# blanco river design guidelines

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TEXAS PARKS & WILDLIFE FOUNDATION

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# introduction



2015 saw two exceptional rainfall events in central Texas and especially within the Blanco River watershed. In May, above average rainfall had resulted in saturated soils with conditions coming together during the Memorial Day weekend for extreme rainfall which produced 10-13" within a time frame of 12 hours near southern Blanco county. This resulted in record river levels that produced catastrophic flood damage to property and people along the Blanco River. The Fort Worth National Weather Service Office reported May 29, 2015 that this singular event produced 35 trillion gallons of water, enough to cover the entire state in 8" of water. Residents of the Blanco barely had time to process this event and its far-reaching effects, when a second 500 year rainfall hit again on October 30, 2015.

The intensification of extreme weather patterns has clearly been documented over the past three decades, and the trend demonstrates an increase in heat waves, drought, intense rain events, and floods, among other weather events. Resilient landscapes help mitigate the effects of these intense events and can even offset some of the outcomes. This resilience emanates from the prolific amount of species that once covered over 15,000,000 acres in central Texas. Land use is the most important driver of global biodiversity change in the twenty-first century (Sala et al. 2000), and the reduction of diversity can alter, reduce, or eliminate ecosystem services such as air cleansing, carbon sequestration, temperature moderation, freshwater provision and cleansing, and slowing the flow of stormwater runoff (Cardinale et al. 2012). Simply put, common development practices and residential property construction and maintenance have considerably reduced the land's capacity to absorb and minimize adverse impacts by compacting soils, reducing native plant communities, introducing invasive species, and increasing impervious

surfaces. Damaged soils increase rainwater runoff conveying excessive amounts directly into our creeks, streams, and rivers and the resulting flood damage can alter the hydrologic system.

The good news is that we can control how our landscapes function and ultimately choose to design our surroundings so that they retain important qualities that cumulatively mitigate the disruptive effects of inadequately planned and poorly managed development. If we accept and embrace the fact that landscapes are inherently dynamic, then we can accommodate natural processes into our designs. For riparian areas, this means understanding that disturbance events such as floods are integral to many organisms that are dependent upon these events for regeneration. Nature has provided us with a means to address both people's needs and natural processes; we simply need to observe our surroundings and be aware that our actions significantly impact our surroundings for better or worse. We should not concern ourselves with "curbing the influence of human occupancy." Rather, we should create a better understanding of landscape management and prevent damage to the environment, maintaining healthy conditions so that we may enjoy and thrive within wildlands, cities, and their interface. By doing so we will "fulfill the responsibilities of each generation" to preserve the land (Leopold 1933). As President and Mrs. Johnson said, we should not relegate nature to a weekend role in our eagerness for "improvement,"

there is more to America which "God has gladly given," a part that was "here long before we arrived, and will be...long after we depart... beautiful, and changing, always changing" (Johnson 1966).

In this document there is a general discussion regarding riparian function, historical site conditions, and active methods for preserving or enhancing private landscapes, with a case study demonstrating how the Lady Bird Johnson Wildflower Center and the Texas Parks and Wildlife Department would advocate for private property owners to deal with storm water and riparian restoration on their properties. This example also provides a complete design drawing set with commonly found conditions along the Blanco River such as upland, residential, canopy, riparian buffers, and river access points. This design is intended to give landowners options for dealing with rainwater runoff, plantings for areas adjacent to the Blanco, and design suggestions so that landowners may successfully blend "natural" and "formal" areas. Every landowner won't necessarily be able to implement all of the strategies, but they can look at each component (upland, residential, canopy, riparian buffer, river access) and choose those that make the most sense given their property type. Viewing each property as part of a larger riparian system strengthens the impact of the suggested strategies, and more importantly, contributes to the Blanco River's overall health.

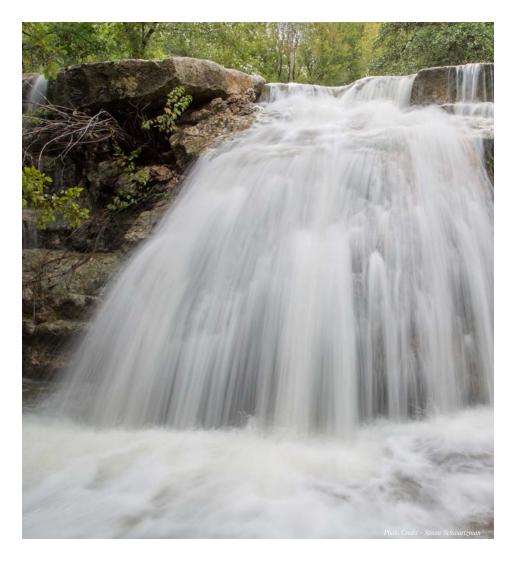
### government permits



A permit is required for construction or fill activities performed within the channel (below the Ordinary High Water Mark). The purpose and scale of the activity will determine which type of 404 permit is required. The USACE has released a Public Notice specific to the flooding events of May 2015 titled, "Flood Recovery and Repair Activities in the Fort Worth District", which can be found at:

http://www.swf.usace.army.mil/Media/PublicNotices/tabid/6600/ Article/589711/public-notice-2015-flood-recovery-and-repair-activities. aspx The term ordinary high water mark means that line on the shore established by the fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas (Army Corps of Engineers 2005).

Please call the City of Wimberley before any digging takes place to ensure that the location of all infrastructure is known (e.g. phone, water, gas, sewage, telephone, electrical). Restoration projects may or may not require permits, but it is best to inquire to avoid penalties such as fines or having to return the site to its prior condition. Submitting thorough sets of plans that clearly illustrate your restoration intent as well as all necessary design/construction drawings will help ensure that your project is permitted in a timely manner, ideally within 45 days.



### government permits

If you do wish to undertake restoration efforts on your land, contact the Army Corps of Engineers Regulatory Division in Fort Worth, TX at (817) - 886 - 1731 to discuss your project to help determine if permits are necessary. Helpful documents to assemble for your conversation:

- Project location: state, county, city or closest town
- Restoration intentions: i.e. repairing flood damage, habitat improvement, site grading, etc.
- Maps documenting existing conditions: soil maps, drainage maps, plats, topographical surveys, etc.
- Design plans: It will be helpful to demonstrate any physical changes to your property through design drawing sets. The more information you have, the better the chances that ACE will either waive permitting or process necessary permits as quickly as possible. If you don't plan on making major changes requiring drawings by a landscape architect, try and visually demonstrate your restoration efforts as best you can.

#### **US Army Corps of Engineers 404 Permit**

Depending upon the size and location of your proposed work, you may be required to provide an application or preconstruction notification (PCN) for USACE review and prior to authorization of your project. For

riparian restoration one of the following 404 permits may apply, however it is possible that a separate permit not listed below may be required. Contacting the USACE is essential to determining the appropriate course of action.

- <u>Nationwide Permit (NWP 13 Bank Stabilization</u> Bank stabilization activities necessary for erosion prevention.
- <u>NWP 18 Minor Discharges</u> For activities that discharge less than 25 cubic yards of fill material.
- <u>NWP 19 Minor Dredging</u> For the dredging of no more than 25 cubic yards below the plane of the OHWM.
- <u>NWP 45 Repair of Uplands Damaged by Discrete Events</u> Authorizes bank stabilization to protect restored uplands damaged by storm, flood, or other discrete events.
- <u>Individual Permit</u> For larger projects or those that do not meet the criteria of a NWP.

Contact the USACE Fort Worth District – Regulatory Division: 817-886-1731

http://www.swf.usace.army.mil/Missions/Regulatory/Permitting.aspx

#### **TPWD Sand and Gravel Permit**

A permit from the Texas Parks and Wildlife Department is required to "disturb or take" streambed materials from streambeds under the State's jurisdiction. This includes the Blanco River. Plant installation should not require a permit if non-mechanized equipment is used.

Contact the TPWD Watershed Conservation Program: 512-389-4583. http://tpwd.texas.gov/faq/landwater/sand\_gravel/

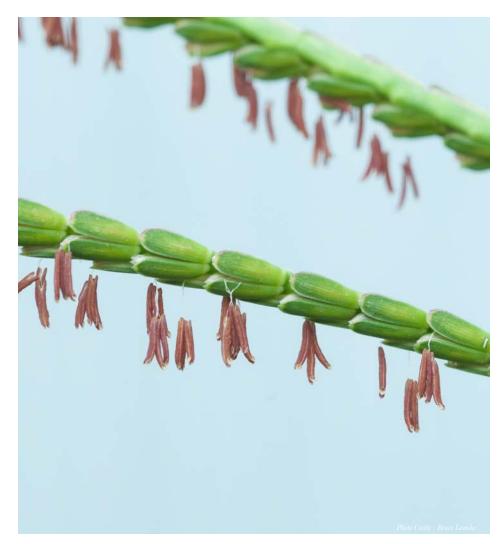
#### **Floodplain Regulations**

The County Floodplain Administrator may regulate construction or other activities occurring in the floodplain as determined by the Federal Emergency Management Agency's Flood Insurance Rate Maps. Contact the county to receive a permit or exemption:

#### Hays County

Clint Garza, Development Services Dir Tom Pope, Floodplain Administrator 512-393-2150

Blanco County Kermit Roeder, County Inspector 830-868-2117





Twenty percent of bottomland forest ecosystems have been lost in the southern states since 1950 (Kellison and Young 1997 as cited in Holcomb 2004); and by 1986, over one-half million acres have been inundated by reservoirs in Texas (McMahan 1986 as cited in Holcomb 2004). The diversity of plant and animal species found in functioning bottomland forests is unparalleled among other ecosystem types throughout the lower 48 United States (Kellison and Young 1997 as cited in Holcomb 2004). It is important to understand that this species richness and diversity resulted from the convergence of wetland and upland associations. In fact, the U.S. Army Corps of Engineers (COE), the Environmental Protection Agency (EPA), the U.S. Fish and Wildlife Service (USFWS), and the Soil Conservation Service (SCS) have expanded their wetland definition criteria to include bottomland hardwood forests (Kellison and Young 1997 as cited in Holcomb 2004).

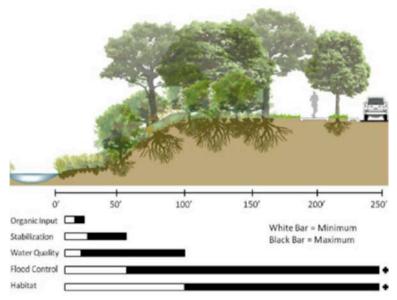


Figure 1 – COA riparian corridor - City of Austin, Watershed Protection Department. Riparian Zone Restoration

Figure 1. This image above shows the various buffer widths associated with riparian zone function. Organic inputs into the stream are important sources of nutrients and habitat (width 15-25 ft). Stream stabilization is maintained by riparian vegetation (width 30-60 ft). Water quality is the ability of the vegetation to intercept runoff, retain sediments, remove pollutants, and promote groundwater recharge (width 20-100 ft). Flood control is the ability for the floodplain to intercept water and reduce peak flows (width 60- 500 ft). Riparian habitat is the ability of the buffer to support diverse vegetation and provide food and shelter for riparian and aquatic wildlife (width 100-1500 ft).

The health of Texas' rivers, streams, and creeks are important contributors to the overall environmental and human health of urban areas. Many of these ecosystems are threatened by non-point pollution, invasive plant growth, degraded/paved watersheds, and the channelization of streams, thus impacting or eliminating beneficial ecosystem services (Allan et al. 1997, Strayer et al. 2003, Townsend et al. 2003).

Riparian areas perform essential hydrological and biological functions, including flood control, surface water storage, ground water supply recharge, and biological diversity (Dickson 1989, Gregory 1991, Williams et al. 1997). Vegetation in riparian corridors act as a filter trapping sediment, organics, excess nutrients, and pollutants from parking lots, roads, residences, and commercial lot surface runoff, improving water quality (Lowrance et al. 1984, Henley et al. 2000).

Riparian areas are complex ecosystems that contain vital habitat for numerous species. The vegetation not only prevents erosion, but also provides food (Halls 1973), cover (Burk et al. 1990, Halls 1973), and breeding habitat for bird, amphibian, mammal (Dickson and Huntley 1987), fish, and reptile species (Rudolph and Dickson 1990, Brode and Bury 1984). Trees (snags), branches, and leaves falling from riparian edges into the water provide habitat for aquatic organisms (Maser and Sedell 1994) and help build soil by slowing water flows. Removal of this cover results in a reduction in biodiversity and landscape performance.

#### **Opportunities to restore ecological function**

There are many opportunities to improve ecological function of the Blanco River in addition to creating stunning landscape designs. To restore ecosystem function is not simply to replace plants but to use restoration principles to restore processes that allow natural systems to repair themselves and remain relatively stable. In practice, the assessment and repair of natural processes begins with the soil. Healthy soil, and the healthy plant communities it can support, comprise the foundation for functional ecosystems.

While the land owners may not be restoring property areas to historical climax conditions, restoration principles, which are informed by historical plant communities, still apply and allow a hybrid condition to exist that will foster greater ecological integrity than present conditions. As an overall strategy, it is often beneficial for restoration efforts to occur incrementally so that the challenges of climate (drought, excessive rain, freezes, etc.) do not overwhelm a significant investment or effort. This incremental approach will allow for fine tuning the restoration methods to what works best on site. Initial efforts should begin in high priority areas.

It is important for land owners to understand that the creation of sustained, successful landscapes will only occur if their designs are based on measures of function rather than measures of structure (Grayson et al. 1998). Structure, or patterns of an ecosystem, describes the various physical and biological parts of that ecosystem, whereas function includes the interactions of organisms with one another and with their physical environment (Grayson et al. 1998). Many projects are designed with the assumption that if the structure (i.e. spatial characteristics) looks right, the system will also function correctly, but many restoration/habitat projects that have been deemed a success, in terms of realized project goals, were ultimately not successful because the measures of function were insufficient or absent (Grayson et al. 1998). It is unlikely that everyone's yard can be returned to historical climax community conditions, but their design strategies can implement such achievable goals by defining major design goals during site assessments. For example, the project could aim to increase plant species diversity and richness or reduce erosion (Grayson et al. 1998).

#### Wetlands

Texas wetlands are some of the state's most endangered ecosystems and are characterized by permanent/semi-permanent water, oxygen poor soils, and obligate plant species adapted living in wet environments (TP WD 2003). Central Texas wetlands included flooded woodlands, river's edges, spring fed pools and seeps. The common feature of functioning wetland ecosystems is the variability of terrain and water depth.

Common wetland species for the site would have been water knotweed (*Polygonum amphibium*), buttonbush (*Cephalanthus occidentalis*), black willow (*Salix nigra*), marsh purslane (*Ludwigia palustris*), water pennywort



(Hydrocotyle ranunculoides), cattail (Typha domingensis), bushy bluestem (Andropogon glomeratus), scouringrush horsetail (Equisetum hyemale), crimsoneyed rosemallow (Hibiscus moscheutos), zigzag iris (Iris brevicaulis), Virginia iris (Iris virginica), cardinal flower (Lobelia cardinalis), bigfoot water clover (Marsilea macropoda), nimblewill (Muhlenbergia schreberi), American white waterlily (Nymphaea odorata), lanceleaf arrowhead (Sagittaria lancifolia), and common elderberry (Sambucus nigra ssp. Canadensis).

#### **Riparian Edges**

Riparian vegetation is a major source of energy and nutrients for stream communities. Overhanging riparian vegetation keeps the streams cool, which is especially important for increasing plant species diversity. The target community for riparian areas frequently consists of a properly functioning gallery forest, dominated by bottomland hardwood species with an herbaceous layer beneath that is composed of species that will enhance bank stability. Historically, the riparian areas along perennial and frequently flowing intermittent streams on the Edwards Plateau consisted of this community type, while intermittent streams and streams in drier areas, like the recharge zone of the Edwards Aquifer, tend to be more reminiscent of the surrounding upland. Gallery forests support the goals of enhanced water quality along stream channels by enhancing bank stability, removing nutrients, pollutants, and sediment, and slow water runoff velocity.

#### **Riparian Plant Community Considerations**

For riparian restoration, a healthy, diverse native plant community adjacent to receiving water bodies and riparian zones helps control erosion, filters sediment and pollutants carried in stormwater, supports the health of aquatic ecosystems, and provides flood control and habitat. The root system of the vegetated area is crucial for achieving this health status. Increased native diversity can be encouraged through selective removal of invasive species and seeding of native woody and herbaceous species. Primary goals guiding species selection in riparian areas are enhanced bank stability and water quality. Many species found in central and southwest Texas have been given draft stability ratings based on their contribution to bank stability (Nelle 2009). Stability ratings range from 1 to 10, with 1 approximating the bare ground and 10 anchored rock. Ideally, riparian areas will be dominated by plants with stability ratings between 6 and 9. Stability ratings of 7 or higher are considered to be the minimum for acceptable bank stability. However, combinations of species, particularly woody species in association with grasses or sedges, can provide higher stabilities than reflected in individual species ratings (Nelle 2009).

In addition to stability ratings, USFWS wetland indicator status should be considered. Riparian areas should contain a mix of obligate wetland, facultative wetland, and facultative species, dependent on water availability. It is important that all riparian areas contain some species from the facultative groups to provide stability as water availability fluctuates.

Establishment of these species can be done passively or actively. Passive establishment is the regeneration of an existing vegetated buffer through the succession of native plants and natural seed dispersal. This is facilitated through elimination of invasive species and selective vegetation thinning. Active establishment is a technique used with little or no existing riparian buffer. This technique involves the creation of a site specific plan detailing the species and location of proposed vegetation. In some cases a combination of the two approaches is ideal, but this decision should be based on a per site basis. An active approach is recommended in areas of extreme erosion.

The active approach requires several steps for effective buffer improvements and establishment. Re-establishing the riparian zone should take place after erosion control measures have been established in the area draining to the Blanco River. First, it is important to remove invasive species from the riparian zone, keeping soil disturbance to a minimum to reduce vegetation loss and erosion. Erosion control techniques should be implemented adjacent to the riparian buffer, especially in any nearby construction areas, to aid in erosion control adjacent to the Blanco River. It is then important to establish different vegetation planting zones: an inner, middle, and outer zone.

The shallow wetland can contain unmanaged vegetation while the drainage and upland areas can contain managed vegetation. When establishing these zones, it is best to plant herbaceous seeding/plantings first before woody species. For tree establishment, it is recommended to plant a mix of balled and burlapped trees and saplings. In general, 30% of the riparian area to be reforested should be planted with 3" caliper trees at 6-7' intervals and 60% of the area with saplings at 15' intervals. These densities and amounts are flexible dependent upon restoration goals. All vegetation will require temporary irrigation after establishment, and the riparian zone will need to be monitored regularly for signs of erosion, sedimentation, debris, native plant establishment or invasive species. Irrigation and monitoring requirements should be detailed in restoration and maintenance plans.



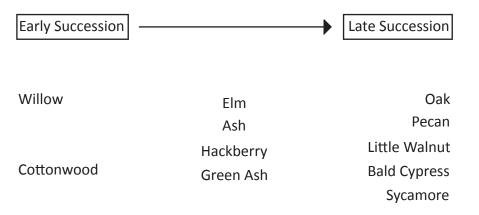
A final consideration is the determination of the riparian buffer width. As mentioned in the site assessment, the current buffer varies with regard to both width and ecological health. When possible, the riparian buffer area shall be as large in size as possible, or a minimum width of 20 feet on either side of the water body. A wider buffer is more effective at filtering and reducing pollutant levels, specifically nitrogen (Mayer et al, 2005). Having a larger buffer zone will also allow for improved bank conditions.

#### **Riparian trees and canopy conditions**

Central Texas has recorded some of the most intense rainfall in the world with some singular events depositing over 40" (Guadalupe- Blanco River Authority 2011), however, this region also experiences extended periods of drought. This climatic dichotomy results in a unique topographical system that includes floodplain and terraces formed from older floodplains (Wharton et al., 1982 as cited in Holcomb 2004). Forests in the floodplain are subject to flooding and the accompanying sediment deposition (Hodges, 1997 as cited in Holcomb 2004). The profile of these areas is characterized by a series of small ridges, flats, and sloughs, which influence water retention, sediment deposition, and soil texture (Hodges, 1997 as cited in Holcomb 2004). Species composition also varies with the topography as you move from mid river to upland (Holcomb 2004). Typical riparian species include pecan, little walnut, willow, bald cypress, and sycamore on the riverbanks; less water tolerant species (e.g. elm, hackberry, and plateau live oak) growing on the ridges; facultative wetland species (e.g. bald cypress, American sycamore, cottonwood) in the sloughs; and mixtures of both types, as well as facultative upland species (e.g. green ash) on the flats (Hodges, 1997 as cited in Holcomb 2004). Three types of dominant overstory plant communities can characterize the limestone-dominated Central Texas/Edwards Plateau region: bald cypress and sycamore; pecan and hackberry; and hackberry and elm. (Wagner 2003).

Source: Holcomb 2004. Example of canopy tree species development over time

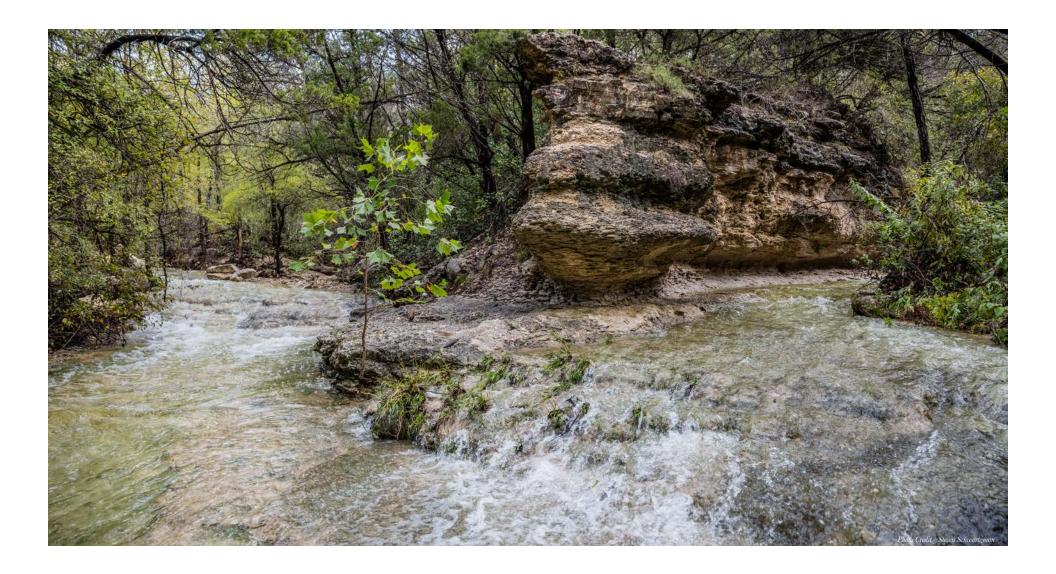
Large portions of the landscape originally would have consisted of canopy communities of elm, live oak, hackberry, and pecan trees (USDA Soil Survey 1974). This community would likely include Bottomland



Range Site and Blackland Prairie species and also Edwards Plateau flora. These species are considered upland associations and although they are not directly affected by the hydrological conditions, they did act as important sources of organic matter for wetlands and helped create microclimates for habitat, and therefore should be considered part of the riparian system (Gregory et al. 1991). The grassland species also played an important role in controlling sheet flow runoff into receiving waterways during intense rain events and helped mitigate floods. Grass and broadleaf plants in these areas can include species such as purpletop (*Tridens flavus*), sideoats grama (*Bouteloua curtipendula*), Virginia wildrye (*Elymus virginicus*), Canada wildrye (*Elymus canadensis*), Eastern gamagrass (*Tripsacum dactyloides*), inland sea oats (*Chasmanthium latifolium*), wild onion (*Allium canadense*), Drummond's wild onion (*Allium drummondii*), blackeyed Susan (*Rudbeckia hirta*), pigeonberry (*Rivina humilis*), tropical sage (*Salvia coccinea*), purple coneflower (*Echinacea purpurea*), heart-leaf skullcap (*Scutellaria ovata ssp. Bracteata*), and shrubs like Turk's cap (*Malvaviscus arboreus var. drummondii*), American beautyberry (*Callicarpa Americana*), common buttonbush (*Cephalanthus occidentalis*), Mexican buckeye (*Ungnadia speciosa*), and evergreen sumac (*Rhus virens*).

#### Uplands

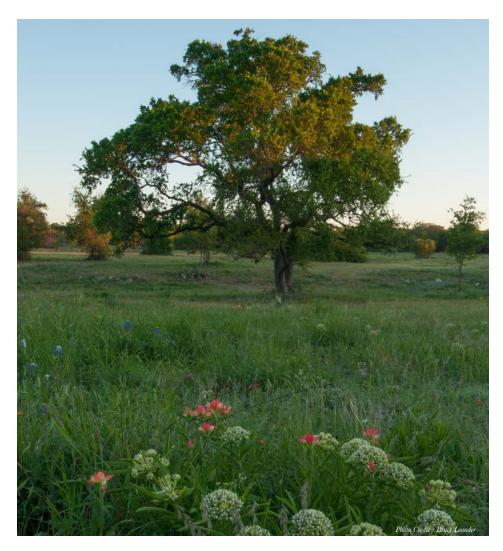
Historically the upland consisted of savanna with 20-25% tree coverage which translates into 2-3 trees per acre. Many properties include closed canopy conditions with turf understory. Removing mature, large shade trees is likely undesirable, however, these areas can be dramatically improved with the removal of invasive species, soil amendment, placement of appropriate plant communities, increase of successional plantings, inclusion of micro-topography, and limb reduction.



#### Tallgrasses and wildflowers for sunny spots

Much of the soil adjacent to the Blanco River ranges from of clay loam, silty clay, cobbly clay, and stony clay to loose sand and sediment, cemented sediment, and bare bedrock. These soil conditions will determine the appropriate plant compositions for properties located along the Blanco River. Grasses and wildflowers help anchor the soil during high flow events due to their extensive fibrous root systems and their ability to lie down and shield underlying soils during high flow flood events. In eroded areas soil depth, content, and compaction will be a limiting factors for the potential of site recovery. Replanting efforts will likely require multiple seeding sessions as well as planting plugs of key species that usually don't appear until ecosystems have reached a stable mature state (USDA Soil Survey 1974).

Vegetation, especially on areas within the 100 year floodplain, should predominantly consist of tall, warm-season perennial bunchgrasses with lesser amounts of midgrasses. This tallgrass prairie was historically dominated by big bluestem (*Andropogon gerardii*), Indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), Eastern gamagrass (*Tripsacum dactyloides*), and little bluestem (*Schizachyrium scoparium*). Midgrasses such as sideoats grama (*Bouteloua curtipendula*), Virginia wildrye (*Elymus virginicus*), Canada wildrye (*Elymus canadensis*), cedar sedge (*Carex planostachys*), Texas



wintergrass (*Nassella leucotricha*), Texas cupgrass (*Erichloa sericea*), fall witchgrass (*Digitaria cognate*), green sprangletop (*Leptochloa dubia*), hairy grama (*Bouteloua hirsuta*), dropseeds (*Sporobolus spp.*) and a wide variety of forbs such as Engelmann's daisy (*Engelmannia peristenia*), Maximilian sunflower (*Helianthus maximiliani*), narrow-leaf coneflower (*Echinacea angustifolia*), pink evening primrose (*Oenothera speciosa*), rattlesnake master (*Eryngium yuccifolium*), prairie clover (*Dalea spp.*), dotted gayfeather (*Liatris punctata*), wild foxglove (*Penstemon cobae*), Hill Country penstemon (*Penstemon triflorus*), and snow on the prairie (*Euphorbia bicolor*) add to the diverse native plant community (USDA Soil Survey 1974).

River access and residential areas can utilize native short and mid grasses to recreate turf conditions. Generally the more species planted within these areas the less weeds landowners will have to contend with as the density created by a diverse species mix helps prevent opportunistic invasive plant establishment. Some of the species that can be planted in "turf" areas can consist of species such as side oats grama (*Bouteloua curtipendula*), curly mesquite (*Hilaria belangeri*), buffalograss (*Bouteloua dactyloides*), hairy grama (*Bouteloua hirsute*), blue grama (*Bouteloua gracilis*), Texas grama (*Bouteloua rigidiseta*), purple threeawn (*Aristida purpurea*). These areas can also contain wildflowers such as purple coneflower (*Echinacea purpurea*), mealy blue sage (*Salvia farinacea*), bluebonnet (*Lupinus texensis*), blue-eyed grass (*Sisyrinchium angustifolium*), Hill Country rain lilly (*Cooperia pedunculata*), crow poison (*Nothoscordum bivalve*), and pink evening primrose (*Oenothera speciosa*).

#### LID

Beyond providing a healthy buffer to enhance water quality and reduce erosion, properties should be evaluated for opportunities to restore and improve hydrological function. As much of the upland areas contribute and drain to the Blanco River, slowing surface flow from locations such as parking lots, turf areas, and buildings through dispersed vegetated systems, add to greater health of the river. Low Impact Development (LID) or Green Infrastructure is a comprehensive hydrological approach to site planning, design, and pollution prevention strategies that create a more economically sustainable and ecologically functional landscape. As such, the LID approach provides many benefits to a community's water resources and overall quality of life. It is a comprehensive approach to land development or re-development to manage stormwater runoff. The LID methodology works with nature to manage stormwater as close to its source as possible, treating runoff as a resource rather than a waste product. Using LID techniques can help:

- Emphasize conservation and the use of on-site features to protect water quality
- Create functional and appealing site drainage
- Keep water on the site and allow infiltration into soils
- Recharge groundwater and the aquifer (where appropriate)

#### **Rain gardens** (bioretention)

Rain gardens (or bioretention) function as a soil and plant-based filtration device that removes pollutants through a variety of physical land biological processes. These depressed areas allow water to be retained in a basin shaped landscape area with plants and soil where the water is allowed to pass through the plant roots and the soil column. These facilities normally consist of a basin or ponding area, organic or mulch layer, and plants. Constructed rain gardens provide stormwater treatment that enhances the quality of downstream water bodies by infiltrating runoff, or when designed with liner or underdrain, temporarily storing runoff and releasing it over a period of days to the receiving water. The vegetation within the constructed rain gardens can provide shade and wind breaks and help absorb noise. Rain gardens are easily integrated into site landscaping and their design and can be formal or informal in character.

#### Swales

Swales are vegetated channels that convey stormwater and remove pollutants by sedimentation and infiltration through soil. Unlike rain gardens that capture, retain, and infiltrate stormwater, swales are primarily stormwater conveyance systems. They can provide sufficient control under light to moderate runoff conditions, but their ability to control large storms is limited. Therefore, they are most applicable in low to moderate sloped areas or along roadsides as an alternative to ditches and curb and gutter drainage. Swales can be more aesthetically pleasing than concrete or rock-lined drainage systems and are generally less expensive to construct and maintain. With this technology, it is important that the swale maintain 100% cover with grasses to be effective.

#### **Design Considerations**

Before implementing any LID techniques on site, it will important to determine the volume of the annual runoff to be managed. This may be specified in existing local regulations. Or, it is possible to analyze historical rainfall data in the region to determine the relationship between the water quality volume and the amount of the annual runoff to be treated. It will also be important to conduct a thorough analysis of the following, at a minimum:

• Soil type and whether modifications are needed



- The storage needed to capture and treat the runoff (based on local conditions)
- The sensitivity of the receiving body
- Future maintenance
- Installation techniques
- The ability to infiltrate the runoff (or if they will be filtration features)
- The desired performance goals of the LID feature

#### **Restoring landscapes**

The restoration techniques mentioned in this booklet are designed to guide landowners in the process of repairing damaged land or converting resource intensive landscapes to areas that are both beautiful and best suited to protect property during high flow flood events. The species listed in this document evolved in disturbance driven ecosystems that included wildfire and flood, and are best adapted to contribute towards the recovery of the Blanco floodplain. Landowners should note that the transition of property from a degraded state dominated by invasive plant growth or severe erosion will be challenging and resemble more of a trajectory rather than a singular intervention. Emphasis should be placed on the positive impacts from the restoration process rather than an end product. Minor disturbances in healthy functioning ecosystems usually self heal and return to a stable functioning state within a relatively small amount of time, however, such healthy systems are rare within or near urban and suburban areas because significant alterations to natural processes such as the water's movement through the landscape (hydrology), nutrient cycling (capture and utilization of soil nutrients), and soil health and organic matter production, have resulted in an inability of the land to reset itself (Whisenant 2005). Additionally, major disturbance events, such as the Memorial Day flood, complicate restoration efforts because they require large-scale intervention on both upland and riparian components, and force us to redefine how we choose to interact with our environment.

During restoration efforts it is very likely that the best laid plans will face setbacks and that multiple efforts will be required to achieve what might be deemed a success, but know that ecosystems are dynamic entities consisting of a complicated network of interconnected biotic (living) and abiotic (physical) components. The Lady Bird Johnson Wildflower Center's restoration experts always face challenges when trying to revive abused or degraded land, and just by simply deciding to slow water and keep it on site, incorporating native plantings in a system based approach (not relegating plants to flower beds), and allowing tallgrass communities to thrive on parts of their property, homeowners will make a major difference and help mitigate damage from flood events. This is not to say that a restoration strategy will completely prevent flood damage, but by embracing these measures Blanco River residents will be able to enjoy a more diverse, healthy, and functional Texas landscape and contribute towards an overall improvement of the river's condition.

This booklet also provides landowners with a demonstration of what these efforts can result in when implemented on an actual property located on the Blanco River that experienced severe damage from the floods. We have divided the property into four parts: an upland component, residential area, canopy dominated area, and riparian buffer. The goal is that all properties might not possess all of these components, but by applying similar strategies property owners can design their landscape so that it embraces both nature and beauty; with the hopes that we may move beyond the argument that natural areas look unkempt leaving homeowners only with the option of St. Augustine lawns if they desire a well designed yard. We need to look beyond landscape design that results in entire swaths of neighborhoods that look exactly the same whether you are in Wimberley, Texas or Portland, Maine. Let's make Texas, Texas.

The following recommended restoration measures are based on the Lady Bird Johnson Wildflower Center's years of experience in ecological restoration and hopefully will provide Blanco residents with a framework and number of actions that will enable people to better understand the landscape and processes that helped form the unique and beautiful ecosystem that is Texas Hill Country. This endeavor can, if applied on a large scale, cumulatively result in a net positive change that will benefit both people and the environment, and make a beneficial, demonstrable impact on the Texas landscape, or as Mrs. Johnson called it, "our heart's home."



### site assessment

#### Introduction

The first step of any restoration effort is a pre-design assessment of existing site conditions. It is tempting to skip this step in order to get started with design and installation, but an accurate predesign assessment will maximize the opportunities for beneficial site performance.

Site assessments can be conducted at several levels of detail, with the simplest being hand drawn maps of erosion and existing plant communities and the most detailed involving professional surveys of soil, drainage patterns and vegetation. Useful information can be gathered at either end of the spectrum.

This booklet will provide an overview of the elements to consider during a site assessment and will provide resources for multiple levels of site assessment.

#### **Elements to consider**

The goal of the site assessment is to identify elements of the site to protect or enhance as well as any problems (erosion, invasive species etc.) that will need to be addressed in the final design. Frequently, the best opportunities for enhancement of the site grow from the site's challenges. The primary elements to consider during the site assessment are: drainage patterns, impervious cover (buildings, roads etc.), soil type and condition, plant community type, arrangement and composition, channel condition, and bank condition.

#### **Preliminary data gathering**

Prior to beginning the on-site assessment, gather the following information.

• EPA level III and IV ecoregion. Ecoregion descriptions will provide you with information on the natural communities that occur in your region and will provide you with some information on species that are appropriate to your area.

-http://www.epa.gov/eco-research/ecoregions-http://www.tceq.state.tx.us/assets/public/comm\_exec/pubs/ as/199.pdf

- --Wimberley, TX
- --Level III ecoregion: Edwards Plateau
- --Level IV ecoregion: Balcones Canyonlands
- 100 year flood plain

-https://msc.fema.gov/portal/search



#### Process

A site assessment is recorded in a series of maps, which can be hand drawn or generated with mapping and design programs such as GIS and CAD. The method is less important than accurately locating important elements spatially which will help to show relationships between them and will often make opportunities stand out. This assessment will focus on the bank and upland areas, not the stream channel itself. The goal is to identify problems and opportunities that the landowner can directly affect, so issues caused by watershed scale processes are not addressed here. Additionally, this is primarily an inventory, not an ecosystem health assessment, though elements of ecosystem health are included.

#### **Topography and flow direction**

The first element to consider is topography. Mapping topography is

important so that existing drainage patterns can be understood and so interventions can be placed where they will be most effective. A topographic, or contour, map of the property needs to be obtained. Topographic maps show changes in elevation using contour lines. Each line represents an elevation. The interval for the map is how much change in elevation there is between each line. USGS topographic typically have a 10 foot interval, so the land either rises or falls 10 feet between the lines. Surveys done prior to most design work have a 1 foot interval. It is a good idea to have a professional survey done with 1 foot contour lines, but an initial pass can be done with a USGS topographic map.

- USGS quadrangles provide rough contours (10 ft. interval)
   -The USGS Store https://store.usgs.gov
   -Download the most recent Road US Topo
   -Turn on the orthoimage to see aerial imagery
  - -Private companies will create custom topographic maps for your area

Here are some typical patterns seen with contour maps and what they mean to drainage patterns.

The steepness of a slope can be determined by how close the contour lines are to one another. The closer the lines, the steeper the slope.

# site assessment

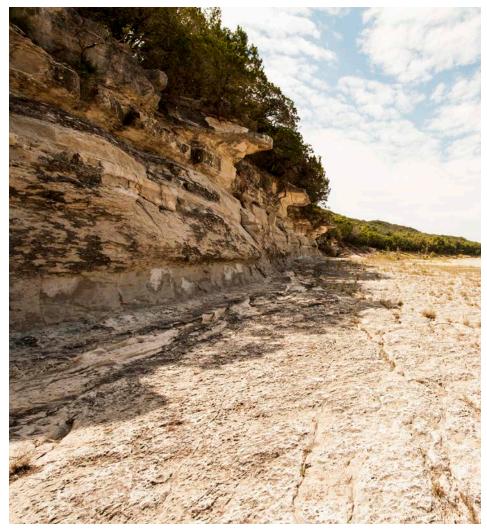




Figure 3.1 Vs or Us are either ridges or valleys. If you are looking at a valley, the point of the V points upstream. Water flow will concentrate in these areas making them more prone to erosion.

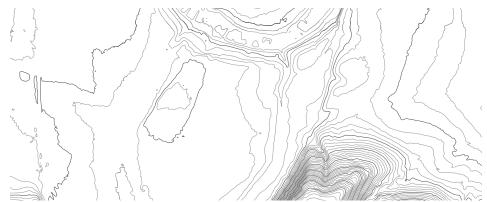


Figure 3.2 Circles are either peaks or depressions. Natural depressions will collect water and create opportunities for elements such as rain gardens.

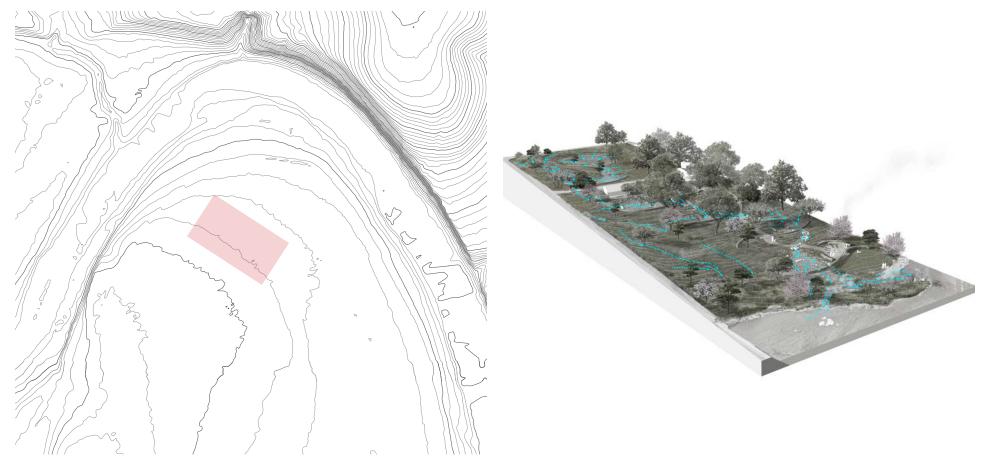


Figure 3.3. Once you have your contour lines, place any existing built elements on the map because these will affect drainage patterns.

Figure 3.4 Finally, map flow direction and existing signs of erosion and sedimentation. Use your topographic map and site inspection to identify where water causing erosion is coming from.

### site assessment

#### **Soils and Plant Cover**

Next consider existing soils and plant cover. A custom soil map for your property can be generated using the Web Soil Survey http:// websoilsurvey.sc.egov.usda.gov/App/HomePage.htm . A tutorial for using the tool exists on the site's home page, and a more detailed tutorial can be found in Appendix A. The soil survey provides a wealth of information about the site. Many properties have more than one soil type and design should take this into account.

When generating your soil report gather the following information at a minimum:

- Soil map
- Ecological site information
- Soil reports
- AOI inventory: component legend, map unit description
- Land classification: hydric soils
- Soil chemical properties
- Soil physical properties: engineering properties, particle size, physical soil properties

In addition to the soil map, it is a good idea to have soil testing done for the site. A soil sample should be taken for each mapped soil type and sent to a soil testing laboratory. Request the following tests: pH, macronutrient (often called routine analysis), organic matter, and texture. This will be important as plant material and other interventions are considered for the site.

Most laboratories will provide instruction for taking soil samples. The Texas A&M laboratory (contact information below) provides instructions on the back of the submittal form. Texas A&M Agrilife Extension Service, Soil, Water and Forage Testing Laboratory http://soiltesting.tamu.edu/ Voice: 979.845.4816 Email: soiltesting@tamu.edu

#### **Plant cover**

The soil map can be used as a base map for mapping plant cover. The most basic plant cover mapping involves breaking the plant communities into types: trees/shrubs/herbaceous/bare ground. If you have a topographic survey done, frequently the trees can be included in that as well. Ideally, this mapping will include identification of some of the species. Focus on identifying the dominant, or most common, species in each layer (tree/shrub/herbaceous) and in identifying potential

problem species such as Arundo or elephant ear. Assistance with plant identification is available from a variety of sources.

Consider the overall make-up of the site. How much is devoted to:

- Woody vs herbaceous. Does the area have an overstory (tall trees), midstory (shrubs), and an herbaceous layer (grasses, sedges, wildflowers)?
- How much of the soil is bare? How much is covered with plants or litter (dead leaves, blades of grass, etc.)?
- Within the plant community, how much is devoted to annuals vs perennials?
- Are desirable species present? Examples of desirable species include:
  - Riparian: bald cypress, black willow, buttonbush, cottonwood, sycamore, pecan, little walnut, switchgrass, Eastern gamagrass, sedges, bushy bluestem
  - Transition/upland: oaks, cedar elm, American elm, native bunchgrasses
- Are undesirable species present? Examples of undesirable species include:
  - Riparian: Arundo, elephant ear
  - Upland: Johnsongrass, King Ranch bluestem
- Is there a variety of species present or just one or two?

- Are there multiple ages present? Ages can be approximated with size for woody species. Divide them into knee height, head height, and taller.
- How much standing dead wood is present? <5%, 5-25%, 25-45% or >45%.

The percent cover, or amount of the ground the element shades, can be estimated visually.



# site assessment

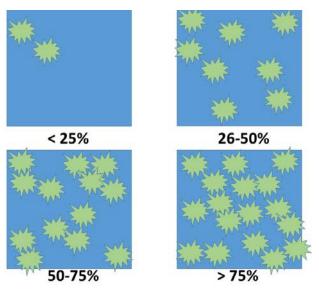


Figure 3.5 percent cover

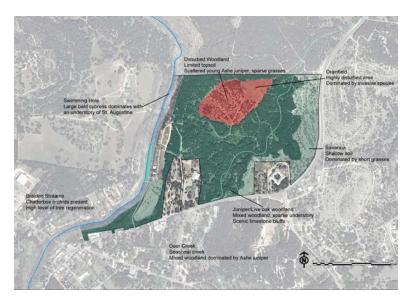


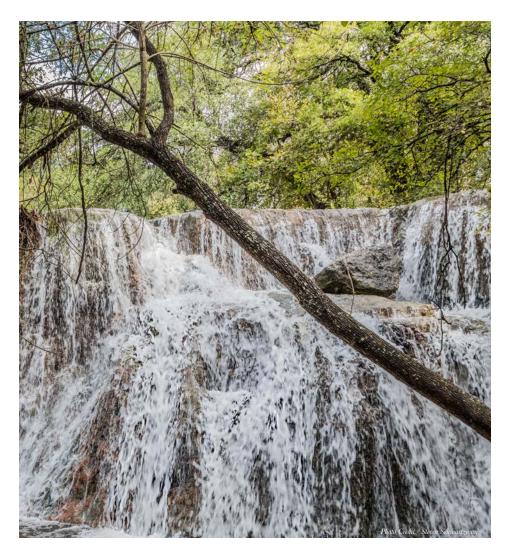
Figure 3.6 Example of plant community map

#### **Channel and Riparian area**

All of the elements described above should be addressed in the area adjacent to the waterway, but this area and the channel itself, bring additional considerations. The presence or absence of large woody debris should be noted. Big woody debris is helpful for riparian health because it slows water, provides a site for sediment to accumulate, and can help provide a safe place for germination. Dense, tall vegetation with stabilizing root mass is important for bank stability. Trees, shrubs, and herbaceous plants like sedges provide good stabilization. Individual species provide different levels of bank stability. This will be discussed in the Plants and Soils section of this booklet.

Bare areas caused by recent sedimentation is fine and will colonize naturally, but excessive bare ground can be a problem.

See Your Remarkable Riparian for an excellent discussion of riparian plants in the Edwards Plateau and and Rio Grande Plains : http://www. remarkableriparian.org/index.php



# uprooted tree depressions

#### Uprooted trees, minor erosion, and sediment deposition

Many property owners experienced erosion and damage to their land from uprooted trees, or had large amounts of sediment deposited along parts of the shoreline. Minor erosion events, places where topography was altered, but not dramatically changed, can be re-graded and restored using methods described in this manual. These efforts will likely include: manipulating eroded soils to restore or improve drainage patterns and topography, importing weed free soils, and revegetating areas with native seed and/or plugs.

Some properties have large depressions left on their land from uprooted trees. If these depressions don't threaten infrastructure, lead to further erosion, or prevent access to the Blanco, they present an opportunity for wetland habitat in the form of vernal pools:

Vernal pools are seasonal, depressional wetlands that are covered by shallow water for variable periods from winter to spring, but may be completely dry for most of the summer and fall. These wetlands range in size from small puddles to shallow lakes and are usually found in a gently sloping plain of grassland. Vernal pools are sometimes connected to each other by small drainages known as vernal swales, forming complexes. Beneath vernal pools lies either bedrock or a hard clay layer in the soil that helps keep water in the pool. Climatic changes associated with each season cause dramatic changes in the appearance of vernal pools. The pools collect water during winter and spring rains, changing in volume in response to varying weather patterns. During a single season, pools may fill and dry several times. In years of drought, some pools may not fill at all. In the spring, wildflowers often bloom in brilliant circles of color that follow the receding shoreline of the pools. By early summer, the water has evaporated, and the clay pools appear brown, barren, and cracked. The unique environment of vernal pools provides habitat for numerous rare plants and animals that are able to survive and thrive in these harsh conditions. Many of these plants and animals spend the dry season as seeds, eggs, and then grow and reproduce with the ponds are again filled with water. In addition, birds such as egrets, ducks, and hawks use vernal pools as a seasonal source of food and water (EPA 2014).

These pools will serve as rich amphibian breeding areas that will rely heavily on the pools to complete their breeding cycle. Few species are able to exist in pools that tend to dry up relatively rapidly and many species of amphibians will avoid ponds that are flooded throughout the year; however, pools that tend to stay wet throughout the year can support native fish populations. Whether or not the depressions will hold water will largely depend upon the underlying soils and proximity to the Blanco River water table. If planned correctly, vernal pools will not create mosquito habitat as mosquitoes generally have evolved to avoid laying eggs in locations where predators, such as fish, amphibians, and dragonflies live. These unique features can dramatically increase species and habitat diversity along the Blanco River and can include plants such as false indigo (Amorpha fruticosa), bushy bluestem (Adropogon glomeratus), creek sedge (Carex blanda), blue mistflower (Conoclinium coelestinum), horsetail (Equisetum hyemale var. affine), zigzag iris (Iris brevicaulis), virginia iris (Iris virginica), cardinal flower (Lobelia cardinalis), creeping water primrose (Ludwigia peploides), clover fern (Marsilea macropoda), nimblewill (Muhlenbergia schreberi), American white water lily (Nymphaea odorata), spring obedient plant (Physostegia intermedia), dwarf palmetto (Sabal minor), lanceleaf arrowhead (Sagittaria lancifolia), buttonbush (Cephalanthus occidentalis), osage orange (Malcura pomifera), American sycamore (Platanus occidentalis), Eastern cottonwood (Populus deltoides ssp. Deltoides), Mexican plum (Prunus Mexicana), and Burr oak (Quercus macrocarpa).

Landowners who received large amounts of rocky/sandy sediment on their property should not move any of the sediment or try to manipulate the shoreline. River morphology (the physical shapes of rivers and their changes over time) determines the location of deposition zones and the dynamic nature of rivers means that these large-scale processes cannot be controlled. Management efforts on gravel and sand bars should be confined to seeding if residents wish to alter the bare sediment condition. Native wildflower species such as bluebonnets (*Lupinus texensis*), clammyweed (*Polanisia dodecandra*), huisache daisy (*Amblyolepis setigera*), tropical sage (*Salvia coccinea*), Texas frogfruit (*Phyla nodiflora*), Indian blanket (*Gaillardia pulchella*), zexmenia (*Wedelia acapulcensis var. hispida*), and grasses such as bushy bluestem (*Andropogon glomeratus*), inland sea oats (*Chasmanthium latifolium*), Eastern gammagrass (*Tripsacum dactyloides*), and green sprangletop (*Leptochloa dubia*) are good pioneer species that will help cover up bare spots, add color, texture, habitat value, and initiate organic matter build up.



# soils and plants

Selecting appropriate plants is important from both an ecological health and a maintenance perspective. Plants should be selected that are suited to the site and that provide the ecological function that is important to the health of the waterway. This discussion will first cover general considerations and then will focus on each zone.

For the purposes of this booklet, the planting zones have been divided into riparian and upland. Soil moisture and frequency of flooding decreases as distance from the waterway's edge increases (Figure 4.1), which affects the plants that can be supported. The ecological function performed by the landscape changes along this gradient as well, with bank stability and organic inputs more important near the water and flood control more important in the uplands (Figure 4.2). Plant species vary in the function they are able to provide to a site and should be selected and arranged accordingly.

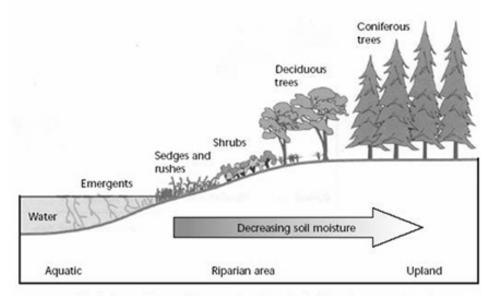
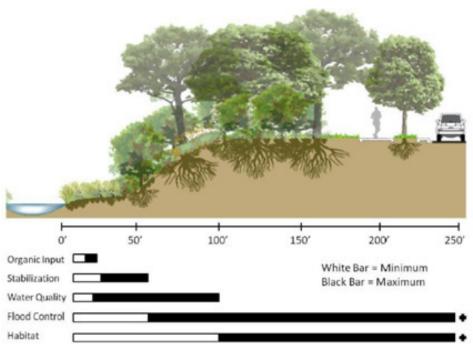


FIGURE 1 Illustration of the moisture gradient in a typical riparian ecosystem (from Stevens et al. 1995:2).

> https://www.crd.bc.ca/education/our-environment/ecosystems/freshwater/riparian-zones Figure 4.1. Moisture gradient in a typical riparian ecosystem.



https://www.austintexas.gov/faq/riparian-zone-restoration Figure 4.2 - Ecological Function - USDA Wetland Indictor Categories

The average moisture in the soil changes on a gradient starting at the water's edge and moving into the uplands, with the wettest soils near the waterway. The USDA has classified plants based on their preferences.

<b>Indicator Code</b>	<b>Indicator Status</b>
OBL	Obligate Wetland
FACW:	Facultative Wetland
FAC:	Facultative
FACU:	Facultative Upland
UPL:	Obligate Upland

#### Comments

Almost always occur in very wet locations Usually found in wet locations Can be found in wet and non-wet locations Usually found in non-wet locations Almost never found in wet locations

#### **Stability Ratings**

Plants do not contribute equally to bank stability. Many riparian plants have been assigned stability ratings (SR) based on how well they resist the erosive forces of water, with SR 1 equal to bare ground and SR 10 equal to anchored rock. A stability rating of 6-7 is considered the minimum to provide good bank stability. The highest stabilities are provided when woody plants are associated with stabilizing grasses and sedges.

#### Succession

Early successional, or colonizer, species are the first on the scene following a disturbance. These species create quick cover, grow and reproduce rapidly, and are often short lived. These provide important services in that they cover and protect soil quickly and begin to trap sediment. However, these species are typically weak rooted and do not provide long term stability.

# soils and plants

Late successional species are longer lived, slower growing, and slower to establish. Most of the plants that provide the best stability for a bank are in this category.

During restoration and management it is important to have both types of species present, with colonizers encouraged immediately after disturbance, and long term management aimed at encouraging late successional, stabilizer plants.

#### Types of plant material

Plant material can be added to the site in a variety of forms ranging from seed to containerized plants. The appropriate mix of plant types depends on the plan for the site, the available resources, and the time frame the manager is working under.

Seed is the least expensive option and generally allows for higher diversity added material. It is slower to provide cover and is vulnerable to predation or being washed away. Temporary irrigation during establishment greatly reduces this risk and improves germination rates.

Seeding rates are generally published by seed suppliers. Contact the supplier to find out if they are using USDA range seeding rates or if they

have increased the rate. If range seeding rates are being used, it is often prudent to double or triple it for restoration efforts.

#### Creating your own seed mix

In order to adjust seeding rates to account for using multiple species, the following calculation can be used: Published seeding rate per acre X percent in mix = adjusted seeding rate.

For example, if combining sideoats grama (Range seeding rate: 7 lbs/ acre) and green sprangletop (Range seeding rate: 2 lbs/acre) at 50% each. Here is the calculation:

Species		Seeding rate in mix
Sideoats grama:	7 lbs/acre X 0.5=	3.5 lbs/acre
Green sprangletop:	2 lbs/acre X 0.5=	1 lb/acre

Live stakes/live roots are the least expensive live specimen option. These specimens arrive without soil and must be installed quickly, with the roots kept moist until installation. Installation can be accomplished relatively quickly with minimal soil disruption. Without supplemental irrigation during establishment, these are best suited to riparian areas in which the soil remains moist.



Containerized or balled and burlapped individuals arrive in various sizes with associated soil around the roots. These require watering while in the container, but do not have to be installed as quickly as live stake or bare root specimens. This is the most expensive option, but provides the fastest results. Containerized plantings will require supplemental irrigation during establishment and require larger holes dug for installation. Additionally, unwanted species can sometimes arrive in the soil, so post installation inspections and weeding should be planned on.

### Soil

Plants must be matched the soil type that is present. The USDA Natural Resources Conservation Service (NRCS) soil survey provides important information about your property's soil. You can generate a free soil report using the web soil survey

Web Soil Survey: http://websoilsurvey.sc.egov.usda.gov/App/ HomePage.htm

### soils and plants

This report will give you an indication of the types of soils present on your property as well as useful ecological information. Gather the following information:

- Physical characteristics
- Chemical characteristics
- Ecological site information: Ecological sites provide you with the types of plant communities that are associated with your soils and can be a useful starting point when considering interventions

The Web Soil Survey homepage provides a brief tutorial for using the system. In addition, Appendix A provides a step by step tutorial on generating you soil report.

In addition to the soil survey, soil testing will provide you with specific information on your soils. Take samples within each soil type on your property and request the following analyses:

- Routine analysis for macronutrients and pH
- Organic matter
- Textural analysis

Having this information in hand will help you select plants that are suited to existing conditions and will help you determine what, if any, soil amendments are necessary. Most labs will provide you with instruction on how to collect a soil sample.

Texas A&M Agrilife Extension Service Soil, Water and Forage Testing Laboratory: http://soiltesting.tamu.edu/

### Zones

Plant lists for each zone are found in Appendix C.

### **Riparian Buffer**

This zone is frequently flooded and soil tends to remain wetter than upland areas.

Function: Trap sediment, build and maintain streambank, filter and buffer water, reduce and dissipate stream energy, provide organic matter and shade to in-stream habitat

Vegetative goals: The plant community here should protect and stabilize the bank, slow stream flow allowing for sedimentation, and enhance habitat both in-stream and on the bank. This area should be dominated by woody species with a strong component of stabilizer herbaceous plants. The woody species can be thought of as the skeleton of the bank as their larger diameter roots help hold the bank in place. Herbaceous stabilizer plants have dense fibrous roots that intertwine with the woody species further enhancing stability. The above ground growth of both woody and herbaceous plants serve to slow water and capture sediment.



Herbaceous plants provide additional protection during flood events because their top growth lays down, protecting the soil and allowing them to remain in place during high flow events.

Plants selected for this area can be obligate wetland (OBL), facultative wetland (FACW), or facultative species (FAC). Obligate wetland plants should be placed near the water's edge where the water table is nearer the surface. Facultative wetland species can be placed at water's edge, or further up the bank where the soil stays reasonably moist. Facultative species can be placed further from the water where the soil is drier. The majority of plants should have stability ratings of 6 or higher.

Immediately after a disturbance, activities that protect soil and slow water movement, such as placing obstructions along contours, will enhance natural recovery processes. Leaving downed wood in place will help the system start to recover. If plant material is added, a focus on colonizer species that will germinate quickly is often employed at this stage, with the goal of increasing the presence of late successional stabilizer plants over time.

### soils and plants

### Upland

Function: Slow and infiltrate overland flow to mitigate flooding, clean water, provide habitat.

Vegetative goals: The plant community, in combination with the soils, should act like a sponge, absorbing runoff. This community can be

more open, with native grasses and wildflowers helping to build the soil and encourage infiltration. Species with deep, fibrous root systems are particularly useful in this respect (Figure 4.3). Species in this area should be primarily facultative and upland species because the soil will remain drier than that in the riparian area.



Figure 4.3. Root Depth and Mass

#### **Riparian Canopy**

The division between riparian areas and upland areas is gradual and there is frequently a transitional area that has characteristics of both zones. Facultative plants are the best choice for this area because they can handle wet or dry conditions.

#### Residential

Residential areas can be placed within either the upland or riparian canopy zones. Plants in this area can be selected to provide the same function as the surrounding area, but arranged in a way that serves human use needs

### Low Impact Development (LID)

Features such as rain gardens, filterstrips, and bioswales are elements that can be added to a landscape to enhance the landscape's ability to capture, infiltrate, and clean water. This is particularly important in areas where impervious cover, such as buildings or roads, are present because the LID features can help to mitigate the hydrologic effects of these improvements. Often these features can be designed to be an amenity in their own right. LID features can be incorporated into any of the zones described above.

More information on LID can be found here: http://www.epa.gov/ green-infrastructure



### site preparation



Preparing the site and soil is the most important step in the success of a project. By clearing existing undesirable plant material and remnant seedbank, the newly planted seedbed will assist in reducing competition for future transplants and seeded species. Management of existing vegetation can be done through mechanical or chemical means, and it is important to seek advice of trained personnel. Additionally, it is important to start at a reasonable scale, allowing proper management of your planting (Shirley 1994, Maywald and Crider).

Any site improvements will most likely consist of some disturbances to the site. Therefore, a preliminary item to consider regarding restoration is how the design will be implemented. Before construction begins it will be crucial to stabilize the site and set up protection measures so that the exposed soil does not runoff into the Blanco River. It is anticipated that the installation/construction processes could result in a lot of fine sediment and topsoil being washed into the river. Construction Best Management Practices (water pollution control) should be established and explored to protect these riparian zones.

Site soil measurements of infiltration, composition, and structure can be compared to expected values found in the soil survey to help determine soil health. These measurements can also inform decisions on plant selection and on appropriate technologies for the site such as rain gardens or bioswales. Because soil restoration is difficult and expensive, effort should be made to identify and protect healthy soil. In some cases, compaction remediation and organic soil amendments may be needed to restore soil health after disturbance. Soil disturbance should be addressed prior to revegetation efforts because damaged soil cannot support healthy plant communities. Healthy, diverse plant communities, that are suited to local conditions, drive ecosystem function. Existing communities can be compared to reference sites with similar conditions and to the ecological sites defined for the projects soils to determine the site's current ecological state and to help determine the appropriate target community for the site. Full shaded areas with bare soil will present a challenge due to the canopy tree's critical root zone. It is recommended that these be lightly roughened and organic matter be incorporated into the soil, but never deeply tilled. If properties have steep slopes, placing brush along contours will enhance natural recovery processes by slowing rainwater runoff, initiating passive soil building, and helping to prevent erosion. Leaving downed wood in place will help the system start to recover and act as a nursery for new trees and germinating vegetation. Large woody debris should not be removed unless it threatens infrastructure in the immediate vicinity, completely blocks access, or contributes to erosion. Large woody debris is typically defined as material greater than 4" diameter and 6' in

length. Clean up of this material can be detrimental to river health and is an essential component of river ecosystems. Large woody debris helps stabilize the stream bank and stream channel, promotes new vegetation growth, and provides habitat for fish and other important riparian animal species. If large woody debris has to be moved because there is concrete evidence that it might contribute to erosion or damage infrastructure, landowners should coordinate their efforts, if possible, with Texas Parks and Wildlife Department or other experts to help determine the best method that will result in the least damage to the land. Some debris may be partially removed by cutting or anchored to the ground so that it still provides benefits without causing damage.

The next step will involve the removal of existing invasive species, making any necessary grading changes, preparing the soil for vegetation establishment, and then seeding or plugging the site according to the landscape zones established in the design plan. Even areas without impervious cover will most likely be compacted if heavy equipment is used. Thus, the next step in site restoration is to conduct soil preparation prior to seeding (or plugging) the areas to be revegetated. It may be necessary to roughen the surface through a means such as ripping/rototilling to a depth of a few inches (1-4"). This method allows for organic matter to move deeper into the soil, serving to anchor soil amendments

### site preparation

and more rapidly establish healthy soil conditions. During this process, organic matter may be added to the soil. Low-nutrient compost is recommended for soil treatment. Ripping and roughening also helps prevent erosion. By increasing soil surface roughness and providing areas for sediment to be captured, runoff volume and erosion is reduced. Soil preparation requires planning and time. If done properly, however, the efforts will reduce time and inputs in the long-term and plant establishment will have a greater chance of success.



#### Weed And Non-Native Grass Removal

The removal of unwanted vegetation is sometimes necessary before restoring native vegetation. These unwanted plants compete with native restored plants for valuable resources such as soil nutrients, water, light, and space.

There are several approaches that you can use to control weeds. Early weed control during site preparation will also reduce seedling competition for moisture and other limiting resources. Before seeding, weeds can be controlled with manual removal, tillage, or herbicides. Post-establishment control methods may consist of mowing, grazing, hoeing, or the use of selective herbicides. Even with ample preparation some weeds will still emerge and compete with planted species. When restoring areas, establishing a cover crop or quickly establishing natives will assist in recovery (Maywald and Crider, Native Prairie Association of Texas).

### **Soil Conditions**

### **Limits of Construction**

Construction impacts from overall site development decrease the capacity of the soil to support the desired vegetation and retain resources. A well developed and communicated soil management plan should be created prior to construction to: limit construction disturbance, assist soil restoration efforts, and define soil protection zones. Soil protection zones should be delineated to prevent any construction activities or storage of equipment on those areas (Sustainable Sites Initiative 2014).

Common signs of impacted soils include:

- Ponding of water on soil surface (poor infiltration)
- Surface water runoff
- Bare soils
- Shallow tree rooting
- Stunted vegetation

#### **Soil Erosion**

Soil erosion is the most damaging form of degradation, degrading the physical, chemical, and biological properties of a site, and is irreversible. Consequently, erosion reduces water-holding capacity of a soil, plant production, and increases mortality of individual plants and communities. Damaged biotic components capture and retain fewer resources, and assessments should begin with soil surface features and associated hydrologic processes. Soil surface stability is assessed as the degree and nature of: soil movement, surface rock and litter, pedestaled plants or rocks, flow patterns, and rills and gullies. Live vegetation, litter, mineral soil crust, surface gravel, or microbiotic crust increase the stability of soil surfaces. Interrill erosion, rills, channels, gullies, and pedestaled plants indicate soil loss. The accumulation of eroded material indicates erosion occurred elsewhere (Whisenant 2005).

### **Repairing Damaged Processes**

Addressing soil surface problems can repair hydrologic and nutrientcycling processes, especially when using adaptive species that improve soil conditions. Adaptive plants grow under existing conditions, initiate autogenic (plant driven) repair, and increase resource retention. Increased resource retention produces more plants. Primary emphasis on soil surface conditions and associated processes should consider soil crusting, erosion, runoff, and infiltration.

Increasing the stability and infiltration rate of the soil surface initiates the repair of damaged soil processes. Management practices that improve soil structure and conserve soil moisture increase a soil's resistance to erosion. Initial soil surface treatments involve: increasing soil roughness and adding aboveground obstructions.

### site preparation

Increasing soil roughness focuses on reducing runoff and erosion by retaining precipitation through roughness, vegetative cover, and reducing distance of unobstructed soil. Soil roughness strategies, such as microcatchments, pits, basins, ripping, and chiseling, affect soil roughness and accompanying infiltration rates.

Surface obstructions promote the retention of water by reducing the amount and velocity of surface and channel flows. Surface obstructions, including organic matter (compost), mulch, and woody debris, improve soil aggregation and provide initial stability to establish vegetation.

These obstructions reduce the flow rates of water and wind, capture and concentrate resources, and increase infiltration rates. All of this leads to an increase in plant establishment and accelerated vegetative development. Onsite sources of logs, felled trees, brush piles, contoured rock rows, or purchased burlap wattles are all examples of surface obstructions that impeded increasing water velocity and improve resource retention (Whisenant 2005).

### **Soil Compaction**

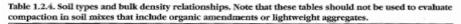
Natural soil forming processes create soil that possesses suitable levels of compaction for ground stability and the growth of plant roots. Soil in undisturbed sites rarely exhibit compaction levels (bulk density) that are beyond the threshold where plants will not grow. Human activity (i.e. mechanical) typically increases the compaction level beyond the threshold, preventing plant root systems to explore the soil profile for needed resources.

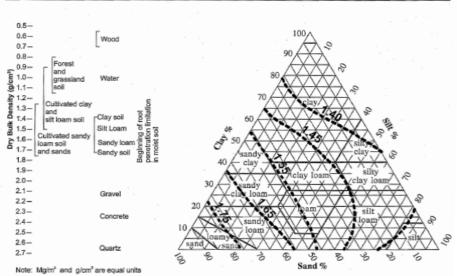
During the process of compaction, organic bonds that bind the soil and provide soil structure are broken. As a result of this activity, pore spaces between soil particles are lost. These pore spaces are essential in the ability of plant root systems to absorb water, nutrients (in solution), and oxygen. The plants have less access to these items, growing fewer roots in the more difficult conditions and stressing the plants. Soils have different densities at which roots will no longer be able to penetrate the soil, In turn, plants vary in their ability to penetrate dense soils or function in soils with reduced pore spaces. Optimum soil compaction for planting soil should be one-tenth of a gram, per cubic centimeter, below the root limiting value (Figures 5.1 ). The root limited bulk density for a clay loam is approximately 1.45g/cm3. Engineers measure compaction as a percent of maximum dry density obtained under optimum moisture content. Proctor density indicates the relationship of Proctor levels to bulk density levels. Compaction levels between 80 and 85 percent dry density will begin to restrict root growth (Urban 2008, USDA-NRCS 2008).

Strategies for improving soil quality:

- Avoid working soil when excessively wet or dry ٠
- Reduce traffic and use controlled traffic patterns ٠
- Avoid using heavy machinery •
- Subsoil amendment (aerate, rip, till, disc) ٠
- Add organic amendments ٠







a. Ranges of soil densities. (Source: Brady et al. 1999)

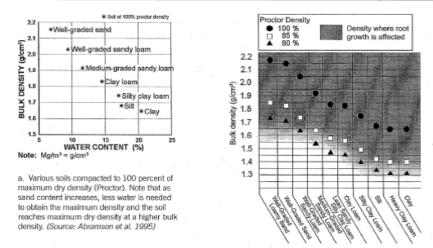
Bulk

b. Root-limiting soil densities. A reasonable specification for compacting planting soil by bulk density would be between 0.1 g/cm3 and 0.25 g/cm3 below the value predicted as root-limiting with some settlement expected at that range. (Source: Adapted from Daddow and Warrington 1983)

Figure 5.1. Soil Types and Bulk Density relationships (Urban 2008).

### site preparation

#### Table 1.2.3. The relationships of soil types to bulk density and Proctor values.



b. Bulk density and levels affecting rooting compared to several Proctor densities. Note that soils to be used for most trees and shrubs should always be compacted to less than 85 percent of maximum dry density. There is limited research comparing bulk density to Proctor value, but a reasonable specification for compacting planting soil would be between 75 and 80 percent, with some settlement expected at that range. Sandier soils can be compacted up to 85 percent, with the exception of well-graded sandy soils. (Source: Data adapted from Daddow and Warrington 1983, Lichter and Lindsay 1994, and Brady et al. 1999)

Figure 5.2 Optimum soil compaction for planting soil and rooting. Recommended soil compaction should be less than 80% Proctor Density (Urban 2008).

#### **Soil Amendment**

At most projects, the mineral soil resource may need to be modified. Soil damage during the construction process (compaction, grading, and contamination) affects the soil's ped structure, chemical and organic composition. Compaction reduction activities (tilling, disking, ripping) and organic soil amendments may be needed to restore it to a useful state. Soil improvement procedures would be benefitted if good records were created on the extent and depth of soil resources during the site analysis phase (Urban 2008).

Adding organic matter to the soil will introduce an artificial structure to repel the tendency toward re-compaction. As the dense soil is fractured, organic matter is incorporated into the mineral soil creating open pore spaces. The organic matter should be stable, low-nutrient, static piled compost similar to native soils of the region. The addition of composted organic matter is the best method of improving soil texture and drainage. In healthy prairies, organic matter content may exceed 3.5 % - up to 4.8% (Native Prairie Association of Texas).

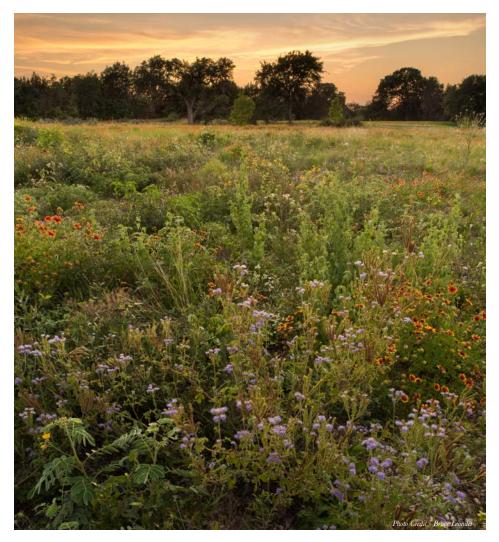
#### **Compost Recommendations**

Composted material for use as organic matter for soil amendment and for seed application should meet ideal ranges and texture recommendations, and must be tested to ensure that it is a healthy material suitable for application to the project.

Incorporate living compost with a low nitrogen and low phosphorus content into the top 3 inches of your prepared soil. DO NOT use tree bark, wood shavings, or mulch, as grass will not grow in this. Particle Size - 98% of the compost material shall pass a 3/4" screen and 75% through 1/2" screen. Texture and Smell - 95% by volume must be indistinguishable from parent material (i.e. should not be apparently 'woody'). The compost must not smell like urine, manure, sewage, or softwood organic compounds (eg. Turbines or 'piney' smell). There MUST be a dominant, sensible fungal (mushroom) smell similar to hardwood forest soils.

### **Alkaline Soils**

Alkaline soils are common in arid regions where evaporation exceeds precipitation. Calcium and magnesium accumulate in the soil, raising the pH higher than neutral (7). When pH exceeds 8, the solubility and availability of nutrients for plant uptake is limited (US Botanical Garden 2014).



### site preparation



Strategies for working with alkaline soils:

- Utilize plants adapted to alkaline soils
- Utilize compost and other organic amendments that can lower soil pH

### **Shallow Soils**

Shallows soils constrict plant roots, tend to be nutrient-deficient, and dry out quickly. Shallow soils consist of a thin layer of soil on top of a dense, clay subsoil or bedrock. Shallow soils can also be caused from construction processes (US Botanical Garden 2014).

Strategies for working with shallow soils:

- Utilize plants adapted to shallow soils (shallow-rooted) and are drought resistant
- Utilize compost or other organic matter and organic amendments
- Cultivate the soil lightly, avoiding large tree roots, and incorporate compost into the soil

### **Seedbed Preparation**

Preparing a seedbed is the most assured method of high establishment rates. Creating a natural appearing, evenly roughened, fertile and friable seedbed to capture and retain water and establish micro-habitat for seed germination and seedling establishment is critical. Within restoration



zones and landscaping areas, ensure ground layer is cleared of leaf litter and other duff prior to seeding. Apply soil amendments prior to tillage operations.

Till soil by contour chisel rip furrowing a minimum of 4 inches deep. Using sufficiently sized machinery, rip soil along natural site contours to a minimum depth of 6 inches. Incorporate soil amendments into the soil profile using a roto-tiller. Do not pulverize the soil. Cultipack or lightly harrow to break up large clods or fill soil voids if necessary. Remove obtrusive and hazardous rocks and debris. Seedbed preparation can require several trips over the ground with equipment suggested, a drag to smooth the seedbed and lastly a roller packer to firm the seedbed just before planting.

### installation

After the site has been graded, stabilized, and invasive plants have been treated and/or removed, seeding is the least expensive method for plant establishment. The ideal times to seed are in early spring for grasses and annual wildflowers or mid to late fall for wildflowers in general. It is recommended to seed wildflowers in the fall for optimal germination. It will be important to monitor the areas to be seeded for any invasive species that might have encroached in these areas if there is a large amount of time between site preparation and seeding. It will be important to remove these species before seeding. Using notill drill is a very effective method for installing seed, especially for large sites. Ask contractors if they have experience planting with no till drills. If you cannot locate a contractor with no till drill experience, or if topography prevents the use of such equipment, seed can be hand broadcast and then raked in by hand or with a tractor-drawn harrow to achieve good soil-seed contact. A majority of the seed can be obtained from a commercial outfit, however it is recommended to additionally add local seed to increase diversity and local genetic stock to ensure that the plants are adapted to that region and add robustness to the mixture. Get in touch with your local Master Naturalist group to see if there are any opportunities for collecting seed from nearby healthy sites. Seeding methods, equipment rentals and types, and exact timing and rates should be further developed in the restoration plan.

There might be areas on the site where establishing vegetation from container plants would be preferred. These areas include fully shaded upland areas or areas with steep slopes. Some of the riparian species are difficult to establish from seed and container plants and may be preferred in these areas as well. Container plants are more expensive than seed, but will establish faster, enhance soil biology, prevent erosion, and provide a more immediate, finished aesthetic.

Immediately after installing the seeds and/or plants, temporary irrigation will be necessary for successful establishment. Irrigation will probably be required for a full growing season; however, specific rates and methods should be established in a site restoration plan. Trees will require higher amounts of watering and longer establishment periods. The formal planting areas surrounding buildings may require more regular irrigation post-establishment than other areas of the site. In this case, an irrigation system can be installed or the areas can be hand watered. Either method could also use rainwater captured from the buildings' rooftops and collected in cisterns. This method would also help promote site educational components including water conservation and stormwater runoff management.

### **Timing/When To Plant**

Depending upon current climatic conditions, ideal planting/sowing windows for each type of plant are listed below.

Spring Planting: March – April

Warm Season Grasses: March – June or Late September – November. If it is excessively hot or if a freeze has occurred, then seeding should be delayed.

Perennial Forbs (wildflowers): Late September through second week of November

Annual Forbs (wildflowers): March - April

Shrubs: Late September - Early November and March - June

Trees: November – February. It is usually better to plant trees when they are dormant during the winter to avoid transplant shock, however they can also be planted, depending on climatic conditions, in fall and early spring.



### **Seeding Methods**

Grass and forb species can be established within a variety of situations using a range of planting techniques. To achieve good vegetative cover, seeds should be placed in contact with the soil surface and where the soil will remain moist during germination and seedling development. Good seed-soil contact is critical.

### installation

The following is a list of planting methods, techniques, and guidelines:

Planting Method	Planting Technique	Planting Guidelines
Broadcast	Fertilizer spreader	Mix with disperser, good for large acreage where cattle rotational graze at high stock densities
	Air seeder	Same as above
	Chaffy seed spreader	Good for small acreage, difficult to calibrate
	Hand broadcast	Good for small acreage
	Hydro-seeder	Uses a hay mulch and water as carrier to blow seed on soil surface. Good for soil erosion control
Seedballs		Good for small to medium acreage or where rocky soil precludes the use of seeding equipment.
Seed hay		Good method of obtaining local genotypes / ecotypes
Drilling chaffy seed	Chaffy seed drill	There are several drills on the market designed to meter. Drills can be rented from multiple sources. Good for large acreage.
	Grain drill	Must mix seed with fertilizer. Not good for grain box if used on large acreage
Live plants	Planted by hand	Plants are started from seed, placed in pots, and grown in the green house. This method is very labor intensive, and best suited to small areas.
Bare roots	Planted by hand	Roots are taken from live plants, placed in a prepared seedbed and watered in. Very high survival rate. Well suited mall garden landscapes

Figure 6.1. Tallgrass restoration manual planting methods, techniques, and guidelines (Native Prairie Association of Texas).

It is recommended the following restrictions be met for seeding and establishment, during one of the identified planting windows.

- Sow seed with spreader or no-till drill. Hand broadcast seed in areas that are difficult to access with spreader. Do not broadcast or drop seed when wind velocity exceeds 5 mph.
- Sow seed mixes at rates as indicated by range site rates or seed provider.
- Rake seed lightly into top 1/8 inch of soil, roll lightly, and water with fine spray.
- Make sure seed is integrated into soil surface, but not buried deeper than top 1/8 inch of soil.
- Lightly roll seeded areas with a cultipack roller and irrigate according to irrigation establishment specifications. Do not let seed dry out for a minimum of ten days.
- Protect seeded areas with slopes exceeding 1:4 with erosion-control blankets and 1:6 with erosion-control fiber mesh installed and stapled according to manufacturer's written instructions.
- Plug Planting Install around 'high energy' areas, spacing plugs approximately 6-12" apart, 2-3" deep



### **Live Plantings**

Seeding is much cheaper than installing plants, but properties might need to employ a planting strategy on areas of steep slopes or if landowners would like to incorporate later successional species that don't often germinate as successfully in newly established native planting areas. By mixing seeding and plantings you can increase the diversity of plantings and provide a short cut to a more mature grassland state. Live plants can be purchased in flats that contain 20 4" container plants or you can purchase larger containers in gallon increments, but the 4" containers are much more economical and allow the landowner to achieve greater coverage. The ideal planting spacing is to install 4" container plants on a 12-18" grid so that the plating area is adequately covered. Seeding and planting on a 12-18" grid will achieve dense coverage in a relatively small amount of time and is great for any areas that have experienced erosion or on slopes were complete cover is absolutely necessary.

When installing live plants the hole should be similar to the size of the planting (e.g. 4", 1 gallon, 3, gallon, etc.). The hole should not be too deep so that the base of the plant is lower than the surrounding ground level. The excavated soil should then be used to fill any air spaces, but the soil should not be over compacted.

### Watering

The following irrigation schedule is recommended for establishment, and may need more if sowing goes into summer months (i.e. June onwards):

WEEKS 1-2: 0.5" per day in two events (dawn and dusk – more frequently if hot and windy) to keep top 2" of soil sensibly (i.e. feels wet to touch) moist, but not so much that the soil is consistently saturated – this will cause seedling rot. This effort might require irrigation twice a day, once in the morning and once in the late afternoon.

WEEKS 3-4: 1" at least twice to three times a week to maintain sensible soil moisture in top 1" to 6" of soil. Note: top  $\frac{1}{2}$ " of can be allowed to periodically dry out.

### installation

WEEKS 5-6: 1" at least twice a week to maintain sensible soil moisture in top 1" to 6" of soil. Note: top  $\frac{1}{2}$ " can be allowed to periodically dry out.

WEEKS 7-16: One 1" event per week to wet at least top 6" of soil.

Irrigation should occur during times when water loss from evaporation is lowest (dawn and/or dusk), but without potentially creating a disease prone environment. Irrigation should not occur after a sufficient rain event or when otherwise unnecessary.

#### Caveat

These are estimates and soil conditions (night and day air temperatures, wind, recent rain, amount of clay, compaction, and arrangement (cracks)) can alter these amounts, so these conditions should be considered as approximations that may need to be adjusted. Substituting for soil moisture sensors, taking cores and using touch to assess the 'sensible' soil moisture to depth is an excellent way to keep constant track of water requirements. This should be at least daily for the first two weeks and thereafter monitored on a weekly basis until good establishment (50% canopy cover) is achieved.

### Long-term irrigation

Once the vegetation is established in four to five months, you may opt to

stop irrigating to save water and allow the plants to go 'drought dormant'. Native grasses will go brown and temporarily stop growing but, adapted to drought, will green-up once rain returns. In prolonged drought (say over 4 weeks in summer with no rain) an irrigation event (if allowed) once every month while not triggering "green-up" will keep the dormant plants alive. However, if a significant drought sets in you might need to extend irrigation during the first season of growth.

Subsequent seasons after the first year of establishment can thrive on rainfall alone, but if landowners wish to ensure regular wildflower blooms they can irrigate during the fall and early spring if seasonal rains are delayed or non-existent.

#### **Bare patches**

Bare patches can occur from a variety of reasons including inadequate irrigation, lack of available nutrients, and erosion events. If bare areas appear landowners should seed these areas as soon as possible even if outside of proper seeding windows as weeds will likely move in if no actions are taken. Roughen the soil (lightly disturbing, but not tilling) so that the seed is incorporated into the top layer of the soil, but not buried deeper than a  $\frac{1}{2}$ " and then follow the appropriate irrigation schedule. The following species are great for repairing bare patches: Grasses - green sprangletop (Leptochloa dubia), sideoats grama (Bouteloua curtipendula), blue grama (Bouteloua gracilis), purple threeawn (Aristida purpurea).

Forbs - Indian blanket (Gaillardia pulchella), pink evening primrose (Oenothera speciosa), lemon mint (Monarda citriodora), Texas star (Lindheimera texana).

### Fertilizing

If soil tests show that there is no available nitrogen, phosphorus, or potassium (N-P-K) it will be necessary to apply organic fertilizer for a frequency of once every two weeks for the first three months until seedlings are on their way to being firmly established. It is important that you only use low N-P-K value (in the range of 3-3-2) organic fertilizer, as synthetic fertilizers N-P-K ratios are too high and will not feed beneficial microorganisms in the soil. If you apply synthetic fertilizers with high N-P-K values you will get a lot of weedy growth. There are plenty of local manufacturers that produce great organic fertilizers such as Natural Gardener's John's Recipe, Gardenville's Sea Tea, and Hasta-Grow's plant and lawn mixes. These organic fertilizers also often contain other ingredients that benefit soil health such as humic acid and horticultural molasses.



### maintenance



#### **Maintenance recommendations**

In general, installing and establishing functional landscapes requires more planning and effort than a traditional landscape. However, as time goes on, maintenance requirements will lessen and fewer inputs and resources (such as watering, fertilizers, and mowing) will be needed. Maintenance is a key component to project success and something that should be considered in the predesign and design phases. Once site preparation or any construction activity on the site begins, maintenance begins as well. Landowners should develop key components of a maintenance plan that includes guidelines for installation, establishment, and long term maintenance covering topics such as: invasive species control, soil health, innovative BMPs to mitigate runoff during installation and immediately after, sequencing of site installation, planting and seeding windows, site hygiene (preventing contamination of site with invasive plant seed that might come in on rental and contractor's equipment) and equipment storage (e.g. parking equipment under trees, driving over prepared soils), reseeding, irrigation, and mowing.

Maintenance and ecological success will rely on the maintenance efforts and strategies working collectively to improve the entire site as one riparian system. Therefore, while the site might have a variety of plant communities requiring unique maintenance practices, it should be understood and planned for that activities in one location will have influences on other locations of the site. The primary maintenance focus should be on considering surface flow across the site to the Blanco by improving vegetative habitats. Through improving water quality and quantity and vegetation diversity, other ecosystem services will be increased resulting in a highly performing landscape.

Mowing will replace the natural disturbances of fire and flooding for the upland locations. Understory plantings could be zoned into no mow and mow locations for ease of maintenance. Provided below are general mowing recommendations for tallgrass areas and short grass locations. These recommendations will need adjustment and refinement based on the ultimate design. Mowing frequencies (and the comprehensive maintenance plan) should respond to things such as climatic conditions, vegetation response, and performance or desired appearance. Maintaining habitats requires adaptive maintenance.

Tallgrass mowing - Tallgrass areas generally do not require mowing on a regular basis and can be maintained by mowing only every three to six years. However, tallgrasses can tolerate annual mowing in winter, when most grasses are dormant, if desired. Mowing at other times of the year may result in loss of that year's seed. Mowing may be undertaken any time after grass seeds have ripened (December), or alternatively may be delayed until very early spring (February) just before the plants begin to green up. Mowing height should be no lower than 6 inches.

Shortgrass mowing - Mow shortgrass prairie areas three times per year, to a height of approximately 3-4 inches. Mow one time in late winter (January - February) to remove dead standing material, after seeds have ripened, and before the spring growing season begins. Mow one time in summer (June - July) to promote spring wildflowers, after wildflowers have dropped their seeds. Mow one time in late summer (September -October) to maintain grass height of approximately 3 inches. To further promote wildflowers in the mixed grass areas, the shortgrass prairie may be mowed more frequently at a height of 3 - 4".

Pruning - Pruning is the removal of plant parts (shoots, branches, roots, flowers, and fruits). Pruning can direct the growth of plants to enhance their performance and function in the landscape. Additionally, pruning can increase the structural strength, trunk quality and aesthetic appeal of trees as a preventative or corrective measure. Since each pruning cut has the potential to change the growth of a tree, causing the tree to allocate resources for wound treatment, no branch should be removed without a



### maintenance



reason. When pruning, it is important not to do more harm than good, by removing more foliage and creating more wounding than the tree can defend. The American National Standards institute A300 (ANSI A300) is the industry standard for tree care operations and maintenance. Several guidelines are available for the pruning process: no more than 1/3 of the foliage should be removed from the lower 2/3 of canopy; and, no more than 5% - 25% of the canopy should be removed per annual pruning period.

Plant Stress – Successful germination is only part of establishing permanent vegetation. Many factors can cause stress during plant growth and can include nutrient deficiency and heat stress. Stressed seedlings or plants will often have yellow or purple blades/leaves with dead tips.

If plants begin to exhibit signs of chlorosis (yellow foliage), a treatment of organic nitrogen should be applied to counteract the nutrient deficiency and prevent mortality. Organic nitrogen is recommended for this project due to the close proximity of a waterway. Additionally, organic nitrogen promotes soil health (i.e. microbial activity) and vegetation growth will be promoted. Organic nitrogen possesses lower nutrient levels which aid in the restoration of native soil properties. Immediately before treatment random soil samples should be taken for soil nutrient analysis. Multiple treatments may be necessary but should only be based upon field observations.

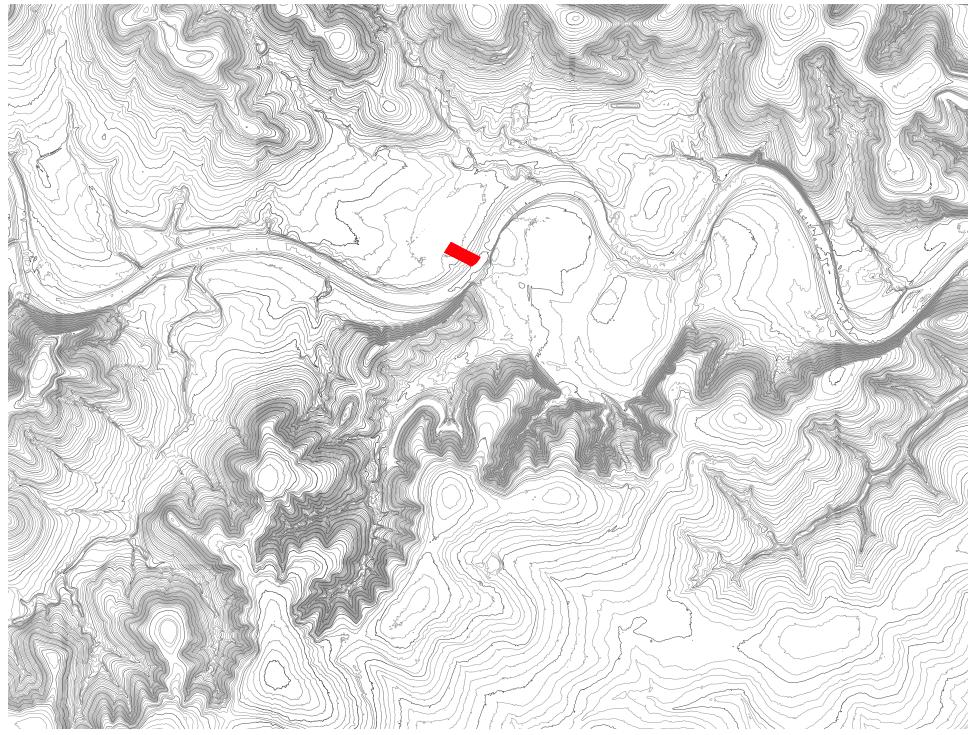
Purple blades/leaves are a result of either heat stress, insufficient water supply, or both. Areas that are planted after preferred establishment windows will most likely suffer from some heat stress. This stress can be extremely detrimental to the development of seedlings and can result in seedling mortality. Young plants have shallow root systems and are unable to source water from lower soil horizons, so the site must be kept consistently moist in order to create a mesic environment.

Invasive Species - Prevention is easier than cure. At a minimum, walkthroughs during the first year should be conducted every two weeks throughout the property to check on desirable species health and identification of unwanted species – this is particularly important during the first 2-3 years of the project establishment. The intent is to spot unwanted species before they flower and become a major problem. Inspection can be reduced to every month for years two and three after establishment, and further reduced to 3 times per year thereafter.

Bare Ground - The upland and riparian buffer should be periodically inspected for new bare ground patches. Determine what is causing the

bare spot. Frequently, bare spots are caused by changes in hydrology, so remember to look upslope for anything that may be changing how water is flowing across the site. Keep a rapid revegetation seed mix on hand to address these patches. Grasses such as side-oats grama (*Bouteloua curtipendula*) and green sprangletop (*Leptochloa dubia*) provide quick cover during the spring and fall. Prairie wildrye (*Elymus canadensis*) and Virginia wildrye (*Elymus virginicus*) provide cool season and shade tolerant options.

Photo-monitoring - The establishment of permanent photopoints is recommended. By taking photographs from the same point with the same azimuth, changes in dominant vegetation can be tracked. These points can be marked on the ground with t-posts, rebar stakes, or even trees or fence posts. Once the first photopoint set has been taken, these images can often be used to find the same point the following year. The best results are achieved by taking the photographs at the same times of year (e.g. spring and late summer) at the same time of day (due to the often over-riding effect of shadows). Field notes listing dominant plant species are useful for later examination.



## case study

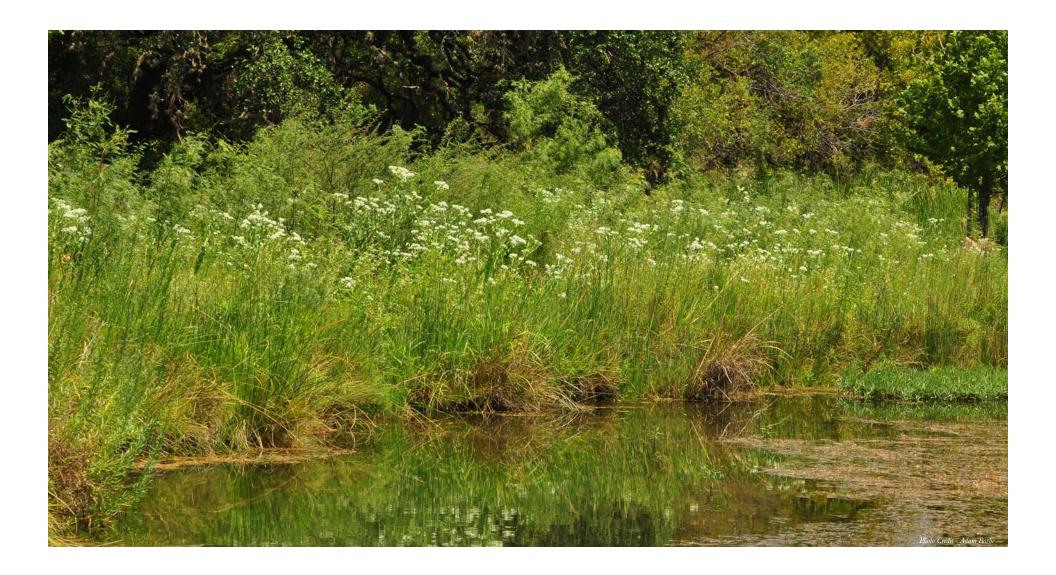
### intent

Many properties and homes were damaged due to the spring and fall floods of 2015. Record rainfall was the main driver for these events, but development trends of property along the Blanco River have resulted in landscapes that are impaired in their ability to slow down rainwater and allow it to either infiltrate into the ground or move as sheet flow over the surface of the land before it empties into the river. If we redefine our perception of beauty so that it incorporates more "natural" or "informal" design elements, we can develop creative solutions that truly celebrate our Texas landscape and are based on the cooperation of science and splendor.

The authors hope that Blanco River residents will adopt some of the measures demonstrated in the following case study. The case study property was chosen because it possesses common conditions – upland (full sun, grass dominated areas), residential (full/part sun or shade, formal landscapes), canopy (part sun or shade, canopy dominated areas with many trees), and riparian buffers (full/part sun to shade, areas immediately adjacent to the river) – that many properties possess. This case study does not suggest that every property should implement a complete redesign, but rather it is our hope that residents will examine some of the suggested strategies and determine actions that are achievable for them. However, the case study that follows also is designed to illustrate what is

possible if landowners think about their property as a whole functioning system, and how they can incorporate both "natural" and "formal" components without compromising fundamental elements such as river access, turf, or shortgrass, areas, and social spaces.





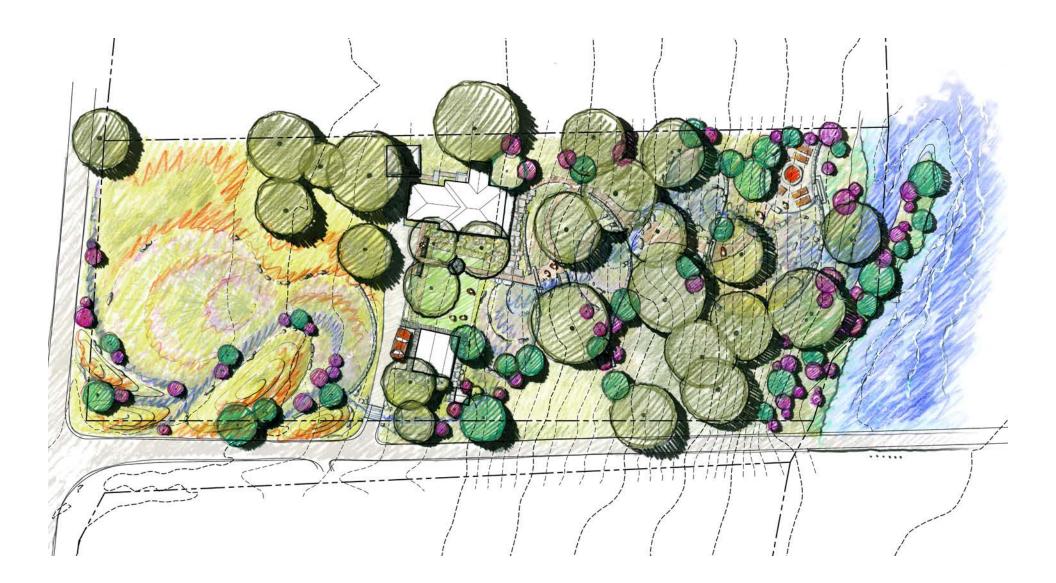
### design evolution



The case study design evolved over several iterations and was developed by the Lady Bird Johnson Wildflower Center's team of ecologists, environmental designers, and landscape architects. If landowners are able and wish to implement large scale restoration measures on their property it is extremely important that they work with restoration experts or landscape architects who can help develop ideas and provide owners with the proper set of construction documentation required by the Army Corps of Engineers. If landowners only choose to engage a commercial landscape contractor, they will likely not achieve the desired restoration or receive proper documentation. This is mainly due to the lack of formal training and the contractor industry's focus on aesthetics instead of function. The majority of landscape design work produced today is a collection of plants and design features with little or no overall design "binding them together into a unity greater than themselves" (Eckbo 2002).

Having said that, many of those affected by the flood might not be able to afford large-scale measures or might not have a budget for landscape design at the present time. Landowners can still follow the restoration measures described in the first half of this booklet by simply assessing their landscape and starting invasive plant treatment/removal in order to prepare their site for restoration at a later point in time. Restoration can be phased so that it fits your schedule and budget, but it is important that Blanco River residents 1) understand the riparian system they are trying to improve, 2) understand the current state of their land, and 3) develop a restoration plan or design that is cohesive and drives all actions so that the end result is a successfully functioning landscape.

All of your efforts are investments into the land, and good investments yield returns, returns that can be enjoyed by both you and generations hereafter.



### site plan

The Jackaroo Ranch case study site was chosen because the property experienced damage during both floods and because the property possesses conditions that are common to many properties along the Blanco River. The design team divided the property into four zones, Upland Restoration, Residential, Riparian Canopy, and Riparian Buffer. Readers can apply similar restoration tactics to comparable areas of their properties or can focus on a single zone if their property is dominated by that condition.

The main idea is to help slow water on site, celebrating it as a feature rather than pushing it off into adjacent ditches. This goal is achieved by connecting both upland and riparian zones so that they both contribute to controlling rainwater runoff. The design also integrates social spaces into the ecological design aspects by establishing a clear connection to the residence and river access area. A series of low, hand stacked rock walls thread their way through the landscape linking the movements of water and people while simultaneously acting as a stormwater diffuser at 5 key points. This plan also significantly reduces mowing to perhaps twice a year – late winter and late summer – and replaces the mowed condition with a tallgrass/midgrass plant community forming a substantial network of roots that dramatically helps reduce erosion. The planting scheme also includes the addition of younger existing trees and a number of other diverse understory species that increase habitat potential, provide greater biodiversity, and create a successional community that will continually replace old growth with new.



N 60'28'00" W 547.53" (547.50")

15 limestone check dams

(17) pedestrian foot bridge

 $_{\rm 18}$  shortgrass meadow

 $_{(19)}$  bioinfiltration zone

 $_{(16)}$  water flume at dry creek bed

# FLITE ACRES ROAD

#### Keynote

- (i) landscape berming
  (j) vegetated swale
  (j) wet meadow restoration
  (j) upland meadow restoration
  (j) understory trees
  (j) cattle guard / water crossing
  (j) parking court w/ tube steel stops
- a main house
  guest house
  residential lawn
  aggregate path
  boardwalk decking
  residential display garden
- (i) residential display garden
   (ii) flagstone patio with fire feature

   (iii) flagstone paving with planted joints
   (iii) stone seat walls
- (22) limestone retaining walls
- (23) waterfront sunbathing lawn
- (24) riparian outflow
- (25) riparian buffer restoration
- (26) existing pecan grove



residential

70 // blanco design guidelines // lady bird johnson wildflower center

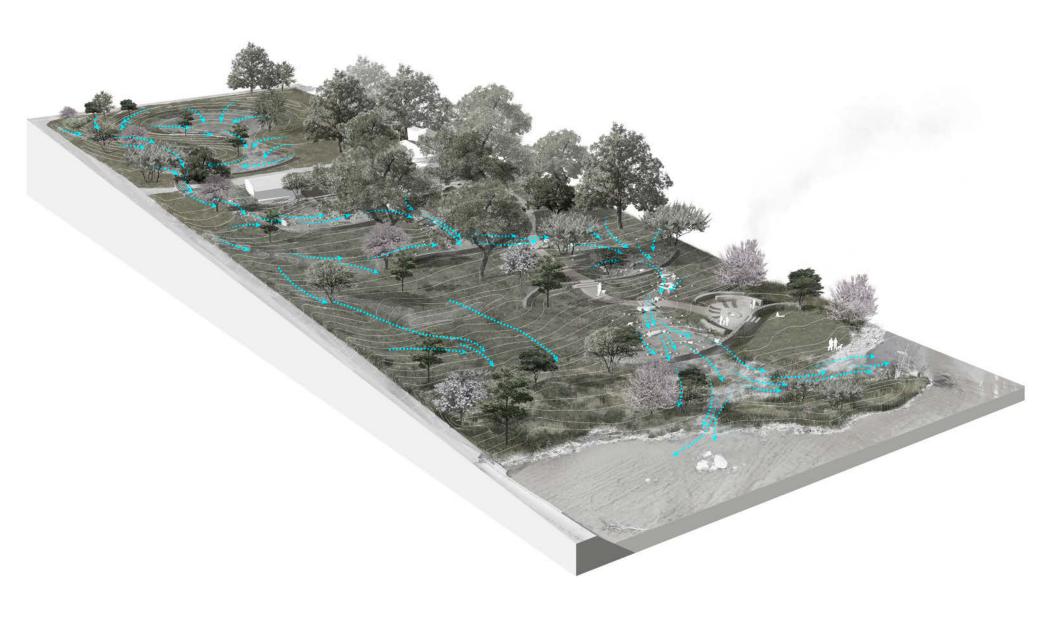


#### Keynote

- 1 landscape berming
- 2 vegetated swale
- $_{3}$  wet meadow restoration
- 5 understory trees
- $_{6}$  cattle guard / water crossing
- 7 parking court w/ tube steel stops
- (8) main house
- (9) guest house
- (10) residential lawn
- (1) aggregate path
- (12) boardwalk decking
- (13) residential display garden
- (14) flagstone paving with planted joints
- (i) water flume at dry creek bed
  (i) pedestrian foot bridge
  (ii) shortgrass meadow
  (ii) bioinfiltration zone
  (20) flagstone patio with fire feature
  (21) stone seat walls
  (22) limestone retaining walls
  (23) waterfront sunbathing lawn
  (24) riparian outflow
  (25) riparian buffer restoration
  (26) existing pecan grove

(15) limestone check dams

18



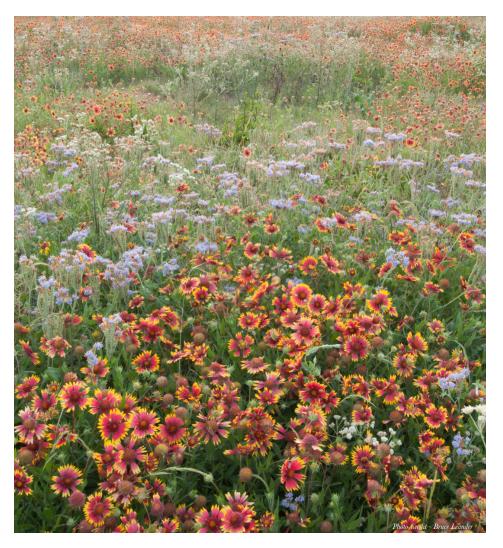


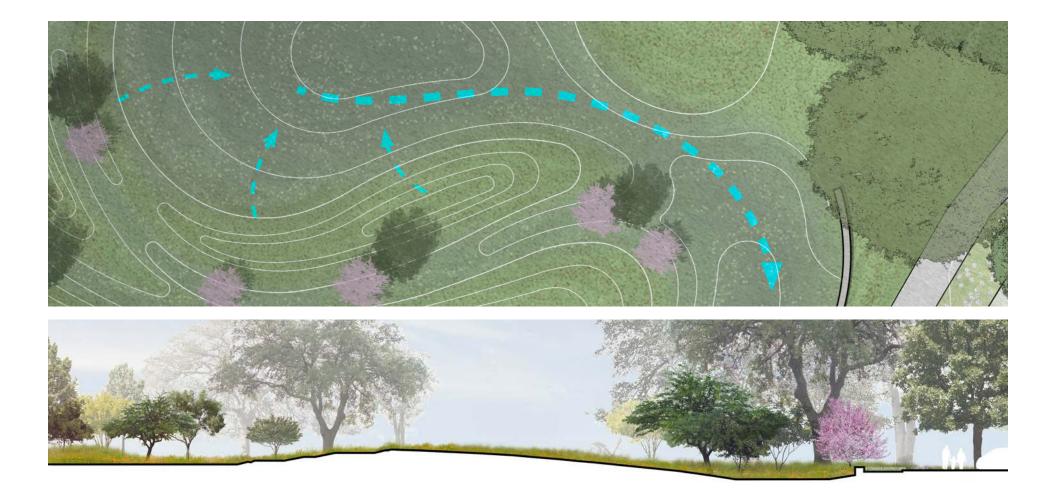
# upland restoration meadow restoration

## upland restoration

The existing condition is comprised of a mostly flat area, dominated by invasive plant species, such as Bermudagrass (*Cydondon dactylon*) and King Ranch bluestem (*Bothriochloa ischaemum*), that was regularly mowed. Rainwater flowed into roadside ditches that dumped runoff into the Blanco at high rates of velocity.

The design strategy pulls water from adjacent ditches and allows it to flow into a rainwater garden depression. Excavation from the rain garden is utilized to form sculptural mounds or "berms" that increases the diversity of soil conditions, allowing the upland to be seeded and planted with a greater diversity of grass and wildflower species. This plant species diversity will become very apparent during the spring and fall when a procession of brilliant bloom patterns slowly shift between pockets dominated by displays of blue, red, orange, pink, purple, and yellow.





## upland restoration

Rainwater will fill the depression during wetter months and eventually dry out during hotter months. The rain garden is designed to hold around 20,000 gallons of water before overflowing, with overflow cascading down through the lower three zones allowing site users to experience ephemeral flows. The extended presence of water in this area will also attract a large number of native birds, insects, reptiles, and amphibians, and creating important habitat in the upland areas is a helpful element in some permits issued by the Army Corps of Engineers.







# residential native display garden

Landscape Architecture Photo Credit - Adam Barbe

### residential

Over the last century, loss of native plant communities in central Texas has led to the loss of wildlife habitat, ecological services, and reduced genetic diversity characteristic of balanced ecosystems. This loss has equally had an adverse impact upon people as the loss of central Texas ecosystems has resulted in a disconnection of people to the land. A majority of the problem arises when we replace native plants with nonnative species in residential landscape plantings. The continual use of a limited palette of non-native plants across the U.S. has produced a homogenized landscape that is susceptible to pests and diseases, and overly dependent upon irrigation, fertilizer, and resource intensive maintenance practices. Residential landscapes provide us with the opportunity to understand the complexities of central Texas' ecosystems through the breaking down of diverse plant communities into simplified planting schemes and designs. We can develop and refine our knowledge of gardening by starting at the smaller scale of individual plants, flowerbeds, or yards. Landowners might feel more comfortable starting with a design for the area immediately surrounding their home before attempting a larger restoration project, especially if they don't have experience with gardening. Establishing native plants in your garden usually requires as much effort as non-native species. However, once the plants are established, you will see savings in time, energy, and money.





### residential

The design team created a residential area that collects water discharged from the upland restoration zone through a vegetated swale. As the rainwater passes by the guest house, it is allowed to slow, pooling behind a stone retaining wall. As the water pauses, its sediment dissipates and the infiltration rates increase. This area is densely planted with native ornamentals and flowering perennials. The planting design here resembles that of a native botanical garden – dense, lush, and regionally appropriate. The residential zone is designed to encourage social interaction between friends and family. A water-wise lawn has been designed to offer an environment that fosters these interactions. The lawn requires minimal maintenance utilizing a drought tolerant seed species mix.

It is here, in the residential zone, where the pedestrian circulation paths appear orderly and most substantial. The parking court north of the guest house is paved with limestone screenings. The parking stops are constructed of tubular steel stock. Near the main house, limestone paving with planted joints offers a unique outdoor patio space with soft edges. Alongside the guest house a cantilevered boardwalk provides an overlook of the riparian canopy restoration in addition to a unique arrival sequence. Near the first set of stairs a concrete flume captures the overflow from the display rain garden and becomes the headwaters of the dry creek bed that slopes down to the Blanco River.





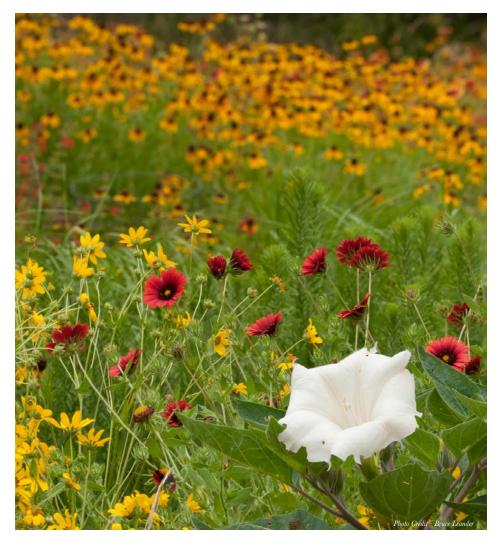


## riparian canopy revegetation & stabilization

### riparian canopy

Currently this area is dominated by pecan trees and invasive grasses, such as Bermudagrass (*Cydondon dactylon*) and King Ranch bluestem (*Bothriochloa ischaemum*), with a good deal of bare ground. Shady areas can be a challenge in central Texas because many of the usual turf grass species need full to part sun or are species that require large amounts of irrigation such as St. Augustine. The area has frequently been mowed and the shady condition has resulted in areas of erosion that will eventually become a larger issue if the problem isn't corrected.

This zone connects with the residential zone by extending some hardscape elements into the shady area, thereby increasing the footprint of social areas around the main residential turf area. The design also incorporates some more formal display areas that the landowners can enjoy in more of a traditional garden setting. The upland restoration overflow swale continues through this area and permits further infiltration of rainwater within the critical root zones (CRZ) of existing canopy trees. The CRZ is very sensitive and so construction and plantings in these areas must be mindful to prevent damage that could contribute to the loss of large trees. Because the existing soil is in poor condition, the trees will benefit from lightly loosening of the soil during site preparation and it is likely that some of the trees will require air spading by arborists to treat existing compacted soils. Once the soil has been prepared and treated to





### riparian canopy

benefit the existing large trees, the area will be seeded and plugged with shade tolerant midgrass species and wildflowers. This plant community will aid in controlling sheet flow as well as preventing erosion during high flow events of the Blanco River. The team also regraded some of the property next to the road to collect some of the water from the adjacent ditch, in order to help slow runoff into the Blanco River.







# riparian buffer edge restoration

## riparian buffer

The existing area received a large amount of erosion during the 2015 spring and fall floods. Most of the topsoil was removed and deep ruts of 2-4' formed as the water rushed over the mowed grass condition. Like most of the site, this area contained invasive grass species whose minimal roots systems could not protect the soil surface. There are some tallgrass invasive species such as Johnsongrass (*Sorghum halpense*), but opportunistic native pioneer species such as clammyweed (*Polanisia dodecandra*) have begun to thrive on the disturbed soil condition as well.

The main goals for this area's design were to provide protection against future flood events and allow river access. Due to erosion, most of this zone will require regrading to eliminate ruts and to shape the path from the residential zone down to the river. The area will be seeded and planted with a mix of both tallgrass and midgrass grass and wildflower species as well as a mixture of smaller riparian tree and shrub species. This mixed plant community will provide optimal protection during high flow events as the network of roots will firmly anchor the soil, and the flexibility of the grasses will allow the above ground biomass to bend and cover the ground providing an extra layer of protection. The design team created a destination spot at the terminus of the path that includes a more formal flagstone area with a fire pit and a shortgrass area immediately adjacent to the water's edge. The hardscape elements





## riparian buffer

are not anchored by mortar or concrete and are intended to break apart during major flood events so that they don't cause damage to the soil by being ripped out, leading to worse erosion. This area provides plenty of access while preventing the major damage experienced during the recent floods.



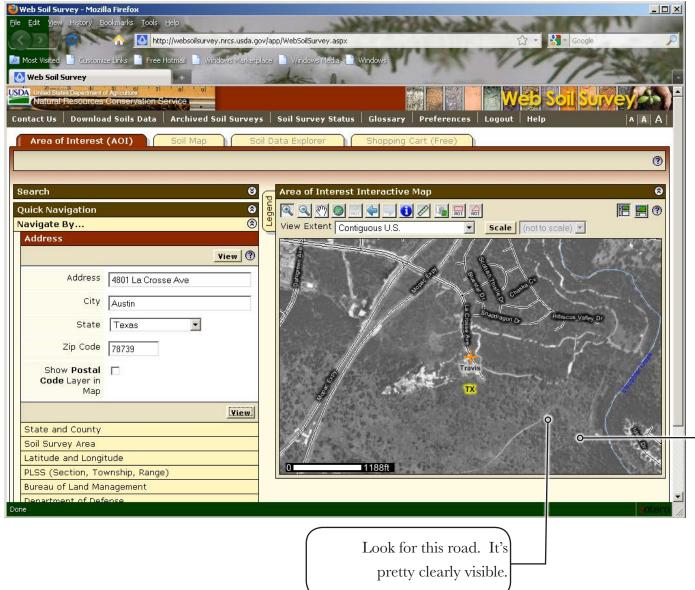




#### To Begin:

Go to: http://websoilsurvey.nrcs.usda. gov/app/HomePage.htm

Look at the 3 basic steps on this page and then start by clicking the green Start WSS button



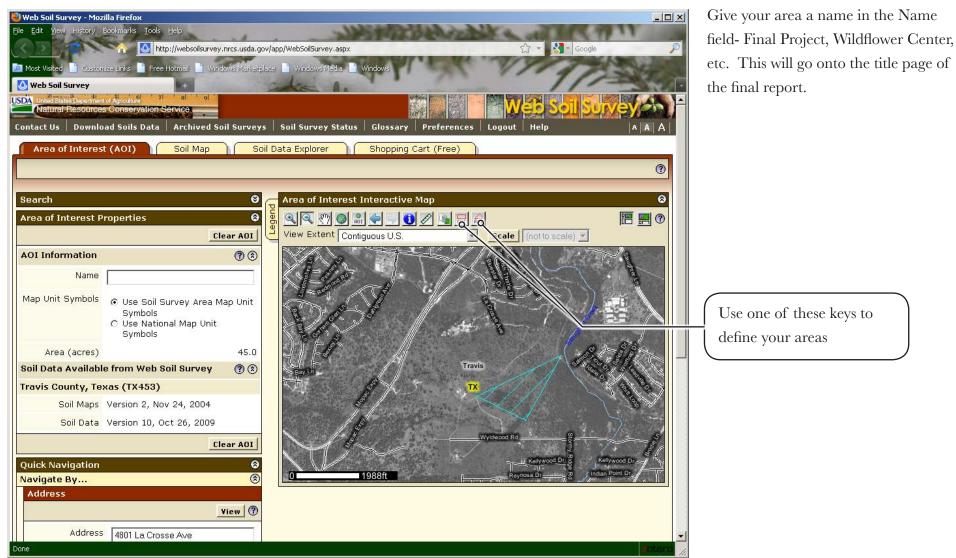
2.

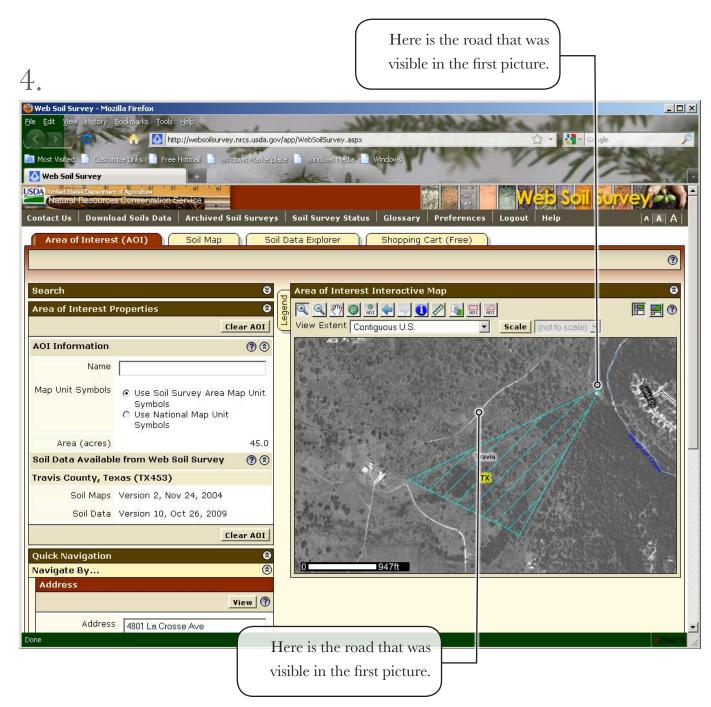
#### Step 1. Define area of interest.

The first step is to define your area of interest. For this exercise, we will be using an area of the Wildflower Center. You can enter the Wildflower Center's address (4801 La Crosse Avenue, Austin, Texas 78739) and then drag the image to our project location at the southwest corner. Alternately, you can enter latitude and longitude coordinates. Once you are close, you can either attempt to outline just our project, or draw a rectangle that encompasses the area. This is your Area of Interest (AOI).

The project is just south of this, bounded in the north by another road, that is visible when you zoom in, but hard to see at this point.

3.

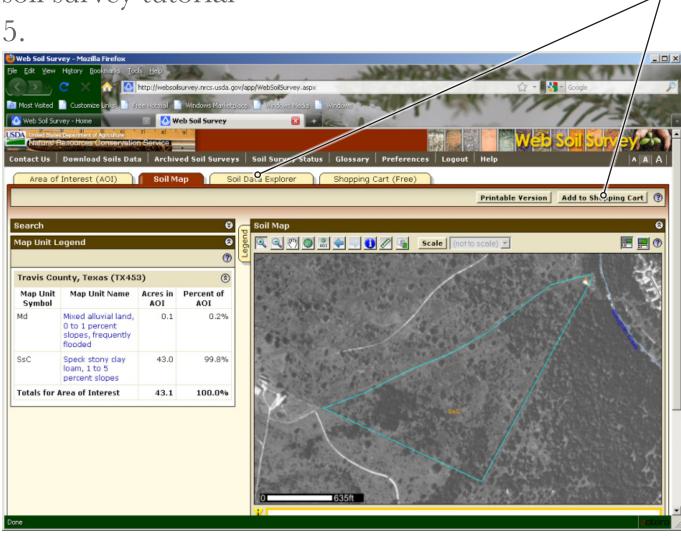




#### Step 2. Explore data

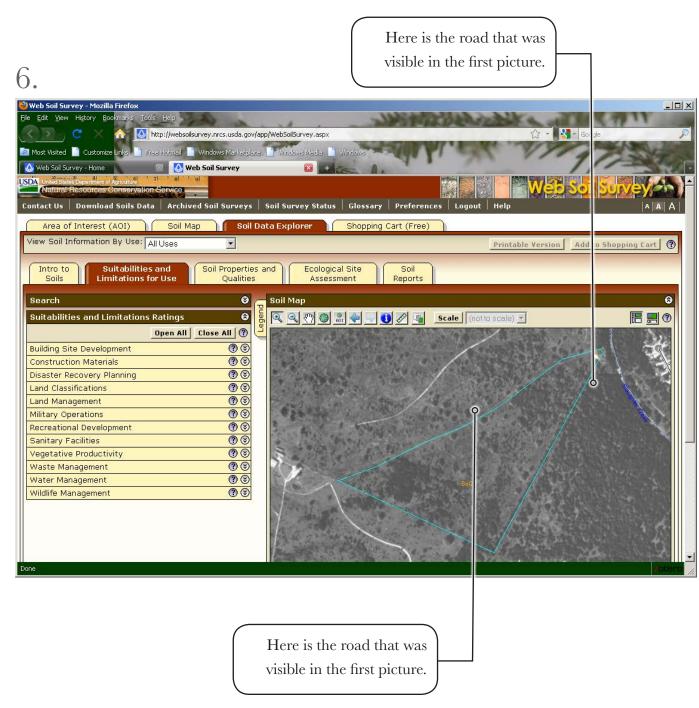
Take note of the 4 tabs: Area of Interest, Soil Map, Soil Data Explorer, & Shopping cart. Use these to navigate the site.

We will want the soil map and several pieces of information available in Soil Data Explorer. As you view each piece of information, you have the option to add it to your shopping cart. The Web Soil Survey will put everything you add to the shopping cart into a single report for you that you can download immediately or later. We will go through each step and conclude with a summary of the information typically needed for restoration projects.



If you are happy with your map, click add to shopping cart and then go to the Soil Data Explorer tab.

It should look something like this. You may or may not have the Md soil layer, depending on how far you extended the north east corner. If you don't have it, you may want to redraw your AOI to get it, because I suspect this is what we have in our drainage.



As you can see, Soil Data Explorer has several sub tabs.

Below, is a summary of what is in each tab and general instructions for getting data, followed by what you will see in each tab, what to click etc.

**Intro to Soils:** This tab provides a nice introduction to soils.

#### **Suitabilities and Limitations**

**for Use:** Pull down any of these that you think would be useful for your project. Building Site Development, Recreational Development, Water Management, and Wildlife management are often worth looking at.

#### Soil Properties and Qualities: Has

detailed information on the physical and chemical properties of your soils. Most of this is summarized in Soil Reports. This section provides more detail than

soil reports, so if there is a particular parameter you need more information on, you would get it here. Otherwise, use the soil reports to collect your information.

**Ecological Site Assessment:** This section and the Soil Reports section are the most useful sections from a restoration point of view. Ecological sites are the updated, and much expanded, versions of the range sites available in paper soil surveys. The focus has shifted from agriculture to ecological function. This is your first step to figuring out what your site is capable of. You should add everything here to your shopping cart.

**Soil Reports:** This section summarizes the physical and chemical properties of your soils and you should add several of these to your report.

General instructions for adding data to your shopping cart.

- 1. Expand the topic from the table at the left of the screen.
- a. Frequently this will open several sub tables.
- 2. Click view

7.

3. Click add to cart.

You must do this for every piece of information you want. There is no way to add all.

4. When you have added all the information you want, from all the tabs, checkout. It's free and you will be given download options.

Soil Data Explorer- Suitabilities and limitations for use. From here you will pick and choose what is most important to your project. Usually going in you have some idea of the types of development that are likely. Much of the information here is summarized in soil reports. You may need to go back to this for more detail after you get further into your design process. Today, add the following to your shopping cart.

You can add as many extras as you like.

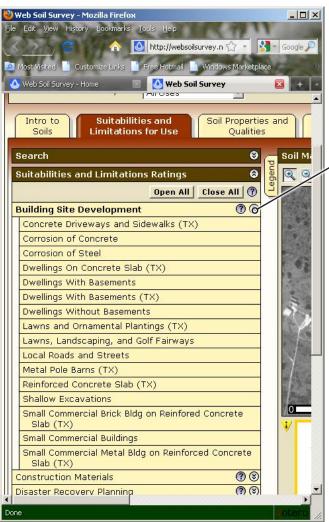




Here is an example of how to add an item.

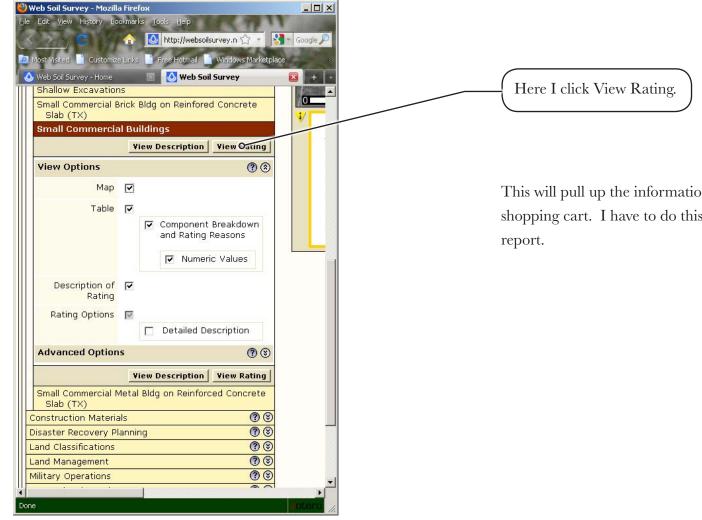
Expand the subject you are interested in by clicking the arrow. Here I'll do Building Site Development.

9.



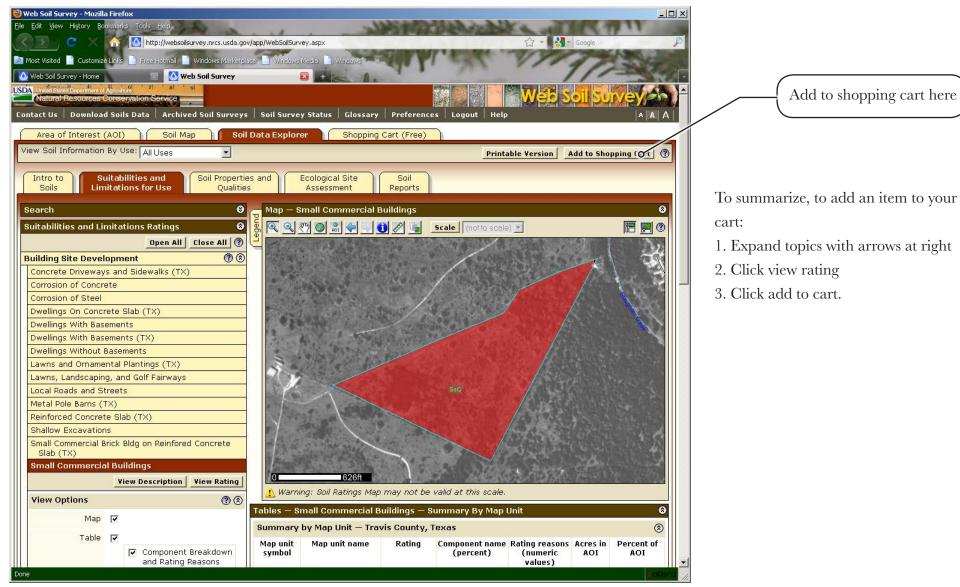
Under building site development, I'm interested in small commercial buildings, so I keep expanding by clicking the arrows

### 10.

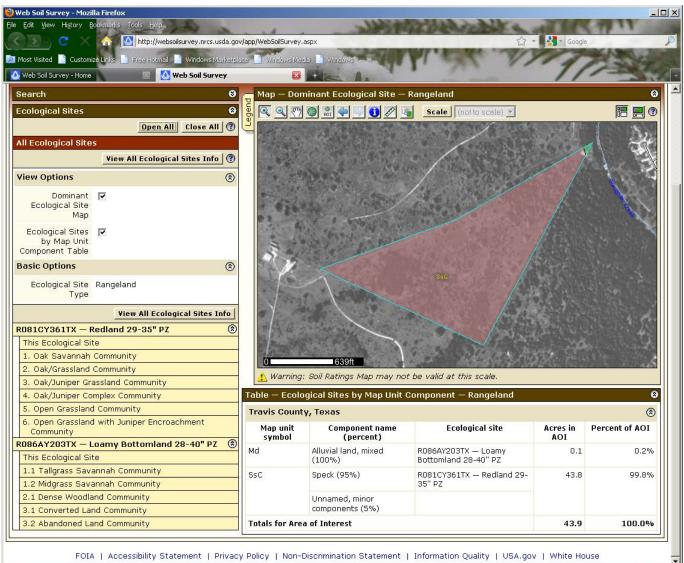


This will pull up the information. Once it's up, I can click add to shopping cart. I have to do this with each item I want to go into the report.

#### 11.







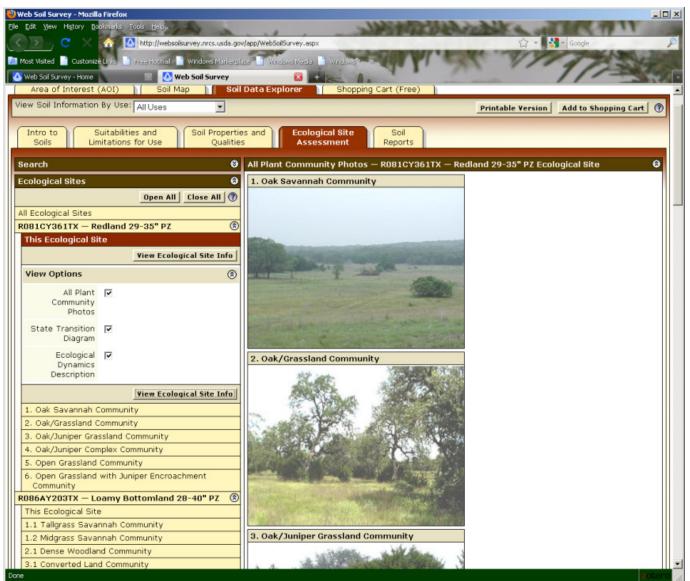
### **Ecological Site Assessment Tab:**

Under ecological site assessment, first click open all so you can see both the ecological sites (redland and loamy bottomland) and all the communities within them. You need to expand and add all of these topics.

Here you expand the tree, then click view all ecological sites info, and then click add to shopping cart.

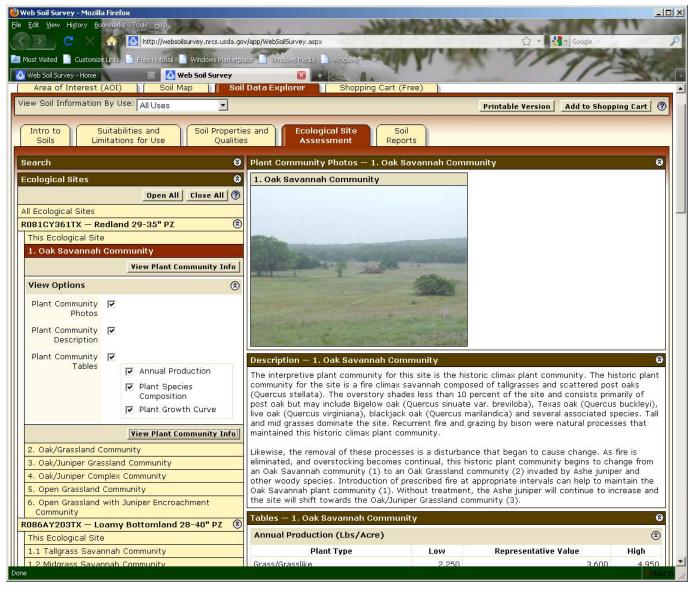
# appendix a soil survey tutorial

13.



**View Ecological Site Info:** You want to be sure all 3 boxes are checked. As you move into the individual community descriptions, you can leave off the photos if you want to, but I find them helpful to have associated with their description.





# View of an individual community

**description:** Plant community photo is optional since you have it in the ecological site description.

Get everything else.

# appendix a soil survey tutorial

15.

## **Summary of Information to Retrieve:**

This is what to retrieve at a minimum. Add it all to your shopping cart. You can add as much additional information as you want. This takes a bit of time, but it will give you a jump start both on your assessments and on your eventual design.

Once you have added all the information, go to the shopping cart tab and check out.

### **Area of Interest**

Define your area of interest and give it a name

## Soil Map

Add your map.

# Soil Data Explorer Main Tab

This tab has 5 subtabs below.

## Intro to Soils Tab

Lots of useful material in here, and it is worth looking through, but adding any of it to your report is optional.

### Suitabilities and Limitations for Use Tab

It is useful to explore this tab. Most of the information can be summarized in the Soil reports tab, so you do not have to add it at this time unless there is a topic you want more detail on.

### **Soil Properties and Qualities Tab**

Similar to Suitabilities and Limitations for use. The information here is summarized in soil reports. This tab provides more detail than what is in soil reports.

## **Ecological Site Assessment Tab**

Everything in here. First, hit open all so that you can see all of the communities as well as the ecosites.

## **Soil Reports Tab**

AOI Inventory component legend map unit description

Building Site Development dwellings and small commercial buildings roads & streets

Land Classification

hydric soils prime and other important farmlands taxonomic classification – nice but optional

Land Management optional

Recreation Development

these would be nice if you suspect these elements may be in your design

Soil Chemical Properties chemical soil properties

Soil Erosion rusle2 related attributes

Soil Physical Properties engineering properties particle size physical soil properties

Soil Qualities and Features soil features

Vegetative Productivity irrigated yield- optional rangeland productivity – optional

Water Management - optional, but possibly useful

# appendix b document set

#### abbreviations

AFF	above finish floor	DWG	drawing	MTL	metal	SST	stainless steel
AC	acres	DF	drinking fountain	M	meter(s)	STD	standard
ADD	addendum			MM	millimeter(s)	STA	station
ADJ	adjustable	EW	each way	MIN	minimum	STL	steel
AGG	aggregate	F	east	MISC	miscellaneous	SD	storm drain
ALT	alternate	ELEC	electric(al)	MOD	modular	ST	steel
				MUD	moduar		
ALUM	aluminum	EL	elevation			STR	structural
ANC	anchor, anchorage	ENCL	enclosure(ure)	NOM	nominal		
ANOD	anodized	ENG	engineer	N	north	T	top
APPROX	approximate	EQ	equal	NIC	not in contract	TAN	tangent
ARCH	architect(ural)	EQUIP	equipment	NTS	not to scale	TB	top of bridge
AD	area drain	EST	estimate	NO	number	TC	top of curb
				100	TUTIDE		
ASPH	asphalt	EXIST	existing _			TEL	telephone
		EXP	exposêd	OC	on center(s)	TEE	top of fire feature
B&B	balled and burlapped	EXT	exterior	OPP	opposite	TH	thick(ness)
BM	bench mark			OH	opposite hand	TOL	tolerance
BIT	bituminous	FIN	finish(ed)	OD	outside diameter	TC	top of curb
BLK	block	FFF	finished floor elevation			TS	top of steps
BTM	bottom	FG	finish grade	PTD	paint(ed)	TSL	top of slab
BC	bottom of curb	FLG	flashing	PVG	pave(ing)	TW	top of wall
BS		FLX		PVMT		TWF	
	bottom of steps		flexible		pavement		top of water feature
BW	bottom of wall	FH	fire hydrant	PERF	perforate(d)	TRD	tread
BRK	brick	FL	floor	PL	plate	TYP	typical
BLDG	building	FT	foot, feet	PWD	plywood		
		FTG	footing	PT	point	UON	unless otherwise noted
CAL	caliper	FND	foundation	PVC.	polyvinyl chloride		
ČK.	calk(ing) caulk(ing)	FUT	future	PSF	pounds per square foot	VAR	varies
CI	cast iron	101	luiule	PSI		VEY	verity
CIPC				POB	pounds per square inch		
	cast-in-place concrete	GA	gage, gauge		point of beginning	VERT	vertical
CB	catch basin	GALV	galvanized	PCC	point of compound curvature	VC	vertical curve
CEM	cement	GV	gas value	PC	point of curvature		
CL	centerline	GC	general contract(or)	PI	point of intersection	W	west
CM	centimeter(s)	GD	grade, grading	PRC	point of reverse curvature	WHS	wheel stop
CHAM	chamfer	GVL	gravel	PT	point of tangent	W	width, wide
CLE	chain-link fence	G	gutter	PVC	point of vertical curvature	ŵ/	with
CB		G	guier	PVC			
	circle				point of vertical intersection	W/O	without
CIRC	circumference	HDW	hardware	PVT .	point of vertical tangent	WD	wood
CLR	clear(ance)	HWD	hardwood	PL	property line	WWW.	woven wire mesh
CONC	concrete	HDR	header			WWF	welded wire fabric
CMU	concrete masonry unit	HD	heavy duty	R	radius		
CONST	construction	HT	height	RL	rail(ing)		
CONT	container	HP	high point	RWC	rainwater conductor		
	contract limit line	HOR	horizontal	REF	reference	SVr	nbols
CJ		HB	hose bibb	REBAR	reinforcement bar		110010
	contraction joint	пв	nose bibb	RCP		11	
CMP	corrugated metal pipe				reinforced concrete pipe		align
CORR	corrugated	INC	include (d), (ing)	REINF	reinforcing	@	at
CSK	countersink	ID	inside diameter	REV	revision(s), revised		feet, minutes
CRS	course(s)	INT	interior	RE	rim elevation		inches, seconds
CS	cross-slope	INV	invert	REQ	required	0	degrees
CF	cubic foot	IJ	isolation joint	ROW	right-of-way	ē	centerline
CY	cubic yard			RIS	riser	Ā	central/deflection angle
		JT	ioint	RD	road	ä	dameter
DMP	damporopling	-	lou r	nD	1040	#	pound, number
						#	pound, number
DP	deep, depth	L.	length (of curve)	SAN	sanitary		
D	degree of curvature	LA	landscape architect	SCH	schedule		
DEMO	demolish, demolition	LT	light	SC	score line		
DEP	depressed	LF	linear feet	SEC	section		
DTL	detail	LP	low point	SHT	sheet		
DIAG	diagonal			SIM	similar		
DIA	diameter	MH	manhole	SLV	sleeve		
DBH	diameter breast height	MFB	manufacture(er)	SL	slope		
DIM	dimension	MAT	material	S	south		
DIM	division	MAX		SP(S)	space(s)		
DN			maximum	SPEC			
	downspout	MECH	mechanic(al)		specification		
DT	drain tile	MED	medium	SQ	square		

#### standard environmental notes

NTOWA APPENDETE: ALL ASSOCIATED FEMITS AND FEES SHALL BE THE SOLE RESPONSIBILITY OF THE CONTRACTOR CONTRACTOR MUST INSTALL AND WARKIN REDSONDEEDMENTATION CONTROLS AND THEE PROTECTION FOR ALL SUCH APPEN IN COCORDANCE WITH THE APPENDED SUBJECT TO A THE FOLD BY THE CONTERS ENTRESINTAINE.

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#### PROJECT CONSTRUCTION:

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- COMPLETE RESTORATION OF ALL AREAS DISTURBED BY CONSTRUCTION ACTIVITIES FOR THIS PROJECT. (PERMANENT E/S
- CONTROLS) HOLD ENVIRONMENTAL POST-CONSTRUCTION CONFERENCE ON SITE WITH THE CONTRACTOR, OWNERS REPRESENTATIVE, AND LANDSCAPE ARCHITECT. ALL PERMANENT ES CONTROLS MUST BE ACCEPTED BY THE OWNERS
- REPRESENTATIVE. FOLLOWING RINAL ACCEPTANCE OF PERMANENT E/S CONTROLS BY THE OWNER'S REPRESENTATIVE, REMOVE TEMPORARY E/S CONTROLS. CLEAN EXISTING STORM DRAINAGE SYSTEMS AS NECESSARY DUE TO CONSTRUCTION
- OPERATIONS. DRESS, I DIAND RESTORE ANY ADEAS DISTUBBED BY DEMOVAL OF TEMPORARY E/S CONTROLS DESCRIBED ABOVE

#### general project notes

THE DRAWINGS, SPECIFICATIONS, AND ADDENDA DESCRIBING WORK FOR LANDSCAPE, HARDSCAPE AND IRRGATION PORTIONS OF THE PROJECT SHALL BE REFERRED TO AS THE LANDSCAPE CONSTRUCTION DOCUMENTS.

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#### hardscape construction notes

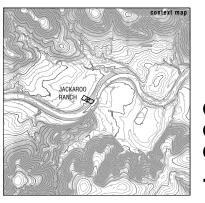
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- A BEAMED AND THE SECONDARY CONTRACTOR STATUS OF THE CONTRACTOR EVALUATE CONTRACTOR STATUS OF THE CONTRACTOR AND TAKES AND TAKE

#### layout notes

- 1. CAD FILES WILL BE MADE AVAILABLE TO THE CONTRACTOR TO FACILITATE ACCURATE LAYOUT OF ALL HARDSCAPE ELEMENTS. SOME DIMENSIONS ARE PROVIDED ON THE DRAWINGS TO ALLOW
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landscape architect COLLABORATIVE WORKSHOP, LLC ADAM BARBE 2001 FARO DRIVE #15 AUSTIN, TEXAS 78741 t 256 312 4809

environmental designer ECOSYSTEM DESIGN GROUP, LADY BIRD JOHNSON WILDPL, OWER CENTER UNIVERSITY OF TEXAS AT AUSTIN JOHN HART ASHER 4001 LA CROSSE AVENUE AUSTIN, TEXAS 78739

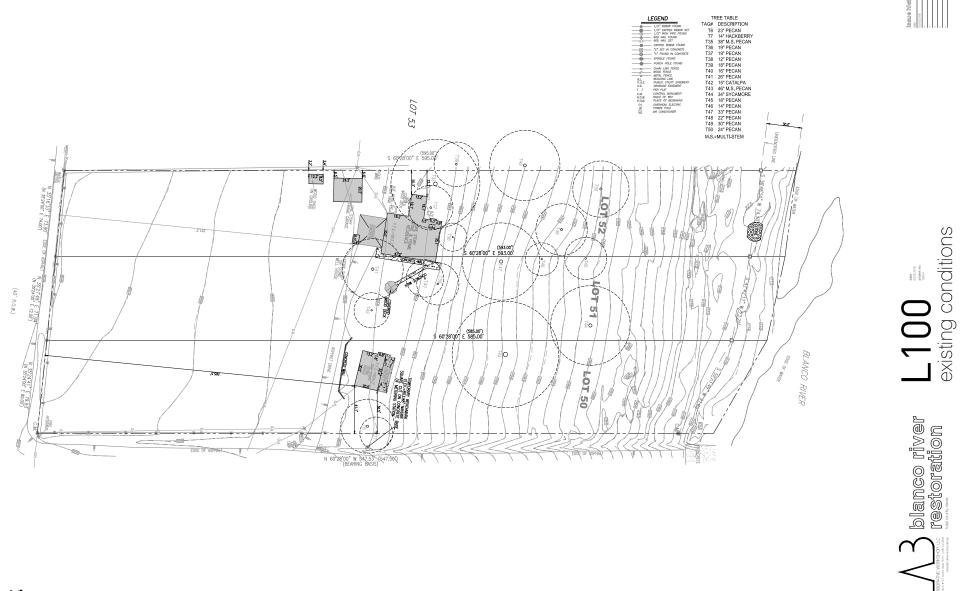
blanco river restoration

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cover sheet

### blanco river restoration LANDSCAPE ARCHITECTURAL SUBMITTAL



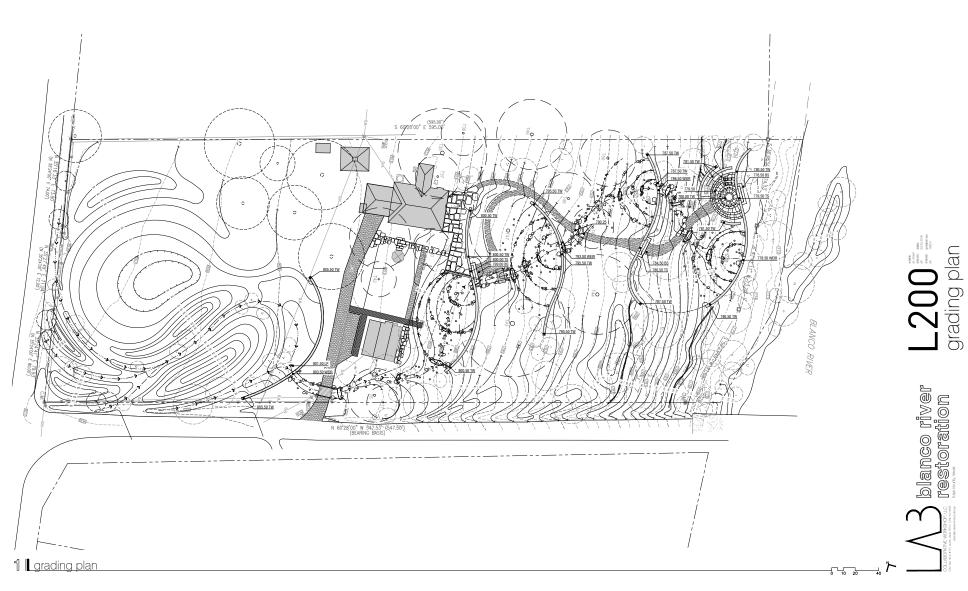


1 existing conditions

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material/finish schedule

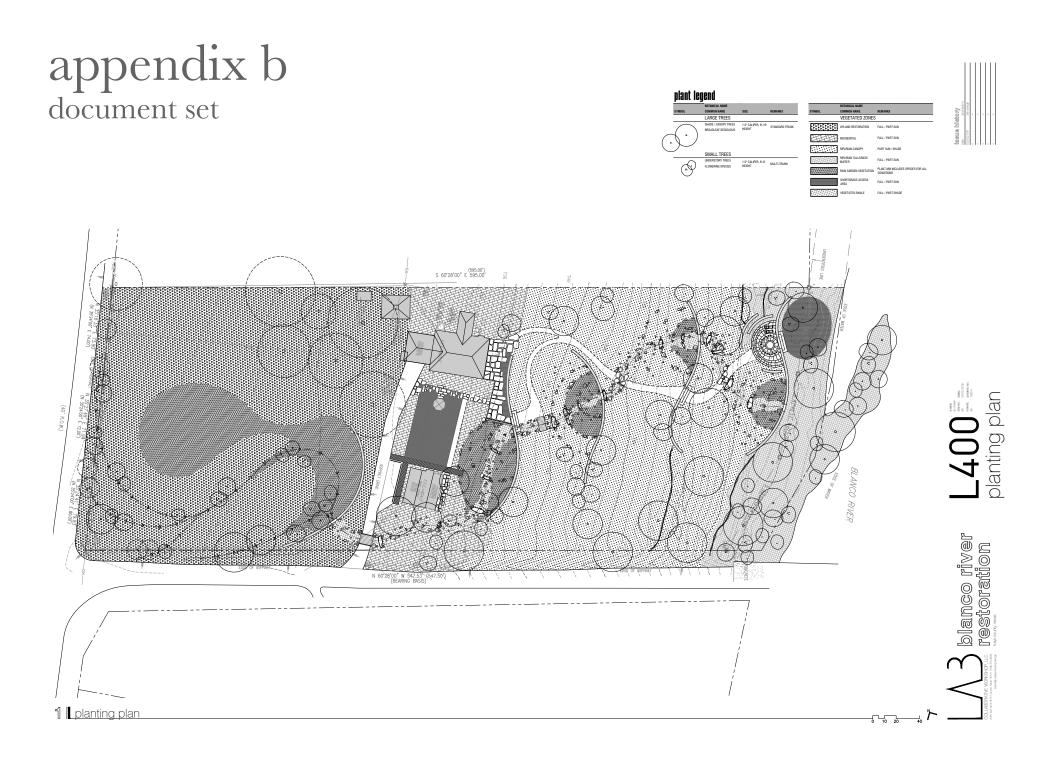
AVEMENT & MISC. STI

3.0		SITE FEATURES & FURNISHINGS									
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	22	LEDGESTONE BOULDERS	CEDGESTINE BOULDERS, SIZES FER PLAN	NATIFAL	AUDRE.	LOCAL SOURCE	PROVIDE SAUPLES ON-SITE FOR LA APPROVAL				
		49990X522:1-0-x1-0-x2									
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	6	AMMERICS 21212-0									
	22	CEDESTORS CHECK DAMS	CENESTINE SLASS	NATURAL	aduke.	LOLAL SOLRIS	CHECKS DAMS TO SLOW INVERT RLOW, USE IN CONLINCTION WITH BOULDERS				
	2.4	LEP. BORROFORM CONCRETE RAMMATER RUME									
4.0		RAILINGS, FENCING & MISC METALS									
	4.1	STEEL HEAVER		NATURAL STEEL		LOLAL SOLRIS	PROVED SAUPLES OF STE FOR LA APPROVAL				
	42	STEEL MHER, STOPS	2 OA. TURULAR STEEL WHEEL STOPS	NATURAL STEEL	MLL FRISH	LOCAL SOLING	ANCHOR TO CONCRETE FOOTING				
5.0		MISCELLANEOUS									
	\$1	STEEL REDESTRAN BRIDGE	1690 STER.	NATURAL	12-W & 1-12-IX, 11 GA HRPD STIGL TRACTION TREAT REFERRATED PLANK	MC NICHELS 877-884-4853	SUBINIT SHOP DRAWINGS TO LA FOR APPROVAL; PROVIDE SAMPLES ON-SITE FOR LA APPROVAL				
	52	TONS BLOD RIVER ROOK @ VESCOTES SMALL	2 TO STEWAS RUND RIVER ROCK	TECKS RLEND	SMOOTH, WASHED	KELLER MATERIALS OR	FEATHER OUT EDGES OF ROCK WTO LANDSCHPE;				



lady bird johnson wildflower center // blanco design guidelines // 117

4







State of Drawings - Schematic Design Project Number: 15004 Print Date 3/5/2016

Item:	unit	qty.	unit cost	total	comments
PCIAL PROJECT START-UP COSTS					
eneral Expenses					
survey / layout	allow.	1	\$1,000.00	\$1,000.00	as needed
tree protection fencing	allow.	1	\$2,500.00	\$2,500.00	wire fencing / wood slats
					-
	(	General Expension	ses Subtotal:	\$3,500.00	
		Proje	ected Budget	\$3,500.00	
ANDSCAPE RESTORATION					
emolition & Site Preparation			<b>AA AAA AA</b>	<b>Aa a a a a a</b>	
existing hardscape removal / recycling	allow.	1	\$2,000.00	\$2,000.00	haul-off / sorting
debris removal / processing	allow.	1	\$3,500.00	\$3,500.00	haul-off / sorting
fine grading / berming / soil amendments	sf	58,000	\$0.20	\$11,600.00	ref. plans and soils report
	Demolition a	& Site Preparat	ion Subtotal:	\$17,100.00	
indscape and Irrigation					
shade tree - 1.5" cal.	ea.	10	\$250.00	\$2,500.00	successional growth
understory tree - 1.5" cal.	ea.	25	\$150.00	\$3,750.00	successional growth
seeded areas (labor costs)	sf	131,347	\$0.06	\$7,486.78	\$2,500 / acre (labor cost)
seeded areas (material costs)	allow.	1	\$5,958.00	\$5,958.00	
shrub bed plantings (Mix 60% 5gal, 20% 3gal, 20% 1gal)	ea.	457	\$15.00	\$6,855.00	6335sf @ 48" O.C. spacing
	sf	10,635	\$0.30	\$3,190.50	
hardwood mulch @ 3" depth		1	\$10,000.00	\$10,000.00	above ground
hardwood mulch @ 3" depth temporary irrigation system (until establishment)	allow.				
•	allow. sf	2,730	\$1.25	\$3,412.50	bubblers at tree installation
temporary irrigation system (until establishment)	sf	2,730 ape and Irrigat	• -	\$3,412.50 \$43,152.78	bubblers at tree installation

#### HARDSCAPE ELEMENTS

avements .1 limestone screenings - VEH	sf	2,442	\$4.00	\$9,768.00	1/4" minus with fines
1.2 limestone screenings - PED	sf	2,205	\$3.00	\$6,615.00	1/4" minus with fines
1.3 stone paving w/ mortar joints	sf	701	\$17.64	\$12,365.64	natural finish, whole pieces
1.4 stone paving (stepping stones)	ea	10	\$150.00	\$1,500.00	natural finish, whole pieces
1.5 stone paving with planted joints	sf	1,500	\$10.00	\$15,000.00	natural finish w/ planting soil
1.6 cut limestone steps	lf	1,500	\$25.00	\$3,925.00	bush-hammered pieces, mortar set
1.7 wood decking	sf	209	\$20.00	\$4,180.00	cedar planks, treated pine structure
	5	203	φ20.00	φ4,100.00	
		Paveme	nts Subtotal:	\$53,353.64	
Site Walls					
2.1 segmented limestone block site walls	lf	91	\$125.00	\$11,312.50	natural faces, sawn tops & ends; 36" lengths
2.2 dry stack stone retaining walls	lf	713	\$55.00	\$39,215.00	natural stone, local source
		Site Wa	alls Subtotal:	\$50,527.50	
Site Features					
3.1 limestone fire pit	lf	25	\$55.00	\$1,375.00	natural stone, local source
3.2 limestone ledgestone boulders					•
a ledgestone boulders size a	ea	55	\$15.00	\$825.00	field stone, local source
b ledgestone boulders size b	ea	36	\$25.00	\$900.00	field stone, local source
c ledgestone boulders size c	ea	24	\$40.00	\$960.00	field stone, local source
d ledgestone boulders size d	ea	12	\$60.00	\$720.00	field stone, local source
e ledgestone boulders size e	ea	45	\$80.00	\$3,600.00	field stone. local source
3.3 ledgestone check dams	ea	15	\$250.00	\$3,750.00	field stone, local source
3.4 c.i.p. board form concrete rainwater flume	allow.	1	\$5,000.00	\$5,000.00	2x4 forms
		Site Featu	res Subtotal:	\$17,130.00	
Misc. Metals					
4.1 steel header 1/4" x 4"	lf	165	\$8.00	\$1,320.00	natural steel, unfinished
4.2 steel tube wheel stops	lf	42	\$25.00	\$1,050.00	natural steel, unfinished
				\$1,000.00	natara eteen, annienea
		Site Wa	alls Subtotal:	\$2,370.00	
Miscellaneous					
5.1 steel pedestrian bridge	allow.	1	\$3,000.00	\$3,000.00	HRPO finish, steel tread plank
5.2 Texas blend river rock @ vegetated swale	sf	3,453	\$1.50	\$5,179.50	local source
5.3 brush-pile check dams	lf	240	\$7.00	\$1,680.00	from onsite materials
		Site Wa	alls Subtotal:	\$9,859.50	
		Proje	ected Budget	\$133,240.64	
				<b>•</b> ··••; <b>-</b> ·•••	
		Proje	ected Budget	\$196,993.42	
	Area Tota	I – Scope Area	of Influence	137 982	f 3.16 acres

Note: This document represents an opinion of the probable coast of construction based on items defined and similar unit costs within this market. This estimate can provide guidance for your decision making, however it is not intended to be a guarantee of the actual cost of a project. Frequent fluctuations in labor, material costs, and the local bid climate, can substantially alter the construction cost of an individual project. The final determination of construction cost is made through the bidding process with a contractor using a defined design and appropriate documents.

# appendix c plant list - riparian buffer

su.	Species	Scientific name	Wetland Indicator Status	Stability Rating	Colonizer	Shade tolerant	Habitat value	Ornamental value
Fer	Maidenhair fern	Adiantum capillus-veneris	FACW	5		Yes	Yes	Yes
<u> </u>	Horsetail	Equisetum laevigatum	OBL	6		Yes	Yes	Yes
	River fern	Thlypteris ovata	FAC	6		Yes	Yes	Yes

			Wetland Indicator	Stability		Shade	Habitat	Ornamental
	Species	Scientific name	Status	Rating	Colonizer	tolerant	value	value
0	Bushy bluestem	Andropogon glomeratus	FACW	5	Yes		Yes	Yes
like	Emory sedge	Carex emoryi	OBL	9	Yes	Yes	Yes	
	Inland seaoats	Chasmanthium latifolium	FAC	5	Yes	Yes	Yes	Yes
Grass/Grass	Sawgrass	Cladium mariscoides	OBL	9			Yes	
	Flat sedge	Cyperus sp.	FACW	5	Yes		Yes	
<b>)</b>	Spikerush	Eleocharis sp.	OBL	6			Yes	
<b>S</b> E	Lindheimer muhly	Muhlenbergia linheimeri	FAC	7			Yes	Yes
	Switchgrass	Panicum virgatum	FAC	8-9			Yes	
0	Knotgrass	Paspalum distichum	FACW	6	Yes		Yes	
	Rustyseed paspalum	Paspalum langei	FAC	5-6		Yes	Yes	
	White top sedge	Rynchospora colorata	FACW	6			Yes	
	Eastern gamagrass	Tripsacum dactyloides	FAC	9			Yes	

			Wetland					
			Indicator	Stability		Shade	Habitat	Ornamental
	Species	Scientific name	Status	Rating	Colonizer	tolerant	value	value
	Indigobush	Amorpha fruticosa	FACW	7			Yes	Yes
	Roosevelt weed	Baccharis neglecta	FAC	6	Yes		Yes	
	Brickellbush	Brickellia sp.	UPL	4	Yes		Yes	Yes
	Pecan	Carya illinoinensis	FAC	6			Yes	Yes
	Sugar hackberry	Celtis laevigata	FAC	5-6			Yes	
	Buttonbush	Cephalanthus occidentalis	OBL	8		Yes	Yes	
Trees/Shrubs	Desert willow	Chilopsis linearis	FACU	6			Yes	Yes
2	Roughleaf dogwood	Cornus drummondii	FAC	6		Yes	Yes	Yes
- К	Green ash	Fraxinus pennsylvanica	FACW			Yes	Yes	
s/	Possumhaw	llex decidua	FACW	6		Yes	Yes	Yes
ee	Little walnut	Juglans microcarpa	FAC	6-7			Yes	
Ĕ	Black walnut	Juglans nigra	FACU	6			Yes	
•	Turkscap	Malvaviscus arboreus	FAC			Yes	Yes	Yes
	Retama	Parkinsonia aculeata	FACW	6			Yes	Yes
	Sycamore	Platanus occidentalis	FAC	6			Yes	Yes
	Eastern cottonwood	Populus deltoides	FAC	7	Yes		Yes	Yes
	Flame-leaf sumac	Rhus lanceolata	FAC			Yes	Yes	Yes
	Arroyo willow	Salix exigua	FACW	7			Yes	
	Black willow	Salix nigra	FACW	7	Yes		Yes	
	Bald cypress	Taxodium distichum	OBL	9			Yes	Yes
	Cedar elm	Ulmus crassifolia	FAC	6		Yes	Yes	Yes

# appendix c plant list - riparian buffer

			Wetland					
			Indicator	Stability		Shade	Habitat	Ornamental
	Species	Scientific name	Status	Rating	Colonizer	tolerant	value	value
	Spiny aster	Aster spinosa	FACW	8			Yes	
	Gregs mistflower	Conoclinium gregii	FACU				Yes	Yes
SC	Cardinal flower	Lobelia cardinalis	FACW	5		Yes	Yes	Yes
Forbs	Water primrose	Ludwigia sp.	OBL/FACW	3-4	Yes		Yes	
Ч	Nimblewill	Muhlenbergia schreberi	OBL			Yes	Yes	
	Frogfruit	Phyla nodiflora	FACW	4	Yes		Yes	Yes
	Drummonds's wild petunia	Ruellia drummondiana				Yes	Yes	Yes
	Lindheimer senna	Senna lindheimeriana	UPL	6-7	Yes	Yes	Yes	
	Tall goldenrod	Solidago altissima	FACW	6-7	Yes		Yes	Yes
	Plateau goldeneye	Viguiera dentata	UPL	5			Yes	Yes

			Wetland Indicator		Shade	Habitat	Ornamental
	Species	Scientific name	Status	Colonizer	tolerant	value	value
				Colonizer		value	
	American beautyberry	Callicarpa americana	FACU		Yes		Yes
S	Cenizo	Leucophyllum candidum				Yes	Yes
с Ч	Agarita	Mahonia trifoliolata			Yes	Yes	Yes
Shrubs	Turks cap	Malvaviscus arboreus	UPL		Yes	Yes	Yes
S	Pigeonberry	Rivina humilis	FAC		Yes	Yes	Yes
	Palmetto	Sabal minor	FACW		Yes		Yes
	Tropical sage	Salvia coccinea					Yes
	Mealy bluesage	Salvia farinacea					Yes
	Heartleaf skullcap	Scutellaria ovata	FACU		Yes		Yes

			Wetland				
			Indicator		Shade	Habitat	Ornamental
S	Species	Scientific name	Status	Colonizer	tolerant	value	value
Tallgrasses	Big bluestem	Andropogon gerardii	FACU			Yes	
as	Silver bluestem	Bothriochloa laguroides		Yes		Yes	Yes
<u>18</u>	Canada wildrye	Elymus canadensis	FACU	Yes	Yes	Yes	
all	Prairie wildrye	Elymus virginicus	FACU	Yes	Yes	Yes	
	Green sprangletop	Leptochloa dubia		Yes		Yes	
	Little bluestem	Schizachyrium scoparium	FACU		Yes	Yes	Yes
	Indiangrass	Sorghastrum nutans	FACU			Yes	Yes

			Wetland				
ies			Indicator		Shade	Habitat	Ornamental
tgrasses	Species	Scientific name	Status	Colonizer	tolerant	value	value
LB:	Buffalograss	Bouteloua dactyloides	FACU			Yes	Yes
ort	Blue grama	Bouteloua gracilis				Yes	Yes
Sh	Texas grama	Bouteloua rigidiseta				Yes	Yes
	Curly mesquite	Hilaria belangeri				Yes	Yes

# appendix c plant list - upland/riparian canopy

			Wetland				
ses			Indicator		Shade	Habitat	Ornamental
tgrasses	Species	Scientific name	Status	Colonizer	tolerant	value	value
5	Buffalograss	Bouteloua dactyloides	FACU			Yes	Yes
L0	Blue grama	Bouteloua gracilis				Yes	Yes
Sh	Texas grama	Bouteloua rigidiseta				Yes	Yes
•••	Curly mesquite	Hilaria belangeri				Yes	Yes

			Wetland				
			Indicator		Shade	Habitat	Ornamental
	Species	Scientific name	Status	Colonizer	tolerant	value	value
	Purple threeawn	Aristida purpurea	UPL			Yes	Yes
S	Silver bluestem	Bothriochloa laguroides				Yes	
Midgrasses	Sideoats grama	Bouteloua curtipendula		Yes		Yes	Yes
ູ່ອຸດ	Buffalograss	Buchloe dactyloides				Yes	
<u>6</u>	Inland seaoats	Chasmanthium latifolium	FAC		Yes	Yes	Yes
lic	Prairie wildrye	Elymus canedensis	FACU	Yes		Yes	
2	Green sprangletop	Leptochloa dubia				Yes	
	Lindheimer's muhly	Muhlenbergia lindheimeri	FACW			Yes	Yes
	Texas wintergrass	Nasella leucotricha			Yes	Yes	
	Texas bluegrass	Poa arachnifera			Yes	Yes	Yes
	Foxtail grass	Setaria scheelei			Yes	Yes	Yes

S	Species	Scientific name	Wetland Indicator Status	Colonizer	Shade tolerant	Habitat value	Ornamental value
Se	Big bluestem	Andropogon gerardii	FACU			Yes	
as	Silver bluestem	Bothriochloa laguroides		Yes		Yes	Yes
28	Canada wildrye	Elymus canadensis	FACU	Yes	Yes	Yes	
Tallgrasses	Prairie wildrye	Elymus virginicus	FACU	Yes	Yes	Yes	
⊢ –	Green sprangletop	Leptochloa dubia		Yes		Yes	
	Little bluestem	Schizachyrium scoparium	FACU		Yes	Yes	Yes
	Indiangrass	Sorghastrum nutans	FACU			Yes	Yes

# appendix c plant list - upland/riparian canopy

			Wetland				
			Indicator		Shade	Habitat	Ornamental
	Species	Scientific name	Status	Colonizer	tolerant	value	value
	Horseherb	Calyptocarpus vialis	FAC		Yes	Yes	Yes
	Indain paintbrush	Castilleja indivisa	FAC			Yes	Yes
	American basketflower	Centaurea americana				Yes	Yes
	Partridge pea	Chamaecrista fasciculata	FACU	Yes		Yes	
	Goldenwave	Coreopsis basalis					Yes
	Plains coreopsis	Coreopsis tinctoria	FAC			Yes	Yes
	Scrambled eggs	Corydalis curvisiliqua					Yes
	Illinois bundle flower	Desmanthus illinoensis	FACU	Yes		Yes	
S	Engelmann's daisy	Engelmannia peristenia				Yes	Yes
Forbs	Eryngo	Eryngium leavenworthii				Yes	Yes
Ō	Snow on the mountain	Euphorbia marginata	FACU				Yes
-	Indian blanket	Gaillardia pulchella	UPL	Yes		Yes	Yes
	Maximillian sunflower	Helianthus maximiliani	FACU			Yes	Yes
	Standing cypress	Ipomopsis rubra		Yes		Yes	Yes
	Texas yellowstar	Lindheimera texana				Yes	Yes
	Bluebonnet	Lupinus texensis					Yes
	Horsemint	Monarda citriodora	UPL			Yes	Yes
	Frogfruit	Phyla nodiflora	FAC		Yes	Yes	Yes
	Mexican hat	Ratibida columnifera		Yes		Yes	Yes
	Black-eyed Susan	Rudbeckia hirta	FACU			Yes	Yes
	Tall goldenrod	Solidago altissima	FACU	Yes		Yes	Yes
	Giant spiderwort	Tradescantia gigantea			Yes	Yes	Yes
	Pink evening primrose	Oenothera speciosa		Yes		Yes	Yes

			Wetland				
			Indicator		Shade	Habitat	Ornamental
	Species	Scientific name	Status	Colonizer	tolerant	value	value
	American beautyberry	Callicarpa americana	FACU		Yes		Yes
S	Cenizo	Leucophyllum candidum				Yes	Yes
Shrubs	Agarita	Mahonia trifoliolata			Yes	Yes	Yes
, L	Turks cap	Malvaviscus arboreus	UPL		Yes	Yes	Yes
S	Pigeonberry	Rivina humilis	FAC		Yes	Yes	Yes
	Palmetto	Sabal minor	FACW		Yes		Yes
	Tropical sage	Salvia coccinea					Yes
	Mealy bluesage	Salvia farinacea					Yes
	Heartleaf skullcap	Scutellaria ovata	FACU		Yes		Yes

			Wetland Indicator		Shade	Habitat	Ornamental
	Species	Scientific name	Status	Colonizer	tolerant	value	value
	Sugar hackberry	Celtis laevigata	FAC	Yes	Yes	Yes	
6	Texas ash	Fraxinus albicans	FACU		Yes	Yes	Yes
Trees	Sycamore	Platanus occidentalis	FAC			Yes	Yes
L P	Texas red oak	Quercus buckleyi			Yes	Yes	Yes
	Bur oak	Quercus macrocarpa	FACU			Yes	Yes
	Post oak	Quercus stellata	FACU			Yes	Yes
	Live oak	Quercus virginiana	FACU			Yes	Yes
	American elm	Ulmus americana	FAC			Yes	Yes
	Cedar elm	Ulmus crassifolia	FAC	Yes	Yes	Yes	Yes

# appendix c plant list - upland/riparian canopy LID feature

) S	Species	Scientific name
es/ ubs	Possumhaw holly	Ilex decidua
hr hr	Sycamore	Platanus occidentalis
	Bald cypress	Taxodium distichum

S	Species	Scientific name
цр.	Inland sea oats	Chasmanthium latifolium
		Andropogon glomeratus
1	Upland switchgrass	Panacum virgatum
sses	Indiangrass	Sorghastrum nutans
SS E	sedges	Carex spp.
) ra	Obedient plant	Physostegia angustifolia
U	Goldenrod	Solidago altissima

# appendix d

# **Publications**

# Design

Bisgrove, Richard. 1992. The Gardens of Gertrude Jekyll. Frances Lincoln Publishers, London, United Kingdom.

Eckbo, Garrett. 2002. Landscape for Living. University of Massachusetts Press, Amherst, Massachesetts.

Oudolf, Piet and Noel Kingsbury. 2013. Planting: A New Perspective. Timber Press, Portland, Oregon.

Rainer, Thomas and Claudia West. 2015. Planting in a Post-Wild World: Designing Plant Communities for Resilient Landscapes. Timber Press, Portland, Oregon.

# Plants

Fleenor, Scott and Stephen W. Taber. 2009. Plants of Central Texas Wetlands. Texas Tech University Press, Lubbock, Texas.

Nueces River Authority. 2015. Your Remarkable Riparian: A Field Guide to Riparian Plants Within the Nueces River Basin of Texas. Nueces River Authority.

Wasowski, Sally and Andy Wasowski. 2008. Native Texas Plants: Landscaping Region by Region. Lone Star Books, Lanham, Maryland.

# Restoration

Biebighauser, Thomas. 2011. Wetland Restoration and Construction: A Technical Guide. Thomas Biebighauser Publisher, China.

Helzer, C. 2010. The Ecology and Management of Prairies in the Central United States. University of Iowa Press, Iowa City, Iowa.

Maywald, P.D. and D.L. Doan-Crider. Restoration Manual for Native Habitats of South Texas. Caesar Kleberg Wildlife Research Institute. Texas A&M University – Kingsville, Texas.

Whisenant, Steven. Repairing Damaged Wildlands: A Process Orientated, Landscape-Scale Approach. 2005. Cambridge University Press: New York City, New York.

# Soils

Urban, James. 2008. Up by Roots: Healthy Soils and Trees in the Built Environment. International Society of Arboriculture. Champaign, Illinois.

# Websites

Managing Riparian Habitats For Wildlife – Texas Parks and Wildlife Department https://tpwd.texas.gov/publications/pwdpubs/media/pwd\_br\_ w7000\_0306.pdf

Texas wildscapes: Texas Parks and Wildlife Department http://tpwd.texas.gov/huntwild/wild/wildlife\_diversity/wildscapes/

Native Texas Lawns - Lady Bird Johnson Wildflower Center http://www.wildflower.org/habiturf/

Recreating a Prairie – Lady Bird Johnson Wildflower Center http://www.wildflower.org/howto/show.php?id=22

Your Remarkable Riparian – Nueces River Authority http://www.remarkableriparian.org/index.php

Riparian Zone Restoration – City Of Austin Watershed Protection Department https://www.austintexas.gov/faq/riparian-zone-restoration

City of Austin Invasive Species Management Plan https://austintexas.gov/sites/default/files/files/Watershed/invasive/

# COA-ISMP-Final-7-11-12.pdf

Central Texas Invasive Plants Field Guide – City of Austin http://www.austintexas.gov/sites/default/files/files/Watershed/ invasive/2013\_Invasives\_guide\_small.pdf

USDA plants website http://plants.usda.gov/java/

Native Plant Information Network https://www.wildflower.org/plants/ https://www.wildflower.org/collections/collection. php?collection=centex\_wetland

Texas invasives http://texasinvasives.org/

# appendix e

Allan, J. D. 1995. Stream ecology: structure and function of running waters. Kluwer, Dordrecht, The Netherlands.

Allan, J. D., D. L. Erickson, J. Fay. 1997. The influence of catchment land use on stream integrity across multiple spatial scales. Freshwater Biology 37:149–61.

Army Corps of Engineers. Army Corps of Engineers - Regulatory guidance letters - ordinary high water mark identification [Internet]. 07/2005. Army Corps of Engineers.

Brode, J. M. and R. B. Bury. 1984. The importance of riparian systems to amphibians and reptiles. Pages 30-36 in R. E. Warner and K. M. Hendrix, eds. California riparian system: ecology, conservation, and productive management. Univ. of California Press: Berkeley.

Burk, J. D., G. A. Hurst, D. R. Smith, B. D. Leopold, and J. G. Dickson. 1990. Wild turkey use of streamside management zones in loblolly pine plantations. Proceedings of the National Wild Turkey Symposium 6:84-89.

Cardinale, B. J., J. E. Duffy, A. Gonzalez, D. U. Hooper, C. Perrings, P. Venail, A. Narwani, G. M. Mace, et al. 2012. Biodiversity loss and its impact on humanity. Nature: 486:59–67. doi: 10.1038/nature11148.

Dickson, J. G. 1989. Streamside zones and wildlife in southern U.S. forests. Pages131-133 in Greswell, R. E., and B. Kershner, eds. Practical approaches to riparian resource management: an educational workshop. U.S. Bureau of Land Management, Billings, Montana.

Dickson, J. G., and J. C. Huntley. 1987. Riparian zones and wildlife in southern forest: the problem and squirrel relationships. Pages 37-39 in J.G. Dickson and O. E. Maughan, eds. Managing southern forests for wildlife and fish. U.S. Forest Service. Gen. Tech. Rep. SO-65.

Eckbo, Garrett. 2002. Landscape for living. University of Massachusetts Press, Amherst, Massachusetts.

Fleenor, S. B., and S. W. Taber. 2009. Plants of Central Texas wetlands. Texas Tech. University Press, Lubbock, TX.

Grayson, J. E., M. G. Chapman, and A. J. Underwood. 1998. The assessment of restoration of habitat in urban wetlands. Centre for Research on Ecological Impacts of Coastal Cities, Marine Ecology, University of Sydney, Sydney, Australia.

Gregory, S. V., F. J. Swanson, W. A. McKee and K. W. Cummins. 1991. An ecosystem perspective of riparian zones. Bioscience 41:540-551.

Griffith, G. E., et al. 2004. Ecoregions of Texas. Environmental Protection Agency, Western Ecology Division. Halls, L. K. 1973. Managing deer habitat in loblolly-shortleaf pine forest. Journal of Forestry 71:752-757.

Helzer, C. 2010. The ecology and management of prairies in the Central United States. University of Iowa Press, Iowa City, IA.

Henley, W. F., M. A. Patterson, R. J. Neves, and A. D. Lemly. 2000. Effects of sedimentation and turbidity on lotic food webs: a concise review for natural resource managers. Reviews in Fisheries Science 8 (2):125-139.

Holcomb, S. S. 2004. An examination of the riparian bottomland forest in North Central Texas through ecology, history, field study, and computer simulation (Master's thesis). University of North Texas, Denton, TX.

Johnson, L. B. 1966. Public Papers of the Presidents of the United States: Lyndon B. Johnson, 1965. Volume II, entry 576, pp. 1072-1075. Government Printing Office, Washington, DC.

Jones-Lewey, M. E. S. (2015) Your remarkable riparian: a field guide to riparian plants within the Nueces River Basin of Texas, Nueces River Authority. Uvalde, TX.

Kutac, E. A., and S. C. Caran. 1994. Birds and other wildlife of South Central Texas: a handbook. The University of Texas, Austin, TX.

Leopold, Aldo. 1933. Game management. Charles Scribner's Sons, N.Y. Reprinted in 1986 by University of Wisconsin Press, Madison, WI.

Lowrance, R. T., J. Fail, Jr., O. Hendrickson, Jr., R. Leonard, and L. Asmussen. 1984. Riparian forest as nutrient filters in agricultural watersheds. Bioscience 34:374-377.

Maser, C., and J. Sedell. 1994. From the forest to the sea: the ecology of wood in streams, rivers, estuaries, and oceans. St. Lucie Press: Delray Beach, FL.

Mayer, P., S. Reynolds and T. Canfield. United States Environmental Protection Agency Office of Research and Development. 2005. Riparian buffer width, vegetative cover, and nitrogen removal effectiveness: a review of current science and regulations. http://www.epa.gov/nrmrl/ pubs/600R05118/600R05118.pdf)

Maywald, P. D., and D. L. Doan-Crider. Restoration manual for native habitats of South Texas. Caesar Kleberg Wildlife Research Institute. Texas A&M University, Kingsville, TX.

Messina, M. G., and W. H. Conner, eds. 1998. Southern forested wetlands: ecology and management. Lewis Publishers, Boca Raton, FL.

Native Prairie Association of Texas. Tallgrass restoration manual. (http://texasprairie.org/index.php/manage/restoration\_entry/tallgrass\_restoration\_manual/)

# appendix e

Nelle, S. 2009. Common plants of riparian areas--Central--Southwest Texas with Wetland Indicator (WI) and proposed stability rating (SR). Natural Resources Conservation Service, San Angelo, TX. Contact: steve.nelle@tx.usda.gov.

Rudolph, D. C., and J. G. Dickson. 1990. Streamside zone width and amphibians and reptiles abundance. Southwestern Naturalist 35:472-476.

Sala, O. E, F. S. Chapin, J. J. Armesto, E. Berlow, J. Bloomfield, R. Dirzo, E. Huber-Sanwald, L. F.Huenneke, et al. 2000. Global biodiversity scenarios for the year 2100. Science 287:1770–1774. doi: 10.1126/science.287.5459.1770.

Shirley, S. 1994. Restoring the tallgrass prairie. University of Iowa Press, Iowa City, IA.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. 1974. Hays County Texas soil survey.

Strayer, D. L., R. E. Beighley, L. C. Thompson, S. Brooks, C. Nilsson, et al. 2003. Effects of land cover on stream ecosystems: roles of empirical models and scaling issues. Ecosystems 6:407–23.

Sustainable Site Initiative. 2014. SITES V2 Reference Guide for sustainable land design and development. The Lady Bird Johnson Wildflower Center at The University of Texas. Urban, J. 2008. Up by roots: healthy soils and trees in the built environment. International Society of Arboriculture. Champaign, IL. U.S. Botanical Garden and Lady Bird Johnson Wildflower Center. 2014. Landscape for Life – based on the principals of the Sustainable Site initiative.

Wagner, M. 2003. Managing riparian habitats for wildlife. Texas Parks and Wildlife Department. PWD BR W7000-306.

Wanielista, M. P., N-B. Chang, M. Chopra, Z. Xuan, K. Islam, and Z. Marimon. 2012. Floating wetland systems for nutrient removal in stormwater ponds. Stormwater Management Academy Civil, Environmental, and Construction Engineering Department, University of Central Florida, Orlando, FL.

Whisenant, S. 2005. Repairing damaged wildlands: a process orientated, landscape-scale approach. Cambridge University Press: New York, NY.

Williams, J. E., C. A. Wood, and M. P. Dombeck, eds. 1997. Watershed restoration: principles and practices. American Fisheries Society, Bethesda, MD.

Woodson, D. 2013. Irrigation efficiency. Lecture conducted at the Texas AgriLife Research and Extension, Dallas, TX.