Landscape:

1.0 Landscape and Aesthetics Guidance

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1.0 Landscape and Aesthetics Guidance

1.1 Introduction

Landscaping is a critical element in the design of stormwater facilities for water quantity and quality management, serving both functional and aesthetic purposes. Plants and vegetation perform a number of functions in stormwater controls and conveyance facilities, including:

- Slowing and retarding flow by increasing hydraulic roughness
- Preventing the erosion of bare soil
- Enhancing infiltration of runoff into the soil
- Providing pollutant removal through vegetative uptake
- Preventing access to deep open water areas
- Contributing to wildlife and fish habitat
- Improving the overall appearance of stormwater facilities

The purpose of this section is to provide guidance on landscaping and plant selection for stormwater facilities and structural controls, as well as provide an overview on developing aesthetically-pleasing stormwater facilities. This section is divided into the following subsections:

- Section 1.2 covers general landscaping guidance that should be considered when landscaping any stormwater facility.
- Section 1.3 discusses the physical site factors and considerations involved in selecting plant material for stormwater facility landscaping.
- Section 1.4 includes key factors to consider in selecting plant material for stormwater landscaping are reviewed, including hardiness, physiographic regions, inundation tolerance, and other factors.
- Section 1.5 outlines more specific guidance on landscaping criteria and plant selection for individual structural stormwater control designs, including:
  - Stormwater Ponds and Wetlands
  - Bioretention Areas
  - Infiltration Trench and Surface Sand Filter Facilities
  - Enhanced Swales and Grass Channels
  - Filter Strips and Stream Buffers
  - Green Roofs
- Section 1.6 contains a detailed plant list of trees and shrubs that may be used when preparing a vegetation and landscaping planting plan for a stormwater facility.

Review local landscape ordinance requirements before developing a landscape plan.

For information on native and adapted plants and trees to create landscapes that need less water, pesticides, and fertilizer to thrive in the North Central Texas climate, visit the North Central Texas SmartScape website at www.txsmartscape.com. Using native and adapted plants reduces the need for excessive fertilizer in runoff, which can lead to “overgrowth” of submerged plants.

1.2 General Landscaping Guidance

Below are general guidelines that should be followed in the landscaping of any stormwater control or conveyance facility.

DO NOT:

- Plant trees, scrubs or any type of woody vegetation on an embankment
- Plant trees and shrubs within 15 feet of the toe of slope of a dam.
- Plant trees or shrubs known to have long tap roots within the vicinity of the earthen dam or embankment, or subsurface drainage facilities.
- Plant trees and shrubs within 25 feet of a principal spillway structure (e.g., riser)
- Plant trees and shrubs within 25 feet of perforated pipes.
- Block maintenance access to structures with trees or shrubs.
- Plant trees and shrubs within 25 feet of a structural concrete dam.

DO:

- Review the local landscape ordinance requirements.
- Take into account site characteristics and plant selection guidelines (see *Sections 1.3 and 1.4*, respectively) when selecting plants for stormwater facilities.
- Consider how plant characteristics will affect the landscape and the performance of a structural stormwater control or conveyance.
- Carefully consider the long-term vegetation management strategy for the structural control, keeping in mind the maintenance legacy for the future owners.
- Preserve existing natural vegetation when possible.
- Avoid the overuse of any plant materials.
- Have soils tested to determine if there is a need for amendments.
- Select plants that can thrive in on-site soils with no additional amendments or a minimum of amendments.
- Consider water availability, particularly for wetland and water-intensive plantings.
- Decrease the areas where turf is used. Use low maintenance ground cover to absorb run-off.
- Plant stream and edge of water buffers with trees, shrubs, ornamental grasses, and herbaceous materials where possible, to stabilize banks and provide shade.
- Provide slope stabilization methods for slopes steeper than 2:1, such as planted erosion control mats. Also, use seed mixes with quick germination rates in this area. Augment temporary seeding measures with container crowns or root mats of more permanent plant material.
- Utilize erosion control mats and fabrics to protect inverts of channels that are subject to frequent wash outs.
- Stabilize all water overflows with plant material that can withstand strong current flows. Root material should be fibrous and substantial but lacking a tap root.
- Sod area channels that are not stabilized using erosion control mats.
- Divert flows temporarily from seeded areas until stabilized.
- Check water tolerances of existing plant materials prior to inundation of area.

- ❑ Stabilize aquatic and safety benches with emergent wetland plants and wet seed mixes.
- ❑ Provide a 15-foot clearance from a non-clogging, low flow orifice.
- ❑ Limit herbaceous embankment plantings to 10 inches in height, to allow visibility for the inspector who is looking for burrowing rodents that may compromise the integrity of the embankment.
- ❑ Shade inflow and outflow channels, as well as the southern exposures of pond, to reduce thermal warming
- ❑ Avoid plantings that will require routine or intensive chemical applications (i.e. turf area).
- ❑ Maintain and frame desirable views. Be careful not to block views at entrances, exits, or difficult road curves. Screen or buffer unattractive views into the site.
- ❑ Use plants to prohibit pedestrian access to pools or slopes that may be unsafe.
- ❑ Keep maintenance area open to allow future access for pond maintenance.
- ❑ Provide a planting surface that can withstand the compaction of vehicles using maintenance access roads.
- ❑ Make sure the facility maintenance agreement includes a maintenance requirement of designated plant material.
- ❑ Provide signage for:
  - Stormwater management facilities to help educate the public
  - Wildflower areas to designate limits of mowing
  - Preserving existing natural vegetation

1.3 Site Considerations

A development site's characteristics often will help to determine which plant materials and planting methods the site designer should select and will help improve plant establishment. Primary site considerations include:

(1) Soil Characteristics
(2) Drainage
(3) Slope
(4) Orientation

Soil Characteristics

Plant establishment and growth can be limited by a number of different soil characteristics including:

- Soil texture
- PH -- whether acid, neutral, or alkali
- Nutrient levels -- nitrogen, phosphorus, potassium
- Minerals -- such as chelated iron, lime
- Salinity
- Toxicity

Soils are made up of four basic ingredients: mineral elements, pore space, organic matter and other items consisting mainly of living organisms including fungi, bacteria, and nematodes. One classification of soils is based upon the mineral part of soil and consists of four sizes of particles. Clay particles are the smallest, followed by silt, sand, and gravel. The USDA has devised another system of classifying soil particles. In this system soil is divided into seven categories: clay, silt, and five sizes of sand.

Soil texture is determined by the percentage of sand, silt, and clay in the soil. The structure of a soil is influenced by soil texture and also by the aggregation of small soil particles into larger particles. The amount of aggregation in a soil is strongly influenced by the amount of organic matter present.

Soil samples should be analyzed by experienced and qualified individuals who can explain the results and provide information on any soil amendments that are required. Soil fertility can often be corrected by applying fertilizer or by increasing the level of organic matter in the soil. Soil pH can be corrected with applications of lime. Where poor soils can't be amended, seed mixes and plant material must be selected to establish ground cover as quickly as possible.

Areas that have recently been involved in construction can become compacted so that plant roots cannot penetrate the soil. Seeds lying on the surface of compacted soils can be washed away or be eaten by birds. Soils should be loosened to a minimum depth of two inches, preferably to a four-inch depth. Hard soils may require discing to a deeper depth. Loosening soils will improve seed contact with the soil, provide greater germination rates, and allow the roots to penetrate into the soil. If the area is to be sodded, discing will allow the roots to penetrate into the soil.

Whenever possible, topsoil should be spread to a depth of four inches (two inch minimum) over the entire area to be planted. This provides organic matter and important nutrients for the plant material. This also allows the stabilizing materials to become established faster, while the roots are able to penetrate deeper and stabilize the soil, making it less likely that the plants will wash out during a heavy storm. If topsoil has been stockpiled in deep mounds for a long period of time, it is desirable to test the soil for pH as well as microbial activity. If the microbial activity has been destroyed, it may be necessary to inoculate the soil after application.

Drainage

Soil moisture and drainage have a direct bearing on the plant species and communities that can be supported on a site. Factors such as soil texture, topography, groundwater levels and climatic patterns all influence soil drainage and the amount of water in the soil. Identifying the topography and drainage of the site will help determine potential moisture gradients. The following categories can be used to describe the drainage properties of soils on a site:

Flooded - Areas where standing water is present most of the growing season.

Wet - Areas where standing water is present most of the growing season, except during times of drought. Wet areas are found at the edges of ponds, rivers, streams, ditches, and low spots. Wet conditions exist on poorly drained soils, often with a high clay content.

Moist - Areas where the soil is damp. Occasionally, the soil is saturated and drains slowly. These areas usually are at slightly higher elevations than wet sites. Moist conditions may exist in sheltered areas protected from sun and wind.

Well-drained - Areas where rain water drains readily and puddles do not last long. Moisture is available to plants most of the growing season. Soils usually are medium textures with enough sand and silt particles to allow water to drain through the soil.

Dry - Areas where water drains rapidly through the soil. Soils are usually coarse, sandy, rocky or shallow. Slopes are often steep and exposed to sun and wind. Water runs off quickly and does not remain in the soil.

Slope

The degree of slope can also limit its suitability for certain types of plants. Plant establishment and growth requires stable substrates for anchoring root systems and preserving propagules such as seeds and plant fragments, and slope is a primary factor in determining substrate stability. Establishing plants directly on or below eroding slopes is not possible for most species. In such instances, plant species capable of rapid spread and anchoring soils should be selected or bioengineering techniques should be used to aid the establishment of a plant cover.

In addition, soils on steep slopes generally drain more rapidly than those on gradual slopes. This means that the soils may remain saturated longer on gradual slopes. If soils on gradual slopes are classified as poorly drained, care should be taken that plant species are selected that are tolerant of saturation.

Site topography also affects maintenance of plant species diversity. Small irregularities in the ground surface (e.g., depressions, etc.) are common in natural systems. More species are found in areas with many micro-topographic features than in areas without such features. Raised sites are particularly important in wetlands because they allow plants that would otherwise die while flooded to escape inundation.

In wetland plant establishment, ground surface slope interacts with the site hydrology to determine water depths for specific areas within the site. Depth and duration of inundation are principal factors in the zonation of wetland plant species. A given change in water levels will expose a relatively small area on a steep slope in comparison with a much larger area exposed on a gradual or flat slope. Narrow planting zones will be delineated on steep slopes for species tolerant of specific hydrologic conditions, whereas gradual slopes enable the use of wider planting zones.

Orientation

Slope exposure should be considered for its effect on plants. A southern-facing slope receives more sun and is warmer and drier, while the opposite is true of a northern slope. Eastern- and western-facing slopes are intermediate, receiving morning and afternoon sun, respectively. Western-facing slopes tending to receive more wind.

1.4 Plant Selection for Stormwater Facilities

1.4.1 Hardiness Zones

Hardiness zones are based on historical annual minimum temperatures recorded in an area. A site's location in relation to plant hardiness zones is important to consider first because plants differ in their ability to withstand very cold winters. This does not imply that plants are not affected by summer temperatures. Given that Texas summers can be very hot, heat tolerance is also a characteristic that should be considered in plant selection.

It is best to recommend plants known to thrive in specific hardiness zones. The plant list included at the end of this section identifies the hardiness zones for each species listed as a general planting guide. It should be noted, however, that certain site factors can create microclimates or environmental conditions which permit the growth of plants not listed as hardy for that zone. By investigating numerous references and based on personal experience, a designer should be able to confidently recommend plants that will survive in microclimates.

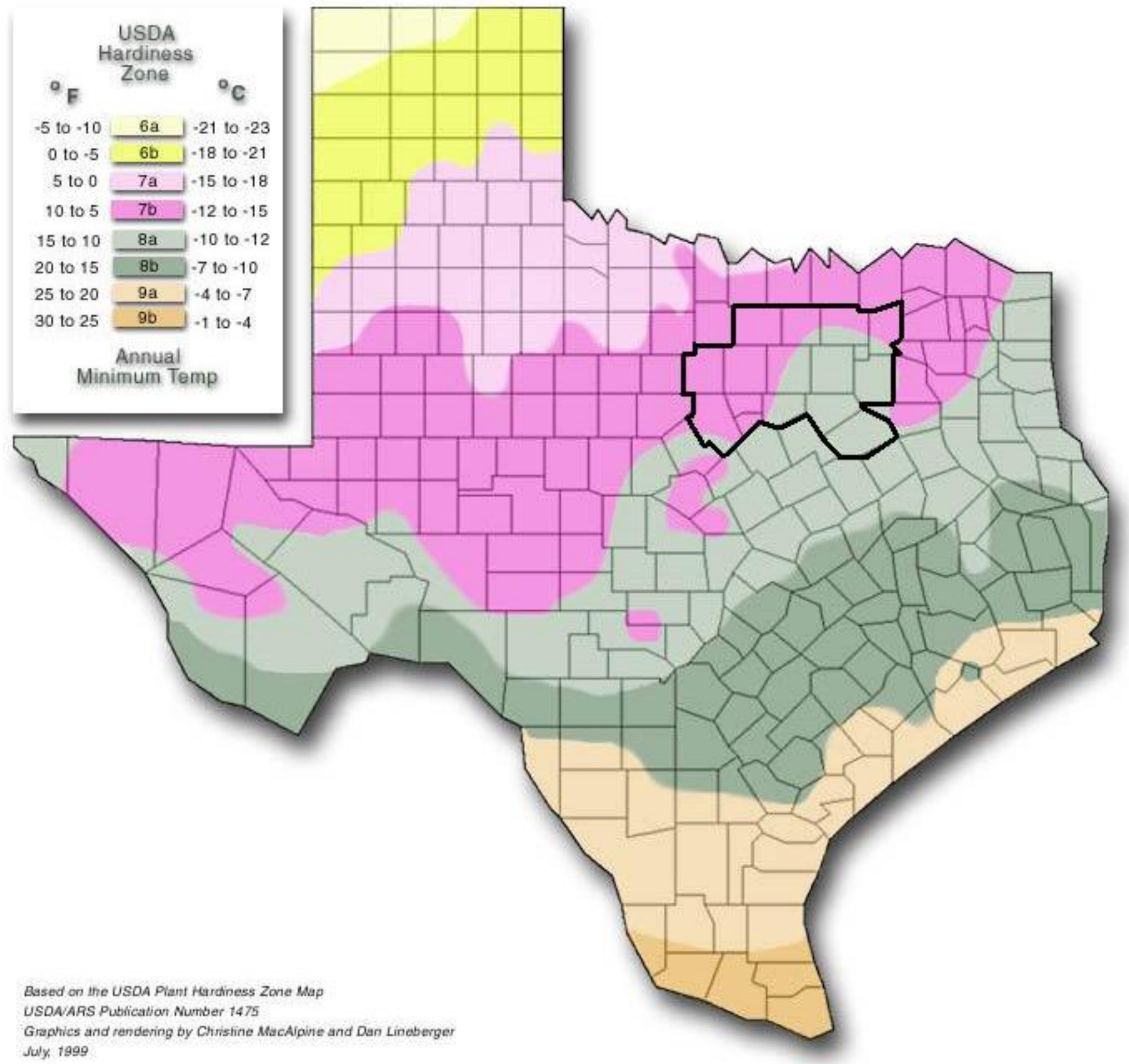
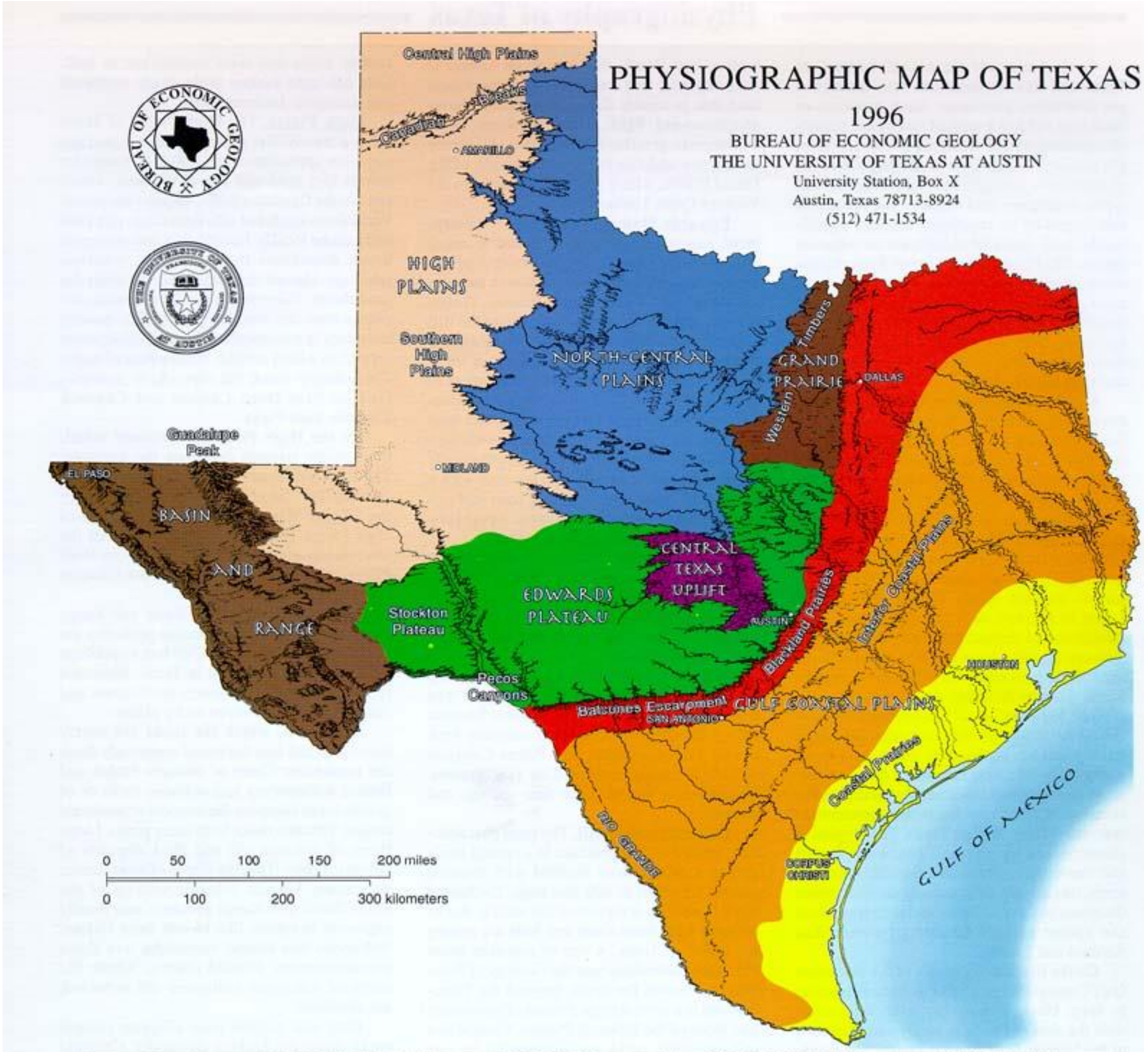


Figure 1.1 USDA Plant Hardiness Zones in Texas

1.4.2 Physiographic Provinces

There are three physiographic provinces in Texas that describe distinct geographic regions in the state with similar physical and environmental conditions (Figure 1.2). These physiographic provinces include, from northwest to southeast, High Plains, Edwards Plateau, and Gulf Coastal Plains (subdivided into multiple subregions). Each physiographic region is defined by unique geological strata, soil type, drainage patterns, moisture content, temperature and degree of slope which often dictate the predominant vegetation. Because the predominant vegetation has evolved to live in these specific conditions, a successful stormwater management facility planting design can be achieved through mimicking these natural associations. The three physiographic regions are described below with associated vegetation listed as general planting guidance.



PROVINCE	MAX. ELEV. (ft)	MIN. ELEV. (ft)	TOPOGRAPHY	GEOLOGIC STRUCTURE	BEDROCK TYPES
Gulf Coastal Plains					
Coastal Prairies	300	0	Nearly flat prairie, <1 ft/mi to Gulf	Nearly flat strata	Deltaic sands and muds
Interior Coastal Plains	800	300	Parallel ridges (questas) and valleys	Beds tilted toward Gulf	Unconsolidated sands and muds
Blackland Prairies	1000	450	Low rolling terrain	Beds tilted south and east	Chalks and marls
Grand Prairie	1250	450	Low stairstep hills west; plains east	Strata dip east	Calcareous east; sandy west
Edwards Plateau					
Principal	3000	450	Flat upper surface with box canyons	Beds dip south; normal faulted	Limestones and dolomites
Pecos Canyons	2000	1200	Steep-walled canyons		Limestones and dolomites
Stockton Plateau	4200	1700	Mesa-formed terrain; highs to west	Unfaulted, near-horizontal beds	Carbonates and alluvial sediments
Central Texas Uplift	2000	800	Knobby plain; surrounded by questas	Centripetal dips, strongly faulted	Granites; metamorphics; sediments
North-Central Plains	3000	900	Low north-south ridges (questas)	West dip; minor faults	Limestones; sandstones; shales
High Plains					
Central	4750	2900	Flat prairies slope east and south	Slight dips east and south	Eolian silts and fine sands
Canadian Breaks	3800	2350	Highly dissected; local solution valleys		
Southern	3800	2200	Flat; many playas; local dune fields		
Basin and Range	8750	1700	North-south mountains and basins	Some complex folding and faulting	Igneous; metamorphics; sediments

Figure 1.2 Physiographic map of Texas

Gulf Coastal Plains. The Gulf Coastal Plains include three subprovinces named the Coastal Prairies, the Interior Coastal Plains, and the Blackland Prairies. The Coastal Prairies begin at the Gulf of Mexico shoreline. Young deltaic sands, silts, and clays erode to nearly flat grasslands that form almost imperceptible slopes to the southeast. Trees are uncommon except locally along streams and in Oak mottes, growing on coarser underlying sediments of ancient streams. Minor steeper slopes, from 1 foot to as much as 9 feet high, result from subsidence of deltaic sediments along faults. Between Corpus Christi and Brownsville, broad sand sheets pocked by low dunes and blowouts forming ponds dominate the landscape.

The Interior Coastal Plains comprise alternating belts of resistant uncemented sands among weaker shales that erode into long, sandy ridges. At least two major down-to-the coast fault systems trend nearly parallel to the coastline. Clusters of faults also concentrate over salt domes in East Texas. That region is characterized by pine and hardwood forests and numerous permanent streams. West and south, tree density continuously declines, pines disappear in Central Texas, and chaparral brush and sparse grasses dominate between San Antonio and Laredo.

On the Blackland Prairies of the innermost Gulf Coastal Plains, chalks and marls weather to deep, black, fertile clay soils, in contrast with the thin red and tan sandy and clay soils of the Interior Gulf Coastal Plains. The blacklands have a gentle undulating surface, cleared of most natural vegetation and cultivated for crops.

From sea level at the Gulf of Mexico, the elevation of the Gulf Coastal Plains increases northward and westward. In the Austin San Antonio area, the average elevation is about 800 feet. South of Del Rio, the western end of the Gulf Coastal Plains has an elevation of about 1,000 feet.

Grand Prairie. The eastern Grand Prairie developed on limestones; weathering and erosion have left thin rocky soils. North and west of Fort Worth, the plateau like surface is well exposed, and numerous streams dissect land that is mostly flat or that gently slopes southeastward. There, silver bluestem-Texas wintergrass grassland is the flora. Primarily sandstones underlie the western margin of the Grand Prairie, where post oak woods form the Western Cross Timbers.

Edwards Plateau. The Balcones Escarpment, superposed on a curved band of major normal faults, bounds the eastern and southern Edwards Plateau. Its principal area includes the Hill Country and a broad plateau. Stream erosion of the fault escarpment sculpts the Hill Country from Waco to Del Rio. The Edwards Plateau is capped by hard Cretaceous limestones. Local streams entrench the plateau as much as 1,800 feet in 15 miles. The upper drainages of streams are waterless draws that open into box canyons where springs provide permanently flowing water. Sinkholes commonly dot the limestone terrain and connect with a network of caverns. Alternating hard and soft marly limestones form a stair-step topography in the central interior of the province.

The Edwards Plateau includes the Stockton Plateau, mesa like land that is the highest part of this subdivision. With westward decreasing rainfall, the vegetation grades from mesquite juniper brush westward into creosote bush tarbush shrubs.

The Pecos River erodes a canyon as deep as 1,000 feet between the Edwards and Stockton Plateaus. Its side streams become draws forming narrow blind canyons with nearly vertical walls. The Pecos Canyons include the major river and its side streams. Vegetation is sparse, even near springs and streams.

Central Texas Uplift. The most characteristic feature of this province is a central basin having a rolling floor studded with rounded granite hills 400 to 600 feet high. Enchanted Rock State Park is typical of this terrain. Rocks forming both basin floor and hills are among the oldest in Texas. A rim of resistant lower Paleozoic formations surrounds the basin. Beyond the Paleozoic rim is a second ridge formed of limestones like those of the Edwards Plateau. Central live oak mesquite parks are surrounded by live oak ash juniper parks.

North-Central Plains. An erosional surface that developed on upper Paleozoic formations forms the North-Central Plains. Where shale bedrock prevails, meandering rivers traverse stretches of local prairie. In areas of harder bedrock, hills and rolling plains dominate. Local areas of hard sandstones and limestones cap steep slopes severely dissected near rivers. Lengthy dip slopes of strongly fractured limestones display extensive rectangular patterns. Western rocks and soils are oxidized red or gray where gypsum dominates, whereas eastern rocks and soils weather tan to buff. Live oak ash juniper parks grade westward into mesquite lotebush brush.

High Plains. The High Plains of Texas form a nearly flat plateau with an average elevation approximating 3,000 feet. Extensive stream-laid sand and gravel deposits, which contain the Ogallala aquifer, underlie the plains. Windblown sands and silts form thick, rich soils and caliche locally. Havard shin oak mesquite brush dominates the silty soils, whereas sandsage Havard shin oak brush occupies the sand sheets. Numerous playa lakes scatter randomly over the treeless plains. The eastern boundary is a westward-retreating escarpment capped by a hard caliche. Headwaters of major rivers deeply notch the caprock, as exemplified by Palo Duro Canyon and Caprock Canyons State Parks.

On the High Plains, widespread small, intermittent streams dominate the drainage. The Canadian River cuts across the province, creating the Canadian Breaks and separating the Central High Plains from the Southern High Plains. Pecos River drainage erodes the west-facing escarpment of the Southern High Plains, which terminates against the Edwards Plateau on the south.

Basin and Range. The Basin and Range province contains eight mountain peaks that are higher than 8,000 feet. At 8,749 feet, Guadalupe Peak is the highest point in Texas. Mountain ranges generally trend nearly north-south and rise abruptly from barren rocky plains.

Plateaus in which the rocks are nearly horizontal and less deformed commonly flank the mountains. Cores of strongly folded and faulted sedimentary and volcanic rocks or of granite rocks compose the interiors of mountain ranges. Volcanic rocks form many peaks. Large flows of volcanic ash and thick deposits of volcanic debris flank the slopes of most former volcanoes. Ancient volcanic activity of the Texas Basin and Range province was mostly explosive in nature, like Mount Saint Helens. Volcanoes that poured successive lava flows are uncommon. Eroded craters, where the cores of volcanoes collapsed and subsided, are abundant.

Gray oak, pinyon pine, and alligator juniper parks drape the highest elevations. Creosote bush and lechuguilla shrubs sparsely populate plateaus and intermediate elevations. Tobosa black grama grassland occupies the low basins.

Floodplain Plant Communities – Floodplain areas are a microclimatic area that results in a characteristic plant community that is similar in all three physiographic provinces. Floodplain plant communities are an important reference community since many stormwater practices are located with this area. Floodplains occur along streams in both steep and level areas. The most noteworthy plants found along floodplains are River Birch, Willows, Poplars, Maple, Sweet Gum, Sycamore, Box Elder, Green Ash, American Elm, Swamp White Oak, Bur Oak, Honeylocust and Hackberry. Shrubs commonly found in floodplains include Shrub Willows, Yaupon, Buttonbush, Blackberry, and Elderberry.

1.4.3 Other Considerations in Plant Selection

Use or Function

In selecting plants, consideration must be given to their desired function in the stormwater management facility. Is the plant needed as ground cover, soil stabilizer, biofilter or source of shade? Will the plant be placed for functional or aesthetic purposes? Does the adjacent use provide conflicts or potential problems and require a barrier, screen, or buffer? Nearly every plant and plant location should be provided to serve some function in addition to any aesthetic appeal.

Plant Characteristics

Certain plant characteristics are so obvious, they may actually be overlooked in the plant selection. These are:

- Size
- Shape

For example, tree limbs, after several years, can grow into power lines. A wide growing shrub may block maintenance access to a stormwater facility. Consider how these characteristics can work for you or against you, today and in the future.

Other plant characteristics must be considered to determine how the plant grows and functions seasonally, and whether the plant will meet the needs of the facility today and in the future. Some of these characteristics are:

- Growth Rate
- Regeneration Capacity
- Maintenance Requirements (e.g. mowing, harvesting, leaf collection, etc.)
- Aesthetics

In urban or suburban settings, a plant's aesthetic interest may be of greater importance. Residents living next to a stormwater system may desire that the facility be appealing or interesting to look at throughout the year. Aesthetics is an important factor to consider in the design of these systems. Failure to consider the aesthetic appeal of a facility to the surrounding residents may result in reduced value to nearby lots. Careful attention to the design and planting of a facility can result in maintained or increased values of a property.

Availability and Cost

Often overlooked in plant selection is the availability from wholesalers and the cost of the plant material. There are many plants listed in landscape books that are not readily available from the nurseries. Without knowledge of what is available, time spent researching and finding the one plant that meets all the needs will be wasted, if it is not available from the growers. It may require shipping, therefore, making it more costly than the budget may allow. Some planting requirements, however, may require a special effort to find the specific plant that fulfills the needs of the site and the function of the plant in the landscape.

Native versus Nonnative Species

This Manual encourages the use of native plants in stormwater management facilities, since they are best suited to thrive under the physiographic and hardiness conditions encountered at a site. Unfortunately, not all native plants provide the desired landscape or appearance, and may not always be available in quantity from local nurseries. Therefore, naturalized plants that are not native species, but can thrive and reproduce in the new area may be a useful alternative. For information on native and adapted plants and trees to create landscapes that need less water, pesticides, and fertilizer to thrive in the North Central Texas climate, visit the North Central Texas SmartScape website at www.txsmartscape.com.

Because all landscaping needs may not be met by native or naturalized plants, some ornamental and exotic species are provided in this guide that can survive under difficult conditions encountered in a stormwater management facility. Since many stormwater facilities are adjacent to residential areas, the objectives of the stormwater planting plan may shift to resemble the more controlled appearance of nearby yards, or to provide a pleasing view. Great care should be taken; however, when introducing plant species so as not to create a situation where they may become invasive and take over adjacent natural plant communities.

Moisture Status

In landscaping stormwater management facilities, hydrology plays a large role in determining which species will survive in a given location.

For areas that are to be planted within a stormwater management facility it is necessary to determine what type of hydrologic zones will be created within the facility.

The six zones shown in Table 1.1 in the next section describe the different conditions encountered in stormwater management facilities. Every facility does not necessarily reflect all of these zones. The hydrologic zones designate the degree of tolerance the plant exhibits to differing degrees of inundation by water. Each zone has its own set of plant selection criteria based on the hydrology of the zone, the stormwater functions required of the plant and the desired landscape effect.

1.5 Specific Landscaping Criteria for Structural Stormwater Controls

1.5.1 Stormwater Ponds and Wetlands

Stormwater ponds and wetlands are engineered basins and wetland areas designed to control and treat stormwater runoff. Aquatic vegetation plays an important role in pollutant removal in both stormwater ponds and wetlands. In addition, vegetation can enhance the appearance of a pond or wetland, stabilize side slopes, serve as wildlife habitat, and can temporarily conceal unsightly trash and debris.

Within a stormwater pond or wetland, there are various hydrologic zones as shown in Table 1.1 that must be considered in plant selection. These hydrologic zones designate the degree of tolerance a plant must have to differing degrees of inundation by water. Hydrologic conditions in an area may fluctuate in unpredictable ways; thus the use of plants capable of tolerating wide varieties of hydrologic conditions greatly increases the successful establishment of a planting. Plants suited for specific hydrologic conditions may perish when those conditions change, exposing the soil, and therefore, increasing the chance for erosion. Each of the hydrologic zones is described in more detail below along with examples of appropriate plant species.

Table 1.1 Hydrologic Zones

Zone #	Zone Description	Hydrologic Conditions
Zone 1	Deep Water Pool	1-6 feet depth (permanent pool)
Zone 2	Shallow Water Bench	Normal pool elevation to 1 foot depth
Zone 3	Shoreline Fringe	Regularly inundated
Zone 4	Riparian Fringe	Periodically inundated
Zone 5	Floodplain Terrace	Infrequently inundated
Zone 6	Upland Slopes	Seldom or never inundated

Zone 1: Deep Water Area (*1- 6 Feet)*

Ponds and wetlands both have deep pool areas that comprise Zone 1. These pools range from one to six feet in depth, and are best colonized by submergent plants, if at all.

This pondscaping zone is *not* routinely planted for several reasons. First, the availability of plant materials that can survive and grow in this zone is limited, and it is also feared that plants could clog the stormwater facility outlet structure. In many cases, these plants will gradually become established through natural recolonization (e.g., transport of plant fragments from other ponds via the feet and legs of waterfowl). If submerged plant material is commercially available and clogging concerns are addressed, this area can be planted. The function of the planting is to reduce resedimentation and improve oxidation while creating a greater aquatic habitat.

- ❑ Plant material must be able to withstand constant inundation of water of one foot or greater in depth.
- ❑ Plants may be submerged partially or entirely.
- ❑ Plants should be able to enhance pollutant uptake.

- Plants may provide food and cover for waterfowl, desirable insects, and other aquatic life.

Some suggested emergent or submergent species include, but are not limited to: Water Lily, Deepwater Duck Potato, Spatterdock, Wild Celery and Redhead Grass.

Zone 2: Shallow Water Bench (***Normal Pool To 1 Foot)***

Zone 2 includes all areas that are inundated below the normal pool to a depth of one foot, and is the primary area where emergent plants will grow in stormwater wetlands. Zone 2 also coincides with the aquatic bench found in stormwater ponds. This zone offers ideal conditions for the growth of many emergent wetland species. These areas may be located at the edge of the pond or on low mounds of earth located below the surface of the water within the pond. When planted, Zone 2 can be an important habitat for many aquatic and nonaquatic animals, creating a diverse food chain. This food chain includes predators, allowing a natural regulation of mosquito populations, thereby reducing the need for insecticidal applications.

- Plant material must be able to withstand constant inundation of water to depths between six inches and one foot deep.
- Plants will be partially submerged.
- Plants should be able to enhance pollutant uptake.
- Plants may provide food and cover for waterfowl, desirable insects and other aquatic life.

Common emergent wetland plant species used for stormwater wetlands and on the aquatic benches of stormwater ponds include, but are not limited to: Arrowhead/Duck Potato, Soft Rush, various Sedges, Softstem Bulrush, Switchgrass, Pickerelweed, Pond Cypress and various Asters.

Zone 3: Shoreline Fringe (***Regularly Inundated)***

Zone 3 encompasses the shoreline of a pond or wetland, and extends vertically about one foot in elevation from the normal pool. This zone includes the safety bench of a pond, and may also be periodically inundated if storm events are subject to extended detention. This zone occurs in a wet pond or shallow marsh and can be the most difficult to establish since plants must be able to withstand inundation of water during storms, when wind might blow water into the area, or the occasional drought during the summer. In order to stabilize the soil in this zone, Zone 3 must have a vigorous cover.

- Plants should stabilize the shoreline to minimize erosion caused by wave and wind action or water fluctuation.
- Plant material must be able to withstand occasional inundation of water. Plants will be partially submerged partially at this time.
- Plant material should, whenever possible, shade the shoreline, especially the southern exposure. This will help to reduce the water temperature.
- Plants should be able to enhance pollutant uptake.
- Plants may provide food and cover for waterfowl, songbirds, and wildlife. Plants could also be selected and located to control overpopulation of waterfowl.
- Plants should be located to reduce human access, where there are potential hazards, but should not block the maintenance access.
- Plants should have very low maintenance requirements, since they may be difficult or impossible to reach.
- Plants should be resistant to disease and other problems which require chemical applications (since chemical application is not advised in stormwater ponds).

Many of the emergent wetland plants that perform well in Zone 2 also thrive in Zone 3. Some other species that do well include Broom Grass, Upland Sea-Oats, Dwarf Tickseed, various Ferns, Hawthorns. If shading is needed along the shoreline, the following tree species are suggested: Boxelder, Ash, Willow, Red Maples and Willow Oak.

Zone 4: Riparian Fringe ***(Periodically Inundated)***

Zone 4 extends from one to four feet in elevation above the normal pool. Plants in this zone are subject to periodic inundation after storms, and may experience saturated or partly saturated soil inundation. Nearly all of the temporary extended detention (ED) storage area is included within this zone.

- Plants must be able to withstand periodic inundation of water after storms, as well as occasional drought during the warm summer months.
- Plants should stabilize the ground from erosion caused by run-off.
- Plants should shade the low flow channel to reduce the pool warming whenever possible.
- Plants should be able to enhance pollutant uptake.
- Plant material should have very low maintenance, since they may be difficult or impossible to access.
- Plants may provide food and cover for waterfowl, songbirds and wildlife. Plants may also be selected and located to control overpopulation of waterfowl.
- Plants should be located to reduce pedestrian access to the deeper pools.

Some frequently used plant species in Zone 4 include Broom Grass, Yellow Indian Grass, Joe Pye Weed, Lilies, Flatsedge, Hollies, Forsythia, Lovegrass, Hawthorn and Sugar Maples.

Zone 5: Floodplain Terrace (***Infrequently Inundated)***

Zone 5 is periodically inundated by flood waters that quickly recede in a day or less. Operationally, Zone 5 extends from the maximum two year or SP_v water surface elevation up to the 25 or 100 year maximum water surface elevation. Key landscaping objectives for Zone 5 are to stabilize the steep slopes characteristic of this zone, and establish a low maintenance, natural vegetation.

- Plant material should be able to withstand occasional but brief inundation during storms, although typical moisture conditions may be moist, slightly wet, or even swing entirely to drought conditions during the dry weather periods.
- Plants should stabilize the basin slopes from erosion.
- Ground cover should be very low maintenance, since they may be difficult to access on steep slopes or if the frequency of mowing is limited. A dense tree cover may help reduce maintenance and discourage resident geese.
- Plants may provide food and cover for waterfowl, songbirds, and wildlife.
- Placement of plant material in Zone 5 is often critical, as it often creates a visual focal point and provides structure and shade for a greater variety of plants.

Some commonly planted species in Zone 5 include many wildflowers or native grasses, many Fescues, many Viburnums, Witch Hazel, Blueberry, American Holly, American Elderberry and Red Oak.

Zone 6: Upland Slopes ***(Seldom or Never Inundated)***

The last zone extends above the maximum 100 year water surface elevation, and often includes the outer buffer of a pond or wetland. Unlike other zones, this upland area may have sidewalks, bike paths, retaining walls, and maintenance access roads. Care should be taken to locate plants so they will not overgrow these routes or create hiding places that might make the area unsafe.

- Plant material is capable of surviving the particular conditions of the site. Thus, it is not necessary to select plant material that will tolerate any inundation. Rather, plant selections should be made based on soil condition, light, and function within the landscape.
- Ground covers should emphasize infrequent mowing to reduce the cost of maintaining this landscape.

Placement of plants in Zone 6 is important since they are often used to create a visual focal point, frame a desirable view, screen undesirable views, or serve as a buffer.

Some frequently used plant species in Zone 6 include most ornamentals (as long as soils drain well, many wildflowers or native grasses, Linden, False Cypress, Magnolia, most Spruce, Mountain Ash and most Pine.

- Table 1.2 provides a list of selected wetland plants for stormwater ponds and wetlands. For hydrologic zones 1-4, provide shade to allow a greater variety of plant materials. Particular attention should be paid to seasonal color and texture of these plantings.

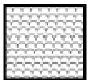
Table 1.2 Wetland Plants (Herbaceous Species) for Stormwater Facilities

Scientific Name	Common Name	Hydrologic Zone
Acorus calumus	Sweetflag	2
Andropogon gerardii	Big Bluestem	6
Andropogon glomeratus	Bushy Broom Grass	3
Andropogon virginicus	Broom Grass	4
Asclepias tuberosa	Butterfly-weed	6
Bouteloua certipendula	Sideoats Grama	6
Buchloe dactyliodes	Buffalograss	6
Carex spp.	Caric Sedges	2
Chasmanthium latifolium	Upland Sea-Oats	3
Coreopsis tinctoria	Dwarf Tickseed	3
Cynodon dactylon	Bermuda Grass	5,6
Echinacea purpurea	Purple Coneflower	6
Elocharis quadrangulata	Square Stem Spikerush	2
Elymus Canadensis	Canada Wildrye	4,5
Elymus virginicus	Virginia Wildrye	4,5
Eupatorium fistolosum	Joe Pye Weed	4
Euptorium serotinum	Late Boneset	3,4
Eustoma grandiflora	Texas Bluebells	4
Helianthus angustifolius	Swamp Sunflower	2
Helianthus maximiliani	Maximilian Sunflower	3,4,5,6
Hibiscus laevis	Halberdleaf Hibiscus	2,3

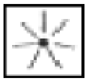
Table 1.2 Wetland Plants (Herbaceous Species) for Stormwater Facilities		
Scientific Name	**Common Name**	**Hydrologic Zone**
Juncus effuses	Soft Rush	2
Leersia oryzoides	Rice Cut Grass	2
Leptochola dubia	Green Spangletop	6
Liatris mucronata	Gayfeather	6
Liatris punctata	Gayfeather	6
Liatris pycnostachya	Gayfeather	5,6
Liatris spicata	Spiked Gayfeather	3
Lobelia cardinalis	Cardinal Flower	3
Malvaviscus drummondii	Turk’s Cap	4,5,6
Nuphar luteum	Spatterdock	1
Nymphaea mexicana	Yellow Water Lily	1
Nymphaea odorata	Fragrant Water Lily	1
Osmunda cinnamomea	Cinnamon Fern	3
Osmunda regalis	Royal Fern	3
Panicum capillare	Witchgrass	3,4,5,6
Panicum virgatum	Switchgrass	2
Peltandra virginica	Green Arum	2
Pennisetum alopecuroides	Fountaingrass	6
Poa arachnifera	Texas Bluegrass	6
Polygonum hydropiperoides	Smartweed	2
Pontederia cordata	Pickerelweed	2,3
Pontederia lanceolata	Pickerelweed	2
Rudbeckia hirta	Black-eyed Susan	4
Sagittaria lancifolia	Lance-leaf Arrowhead	2
Sagittaria latifolia	Duck Potato	2
Salvia farinacea	Mealy Blue Sage	6
Salvia greggii	Autumn Sage	6
Saururus cernuus	Lizard’s Tail	2
Schizachyrium scoparium	Little Bluestem	6
Scirpus americanus	Three-square	2
Scirpus californicus	Giant Bulrush	2
Scirpus validus	Softstem Bulrush	2,3

Table 1.2 Wetland Plants (Herbaceous Species) for Stormwater Facilities		
Scientific Name	**Common Name**	**Hydrologic Zone**
Sorgham nutans	Yellow Indian Grass	4
Tripsacum dactyloides	Eastern Gammagrass	3,4,5,6
Valpia octoflora	Common Sixweeksgrass	6
Woodwardia virginica	Virginia Chain Fern	2

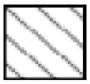
Source: Aquascape, Inc.
Texas Parks and Wildlife Department



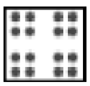
Zone 1: 12 to 36 inch depth below normal pool elevation
Water Lily, Deep Water Duck Potato, Spatterdock, Wild Celery, Redhead Grass



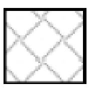
Zone 2: 0 to 12 inch depth below normal pool elevation
Arrowhead/Duck Potato, Soft Rush, various Sedges, Softstem Bulrush, Switchgrass, Southern Blue Flag Iris, Swamp Hibiscus, Swamp Lily, Pickerelweed, Pond Cypress, various Asters



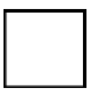
Zone 3: 0 to 12 inch elevation above normal pool elevation
Various species from above, Broom Grass, Upland Sea-Oats, Dwarf Tickseed, various Ferns, Hawthorns, Boxelder, Ash, Willow, Red Maple, Willow Oak



Zone 4: 1 to 4 foot elevation above normal pool elevation
Broom Grass, Yellow Indian Grass, Ironweed, Joe Pye Weed, various Lilies, Flatsedge, Hollies, Lovegrass, Hawthorn, Sugar Maple



Zone 5: SP_v to Q_p or Q_f water surface elevation
Many wildflowers or native grasses, many Fescues, many Viburnums, Witch Hazel, Blueberry, American Holly, American Elderberry, Red Oak



Zone 6: Q_f water surface elevation and above
Many ornamentals as long as soils drain well, many wildflowers or native grasses, Linden, False Cypress, Magnolia, most Spruce, Mountain Ash, most Pine

Figure 1.3 Legend of Hydrologic Zones Around Stormwater Facilities

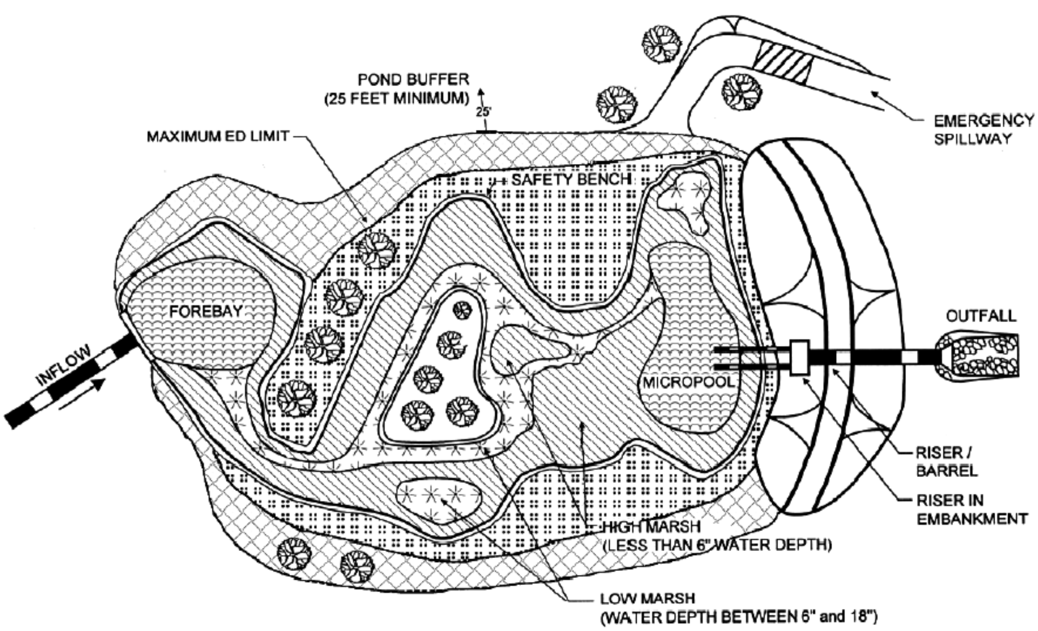


Figure 1.4 Plan View of Hydrologic Zones around Stormwater Wet ED Pond

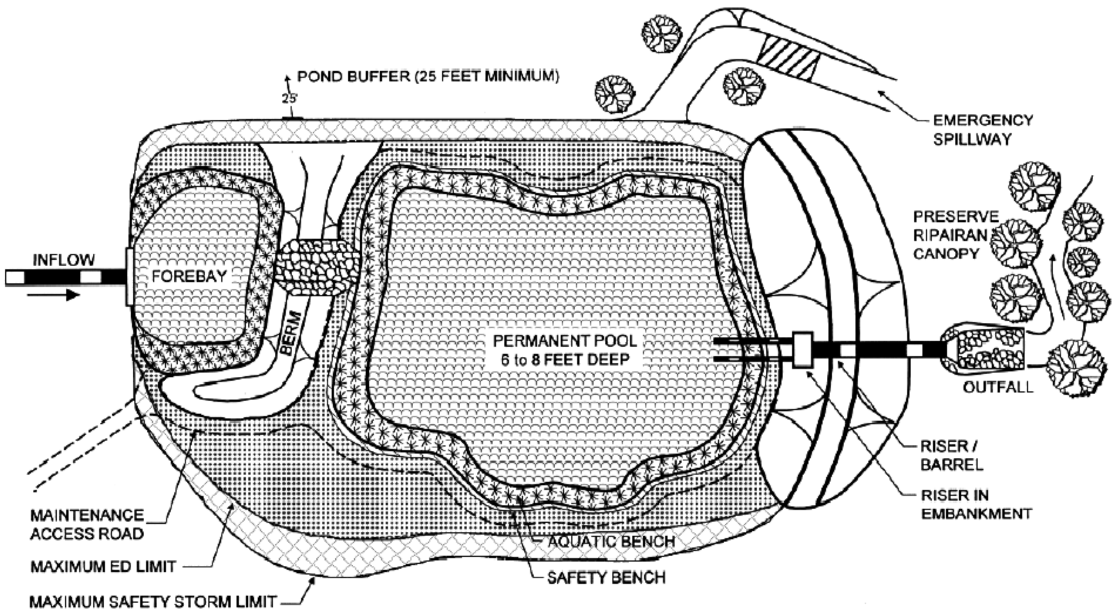


Figure 1.5 Plan View of Hydrologic Zones around Stormwater ED Shallow Wetland

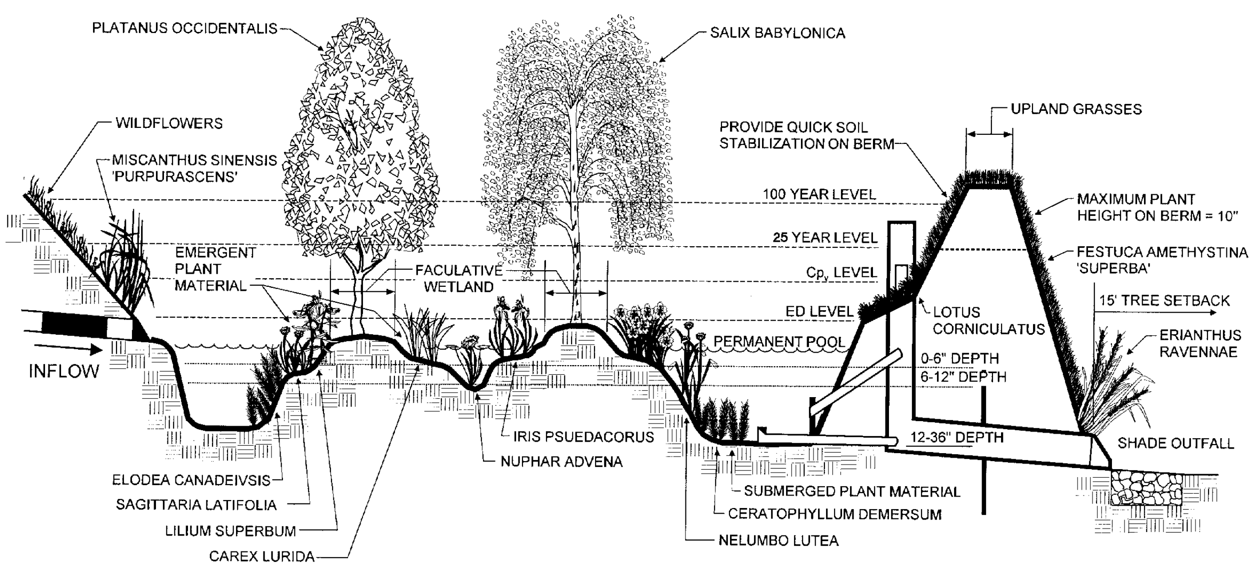


Figure 1.6 Section of Typical Shallow ED Wetland

1.5.2 Bioretention Areas

Bioretention areas are structural stormwater controls that capture and treat runoff using soils and vegetation in shallow basins or landscaped areas. Landscaping is therefore critical to the performance and function of these facilities. Below are guidelines for soil characteristics, mulching, and plant selection for bioretention areas.

Planting Soil Bed Characteristics

The characteristics of the soil for the bioretention facility are perhaps as important as the facility location and size. The soil must be permeable enough to allow runoff to filter through the media, while having characteristics suitable to promote and sustain a robust vegetative cover crop. In addition, much of the nutrient pollutant uptake (nitrogen and phosphorus) is accomplished through adsorption and microbial activity within the soil profile. Therefore, the soils must balance soil chemistry and physical properties to support biotic communities above and below ground.

The planting soil should be a sandy loam, loamy sand, loam, or a loam/sand mix (should contain a minimum of 35 to 60% sand, by volume). The clay content for these soils should by less than 25% by volume. Soils should fall within the SM, ML, SC classifications of the Unified Soil Classification System (USCS). A permeability of at least 1.0 feet per day (0.5"/hr) is required (a conservative value of 0.5 feet per day should be used for design). The soil should be free of stones, stumps, roots, or other woody material over 1" in diameter. Brush or seeds from noxious weeds, such as Johnson Grass, Mugwort, Nutsedge, and Canadian Thistle should not be present in the soils. Placement of the planting soil should be in lifts of 12 to 18", loosely compacted (tamped lightly with a dozer or backhoe bucket). The specific characteristics are presented in Table 1.3.

Table 1.3 Planting Soil Characteristics

Parameter	Value
pH range	5.2 to 7.00
Organic matter	1.5 to 4.0%
Magnesium	35 lbs. per acre, minimum (0.0072 lbs/Sq yd)
Phosphorus (P_2O_5)	75 lbs. per acre, minimum (0.0154 lbs/Sq yd)
Potassium (K_2O)	85lbs. per acre, minimum (0.0175 lbs/Sq yd)
Soluble salts	500 ppm
Clay	10 to 25%
Silt	30 to 55%
Sand	35 to 60%

(Adapted from EQR, 1996; ETAB, 1993)

Mulch Layer

The mulch layer plays an important role in the performance of the bioretention system. The mulch layer helps maintain soil moisture and avoids surface sealing which reduces permeability. Mulch helps prevent erosion, and provides a micro-environment suitable for soil biota at the mulch/soil interface. It also serves as a pretreatment layer, trapping the finer sediments which remain suspended after the primary pretreatment. The mulch layer should be standard landscape style, single or double, shredded hardwood mulch or chips. The mulch layer should be well aged (stockpiled or stored for at least 12 months), uniform in color, and free of other materials, such as weed seeds, soil, roots, etc. The mulch should be applied to a maximum depth of three inches. Grass clippings should not be used as a mulch material.

Planting Plan Guidance
Plant material selection should be based on the goal of simulating a terrestrial forested community of native species. Bioretention simulates an ecosystem consisting of an upland-oriented community dominated by trees, but having a distinct community, or sub-canopy, of understory trees, shrubs and herbaceous materials. The intent is to establish a diverse, dense plant cover to treat stormwater runoff and withstand urban stresses from insect and disease infestations, drought, temperature, wind, and exposure.

The proper selection and installation of plant materials is key to a successful system. There are essentially three zones within a bioretention facility (Figure 1.7). The lowest elevation supports plant species adapted to standing and fluctuating water levels. The middle elevation supports a slightly drier group of plants, but still tolerates fluctuating water levels. The outer edge is the highest elevation and generally supports plants adapted to dryer conditions. A sample of appropriate plant materials for bioretention facilities are included in Table 1.4. More potential bioretention species can be found in the wetland plant list in *Section 1.6*.

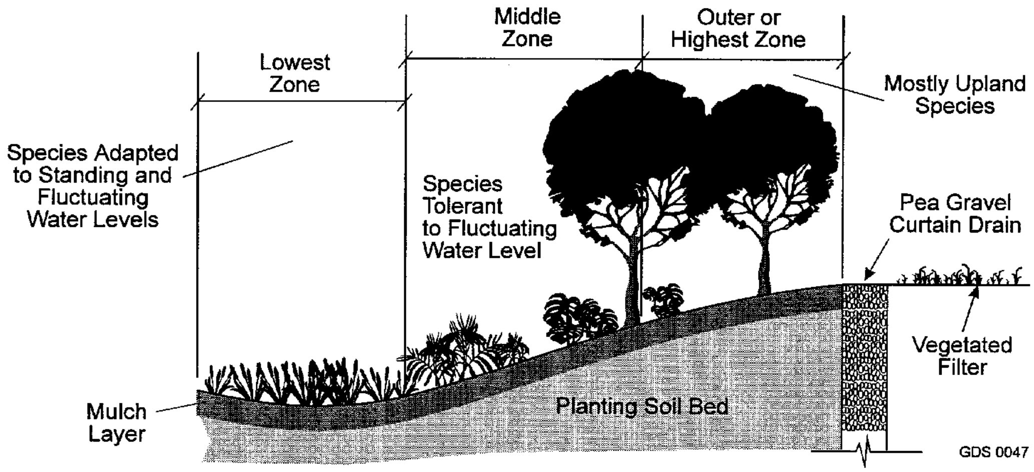


Figure 1.7 Planting Zones for Bioretention Facilities

The layout of plant material should be flexible, but should follow the general principals described below. The objective is to have a system that resembles a random and natural plant layout, while maintaining optimal conditions for plant establishment and growth.

- Native plant species should be specified over exotic or foreign species.
- Appropriate vegetation should be selected based on the zone of hydric tolerance
- Species layout should generally be random and natural.

The tree-to-shrub ratio should be 2:1 to 3:1. On average, the trees should be spaced 8 feet apart.
Plants should be placed at irregular intervals to replicate a natural forest.
Woody vegetation should not be specified at inflow locations.

A canopy should be established with an understory of shrubs and herbaceous materials.

- Woody vegetation should not be specified in the vicinity of inflow locations.

- Trees should be planted primarily along the perimeter of the bioretention area.
- Urban stressors (e.g., wind, sun, exposure, insect and disease infestation, drought) should be considered when laying out the planting plan.
- Noxious weeds should not be specified.
- Aesthetics and visual characteristics should be a prime consideration.
- Traffic and safety issues must be considered.
- Existing and proposed utilities must be identified and considered.

Plant materials should conform to the American Standard Nursery Stock, published by the American Association of Nurserymen, and should be selected from certified, reputable nurseries. Planting specifications should be prepared by the designer and should include a sequence of construction, a description of the contractor's responsibilities, a planting schedule and installation specifications, initial maintenance, and a warranty period and expectations of plant survival. Table 1.5 presents some typical issues for planting specifications. Figure 1.8 shows an example of a sample planting plan for a bioretention area.

Table 1.4 Commonly Used Species for Bioretention Areas

Trees	**Shrubs**	**Herbaceous Species**
Acer rubrum Red Maple (Zones 2, 3, 4)	*Amorpha fruticosa* False Indigo (Zones 3, 4)	*Andropogon virginicus* Broom Sedge/ Grass (Zone 4)
Betula nigra River Birch (Zones 4, 5)	*Aronia arbutifolia* Red Chokeberry (Zones 2, 3)	*Eupatorium fistolosum* Joe Pye Weed (Zone 4)
Cercis canadensis Eastern Redbud (Zones 4, 5)	*Callicarpa Americana* American Beautyberry (Zones 4, 5)	*Iris pseudacorus* Yellow Iris
Crataegus reverchonii Reverchon's Hawthorn (Zone 6)	*Hamemelis virginiana* Witch Hazel (Zone 5)	*Lobelia cardinalis* Cardinal Flower (Zone 3)
Juglans nigra Black Walnut (Zone 6)	*Lindera benzoin* Spicebush	*Malvaviscus drummondii* Turk's Cap (Zones 4, 5, 6)
Juniperus virginiana Eastern Red Cedar (Zones 5, 6)	*Myrica pennsylvanica* Bayberry	*Panicum capillare* Witchgrass (Zones 3, 4, 5, 6)
Platanus occidentalis Sycamore	*Prunus mexicana* Mexican Plum (Zones 5, 6)	*Panicum virgatum* Switchgrass (Zone 2)
Quercus phellos Willow Oak (Zones 3, 4, 5)	*Rhamnus caroliniana* Carolina Buckthorn (Zones 4, 5, 6)	*Pennisetum alopecuroides* Fountaingrass (Zone 6)
Quercus macrocarpa Bur Oak (Zones 5, 6)	*Viburnum rufidumlum* Rusty Blackhaw (Zones 4, 5, 6)	*Rudbeckia hirta* Black Eyed Susan (Zone 4)

Table 1.5 Planting Plan Specification Issues for Bioretention Areas	
Specification Element	**Elements**
Sequence of Construction	Describe site preparation activities, soil amendments, etc.; address erosion and sediment control procedures; specify step-by-step procedure for plant installation.
Contractor's Responsibilities	Specify the contractors responsibilities, such as watering, care of plant material during transport, timeliness of installation, repairs due to vandalism, etc.
Planting Schedule and Specifications	Specify the materials to be installed, the type of materials (e.g., B&B, bare root, containerized); time of year of installations, sequence of installation of types of plants; fertilization, stabilization seeding, if required; watering and general care.
Maintenance	Specify inspection periods; mulching frequency; removal and replacement of dead and diseased vegetation; treatment of diseased trees; watering schedule after initial installation (once per day for 14 days is common); repair and replacement of staking and wires.
Warranty	Specify warranty period, the required survival rate, and expected condition of plant species at the end of the warranty.

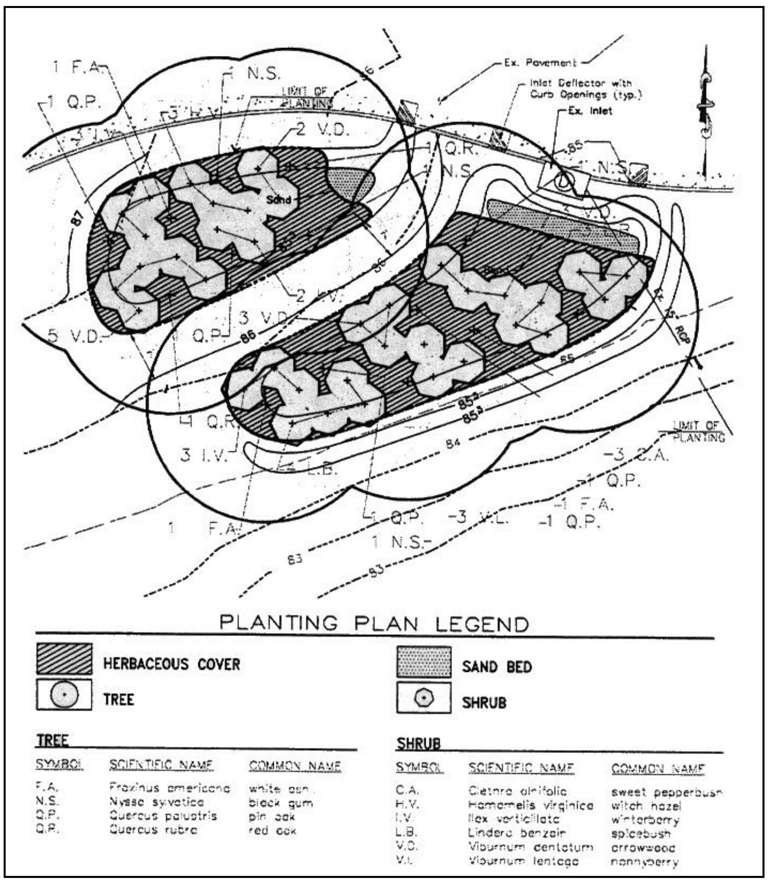


Figure 1.8 Sample Bioretention Area Planting Plan
(Source: VDCR, 1999)

1.5.3 Surface Sand Filters and Infiltration Trenches

Both surface sand filters and infiltration trenches can be designed with a grass cover to aid in pollutant removal and prevent clogging. The sand filter or trench is covered with permeable topsoil and planted with grass in a landscaped area. Properly planted, these facilities can be designed to blend into natural surroundings.

Grass should be capable of withstanding frequent periods of inundation and drought. Vegetated filter strips and buffers should fit into and blend with surrounding area. Native grasses are preferable, if compatible.

Design Constraints:

- Check with your local review authority to see if the planning of a grass cover or turf over a sand filter or infiltration trench is allowed.
- Do not plant trees or provide shade within 15 feet of infiltration or filtering area or where leaf litter will collect and clog infiltration area.
- Do not locate plants to block maintenance access to the facility.
- Sod areas with heavy flows that are not stabilized with erosion control mats.
- Divert flows temporarily from seeded areas until stabilized.
- Planting on any area requiring a filter fabric should include material selected with care to insure that no tap roots will penetrate the filter fabric.

1.5.4 Enhanced Swales, Grass Channels and Filter Strips

Table 1.6 provides a number of grass species that perform well in the stressful environment of an open channel structural control such as an enhanced swale or grass channel, or for grass filter strips. In addition, wet swales may include other wetland species (see *Section 1.5.1*). Select plant material capable of salt tolerance in areas that may include high salt levels.

Table 1.6 Common Grass Species for Dry and Wet Swales and Grass Channels

Common Name	**Scientific Name**	**Notes**
Bermuda grass	*Cynodon dactylon*	1,2
Big Bluestem	*Andropogon gerardii*	2, 3, Not for wet swales
Witchgrass	*Panicum capillare*	2,3, Not for wet swales
Switchgrass	*Panicum virgatum*	3
Buffalograss	*Buchloe dactyloides*	1, 2, 3
Bushy Bluestem	*Andropogon glomeratus*	2,3
Virginia Wildrye	*Elymus virginicus*	2,3,4 Not for wet swales
Texas Bluegrass	*Poa arachnifera*	2,3, Not for wet swales
Common Sixweeksgrass	*Vulpia octoflora*	2,3
Green Sprangletop	*Leptochloa dubia*	2,3
Canada Wildrye	*Elymus canadensis*	2,3,4, Wet swales
Longleaf Chasmanthium / Upland Sea Oats	*Chasmanthium latifolium*	2,3,4
Eastern Gammagrass	*Tripsacum dactyloides*	2,3

Note 1: These grasses are sod-forming and can withstand frequent inundation, and are thus ideal for the swale or grass channel environment. Most are salt-tolerant, as well.
Note 2: Where possible, one or more of these grasses should be in the seed mixes
Note 3: Native Texas grasses
Note 4: Shade tolerant

1.5.5 Green Roofs

- The growth medium is generally 2 to 6 inches thick and made of a material that drains relatively quickly. Commercial mixtures containing coir (coconut fiber), pumice, or expanded clay are available. Sand, gravel, crushed brick, and peat are also commonly used. Suppliers recommend limiting organic material to less than 33% to reduce fire hazards. The City of Portland, Oregon has found a mix of 1/3 topsoil, 1/3 compost, and 1/3 perlite may be sufficient for many applications. Growth media can weigh from 16 to 35 psf when saturated depending on the type (intensive/extensive), with the most typical range being from 10-25 psf.
- When dry, all of the growth media are light-weight and prone to wind erosion. It is important to keep media covered before planting and ensure good coverage after vegetation is established.
- Selecting the right vegetation is critical to minimize maintenance requirements. Due to the shallowness of the growing medium and the extreme desert-like microclimate on many roofs, plants are typically alpine, dryland, or indigenous. Ideally, the vegetation should be:
  - Drought-tolerant, requiring little or no irrigation after establishment
  - Self-sustaining, without fertilizers, pesticides, or herbicides
  - Able to withstand heat, cold, and high winds
  - Shallow root structure
  - Low growing, needing little or no mowing or trimming
  - Fire resistant
  - Perennial or self propagating, able to spread and cover blank spots by itself

  Visit www.txsmartscape.com to look up plants meeting the above criteria.
- A mix of sedum/succulent plant communities is recommended because they possess many of these attributes. Certain wildflowers, herbs, forbs, grasses, mosses, and other low groundcovers can also be used to provide additional habitat benefits or aesthetics; however, these plants need more watering and maintenance to survive and keep their appearance.
- Green roof vegetation is usually established by one or more of the following methods: seeding, cuttings, vegetation mats, and plugs/potted plants.
  - Seeds can be either hand sown or broadcast in a slurry (hydraseeded). Seeding takes longer to establish and requires more weeding, erosion control, and watering than the other methods.
  - Cuttings or sprigs are small plant sections. They are hand sown and require more weeding, erosion control, and watering than mats.
  - Vegetation mats are sod-like mats that achieve full plant coverage very quickly. They provide immediate erosion control, do not need mulch, and minimize weed intrusion. They generally require less ongoing maintenance than the other methods.
  - Plugs or potted plants may provide more design flexibility than mats. However, they take longer to achieve full coverage, are more prone to erosion, need more watering during establishment, require mulching, and more weeding.
- Green roof vegetation is most easily established during the spring or fall.

1.6 Trees and Shrubs for Stormwater Facilities

The following pages present a detailed list of wetland trees and shrubs that may be used for stormwater management facilities such as stormwater ponds, stormwater wetlands and bioretention areas. (Source: Garber and Moorhead, 1999)

Table 1.7 Wetland indicator status, growth form, flood tolerance and seed dispersal and treatment for selected native wetland trees and shrubs.

Species	Indicator*	Form	Flood Tolerance**	Seed Dispersal***	Seed Treatments****	Comments
Boxelder *Acer negundo*	FACW-	Tree	T	Sept.-Mar.	Cold Strat. 30-40 Days (Mech. Rup. Peri-carp)	Can propagate by softwood cuttings
Red Maple *Acer rubrum*	FAC	Tree	T	Apr.-July	Strat. not required	Can propagate by softwood cuttings, tissue culture
Hazel Alder *Alnus serrulata*	OBL	Tree	NE	Sept.-Oct.	Cold Strat. 30-60 Days	Can propagate by cuttings, tissue culture
Common Pawpaw *Asimina triloba*	FAC-	Tree	I	Sept.-Oct.	Scarification Re-quired Cold Strat. 60-90 Days	
River Birch *Betula nigra*	FACW	Tree	IT	May-June	Cold Strat. 60-90 Days	Can propagate by softwood cuttings
American Hornbeam *Carpinus caroliniana*	FAC	Tree	WT	Oct.-Spring	Cold Strat. 60 Days	
Water Hickory C *Carya aquatica*	OBL	Tree	IT	Oct.-Dec.	Cold Strat. 30-90 Days Warm Strat. 60 Days	
Bitternut Hickory I *Carya cordiformus*	FAC	Tree	NE	Sept.-Dec.	Cold Strat. 90 Days	
Pecan *Carya illinoensis*	FAC +	Tree	IT	Sept.-Dec.	Cold Strat. 30-90 Days	
Sugarberry *Celtis laevigata*	FAC	Tree	IT	Oct.-Dec.	Cold Strat. 60-90 Days	
Common Buttonbush *Cephalanthus occidentalis*	OBL	Shrub	VT	Sept.-Oct.	Strat. not req.	
American Sycamore *Platanus occidentalis*	FAC +	Tree	T	Feb.-Apr.	Cold Strat. *60-90* Days	
Eastern Cottonwood *Populus deltoides*	FAC	Tree	VT	May-Aug.	Strat. not req.	Can propagate by cuttings
Wafer Ash *Ptelea trifoliata*	FAC	Shrub	NE	Sept.	Cold Strat. *90-120* Days	

Table 1.7 continued

Species	Indicator*	Form	Flood Tolerance**	Seed Dispersal***	Seed Treatments****	Comments
Cherrybark Oak *Quercus pagoda*	FAC +	Tree	I	Aug.-Dec.Cold Strat.	*30-90* Days	Red Oak group
Laurel Oak *Quercus laurifolia*	FACW	Tree	IT	Aug.-Dec.	Cold Strat. *30-90* Days	Red Oak group
Overcup Oak *Quercus lyrata*	OBL	Tree	T	Aug.-Dec.	Strat. not req.	White Oak group
Water Oak *Quercus nigra*	FAC+	Tree	T	Aug.-Dec.	Cold Strat. *30-90* Days	Red Oak group
Willow Oak *Quercus phellos*	FACW	Tree	T	Aug.-Dec.	Cold Strat. *30-90* Days	Red Oak group
Shumard Oak *Quercus shumardii*	FAC	Tree	IT	Aug.-Dec.	Cold Strat. *30-90* Days	Red Oak group
Black Willow *Salix nigra*	FACW+	Tree	VT	June-July	Not required.	Seed will not remain viable in storage. Plant within 10 days after collection.Can propagate by cuttings
Baldcypress *Taxodium distichum* var. *distichum*	OBL	Tree	VT	Oct.-Nov.	Cold Strat. *90* Days.	Soak seed for S min. in ethyl alcohol be-fore placing in cold stratification.
Pondcypress *Taxodium distichum* var. *nutans*	OBL	Tree	VT	Oct.-Nov.	Cold Strat. *60-90* Days.	Soak seed for *24* to *48* hrs. in 0.0196 cit-ric acid before plac-ing in cold stratification.
American Elm *Ulmus Americana*	FAC	Tree	T	Mar.-June	Cold Strat. 60-90 Days	Can propagate by cuttings
Cedar Elm *Ulmus crassifolia*	FAC	Tree	I	Apr.-June	Cold Strat. 60-90 Days	Can propagate by cuttings
Slippery Elm *Ulmus rubra*	FAC	Tree	I	Apr.-June	Cold Strat. 60-90 Days	Can propagate by cuttings
Rough-Leaf Dogwood *Cornus drummondii*	FAC	Tree	T	Aug.-Jan.	Warm Strat. 70°-80° 1 Day Cold Strat. 30 Days	
Hawthornes *Crataegus reverchonii* *Crataegus viridis*	FAC	Shrub	IT	Fall-Winter	May Req. Scari-fication Warm Strat. 70°-80° 30-90 Days Cold Strat. 90-180 Days	
Common Persimmon *Diospyros virginiana*	FAC	Tree	T	Oct.-Nov.	Cold Strat. 60-90 Days	

Table 1.7 continued

Species	Indicator*	Form	Flood Tolerance**	Seed Dispersal***	Seed Treatments****	Comments
Green Ash *Fraxinus pennsylvanica*	FACW-	Tree	VT	Oct.-Feb.	Cold Strat. 60-90 Days	
Waterlocust *Gleditsia aquatica*	OBL	Tree	T	Sept.-Dec.	Req. Scarifica- tion	
Decidious Holly *Illex deciduas*	FACW	Shrub	VT	Sept.-Mar.	Warm Strat. 68°-Day, 86°- Night 60 Days Cold Strat.-60	
Spicebush *Lindera benzoin*	FACW	Shrub	NE	Sept.-Oct.	Cold Strat. 120 Days	
Sweetgum *Liquidamber styraciflua*	FAC	Tree	T	Sept.-Nov.	Cold Strat. *30* Days	
Sweetbay *Magnolia virginiana*	OBL	Tree	IT	Sept.-Nov.	Cold Strat. 90-180 Days	Can propagate by cuttings
Red Mulberry *Morus rubra*	FACU	Tree	IT	June-Aug.	Cold Strat. 30-90 Days	
Southern Bayberry *Myrica cerifera*	FAC	Shrub	NE	Aug.-Oct.	Cold Strat. 60-90 Days	
Redbay *Persea borbonia*	FACW	Tree	MT	Fall	Not established	

* *Indicator*: **OBL-obligate**; **FACW-facultative wetland**; **FAC-facultative**; **FACU-facultative upland**.
Indicators may be modified by (+) or (-) suffix; (+)indicates a species more frequently found in wetlands; (-) indicates species less frequently found in wetlands.

** *Flood Tolerance Mature Plants*:

VT-Very Tolerant: Survives flooding for periods of two or more growing seasons.
T-Tolerant: Survives flooding for one growing season.
I-Intermediately Tolerant: Survives one to three months of flooding during growing season
WT-Weakly Tolerant: Survives several days to several weeks of growing-season flooding.
IT-Intolerant: Cannot survive even short periods of a few days or weeks of growing-season flooding.
NE-Not established.

*** *Seed Dispersal*: Approximate dates across natural range of a given species.

**** *Seed Treatments*:
Cold stratification: Place moist seeds in polyethylene plastic bags and place in refrigerated storage at 33°-41° F for specified time.
Warm stratification: Place moist seeds in polyethylene plastic bags at 68°-86° F for specified time. Scarification-mechanical or chemical treatment to increase permeability of seed coat.

Table 1.8 Seedling response of selected species to flooding conditions

Species	Water Level	Seedling Survival*	Comments
Boxelder *Acer negundo*	Total submersion Growing Season	100% at 2 weeks 70% at 3 weeks 36% at 4 weeks 0% at 32 days	Chlorotic leaves after 4 days. Slow recovery.
Red Maple *Acer rubrum*	Partial submersion Growing season	100% at 5 days 90% at 10 days 0% at 20 days	Adventitious roots developed after 15 days Height growth decreased in saturated soil Soil saturation
	Soil saturation Growing season	Growing season 100% at 32 days	
River Birch *Betula nigra*	Soil saturation Growing season	100% at 32 days	Growth severely stunted
Pecan *Carya illinoensis*	Total submersion Growing season	75% at 4 weeks	
Sugarberry *Celtis laevigata*	Soil saturation Growing season	100% at 60 days	
Common Buttonbush *Cephalanthus occidentalis*	Total submersion Growing season	100% at 30 days	
Green Ash *Fraxinus pennsylvanica*	Total submersion Growing season	100% at 5 days 90% at 10 days 73% at 20 days 20% at 30 days	Lower leaves chlorotic after 8 days Better growth in saturated soil than soil at field capacity
	Partial submersion Growing season	100% at 14 days	
	Soil saturation Growing season	100% at 60 days	
Sweetgum *Liquidambar styraciflua*	Total submersion Growing season	0% at 32 days	
	Partial submersion Growing season	0% at 3 months	
American Sycamore *Platanus occidentalis*	Total submersion Growing season Soil saturation Growing season	100% at 10 days 0% at 30 days 95% at 32 days	Growth decreased by saturated soil
Eastern Cottonwood *Populus deltoids*	Total submersion Growing season	0% at 16 days	Best growth when water table is 2 feet below surface
	Partial submersion Growing season	90% at 10 days 70% at 20 days 47% at 30 days	High mortality when deeply flooded
Cherrybark Oak *Quercus pagoda*	Total submersion Growing season	87% at 5 days 6% at 10 days	Height growth decreased by soil saturation
	Partial submersion Growing season	0% at 20 days 89% at 15 days 47% at 30 days 13% at 60 days	
Water Oak *Quercus nigra*	Partial submersion Growing season	Survived 2 months	
Willow Oak *Quercus phellos*	Soil saturation Growing season	100% at 50 days	Poorer growth in saturated soil than soil at field capacity
Shumard Oak *Quercus shumardii*	Total submersion Growing season	100% at 5 days 90% at 10 days 6% at 20 days	Height growth poorer in saturated soil than soil at field capacity
	Soil saturation Growing season	100% at 30 days 66% at 60 days	

Adapted from Teskey & Hinkley, 1977

* Seeding survival in relation to length of flooding

Table 1.8 continued

Species	Water Level	Seedling Survival*	Comments
Black Willow *Salix nigra*	Total submersion Growing season	100% at 30 days	Better height growth in sat-urated soil than soil at field capacity
	Soil saturation Growing season	100% at 60 days	
Baldcypress *Taxodium distichum* var. *disti-Chum*	Total submersion Growing season	100% at 4 weeks	
American Elm *Ulmus Americana*	Total submersion Growing season	100% at 10 days 27% at 20 days 0% at 30 days	Height growth decreased in saturated soil
	Soil saturation Growing season	100% at 15 days 94% at 60 days	

* Seeding survival in relation to length of flooding

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