged aquatic vegetation (SAV) beds, cover shellfish beds and tidal flats, fill in riffle pools, and contribute to increased levels of turbidity and nutrients. .

Management measures for eroding streambanks and shorelines should include the following:

- Where stream bank or shoreline erosion is a nonpoint source pollution problem, streambanks and shorelines should be stabilized. Vegetative methods are strongly preferred unless structural methods are more cost-effective, considering the severity of wave and wind erosion, offshore bathymetry, and the potential adverse impact on other streambanks, shorelines, and offshore areas.
- Protect streambank and shoreline features with the potential to reduce NPS pollution.
- Protect streambanks and shorelines from erosion due to uses of either the shorelands or adjacent surface waters.

The following practices are described for illustrative purposes only. Local governments need not require the implementation of these practices. However, as a practical matter, the management measure set forth above generally will be implemented by applying one or more management practices appropriate to the source, location, and climate. The practices set forth below have been found by EPA to be representative of the types of practices that can be applied successfully to achieve the management measure described above. Preservation and protection of shorelines and streambanks can be accomplished through many approaches, but preference in this guidance is for nonstructural practices, such as soil bioengineering and marsh creation, natural systems, that are resilient, sustainable, require minimal maintenance once established, avoid catastrophic failures such as concrete wall collapse, and can enhance water quality and habitat.

6.4.4.1 SOIL BIOENGINEERING AND VEGETATIVE PRACTICES

Soil bioengineering is the installation of living plant material as a main structural component in controlling problems of land instability where erosion and sedimentation are occurring (USDA-SCS, 1992). Soil bioengineering largely uses native plants collected in the immediate vicinity of a project site. This ensures that the plant material will be well adapted to site conditions. While a few selected species may be installed for immediate protection, the ultimate goal is for the natural invasion of a diverse plant community to stabilize the site through development of a vegetative cover and a reinforcing root matrix (USDA-SCS, 1992). Soil bioengineering provides an array of practices that are effective for both prevention and mitigation of NPS problems. This applied technology combines mechanical, biological, and ecological principles to construct protective systems that prevent slope failure and erosion. Adapted types of woody vegetation (shrubs and trees) are initially installed as key structural components, in specified configurations, to offer immediate soil protection and reinforcement. Soil bioengineering systems normally use cut, unrooted plant parts in the form of branches or rooted plants. As the systems establish themselves, resistance to sliding or shear displacement increases in streambanks and upland slopes. Specific soil bioengineering practices include:

Live Staking. Live staking involves the insertion and tamping of live, rootable vegetative cuttings into the ground as shown in Figure 6-16. If correctly prepared and placed, the live stake will root and grow. A system of stakes creates a living root mat that stabilizes the soil by reinforcing and binding soil particles together and by extracting excess soil moisture. Most willow species are ideal for live staking because they root. This is an appropriate technique for the repair of small earth slips and slumps that are frequently wet.

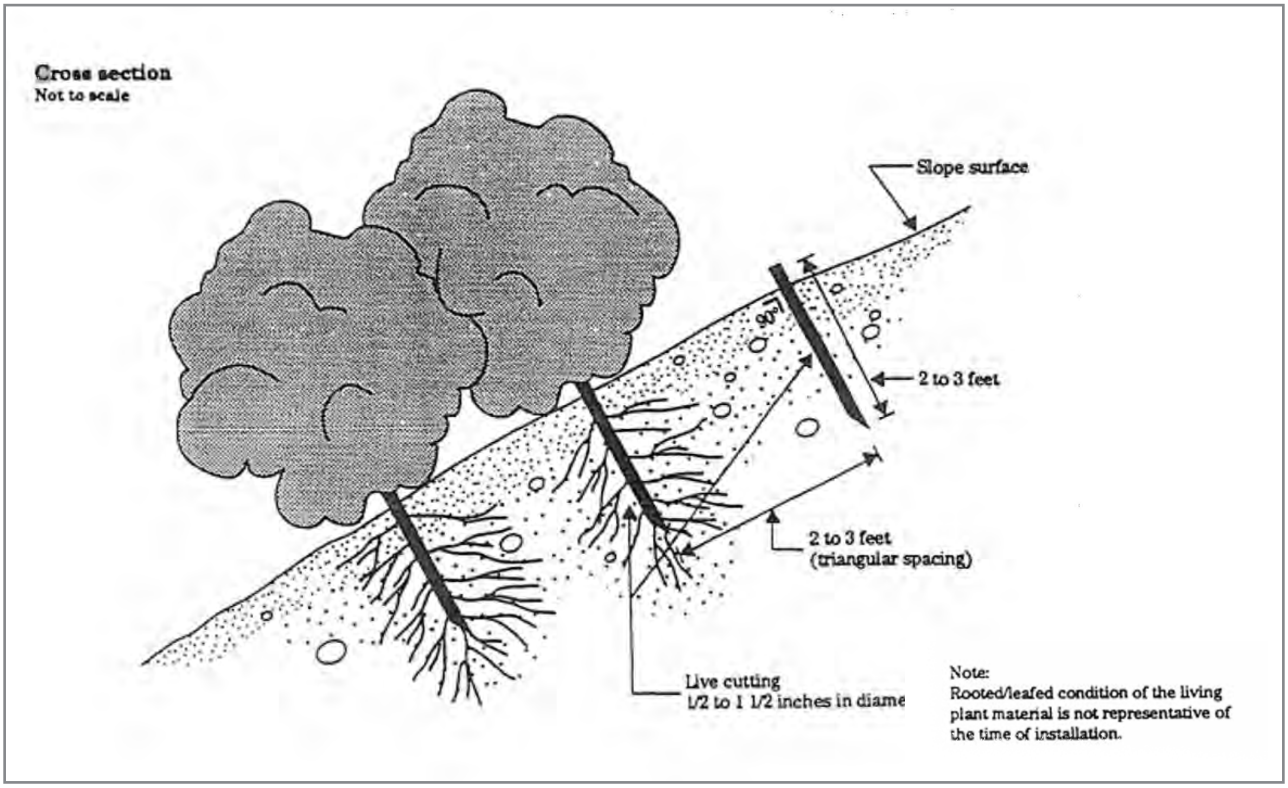


Figure 6-16: Live Staking (Source: EPA)

Live Fascines. Live fascines are long bundles of branch cuttings bound together into sausage-like structures (Figure 6-17). When cut from appropriate species and properly installed, they will root and immediately begin to stabilize slopes. They should be placed in shallow contour trenches on dry slopes and at an angle on wet slopes to reduce erosion and shallow face sliding. This system, installed by a trained crew, does not cause much site disturbance.

Joint Planting. Joint planting (or vegetated riprap) involves tamping live cuttings of rootable plant material

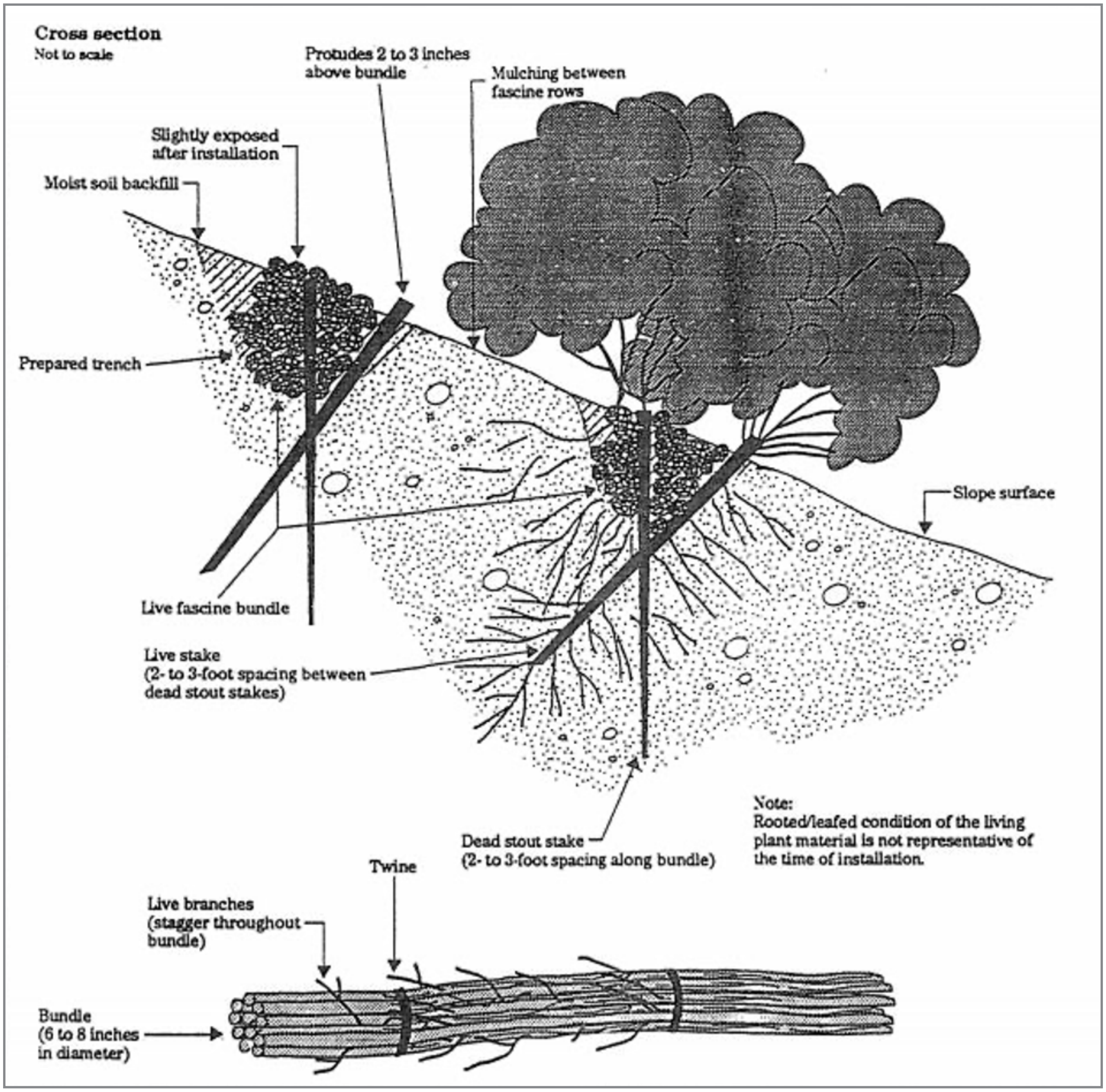


Figure 6-17: Live Fascines (Source: EPA)

into soil between the joints or open spaces in rocks that have previously been placed on a slope (Figure 6-18). Alternatively, the cuttings can be tamped into place at the same time that rock is being placed on the slope face.

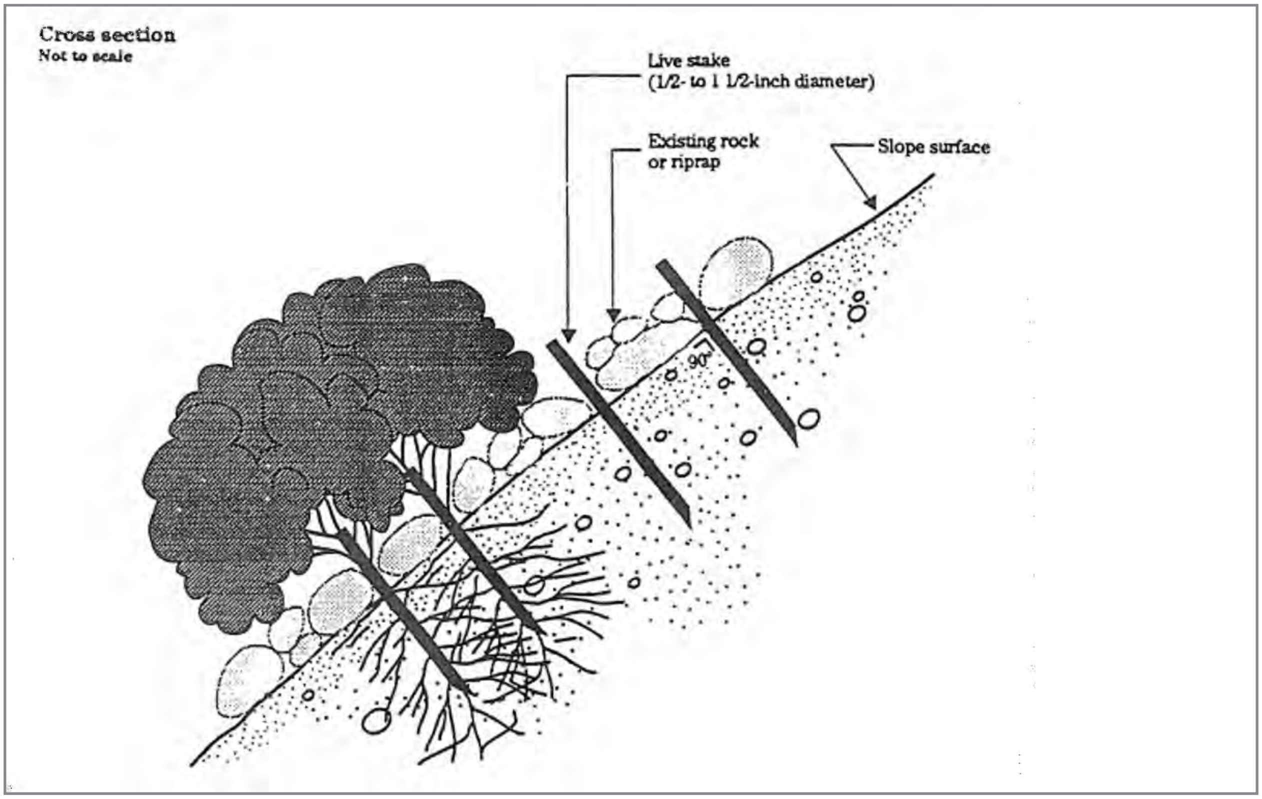


Figure 6-18: Joint Planting (Source EPA)

Marsh creation and restoration is another useful vegetative technique that can be used to address problems with erosion of coastal shorelines, Figure 6-19. Marsh plants perform two functions in controlling shore erosion. First, their exposed stems form a flexible mass that dissipates wave energy. As wave energy is diminished, both the offshore transport and longshore transport of sediment are reduced. Ideally, dense stands of marsh vegetation can create a depositional environment, causing accretion of sediments along the intertidal zone rather than continued erosion of the shore. Second, marsh plants form a dense mat of roots (called rhizomes), which can add stability to the shoreline sediments.

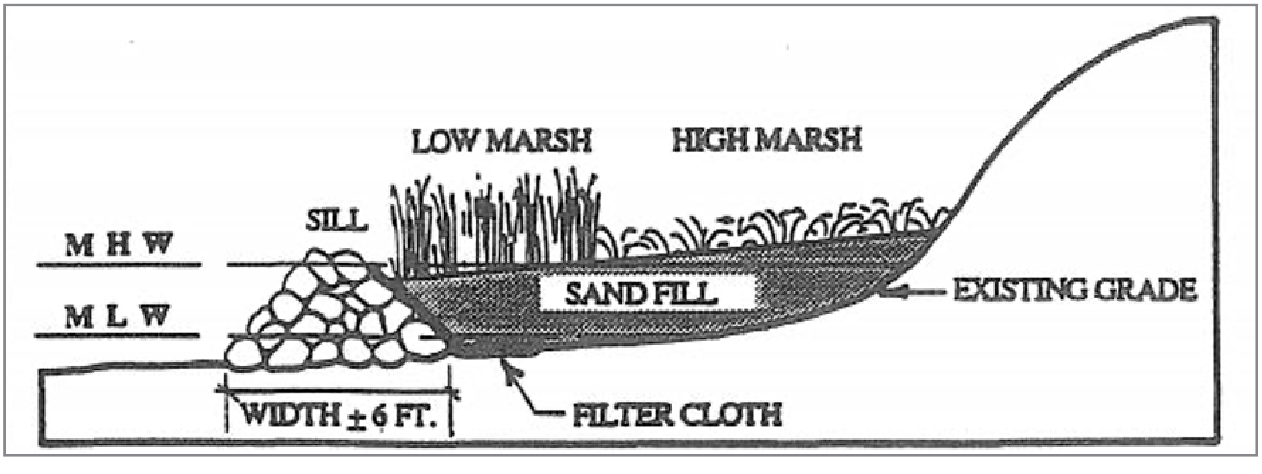


Figure 6-19: Shallow Marsh Creation (Source: EPA)

6.4.4.2 ROCK RIPRAP AND STRUCTURAL TECHNIQUES

For sites where soil bioengineering and marsh creation would not be an effective means of streambank or shoreline stabilization, a variety of engineering approaches can be considered. One approach involves the design and installation of fixed engineering structures and rock rip rap. Bulkheads and seawalls are two types of wave-resistant walls that are similar in design but slightly different in purpose (Figure 6-20). Bulkheads are primarily soil-retaining structures designed also to resist wave attack. Seawalls are principally structures designed to resist wave attack, but they also may retain some soil. Both bulkheads and seawalls may be built of many materials, including steel, timber, or aluminum sheet pile, gabions, or rubble-mound structures.

Although bulkheads and seawalls protect the upland area against further erosion and land loss, they often create a local problem. Downward forces of water, produced by waves striking the wall, can produce a transfer of wave energy and rapidly remove sand from the wall. A stone apron is often necessary to prevent scouring and undermining. With vertical protective structures built from treated wood, there are also concerns about the leaching of chemicals used in the wood preservatives.

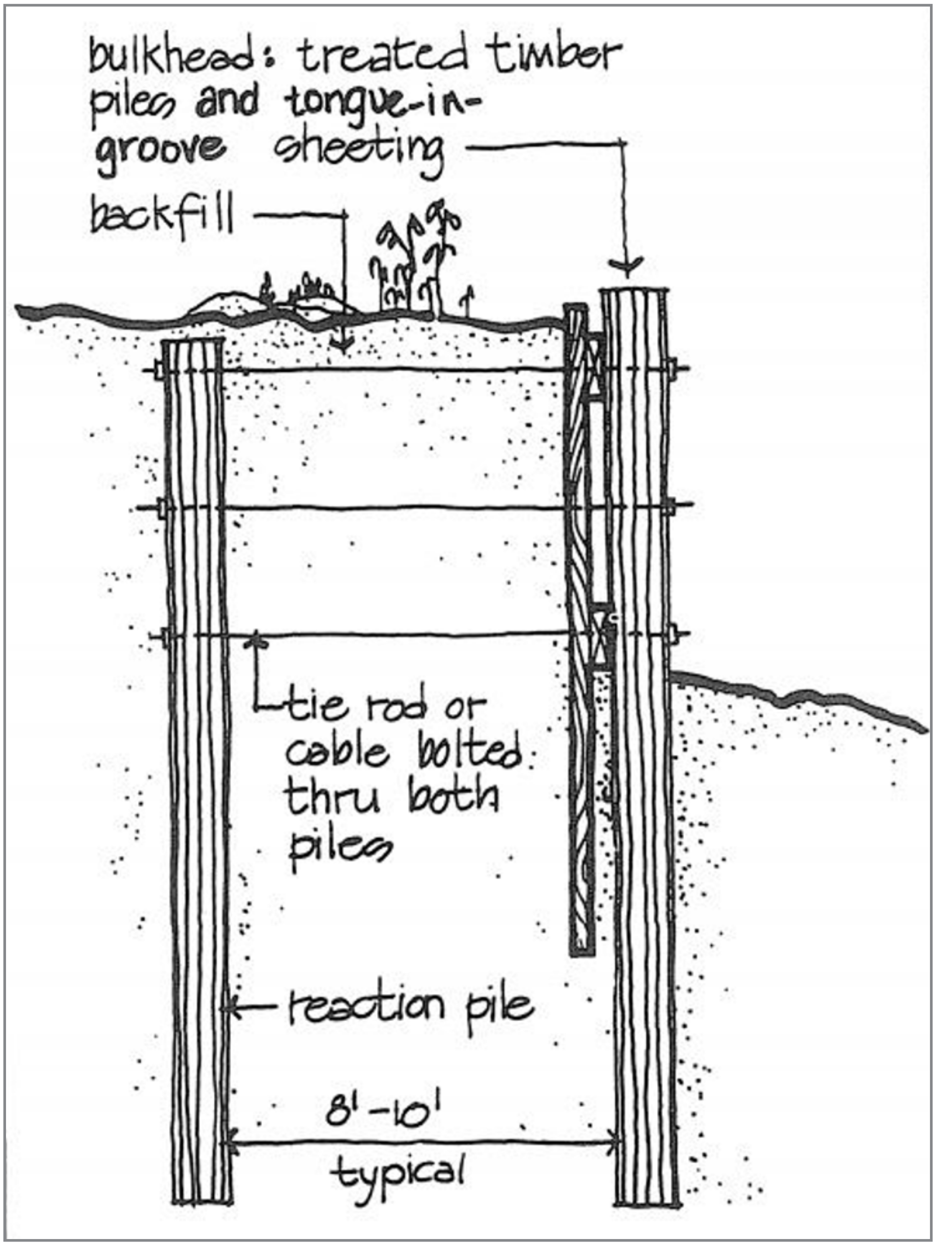


Figure 6-20: Schematic Bulkhead Example (Source: EPA)

Toe Protection for vertical bulkheads has a number of qualitative advantages. Toe protection usually takes the form of a stone apron installed at the base of the vertical structure to reduce wave reflection and scour of bottom sediments during storms (Figure 6-21). The installation of rubble toe protection should include filter cloth and perhaps a bedding of small stone to reduce the possibility of rupture of the filter cloth. Ideally, the rubble should extend to an elevation such that waves will break on the rubble during storms.

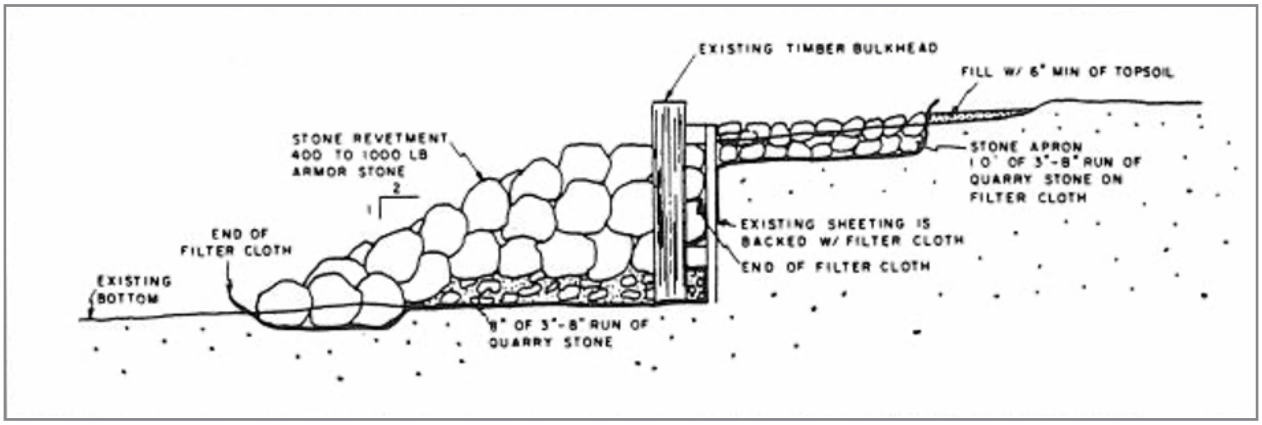


Figure 6-21: Schematic Toe Protection (Source: EPA)

Rock riprap is another type of vertical protective structure used for streambank and shoreline protection. One rock rip rap design contains several layers of randomly shaped and randomly placed stones, protected with several layers of selected armor units or quarry stone (Figure 6-20). The armor units in the cover layer should be placed in an orderly manner to obtain good wedging and interlocking between individual stones. The cover layer may also be constructed of specially shaped concrete units.

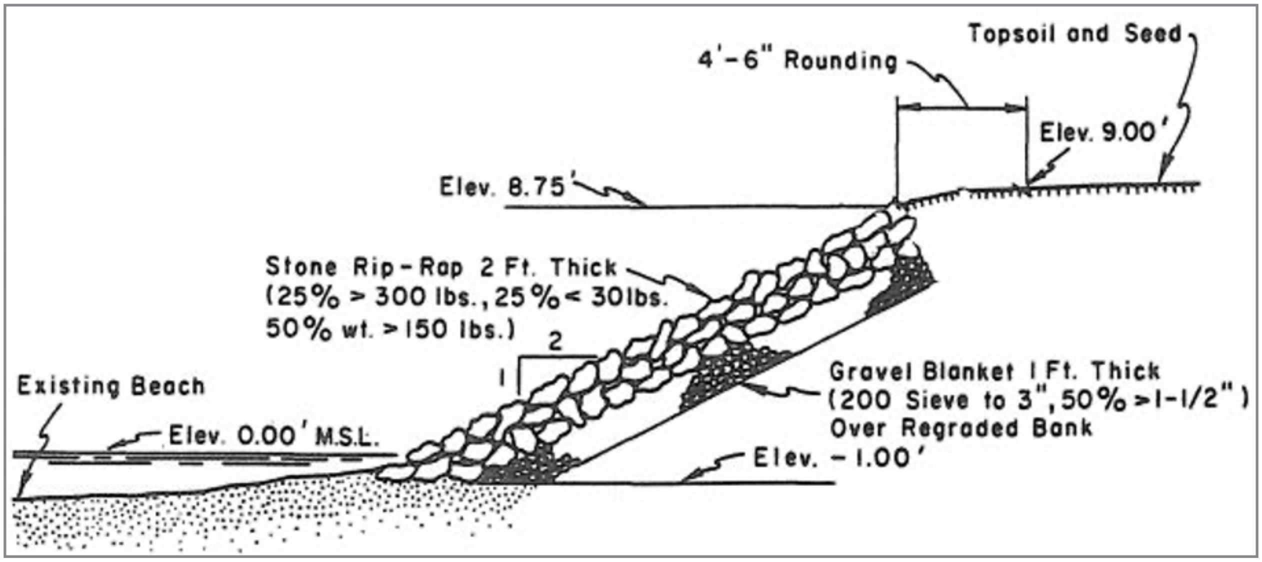


Figure 6-22: Rock Rip Rap Schematic Cross Section (Source: EPA)

Structures of various types can be used to protect the shoreline and streambanks. Some examples include:

Gabions (stone-filled wire baskets) or interlocking blocks of precast concrete are used in the construction of revetments. In addition to the surface layer of armor stone, gab ions, or rigid blocks, successful revetment designs also include an underlying layer composed of either geotextile filter fabric and gravel or a crushed stone filter and bedding layer. This lower layer functions to redistribute hydrostatic uplift pressure caused by wave action in the foundation substrate. Precast cellular blocks, with openings to provide drainage and to allow vegetation to grow through the blocks, can be used in the construction of revetments to stabilize banks. Vegetation roots add additional strength to the bank. In situations where erosion can occur under the blocks, fabric filters can be used to prevent the erosion. Technical assistance should be obtained to properly match the filter and soil characteristics. Typically blocks are hand placed when mechanical access to the bank is limited or costs need to be minimized. Cellular block revetments have the additional benefit of being flexible to conform to minor changes in the bank shape.

Groins are structures that are built perpendicular to the shore and extend into the water. Groins are generally constructed in series, referred to as a groin field, along the entire length of shore to be protected. Groins trap sand in littoral drift and halt its longshore movement along beaches. The sand beach trapped by each groin acts as a protective barrier that waves can attack and erode without damaging previously unprotected upland areas. Unless the groin field is artificially filled with sand from other sources, sand is trapped in each groin by interrupting the natural supply of sand moving along the shore in the natural littoral drift. This frequently results in an inadequate natural supply of sand to replace which is carried away from beaches located farther along the shore in the direction of the littoral drift. If these "downdrift" beaches are kept starved of sand for sufficiently long periods of time, severe beach erosion in unprotected areas can result.

Maintenance of Rock RipRap and Structures is necessary to repair the damage from storms and winter ice and to address the effects of flanking and off-shore profile deepening. The maintenance varies with the practice type, but annual inspections should be made by the property owners. For stone revetments, the replacement of stones that have been dislodged is necessary; timber bulkheads need to be backfilled if there has been a loss of upland material, and broken sheet pile should be replaced as necessary. Gabion baskets should be inspected for corrosion failure of the wire, usually caused either by improper handling during construction or by abrasion from the stones inside the baskets. Baskets should be replaced as necessary since waves will rapidly empty failed baskets. Steel, timber, and aluminum bulkheads should be inspected for sheet pile failure due to active earth pressure or debris impact and for loss of backfill. For all structural types not contiguous to other structures, lengthening of flanking walls may be necessary every few years. Through periodic monitoring and required maintenance, a substantially greater percentage of coastal structures will perform effectively over their design life.

CHAPTER 7

Floodplain Management

7.1 INTRODUCTION

WATER QUALITY MANAGEMENT, GREEN INFRASTRUCTURE & FLOOD MANAGEMENT

Water quality protection and floodplain management work hand-in-hand to manage stormwater drainage in communities across Texas. By using smart development design techniques, low impact development practices, limited impervious cover, open channel drainage systems, rainwater harvesting, and water quality treatment measures, frequent storm runoff rates and volumes can be reduced to background conditions. Measures, labeled as green infrastructure, that maximize the use of natural systems, vegetation, and soils can require less maintenance than conventional stormwater drainage systems and improve appearance. At the same time, these systems can be more resilient than conventional methods using structural approaches.

By reducing stormwater runoff and protecting floodplains, green infrastructure can help manage both localized and riverine floods. In areas impacted by localized flooding, green infrastructure practices absorb rainfall, preventing water from overwhelming pipe networks and pooling in streets or low-lying areas. Green infrastructure practices that enhance infiltration include rain gardens, bioswales, and permeable pavements. In areas impacted by riverine flooding, green infrastructure, open space preservation, and floodplain management can all complement gray infrastructure approaches. These practices reduce the volume of stormwater that flows into streams and rivers, protect the natural function of floodplains, and reduce damage to infrastructure and property.

FLOODPLAIN PROGRAMS

The Texas Floodplain Management Association (TFMA) and Texas Water Development Board (TWDB) provide information and guidance to help citizens and communities understand what floodplain management is and why floodplain development is regulated.

Communities regulate the floodplain to:

- Protect people and property
- Ensure that Federal flood insurance and disaster assistance is available
- Save tax dollars
- Reduce future flood losses
- Reduce liability

Floods have been, and continue to be, the most destructive natural disaster in terms of economic loss to the citizens of Texas with a total coverage of about $156 billion. More than 12% of the State's land area is subject to flooding. Since 1978, Texas flood insurance policy holders have filed over 251,569 flood loss claims totaling $5.8 billion in claim payments (as of 2015). Even though that represents many insurance payments, most flood-prone Texans do not have flood insurance.

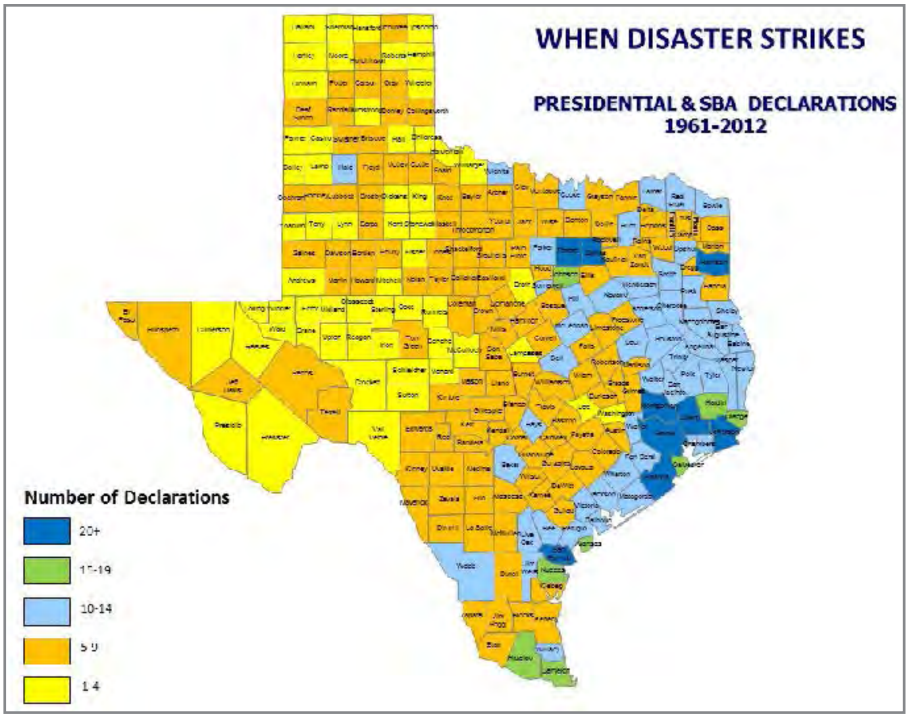


Figure 7-1: Presidential Disaster Area Declarations (1961-2012) source: TWDB.

7.2 NATIONAL FLOOD INSURANCE PROGRAM

The National Flood Insurance Program (NFIP) was created by Congress in 1968 to protect lives and property and to reduce the financial burden of providing disaster assistance. The NFIP is administered by the Federal Emergency Management Agency (FEMA).

Nationwide, over 22,000 communities participate in the NFIP, including many in Texas. The NFIP is based on a mutual agreement between the Federal Government and communities. Communities that participate agree to regulate floodplain development according to certain criteria and standards. The partnership involves:

- ***Flood Hazard Maps:*** FEMA prepares maps that are used by communities, insurance agents, and others.
- ***Flood Insurance:*** Property owners in participating communities are eligible to purchase federal flood insurance for buildings and contents.
- ***Regulations:*** Communities must agree to adopt and enforce floodplain management regulations so that development, including buildings, is undertaken in ways that reduce exposure to flooding.

NFIP Flood Insurance is not available to residents of communities that do not participate in the NFIP. It is also not available for structures built or substantially improved in the Coastal Barrier Resources Act (CBRA) after their designation date, even though the structure may be in a participating community.

NATIONAL FLOOD INSURANCE PROGRAM (NFIP) COMMUNITY RATING SYSTEM (CRS)

The NFIP's CRS program gives "extra credit" to communities in the form of reduced flood insurance rates. **Thus, property owners that live in a community participating in the CRS program receive a discount on their annual flood premium.** Communities must apply to the CRS and commit to implement and certify activities that contribute to reduced flood risk and promote safety. The CRS Fact Sheet provides a program summary and contact information for a community to get started.

The Community Rating System recognizes and encourages community floodplain management activities that exceed the minimum NFIP standards. Depending upon the level of participation, flood insurance premium rates for policyholders can be reduced up to 45%. Besides the benefit of reduced insurance rates, CRS floodplain management activities enhance public safety, reduce damages to property and public infrastructure, avoid economic disruption and losses, reduce human suffering, and protect the environment. Technical assistance on designing and implementing some activities is available at no charge to communities that participate.

Participating in the CRS provides an incentive to maintaining and improving a community's floodplain management program over the years. Implementing some CRS activities can help projects qualify for certain other Federal assistance programs. The CRS provides credit under 19 public information and floodplain management activities described in the *CRS Coordinator's Manual*. Examples of action that a community can take to reduce the flood insurance cost include:

- Preserve open space in the floodplain, such as in the form of parks.
- Enforce higher floodplain development standards for safer development through zoning, stormwater, subdivision, and floodplain damage protection ordinances.
- Develop hazard mitigation plans.
- Obtain floodplain grants to buy, elevate, or floodproof houses and businesses in the floodplain.
- Maintain drainage systems.
- Monitor flood conditions and issue warnings during storm events.
- Inform residents about flood hazards, flood insurance, and methods to reduce flood damage.

A community that already performs some of these activities can apply to the CRS program for approval and provide flood insurance reduction benefits to its residents.

The CRS Brochure provides insight into program specifics and how a community can participate to improve floodplain protection, reduce flood insurance rates, and receive technical assistance at no charge.

Nearly 3.6 million policyholders in 1,444 communities participate in the CRS by implementing local mitigation, floodplain management, and outreach activities that exceed the minimum NFIP requirements.

FLOOD MAPS AND FLOOD ZONES

FEMA prepares Flood Insurance Rate Maps (FIRMs) to show areas that are at high risk of flooding. Since the 1970s, many versions and updates to maps have been produced.

- **"Old format" maps** may include flood zones (like B, C, A1-30) that are not being included in map updates. The maps were only available in hard copy and were often accompanied with Flood Hazard Boundary Maps.
- **"New format" maps** have been produced in order to simplify map zone designations and make map items easier to identify. See Figure 7-2.
- **Flood zones** are geographic areas that FEMA has defined according to varying levels of flood risk. These zones are depicted on a community's Flood Hazard Boundary Map (FHBM) or FIRM and Digital FIRMs (DFIRMs) if the DFIRM is available. Each zone reflects the severity or type of flooding in the area.
- **High Risk Areas** include all A and V Zones, or the area located within the 1% annual chance floodplain (100-year floodplain) identified as a Special Flood Hazard Areas on Flood Insurance Rate Maps. Flood insurance is available to all property owners and renters. Lenders require mandatory purchase of flood insurance.
- **Moderate to Low Risk Areas** include Zone B (moderate), C and X (low) – are areas located outside the one-percent annual chance floodplain. This includes areas protected from flood by certified levees and where area is higher than base flood elevation. Lower-cost flood insurance is available to all property owners and renters. Mandatory Flood insurance purchase requirements do not apply.
- **Undetermined Risk Areas** includes Zone D, which encompass unstudied areas of undetermined but possible flood hazards. Base flood elevations not available. Flood insurance is available to all property owners and renters. Mandatory flood insurance purchase requirements do not apply.

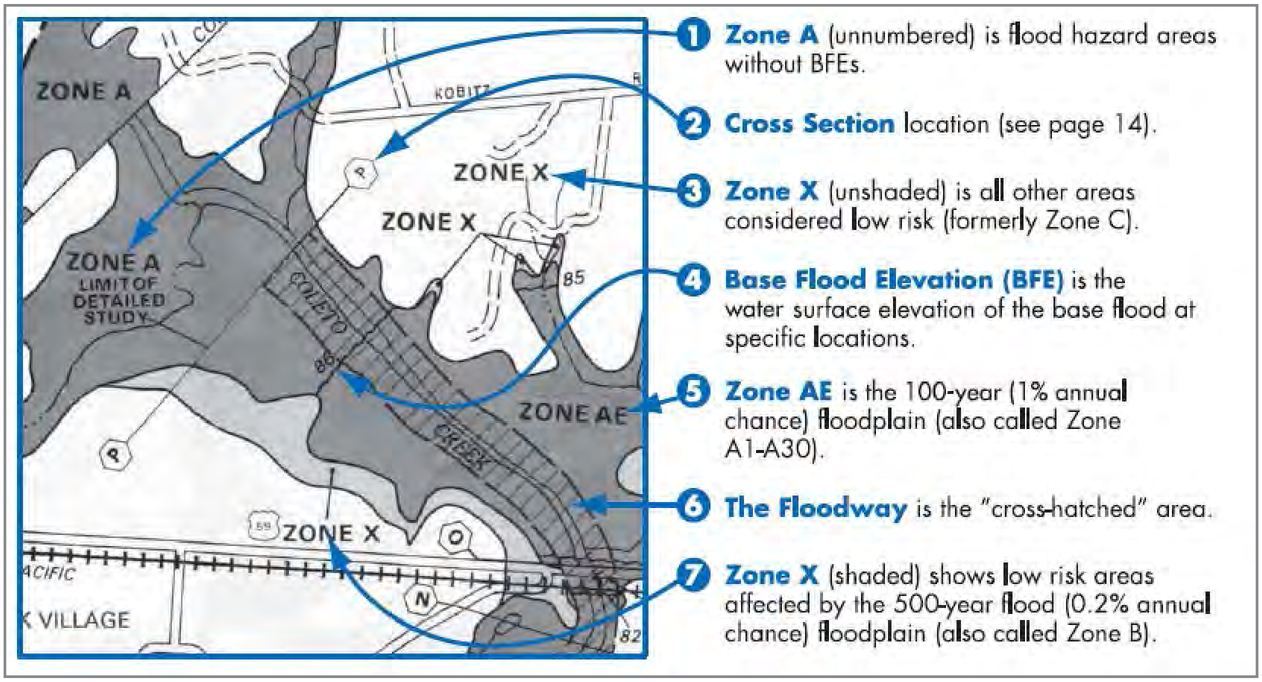
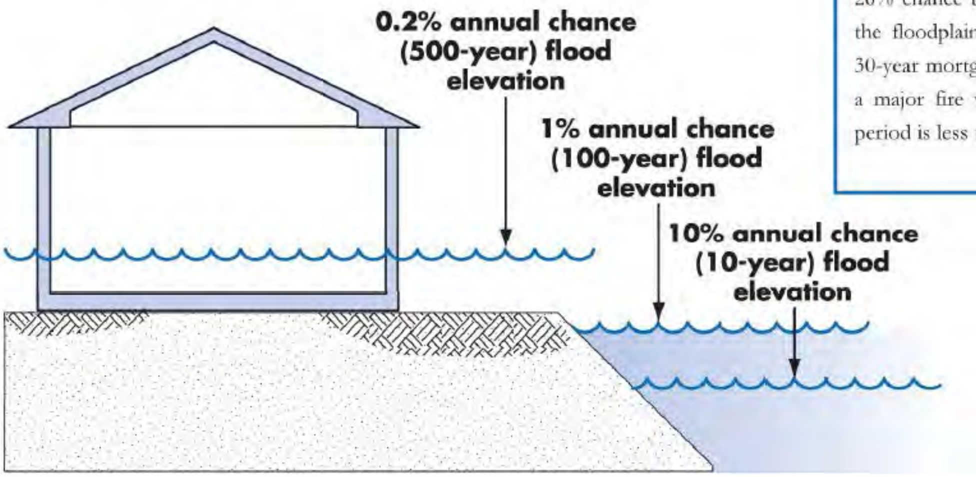


Figure 7-2: Riverine Flood Insurance Rate Map Format

Important Information

Many people don't understand just how risky the floodplain can be. There is a 26% chance that a non-elevated home in the floodplain will be damaged during a 30-year mortgage period. The chance that a major fire will occur during the same period is less than 5%.

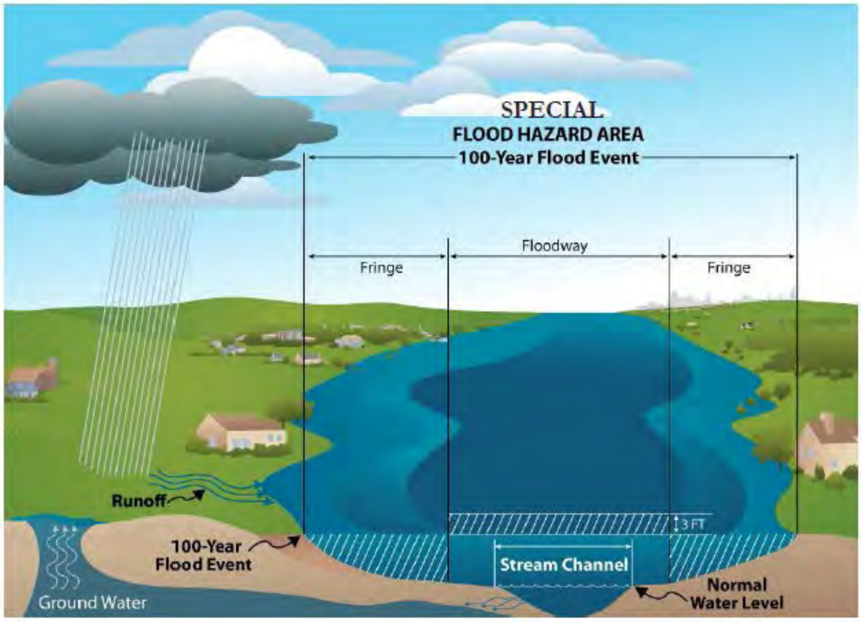


CAUTION: Nature doesn't read the flood map. Major storms and flash floods can cause flooding that rises higher than the 1% annual chance floodplain (BFE). Consider safety - protect your home or business by building higher. See page 34 to see how this will save you money on insurance.

Figure 7-3: Floodplain Risk

7.3 RIVERINE FLOODPLAIN

For floodplains with Base Flood Elevations, check the Flood Insurance Study to find the Flood Profile which shows water surface elevations for different frequency floods.

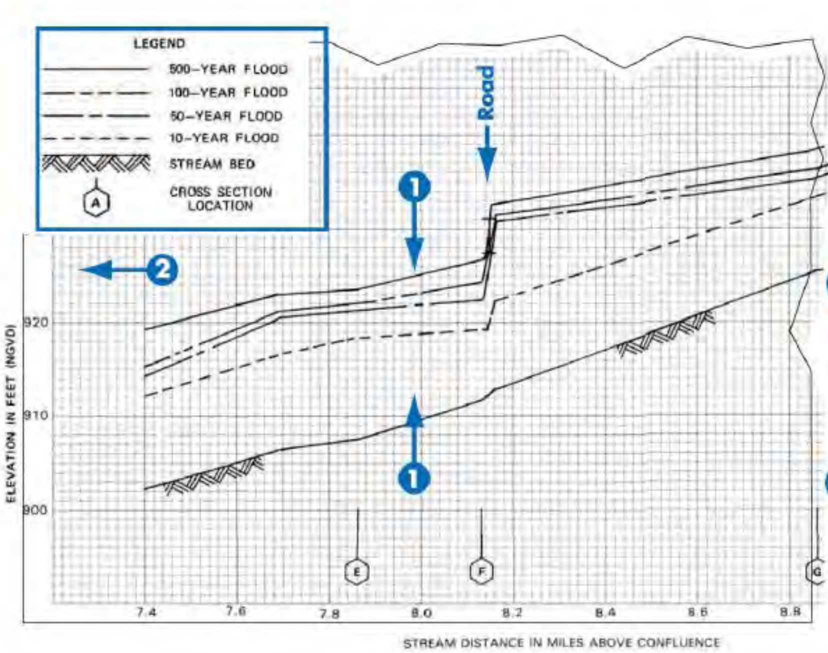


Terms and Definitions

The Special Flood Hazard Area (SFHA) is that portion of the floodplain subject to inundation by the base flood and/or flood-related erosion hazards. SFHAs are shown on FHBMs or FIRMs as Zones A, AE, A1-A30, AH, AO, AR, V, VE, and V1-V30.

The base flood means the flood having a 1% chance of being equaled or exceeded in any given year (also called "100-year floodplain").

Figure 7-4: Riverine Floodplain Illustration



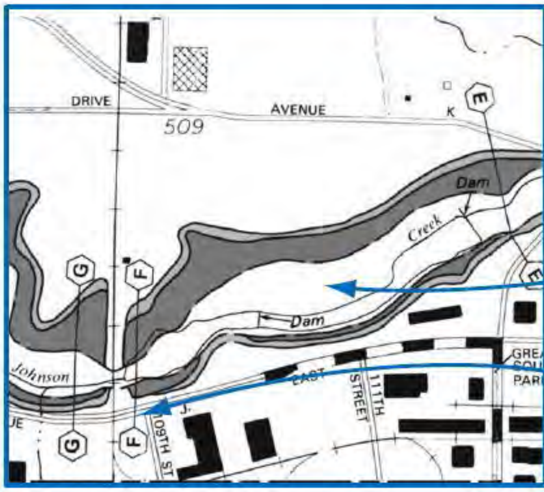
Flood profiles can be used to determine the BFE at a specific site. Profiles also show estimated water surface elevations for floods other than the 1% annual chance flood (100-year flood.)

1. On the effective flood map, locate your site by measuring the distance, along the center line of the stream channel, from a road or cross section, for example, (E) or (F).

2. Scale that distance on the Flood Profile and read up to the profile of interest, then across to determine the elevation.

Figure 7-5: Riverine Flood Profile

FEMA prepares Floodway maps as companions to many FIRMs. Check to see if your project will be in the Floodway because additional engineering may be required.



Important Information

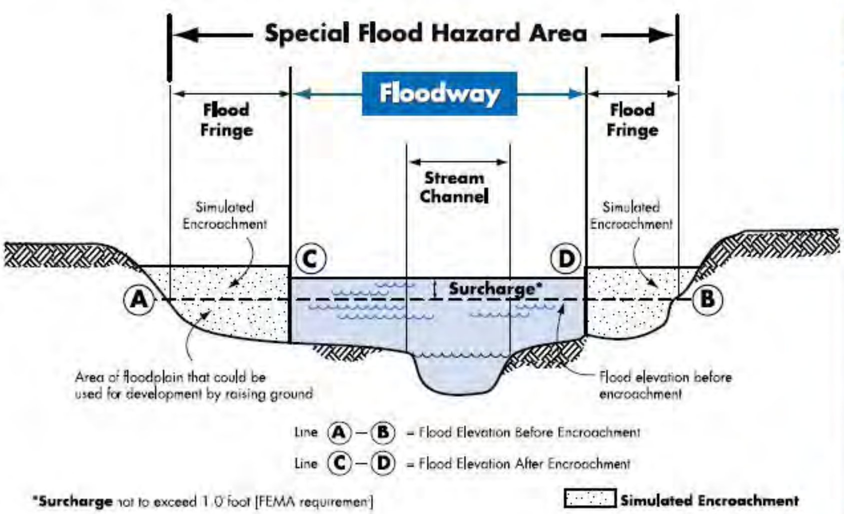
Initial floodplain maps were flood hazard boundary maps accompanied with separate floodway maps.

Floodway maps do not show flood zones or BFEs. Check the companion FIRM and FIS for that information.

1. **The Floodway** is the "white" area along the waterway.
2. **Cross Section** location, where ground surveys determined the shape of the land and how constrictions such as bridges and culverts affect the flow of floodwater.

Figure 7-6: The Riverine Flood Boundary

For any proposed floodway development, before a local floodplain permit can be issued, the applicant must provide evidence that "no rise" will occur You will need a qualified registered engineer to make sure your proposed project won't increase flooding on other properties.



Terms and Definitions

The Floodway is the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to pass the base flood discharge without increasing flood depths.

Computer models of the floodplain are used to simulate "encroachment" or fill in the flood fringe in order to predict where and how much the base flood elevation would increase if the floodplain is allowed to be filled.

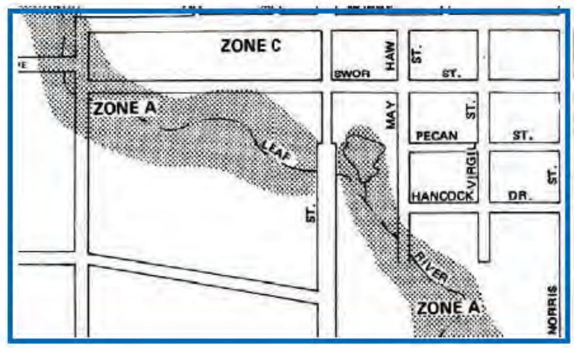
Figure 7-7: Understanding the Floodway

Some floodplains are delineated using approximate methods and therefore do not have specified base flood elevations (BFE). If you need help determining the BFE, check with your community permit office and/or FEMA.

FEMA publication Managing Floodplain Development in Approximate Zone A Areas (FEMA 265) is useful for engineers and community officials.

Terms and Definitions

An Approximate or Unnumbered A Zone is a special flood hazard area where BFE information is not provided.



Topographic maps can be used to estimate the Base Flood Elevation if the FIRM shows approximate or unnumbered A Zones.

Figure 7-8: Approximate Flood Zones and Unnumbered A Zones

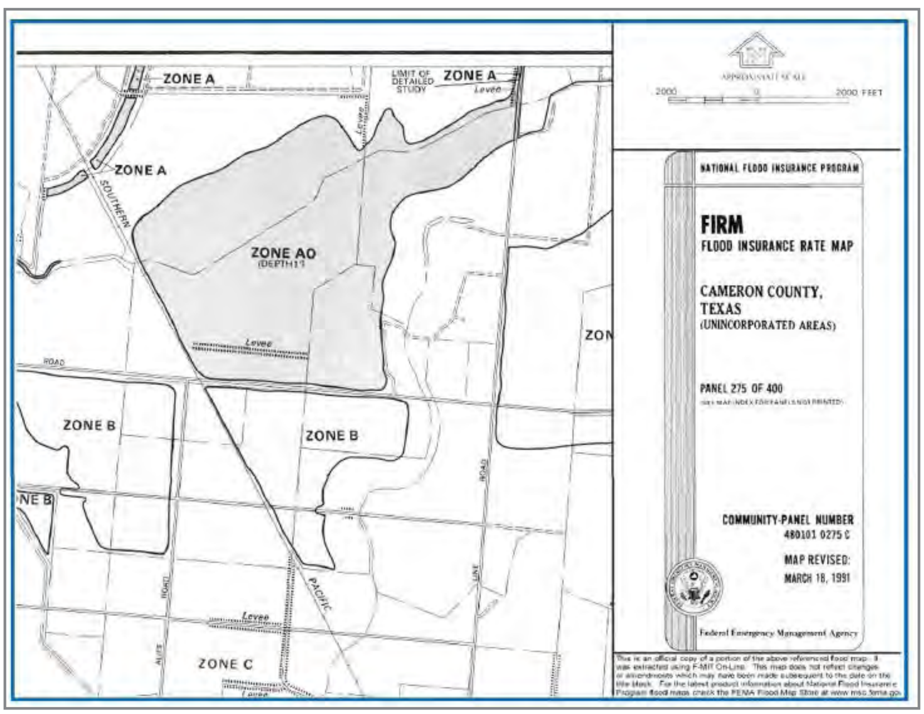


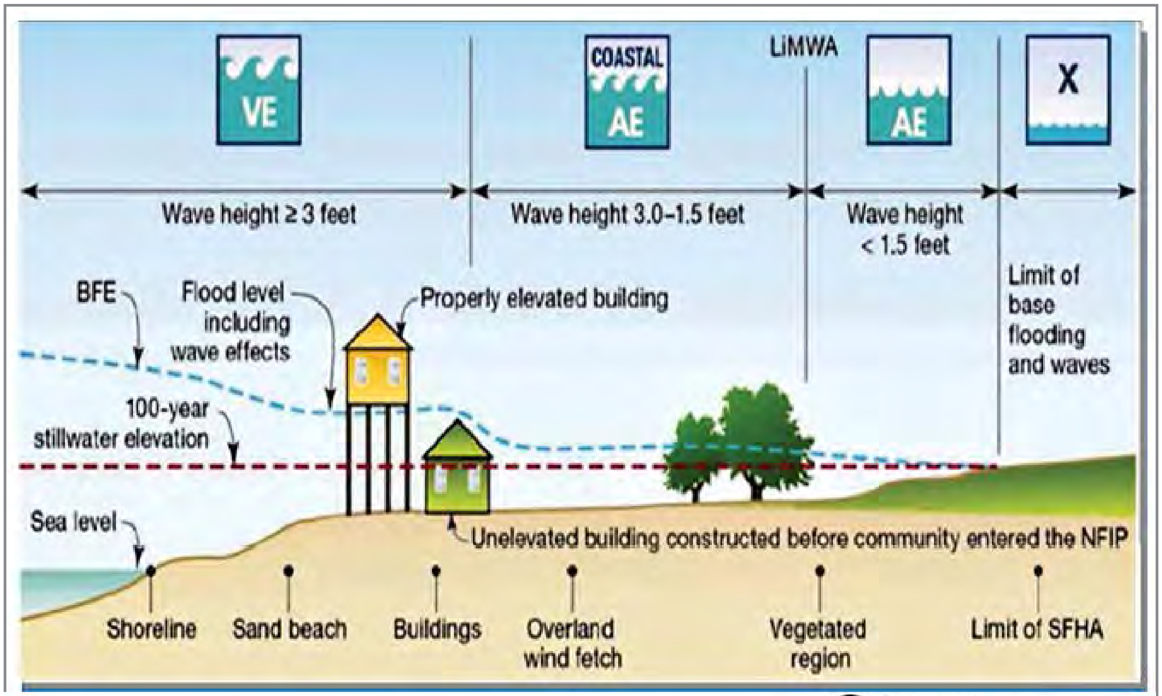
Figure 7-9: Areas of Shallow Flooding

These are areas with a 1% annual chance of a shallow flood (1-3 feet of flood depth) each year.

Zone AH areas usually flood from pondin gin which water is generally not moving across the land.

Zone AO areas usually flood from sheet flow in which water moves across land where there is no defined channel.

7.4 COASTAL FLOODING

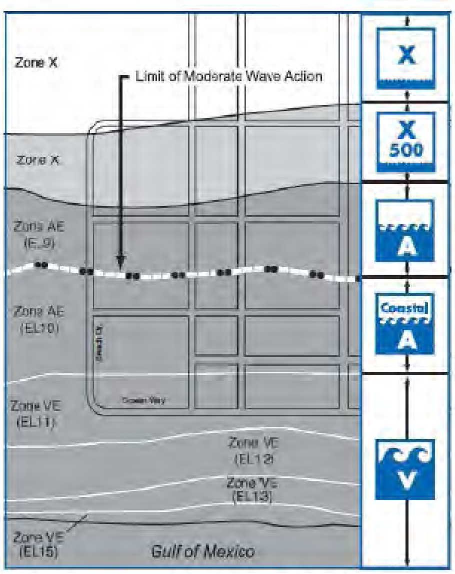


Terms and Definitions

The Coastal High Hazard Area (V Zone) is the Special Flood Hazard Area that extends from offshore to the inland limit of a primary frontal dune along an open coast and any othe area subject to high velocity wave action. The area is designated on the FIRM as Zone V1-V30, VE, or V.

The term Coastal A Zone meand the portion of the SFHA landward of the V Zone or landward of a shoreline that does not have a mapped V Zone. The principal sources of flooding are associated with astronimical tides, storm surges, seiches or tsunamis. Coastal A Zones may be subject to wave effects, velocity flows, erosion, scour, or combinations of these forces and may be treated as V Zones.

Figure 7-10: Coastal Flooding Illustration



For illustration purposes only. Some FIRMs published after 2009

Figure 7-11: The Coastal A Zone

- Post-flood evaluations and laboratory tests confirm that breaking waves as small as 1.5 feet high cause damage to walls and scour around foundations.
- The Limit of Moderate Wave Action (LiMWA)may be shown on revised FIRMs.
- LiMWA conditions are found inland of Zone V and along shorelines without Zone V.
- LiMWA conditions occur where stillwater depths are between 2 and 4 feet, which can support 1.5 to 3-foot waves.
- Scour and erosion should be considered in LiMWA if soils are sandy and erodible.
- Federal flood insurance in LiMWAs is rated using Zone A rates (lower than Zone V rates).

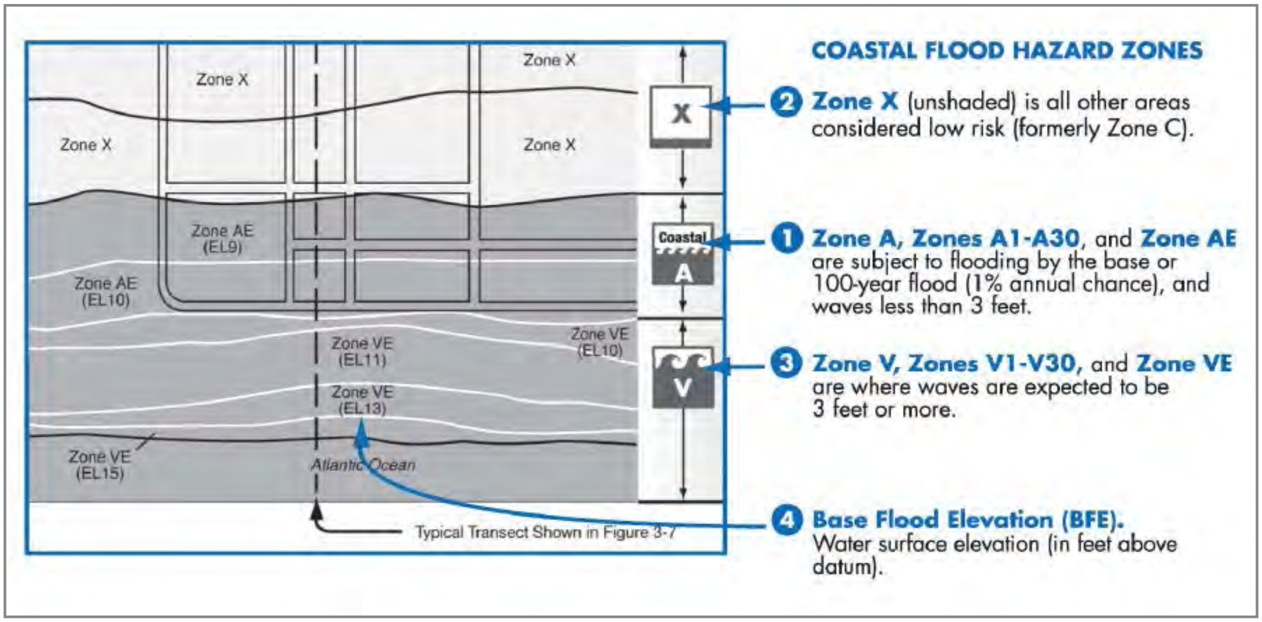
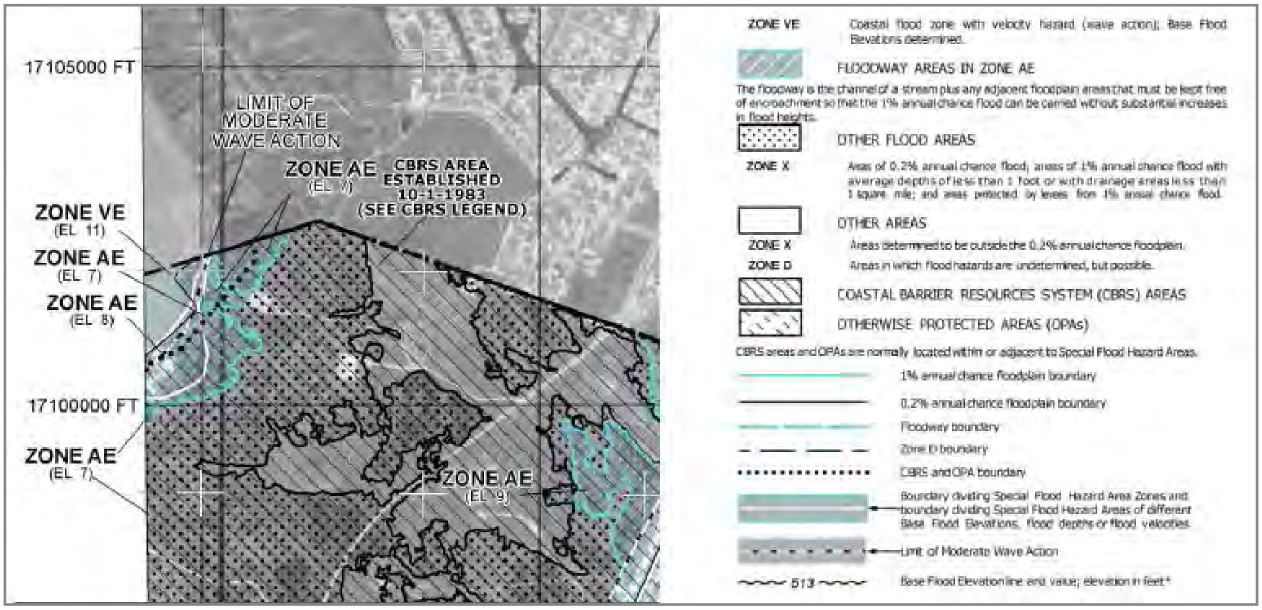


Figure 7-12: Coastal Flood Insurance Rate Map



In areas designated as a Coastal Barrier Resource System (CBRS) or an Otherwise Protected Ara (OPA), NFIP insurance is not available for new for Substantially Improved structures built on or after the designation date.

Figure 7-13: Coastal Barriers Resource System (CBRS) Areas

7.5 FEMA FLOODPLAIN MAP MODIFICATIONS

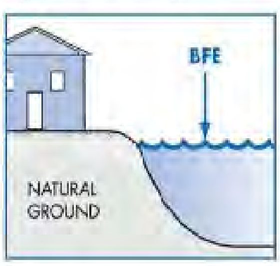
Most changes to FIRMs are made by Letter of Map Change (LOMC) – a letter which reflects an official revision to an effective NFIP map.

1. ***Letter of Map Amendment (LOMA)*** is an official amendment to an effective FIRM that may be issued when a property owner provides additional technical information from a licensed land surveyor or engineer, such as ground elevation relative to the BFF, SFHA, and the building. Lenders may waive the flood insurance requirements if the LOMA documents that a building is on ground above mapped floodplain.
2. ***Electronic Letter of Map Amendment (eLOMA)*** is a web-based application to submit simple LOMAs to FEMA.
3. ***Letter of Map Revision (LOMR)*** is an official revision to an effective FIRM that may be issued to change flood insurance risk zones, special flood hazard area and floodway delineations, BFEs and/or other map features. Lenders may waive the insurance requirement if the approved map revision shows buildings to be outside the SFHA.
4. ***Letter of Map Revision Based on Fill (LOMR-F)*** is an official revision to an effective FIRM that is issued to document FEMA's determination that a structure or parcel of land has been elevated by fill above the BFE, and therefore is no longer in the SFHA. Lenders may waive the insurance requirement if the LOMR-F shows that a building on fill is above the BFE.
5. ***Physical Map Revision (PMR)*** may be issued for major floodplain changes that require engineering analyses, such as bridges, culverts, channel changes, flood control measures, and large fills that change the BFE or Floodway. Physical map revisions are also issued when a new study updates or improves the FIRM.

Requests for map revisions must be coordinated through your community.

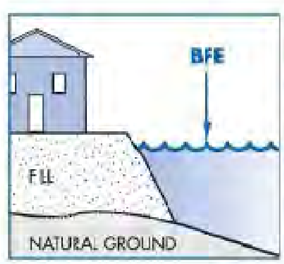
Flood Map Revisions: LOMA and LOMR-F

The most accurate information available is used to make flood maps, including topographic base maps and detailed engineering methods or methods of approximation. FEMA issues map revisions if technical data are submitted to support the changes.



Letter of Map Amendment (LOMA) is an official amendment to an effective FIRM that may be issued when a property owner provides additional technical information from a registered land surveyor or engineer, such as ground elevation relative to the BFE.

Lenders may waive the flood insurance requirement if the LOMA removes a building site from the SFHA because natural ground at the site is above the BFE.



Letter of Map Revision Based on Fill (LOMR-F) is an official revision to an effective FIRM that is issued to document FEMA's determination that a structure or parcel of land has been elevated by fill above the BFE, and therefore is no longer in the SFHA. Lenders may waive the insurance requirement if the LOMR-F removes a building site from the SFHA.

Check online at www.fema.gov/letter-map-amendment-letter-map-revision-based-fill-process for more about map revisions for different user groups (homeowners, floodplain managers, surveyors, engineers and insurance professionals). Also learn about eLOMA, a web-based application for surveyors and engineers to submit applications for simple LOMAs and FEMA.

Figure 7-14: Floodplain Map Revisions

Flood Map Revisions: CLOMR and LOMR

- **Conditional Letter of Map Revision (CLOMR)** is a letter commenting on whether a proposed project, if built as shown on the submitted documentation, would meet the standards for a map revision. Communities may require this evidence prior to issuing a permit, and the Certificate of Occupancy/Compliance should be withheld until receipt of the final LOMR based on "as-built" documentation and certification.

- **Letter of Map Revision (LOMR)** is an official revision to an effective FIRM that may be issued to change flood insurance risk zones, special flood hazard areas and floodway boundary delineations, BFEs and/or other map features. Lenders may waive the insurance requirement if the approved map revision shows buildings to be outside of the SFHA.

To download the forms used to submit map revisions, go to www.fema.gov/library, click on "Search by Resource Title," and search on "MT-EZ", "MT-1", and "MT-2".

Figure 7-15: CLOMR and LOMR Flood Map RevisionsResource System (CBRS) Areas

7.6 FLOODPLAIN FILL

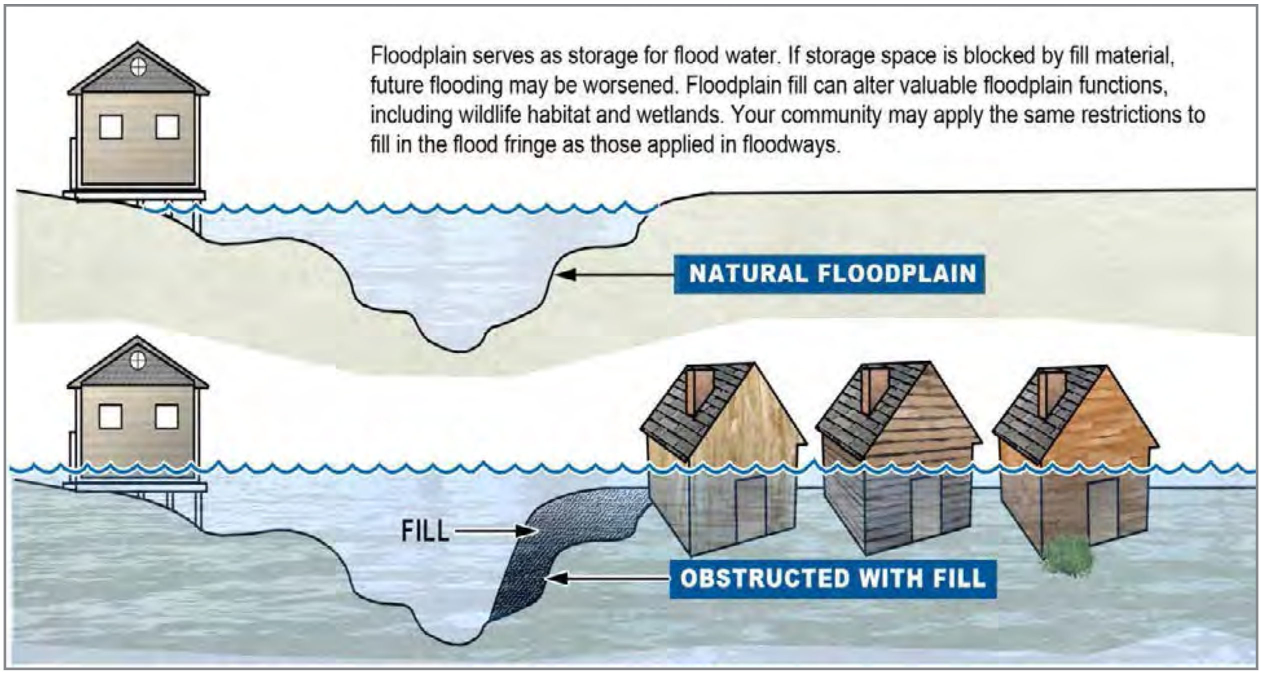


Figure 7-16: Floodplain Fill Can Make Things Worse

Make sure that floodplain fill projects do not harm neighbors. Floodway fill is only allowed if an engineering evaluation demonstrates that no net-rise in the floodplain level will occur. Floodways can be dangerous because water may flow at a fast rate.

CODE OF FEDERAL REGULATIONS - 44 CFR 60.3 D(3): ENCROACHMENT (FILL)

Prohibit encroachments, including fill, new construction, substantial improvements, and other development within the adopted regulatory floodway unless it has been demonstrated through hydrologic and hydraulic analyses performed in accordance with standard engineering practice that the proposed encroachment would not result in any increase in flood levels within the community during the occurrence of the base flood discharge.

7.7. FLOODPLAIN PROTECTION MEASURES

IS YOUR BUILDING SITE ABOVE THE BASE FLOOD ELEVATION?

If your land is shown on the floodplain map as being in the regulatory floodplain, but your building site is higher than the BFE, get a licensed land surveyor or a registered professional engineer to prepare an Elevation Certificate (EC). Submit the EC along with a Letter of Map Amendment to FEMA to verify that your property is above the BFE. If approved, it could remove the mandatory federal requirement to purchase flood insurance if you have a federally backed mortgage.

FREEBOARD: BUILD ABOVE THE BASE FLOOD ELEVATION (BFE)

Want to save some money and have peace of mind at the same time? Add Freeboard to build higher than the minimum elevation requirement. Freeboard is a factor of safety, usually one, two or even three feet above the BFE. Freeboard tends to compensate for the many unknown factors that could contribute to flood heights greater than the BFE.

Annual Flood Insurance Cost If you have:

- a post-FIRM structure
- in an AE Zone
- with $250,000 structural coverage (maximum)
- with $100,000 contents (maximum)

The approximate annual cost for flood insurance:

- +3 ft. $500
- +2 ft. $550
- +1 ft. $700
- BFE $1,100
- -1 ft. $5,000
- -2 ft. expensive (submit for rate)

This is hypothetical and flood insurance premiums change annually, however, it illustrates the value in building above the Base Flood Elevation.

While building owners will save insurance money if they elevate above the BFE, the cost of insurance can more than double if a building is only one foot below the BFE.

In this case, the community may be able to grant a variance, however, the owner will most likely be required to buy insurance.

7.8. FLOODPLAIN MANAGEMENT DESIGN PROCESS GUIDE

The following section outlines the design approach to minimize floodplain damage to new development.

DRAINAGE AND FLOODPLAIN MANAGEMENT PRACTICES

1. Build outside the floodplain and floodway to the maximum extent practical, if floodplain development is proposed, apply the guidance in this Chapter to maximize safety, avoid community impacts, and minimize risk.

2. Minimize flow path alteration in the development design process to attempt to maintain the existing time of concentration.

3. The owner or developer of a site is responsible for conveyance of all existing stormwater flow through the property, even for storm events up to the 100-year storm. Design of on-site conveyance systems including channel, culvert, and drainage easements shall account for future anticipated upstream development.

4. Easements shall be dedicated to the public drainage system to convey the design storm from the upstream contributing drainage area through the property. Maintenance access shall be provided to all drainage improvements including stormwater detention basins or other structural BMPs.

5. Open channels are the preferred conveyance system and shall be designed with 4:1 side slopes where practicable with established vegetation.

6. Develop drainage standards for storm drain systems, culverts, and channels and require the design engineer to apply appropriate hydrologic and hydraulic modeling techniques to demonstrate compliance. Examples include:

    - Five-year design storm for storm drain systems such that the hydraulic grade line is below the top of curb or contained within the channel when the drainage area is less than 200 acres.

    - Twenty-five or 100-year design storm for cross culverts with a contributing drainage area greater than 100 acres such that the hydraulic grade line is below the top of road. Recommend the inclusion of freeboard of at least one foot as cross culverts are prone to debris blockage during large storm events.

7. Require that new development does not increase peak flow rates or floodplain elevations on adjacent or downstream property owners. This can be accomplished by requiring that the developed site peak flow rates remain equal to or less than the existing land use peak flow rates.

    - Common practices include the demonstration that peak flow rates are not increased by development for the 2-, 10-, 25-, and 100-year storms through detention basins, low impact development, and on-site measures.

Drainage Criteria Manual resources to guide proper hydrologic and hydraulic design include:

- City of Corpus Christi
- Aransas County
- Harris County Flood Control District – Hydrology and Hydraulics Guidance Manual

The Harris County Flood Control District also provides numerous other guidance documents relating to drainage, low impact development design, slope protection, detention basins, and other measures including CAD standards. These guidance documents can be found here.

7.9. FLOODPLAIN PERMIT REVIEW GUIDE

Permits can be issued by the local government floodplain administrator. The permit reviewer has to check many things. Some of the key items are:

- Is the site in the mapped floodplain?
- Is the site in the mapped floodway?
- Have other local, State and federal permits been obtained (septic, water quality, wetland)?
- Is the site reasonably safe from flooding?
- Does the site plan show the BFE, development location and the floodplain delineation?
- Is substantial improvement of an older building proposed?
- Is an addition proposed?
- Will new buildings and utilities be elevated properly?
- Will manufactured homes be properly elevated and anchored?
- Do the plans show an appropriate and safe foundation?
- Will an Elevation Certificate be required?

The Community Floodplain Administrator may seek resources or Floodplain Planning (FPP) Grants from the TWDB. This agency is a resource and can help in the funding of floodplain mapping/protection planning and the development of mitigation projects/programs to create a more safe and resilient community in the Texas coastal region.

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APPENDIX A

MODEL ORDINANCE

STORMWATER RUNOFF MANAGEMENT MODEL ORDINANCE

This document is for guidance purposes only and is not a substitute for any existing requirements. Additionally, the information contained in this guidance is not a substitute for professional advice you would receive from an attorney and does not constitute legal advice or a legal opinion.

A stormwater runoff ordinance can improve coastal water quality, manage floodplains, and promote resilient development and infrastructure and enhance water supplies that maximize tourism, recreation, and economic prosperity in the Texas coastal region.

TABLE OF CONTENTS

SECTION 1. GENERAL PROVISIONS

1.1. FINDINGS OF FACT

It is hereby determined that:

Land development projects and associated increases in impervious cover can alter the hydrologic response of local watersheds and can increase stormwater runoff rates and volumes, flooding, stream channel erosion, and sediment transport and deposition;

This stormwater runoff can contribute increased quantities of water-borne pollutants, and;

Stormwater runoff, soil erosion and nonpoint source pollution can be managed through the application of sound stormwater management practices that minimize the impact of development on water quality and flooding; and

Increased stormwater runoff rates and volumes, flooding, stream channel erosion, soil erosion, and nonpoint source pollutants can pose as a threat to the public health.

Therefore, the **(jurisdictional stormwater authority)** establishes this set of stormwater runoff regulations for the purpose of protecting local water resources, managing floods, and enhancing public health and safety.

1.2. PURPOSE

The purpose of this ordinance is to establish minimum stormwater management requirements and controls to protect and safeguard the general health, safety, and welfare of the public residing in watersheds within this jurisdiction. This ordinance seeks to meet that purpose through the following objectives:

1. Minimize increases in stormwater runoff from any development in order to reduce flooding, siltation, increases in stream temperature, and streambank erosion as well as maintain the integrity of stream channels, wetlands, and tidal waters;

2. Minimize increases in nonpoint source pollution caused by stormwater runoff from development which could degrade local water quality;

3. Reduce stormwater runoff rates and volumes, soil erosion and nonpoint source pollution, wherever possible, through stormwater management controls and to ensure that these management controls are properly maintained and pose no threat to public safety;

4. Establish buffer zones along creeks, rivers, wetlands, and tidal waters to enhance water quality management and floodplain protection; and

5. Promote low impact development practices to manage stormwater as a resource and provide beneficial uses to benefit the local water supplies.

1.3. APPLICABILITY

This ordinance shall be applicable to all subdivision or site plan applications for property within the city limits and the city's extraterritorial jurisdiction, unless eligible for an exemption or granted a waiver by the **(jurisdictional stormwater authority)** under the specifications of Section 4 of this ordinance. The ordinance also applies to land development activities that are smaller than the minimum applicability criteria if such activities are part of a larger common plan of development that meets the following applicability criteria, even though multiple separate and distinct land development activities may take place at different times on different schedules. In addition, all development plans must be reviewed by the **(jurisdictional stormwater authority)** to ensure that established water quality standards will be maintained during and after development of the site and that post construction runoff levels are consistent with any local and regional watershed plans.

To manage adverse impacts of stormwater runoff, the **(jurisdictional stormwater authority)** has developed a set of performance standards that must be met at new development and re-development sites. The following activities are exempt from these stormwater performance criteria:

1. Any logging and agricultural activity

2. Additions or modifications to existing single-family structures

3. New development or redevelopment projects that do not disturb more than one acre of land and add less than 10,000 square feet of new impervious cover, provided they are not part of a larger common development plan;

4. Any part of a land development project that was approved by the **(jurisdictional stormwater authority)** prior to the adoption of this ordinance;

5. Redevelopment activities that involve the replacement of impervious cover when the original impervious cover was wholly or partially lost due to natural disaster or other acts of God occurring after the date of ordinance adoption; and

6. Repairs to any stormwater treatment practice deemed necessary by **(jurisdictional stormwater authority)**.

When a site development plan is submitted that qualifies as a redevelopment project as defined in Section 2 of this ordinance, only any newly created impervious cover is subject to these stormwater requirements. Final authorization of all redevelopment projects will be determined after a review by **(jurisdictional stormwater authority)**.

1.4. COMPATIBILITY WITH OTHER PERMIT AND ORDINANCE REQUIREMENTS

This ordinance is not intended to interfere with, abrogate, or annul any other ordinance, rule or regulation, stature, or other provision of law. The requirements of this ordinance should be considered minimum requirements, and where any provision of this ordinance imposes restrictions different from those imposed by any other ordinance, rule or regulation, or other provision of law, whichever provisions are more restrictive or impose higher protective standards for human health or the environment shall be considered to take precedence.

1.5. SEVERABILITY

If the provisions of any article, section, subsection, paragraph, subdivision or clause of this ordinance shall be judged invalid by a court of competent jurisdiction, such order of judgment shall not affect or invalidate the remainder of any article, section, subsection, paragraph, subdivision or clause of this ordinance.

1.6. DEVELOPMENT OF A STORMWATER DESIGN MANUAL

The **(jurisdictional stormwater authority)** has adopted the "Guidance for Sustainable Stormwater Drainage on the Texas Coast" as the local design manual. This manual includes a list of acceptable stormwater treatment practices, including the specific design criteria and operation and maintenance requirements for each stormwater practice. The manual may be updated and expanded from time to time, at the discretion of the local review authority, based on improvements in engineering, science, monitoring and local maintenance experience. Stormwater treatment practices that are designed and constructed in accordance with these design and sizing criteria will be presumed to meet the minimum water quality performance standards of 80% removal of total suspended solids (TSS) and manage the peak rate of runoff from the 1.5-inch storm.

SECTION 2. DEFINITIONS

"Applicant" means a property owner or agent of a property owner who has filed an application for a stormwater management permit.

"Buffer Zone" means the vegetated area free of impervious cover and development adjacent to a creek, river, natural drainageway, wetlands, and tidal waters.

"Building" means any structure, either temporary or permanent, having walls and a roof, designed for the shelter of any person, animal, or property, and occupying more than 100 square feet of area.

"Channel" means a natural or artificial watercourse with a definite bed and banks that conducts continuously or periodically flowing water.

"Conservation development" is a land use approach that adopts principles for sustainable development while protecting the property's natural resources in perpetuity, including open space preservation. A conservation development usually dedicates a minimum of 50% of the total development parcel as open space. High density development can be allocated to the developed portion of the parcel.

"Dedication" means the deliberate appropriation of property by its owner for general public use.

"Developer" means a person who undertakes land disturbance activities.

"Development" means any land modification activity including the construction of buildings, roads, paved storage areas, and parking lots for single-family subdivisions, multi-family, retail, medical, commercial, educational, and retail projects.

"Drainage Easement" means a legal right granted by a landowner to a grantee allowing the use of private land for stormwater management purposes.

"Payment in Lieu" means a payment of money in place of meeting all or part of the storm water performance standards required by this ordinance.

“Impervious Cover” means those surfaces that cannot effectively infiltrate rainfall (including such things as building rooftops, pavement, sidewalks, paved and unpaved driveways, parking areas, and streets, but not including swimming pools and ponds).

“Jurisdictional Wetland" means an area that is inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions, commonly known as hydrophytic vegetation.

“Land Disturbance Activity” means any activity which changes the volume or peak flow discharge rate of rainfall runoff from the land surface. This may include the grading, digging, cutting, scraping, or excavating of soil, placement of fill materials, paving, construction, substantial removal of vegetation, or any activity which bares soil or rock or involves the diversion or piping of any natural or man-made watercourse.

“Landowner” means the legal or beneficial owner of land, including those holding the right to purchase or lease the land, or any other person holding proprietary rights in the land.

“Maintenance Agreement" means a legally recorded document that acts as a property deed restriction, and which provides for long-term maintenance of stormwater management practices.

“Nonpoint Source Pollution” means pollution from any source other than from any discernible, confined, and discrete conveyances, and shall include, but not be limited to, pollutants from agricultural, silvicultural, mining, construction, subsurface disposal and urban runoff sources.

“Off-Site Facility” means a stormwater management measure located outside the subject property boundary described in the permit application for land development activity.

“On-Site Facility” means a stormwater management measure located within the subject property boundary described in the permit application for land development activity.

“Redevelopment” means any construction, alteration or improvement exceeding one acre or 10,000 square feet of new impervious cover in areas where existing land use is high density commercial, industrial, institutional or multi-family residential.

“Site” means the property boundaries encompassing a development and the area described in the permit application.

“Stop Work Order” means an order issued which requires that all construction activity on a site be stopped.

“Storm water pollution prevention plan (SWPPP)” means a plan that is prepared by designers, engineers, or contractors to minimize erosion and sedimentation during the construction process. Often the SWPPP is called a SW3P. The SWPPP is detailed in the TCEQ Construction General Permit TXR150000.

“Stormwater Management” means the use of structural or non-structural practices that are designed to reduce storm water runoff pollutant loads, discharge volumes, peak flow discharge rates and detrimental changes in stream temperature that affect water quality and habitat.

"Stormwater Runoff" means flow on the surface of the ground, resulting from precipitation.

“Stormwater Treatment Practices (STPs)” means measures, either structural or nonstructural, that are determined to be the most effective, practical means of preventing or reducing point source or nonpoint source pollution inputs to stormwater runoff and water bodies.

“Water Quality Volume (WQv)” means the storage needed to capture and treat the design storm identified in the stormwater guidance manual.

“Watercourse” means a permanent or intermittent stream or other body of water, either natural or man-made, which gathers or carries surface water.

SECTION 3. PERMIT PROCEDURES AND REQUIREMENTS

3.1. PERMIT REQUIRED

No land owner or land operator shall receive any of the building, grading or other land development permits required for land disturbance activities without first meeting the requirements of this ordinance prior to commencing the proposed activity.

3.2. APPLICATION REQUIREMENTS

Unless specifically excluded by this ordinance, any land owner or operator desiring a permit for a land disturbance activity shall submit to the **(jurisdictional stormwater authority)** a permit application containing the material required by the stormwater design manual. A pre-development planning meeting shall occur for all single-family development projects greater than 20 acres in area and all commercial (retail, medical, institutional, educational) greater than three (3) acres in area. The meeting will focus on the land plan, stormwater drainage, floodplain setbacks, buffers, water quality and flood reduction practices and may include a site investigation.

The stormwater management plan shall be prepared to meet the requirements of Sec. 5 of this ordinance, the maintenance agreement shall be prepared to meet the requirements of Sec. 7 of this ordinance, and fees shall be those established by the **(jurisdictional stormwater authority)**.

3.3. APPLICATION REVIEW FEES

The fee for review of any land development application shall be based on the amount of land to be disturbed at the site, and the fee structure shall be established by the **(jurisdictional stormwater authority)**. All of the monetary contributions shall be credited to a local budgetary category to support local plan review, inspection and program administration, and shall be made prior to the issuance of any building permit for the development.

3.4. APPLICATION PROCEDURE

1. Applications for land disturbance activity permits must be filed with the **(appropriate review agency)** on any regular business day. This can be a component of the pre-development planning meeting if required based on criteria.
2. A copy of this permit application shall be forwarded to **(jurisdictional stormwater authority)** for review.
3. Permit applications shall include the following: two copies of the stormwater management concept plan, two copies of the maintenance agreement, and any required review fees.
4. Within 20 business days of the receipt of a complete permit application, including all documents as required by this ordinance, the **(jurisdictional stormwater authority)** shall inform the applicant whether the application, plan and maintenance agreement are approved or disapproved.
5. If the stormwater management plan is disapproved, the applicant may revise the stormwater management plan. If additional information is submitted, the **(jurisdictional stormwater authority)** shall have 10 business days from the date the additional information is received to inform the applicant that the plan is either approved or disapproved.
6. If the final stormwater management plan is approved by the **(jurisdictional stormwater authority)**, all appropriate land disturbance activity permits shall be issued.

3.5. PERMIT DURATION

Permits issued under this section shall be valid from the date of issuance through the date the **(jurisdictional stormwater authority)** notifies the permit holder that all stormwater management practices have passed the final inspection required under permit condition.

SECTION 4. WAIVERS TO STORMWATER MANAGEMENT REQUIREMENTS

4.1. WAIVERS FOR PROVIDING STORMWATER MANAGEMENT

Every applicant shall provide for stormwater management as required by this ordinance, unless a written request is filed to waive this requirement. Requests to waive the stormwater management plan requirements shall be submitted to the **(jurisdictional stormwater authority)** for approval.

The minimum requirements for stormwater management may be waived in whole or in part upon written request of the applicant, provided that at least one of the following conditions applies:

1. Alternative minimum requirements for on-site management of stormwater discharges have been established in a stormwater management plan that has been approved by the **(jurisdictional stormwater authority)**, and the implementation of the plan is required by local ordinance. The "*Guidance for Sustainable Stormwater Drainage on the Texas Coast*" provides direction for alternate standards (low impact development practices).
2. Provisions are made to manage stormwater by an off-site facility. The off-site facility is required to be in place, to be designed and adequately sized to provide a level of stormwater control that is equal to or greater than that which would be afforded by on-site practices and to have a legally obligated entity responsible for long-term operation and maintenance of the stormwater practice. This includes the potential for a fee-in-lieu (Section 4.2) of providing on-site stormwater management practices if the **(jurisdictional stormwater authority)** has an established stormwater management fee-in-lieu program.

In instances where one of the conditions above applies, the **(jurisdictional stormwater authority)** may grant a waiver from strict compliance with these stormwater management provisions, as long as acceptable mitigation measures are provided.

Furthermore, where compliance with minimum requirements for stormwater management is waived, the applicant will satisfy the minimum requirements by meeting one of the mitigation measures selected by the **(jurisdictional stormwater authority)**. Mitigation measures may include, but are not limited to, the following:

- The purchase and donation of privately-owned lands, or the grant of an easement to be dedicated for preservation and/or reforestation. These lands should be located adjacent to the stream corridor in order to provide permanent buffer areas to protect water quality and aquatic habitat;
- The creation of a stormwater management facility or other drainage improvements on previously developed properties, public or private, that currently lack stormwater management facilities designed and constructed in accordance with the purposes and standards of this ordinance; and
- Monetary contributions (Payment-in-Lieu) to fund stormwater management activities such as research and studies (e.g., regional wetland delineation studies, stream monitoring studies for water quality and macroinvertebrates, stream flow monitoring, threatened and endangered species studies, hydrologic studies, drainage improvements, and monitoring of stormwater management practices).

4.2. PAYMENT IN LIEU OF STORMWATER MANAGEMENT PRACTICES

Where the **(jurisdictional stormwater authority)** waives all or part of the minimum stormwater management requirements, or where the waiver is based on the provision of adequate stormwater facilities provided downstream of the proposed development, the applicant shall be required to pay a fee in an amount as determined by the **(jurisdictional stormwater authority)**.

When an applicant obtains a waiver of the required stormwater management, the monetary contribution required shall be in accordance with a fee schedule (unless the developer and the stormwater authority agree on a greater alternate contribution) established by the **(jurisdictional stormwater authority)** and based on the amount of impervious cover created by the development in question. All of the monetary contributions shall be credited to an appropriate capital improvements program project and shall be made by the developer prior to the issuance of any building permit for the development.

4.3. DEDICATION OF LAND

In lieu of a monetary contribution, an applicant may obtain a waiver of the required stormwater management by entering into an agreement with the **(jurisdictional stormwater authority)** for the granting of an easement or the dedication of land by the applicant, to be used for the construction of an off-site stormwater management facility. The agreement shall be between the applicant and the **(jurisdictional stormwater authority)** prior to the recording of plats or, if no record plat is required, prior to the issuance of the building permit.

SECTION 5. GENERAL PERFORMANCE CRITERIA FOR STORMWATER MANAGEMENT

Unless judged by the **(jurisdictional stormwater authority)** to be exempt or granted a waiver, the following performance criteria shall be addressed for stormwater management at all sites:

Pre-development planning. A pre-development/concept plan meeting shall occur for all single-family development greater than 20 acres in area and all commercial development greater than three acres in area. The meeting will focus on the land plan, buffers, stormwater drainage, floodplain, and water quality management practices. A development permit application can only be submitted after the completion of this task.

Buffer Zones. Buffer zones protect waterways, wetlands, and tidal waters from the short- and long-term impacts of development activities. Buffer zones shall remain free of construction, development, or other alterations except for utility and roadway crossings and low impact development parks. The number of crossings through the buffer zone shall be minimized. No stormwater treatment practices, golf courses, septic systems, or wastewater irrigation shall be located in the buffer zone. Manicured lawns and the application of herbicides shall not be allowed in the buffer. Stormwater discharge from development and water quality measures should be dispersed into overland sheet flow before reaching the buffer zone.

Creek Buffer Zones

Creeks or swales draining less than 320 acres but more than 40 acres shall have a minimum buffer width of 25 feet from the top of bank on each side of the creek or swale or the 100-year floodplain, whichever is greater.

Creeks or rivers draining 320 or more acres shall have a minimum buffer width of 50 feet from the top of bank on each side of the creek or river or the 100-year floodplain, whichever is greater.

Wetland/Bay/Tidal Waters/Depression Storage Buffer Zones

A buffer of 25 feet shall be maintained along all tidal waters/coastal marshlands, measured horizontally from the estuarine area.

A buffer of 25 feet shall be maintained along all wetlands as measured from the inland edge of the wetland.

A buffer of 25 feet shall be maintained along all depression storage basins as measured from the edge of the high-water mark. Additionally, the volume within the natural depressions deeper than two feet and with a surface area larger than 1 acre shall be calculated and maintained so as to not adversely affect upstream/downstream properties. If there are no practical alternatives to maintain the depression storage volume at its existing location, the loss of volume shall be mitigated for on-site and within the same drainage basin. These depressions can be used toward the required detention storage.

Stormwater Detention. All site designs shall establish stormwater management practices to control the peak flow rates of stormwater discharge associated with specified design storms and reduce the generation of stormwater. At a minimum, the peak flow rate for the post developed condition shall not exceed the pre-developed peak flow rate for the 1.5-inch storm. These practices should seek to utilize pervious areas for stormwater treatment and to infiltrate stormwater runoff from driveways, sidewalks, rooftops, parking lots, and landscaped areas to the maximum extent practical to provide treatment for both water quality and quantity.

Stormwater Practice Sizing. For new development and redevelopment, structural stormwater treatment practices shall be designed to remove 80% of the average annual post development total suspended solids load (TSS) from a 1.5-inch rainfall event. It is presumed that a structural practice complies with this performance standard if it is:

- sized to capture the prescribed water quality volume;
- designed according to the specific performance criteria outlined in the local *Guidance for Sustainable Practices for the Texas Coast* including the low impact development option;
- constructed properly, and
- maintained regularly.

Erosion and Sedimentation Control. Erosion and sedimentation shall be controlled throughout the entire development process in accordance with the *Guidance for Sustainable Stormwater Drainage on the Texas Coast* or the local stormwater design manual and the TCEQ Stormwater Pollution Prevention Plan requirements under TCEQ's Construction General Permit TXR150000.

Water Quality Education. A recipient of a development permit shall implement a water quality education program with residents, homeowners, and building operators using the Texas GLO and/or other approved water quality education materials that focus on water quality protection. This includes the proper use and management of herbicides, pesticides, fertilizer, and chemical handling. In addition, guidance on landscape irrigation, trash management, and septic systems should be shared with the development occupants/operators. The *Guidance for Sustainable Stormwater Drainage on the Texas Coast* can be used as a resource.

Stormwater Practice Maintenance. A maintenance plan developed by the design engineer and acceptable to the **(jurisdictional stormwater authority)** will be required prior to approval of the permit. The maintenance plan shall adhere to the criteria found in the *Guidance for Sustainable Stormwater Drainage on the Texas Coast*. See Section 7 below.

Conservation Development Alternative. Reserved.

SECTION 6. REQUIREMENTS FOR STORMWATER MANAGEMENT PLAN APPROVAL

6.1. STORMWATER MANAGEMENT PLAN REQUIRED FOR ALL DEVELOPMENTS

No application for development will be approved unless it includes a stormwater management plan detailing in concept how runoff and associated water quality impacts resulting from the development will be controlled or managed. This plan must be prepared by an engineer licensed in the State of Texas and must indicate whether stormwater will be managed on-site or off-site and, if on-site, the general location and type of practices.

The stormwater management plan(s) shall be referred for comment to all other interested agencies, and any comments must be addressed in a final stormwater management plan. This final plan must be signed by a licensed professional engineer (PE), who will verify that the design of all stormwater management practices meet the submittal requirements outlined in the Submittal Checklist found in the stormwater design manual. No building, grading, or sediment control permit shall be issued until a satisfactory final stormwater management plan, or a waiver thereof, has undergone a review and been approved by the **(jurisdictional stormwater authority)** after determining that the plan or waiver is consistent with the requirements of this ordinance.

6.2. STORMWATER MANAGEMENT PLAN REQUIREMENTS

A stormwater management plan shall be required with all permit applications and will include the information required by the stormwater guidance manual.

The applicant must ensure access to all stormwater treatment practices at the site for the purpose of inspection and repair by securing all the maintenance easements needed on a permanent basis. These easements will be recorded with the plan and will remain in effect even with transfer of title to the property.

The applicant must execute an easement and an inspection and maintenance agreement binding on all subsequent owners of land served by an on-site stormwater management measure in accordance with the specifications of this ordinance.

6.3. PERFORMANCE BOND/SECURITY

The **(jurisdictional stormwater authority)** may, at its discretion, require the submittal of a performance security or irrevocable letter of credit acceptable to the **(jurisdictional stormwater authority)** in the amount specified in the permit which provides for the construction of temporary erosion and sedimentation controls and site stabilization (not reclamation). The amount of the security or irrevocable letter of credit shall not be less than 100% of the cost as estimated by the professional engineer who seals the permit application. The security or letter of credit shall be released after the final inspection/concurrence letter from the engineer and provision of as-built plans. The performance security shall contain forfeiture provisions for failure to complete work specified in the stormwater management plan.

SECTION 7. MAINTENANCE AND REPAIR OF STORMWATER FACILITIES

7.1. MAINTENANCE EASEMENT

Prior to the issuance of any permit that has a stormwater management facility as one of the requirements of the permit, the applicant or owner of the site must execute a maintenance easement agreement that shall be binding on all subsequent owners of land served by the stormwater management facility. The agreement shall provide for access to the facility at reasonable times for periodic inspection by the **(jurisdictional stormwater authority)**, or their contractor or agent, and for regular or special assessments of property owners to ensure that the facility is maintained in proper working condition to meet design standards and any other provisions established by this ordinance. The easement agreement shall be recorded by the **(jurisdictional stormwater authority)** in the land records.

7.2. MAINTENANCE COVENANTS

Maintenance of all stormwater management facilities shall be ensured through the creation of a formal maintenance covenant that must be approved by the **(jurisdictional stormwater authority)** and recorded into the land record prior to final plan approval. As part of the covenant, a schedule shall be developed for when and how often maintenance will occur to ensure proper function of the stormwater management facility. The covenant shall also include plans for periodic inspections to ensure proper performance of the facility between scheduled cleanouts.

The **(jurisdictional stormwater authority)**, in lieu of a maintenance covenant, may accept dedication of any existing or future stormwater management facility for maintenance, provided such facility meets all the requirements of this chapter and includes adequate and perpetual access by easement or otherwise, for inspection and regular maintenance.

7.3. REQUIREMENTS FOR MAINTENANCE COVENANTS

All stormwater management facilities must undergo, at the minimum, an annual inspection to document maintenance and repair needs and ensure compliance with the requirements of this ordinance and accomplishment of its purposes. These needs may include removal of silt, litter and other debris from all catch basins, inlets and drainage pipes, grass cutting, vegetation removal, and necessary replacement of landscape vegetation. Any maintenance needs found must be addressed in a timely manner, as determined by the **(jurisdictional stormwater authority)**, and the inspection and maintenance requirement may be increased as deemed necessary to ensure proper functioning of the stormwater management facility.

7.4. INSPECTION OF STORMWATER FACILITIES

Inspection programs may be established on any reasonable basis, including but not limited to: routine inspections; random inspections; inspections based upon complaints or other notice of possible violations; inspection of drainage basins or areas identified as higher than typical sources of sediment or other contaminants or pollutants; and joint inspections with other agencies inspecting under environmental or safety laws. Inspections may include but are not limited to: reviewing maintenance and repair records; sampling discharges, surface water, groundwater, and material or water in drainage control facilities; and evaluating the condition of drainage control facilities and other stormwater treatment practices.

7.5. RIGHT-OF-ENTRY FOR INSPECTION

When any new drainage control facility is installed on private property, or when any new connection is made between private property and a public drainage control system, sanitary sewer or combined sewer, the property owner shall grant to the **(jurisdictional stormwater authority)** the right to enter the property at reasonable times and in a reasonable manner for the purpose of inspection. This includes, but is not limited to, the right to enter a property when it has a reasonable basis to believe that a violation of this ordinance is occurring or has occurred, and to enter when necessary for abatement of a public nuisance or correction of a violation of this ordinance.

7.6 FAILURE TO MAINTAIN PRACTICES

If a responsible party fails or refuses to meet the requirements of the maintenance covenant, the **(jurisdictional stormwater authority)**, after reasonable notice, may correct a violation of the design standards or maintenance needs by performing all necessary work to place the facility in proper working condition. In the event that the stormwater management facility becomes a danger to public safety or public health, the **(jurisdictional stormwater authority)** shall notify the party responsible for maintenance of the stormwater management facility in writing. Upon receipt of that notice, the responsible person shall have 60 days to effect maintenance and repair of the facility in an approved manner. After proper notice, the **(jurisdictional stormwater authority)** may assess the owner(s) of the facility for the cost of repair work and any penalties; and the cost of the work shall be a lien on the property, or prorated against the beneficial users of the property, and may be placed on the tax bill and collected as ordinary taxes by the municipality.

SECTION 8. ENFORCEMENT AND PENALTIES

8.1. VIOLATIONS

Any development activity that is commenced or is conducted contrary to this ordinance, may be restrained by injunction or otherwise abated in a manner provided by law.

8.2. NOTICE OF VIOLATION

When the **(jurisdictional stormwater authority)** determines that an activity is not being carried out in accordance with the requirements of this Ordinance, it shall issue a written notice of violation to the owner of the property. The notice of violation shall contain:

1. the name and address of the owner or applicant;
2. the address when available or a description of the building, structure or land upon which the violation is occurring;
3. a statement specifying the nature of the violation;
4. a description of the remedial measures necessary to bring the development activity into compliance with this Ordinance and a time schedule for the completion of such remedial action;
5. a statement of the penalty or penalties that shall or may be assessed against the person to whom the notice of violation is directed; and

6. a statement that the determination of violation may be appealed to the **(jurisdictional stormwater authority)** by filing a written notice of appeal within fifteen (15) days of service of notice of violation.

8.3. STOP WORK ORDERS

Persons receiving a notice of violation will be required to halt all construction activities. This "stop work order" will be in effect until the **(jurisdictional stormwater authority)** confirms that the development activity is in compliance and the violation has been satisfactorily addressed. Failure to address a notice of violation in a timely manner can result in revocation of a permit as well as civil, criminal, or monetary penalties in accordance with the enforcement measures authorized in this ordinance.

8.4. CIVIL AND CRIMINAL PENALTIES

Any person who violates the provisions of this Ordinance may be subject to civil penalties as set forth in chapter 7 of the Texas Water Code. Penalties ranging from $50 to $25,000 for each day of violation may be imposed pursuant to section 7.102 of the Water Code. Criminal penalties may also be imposed for unauthorized discharges, failure to use pollution control devises or practices, or for intentionally or knowingly submitting false information from an application or plan pursuant to Water Code sections 7.147, 7.148 and 7.149. Pursuant to Water Code section 7.187, the criminal penalties can include fines and incarceration.

8.5. RESTORATION OF LANDS

Any violator may be required to restore land to its undisturbed condition. In the event that restoration is not undertaken within a reasonable time after notice, the **(jurisdictional stormwater authority)** may take necessary corrective action, the cost of which shall become a lien upon the property until paid.

8.6. TERMINATION

A development permit shall automatically terminate if the project owner/applicant has not commenced development within two years from the date of permit issuance. Pursuant to this Section, a permit may be terminated by revocation upon violation of a condition to the permit. Upon permit termination, the **(jurisdictional stormwater authority)** may call on the permittee's security bond/irrevocable letter of credit or other financial security in order to provide permanent stabilization of the Site.

8.7. HOLDS ON OCCUPATION PERMITS

Certificates of occupancy or other occupation permits will not be granted until a correction to all stormwater practices has been made and accepted by the **(jurisdictional stormwater authority)**.

Approved by: ______________________________ Date _________________

APPENDIX B

EXAMPLE PROJECT DESIGN: LOW IMPACT DEVELOPMENT

Reserved, to be prepared after Federal manual approval.

APPENDIX C

EXAMPLE PROJECT DESIGN: CONSERVATION DEVELOPMENT

Reserved, to be prepared after Federal manual approval.

APPENDIX D

EXAMPLE PROJECT DESIGN: CONVENTIONAL APPROACH

Reserved, to be prepared after Federal manual approval.

APPENDIX E

EXAMPLE STRUCTURAL PRACTICE MAINTENANCE PLAN

Reserved, to be prepared after Federal manual approval.

APPENDIX F

GRANT RESOURCES

As noted above, there are many grant resources available for communities to obtain funds and resources to support the design and implementation of water quality retrofit projects, flood management projects, programs, watershed protection land management activities, education, and other efforts. The websites listed below are as of October 2018.

WATER QUALITY

- TCEQ: https://www.tceq.texas.gov/waterquality/nonpoint-source/grants/grant-pgm.html
- EPA clearinghouse: https://www.epa.gov/nps/funding-resources-watershed-protection-and-restoration
- EPA LID: https://www.epa.gov/green-infrastructure/green-infrastructure-funding-opportunities
- EPA Focus on parks: https://www.epa.gov/nps/green-infrastructure-parks-guide
- GLO coastal funding: http://www.glo.texas.gov/coast/grant-projects/funding/index.html
- TWDB all funding: http://www.twdb.texas.gov/financial/programs/
- TWDB CWSRF: http://www.twdb.texas.gov/financial/programs/cwsrf/
- CWSRF Green projects: http://www.twdb.texas.gov/financial/programs/GREEN/doc/GreenProjectReserve_CWSRF_brochure.pdf
- NRCS funding: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/?cid=stelprdb1048817

FLOOD MANAGEMENT

- TWDB floodplain planning: Floodplain Planning (FPP) Grants