Houston Parks Board, Wetland Restoration and Management Best Management Practices

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This Wetland Restoration Best Management Practice is meant to provide a framework for restoration practices and principles. The habitat BMPs serve to provide a foundation to a growing program to promote continuity for all staff and ensure a cohesive approach. This serves as a land management document providing an initial restoration toolbox. The BMPs are broad recommendations and should be viewed as starting the process for restoration. Every site is unique and it will be up to the discretion of the conservation team to implement these BMPs in the most appropriate way given the conditions. This BMP is a living document that will be updated overtime as the HPB learns more through implementation and management.

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B. Ecological context and definitions

Wetlands are extremely valuable ecosystems that provide important benefits to humans and other wildlife. Wetland ecology is a relatively new science and definitions vary among organizations and sources. Some of this might be in part because wetlands are the intersection between aquatic and terrestrial ecosystems and contain characteristics of both and therefore are often overlooked by terrestrial and aquatic scientists. Inundation by water is the main defining characteristic which then influences the soils and vegetation. A broad definition of wetlands is provided below:

Wetland

> An ecosystem that arises when inundation by water produces soils dominated by anaerobic processes, which, in turn, forces that bioata, particularly rooted plants, to adapt to flooding. (Paul Keddy Wetland Ecology 2010)

Due to wetlands association with the Earth's irregular topography and therefore holding water for different periods of time, wetlands are widely distributed across the Earth[1]. In *Classification of Wetlands and Deepwater Habitats of the United States* (1979), the USFWS presented a hierarchical system based on five ecosystem types: marine, estuarine, riverine, lacustrine, and palustrine. This can be more broadly categorized into two groups interior (freshwater) and coastal (saltwater) wetlands. The Greater Houston area has both.

Given the proximity to the coast and weather patterns, Houston has a significant number of wetlands. In the Houston area, according to Houston Wilderness *Atlas of Biodiversity*[2] wetlands are located in the inland prairie as part of the landscape complex of pimples and dimples and are often called prairie potholes. Wetlands are also found along riparian systems in floodplains, within wooded swamps, and in coastal marshes as bands along the coast.

[1] https://www.britannica.com/science/wetland/Geographic-distribution-of-wetlands#/media/1/641299/40

[2] https://houstonwilderness.org/coastal-marshes

In part, due to the subtle nature of wetlands, wetland loss is happening at an alarming scale and rate. According to the EPA, the United State loses about 60,000 acres of wetlands each year[3]. Wetlands are sensitive environmental features that can be negatively affected by pollution, climate change, development, and water level changes. Using a Precipitation Topographic Wetness Index (PTWI) and global remote sensing training samples it is estimated that the earth would have had, before human intervention, approximately 29.83 million km2 of wetlands. As of 2009, at least 33% of global wetlands have been lost (Hu et al. 2017).

Low Impact Development (LID)

Beyond wetland restoration and creation, properties should be evaluated for other innovative opportunities to restore and improve hydrological function. Because upland areas contribute and drain to Houston's Bayous, slowing surface flow from locations such as parking lots, turf areas, and buildings through distributed vegetated systems are integral to the larger riparian health and function of the river and to the watershed as a whole.

LID

> LID is a comprehensive hydrological approach to site planning, design and pollution prevention strategies that creates 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
- Creates functional and appealing site drainage
- Keeps water on the site and allows infiltration into soils
- Recharge groundwater and the aquifer (where appropriate)
- Require site installation techniques be more thoughtful of hydrology
- The ability to increase infiltration (if they will be filtration features)
- Define the desired performance goals of the LID feature and provide quantitative data

Rain gardens

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

[3] https://www.epa.gov/wetlands/wetlands-factsheet-series

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.

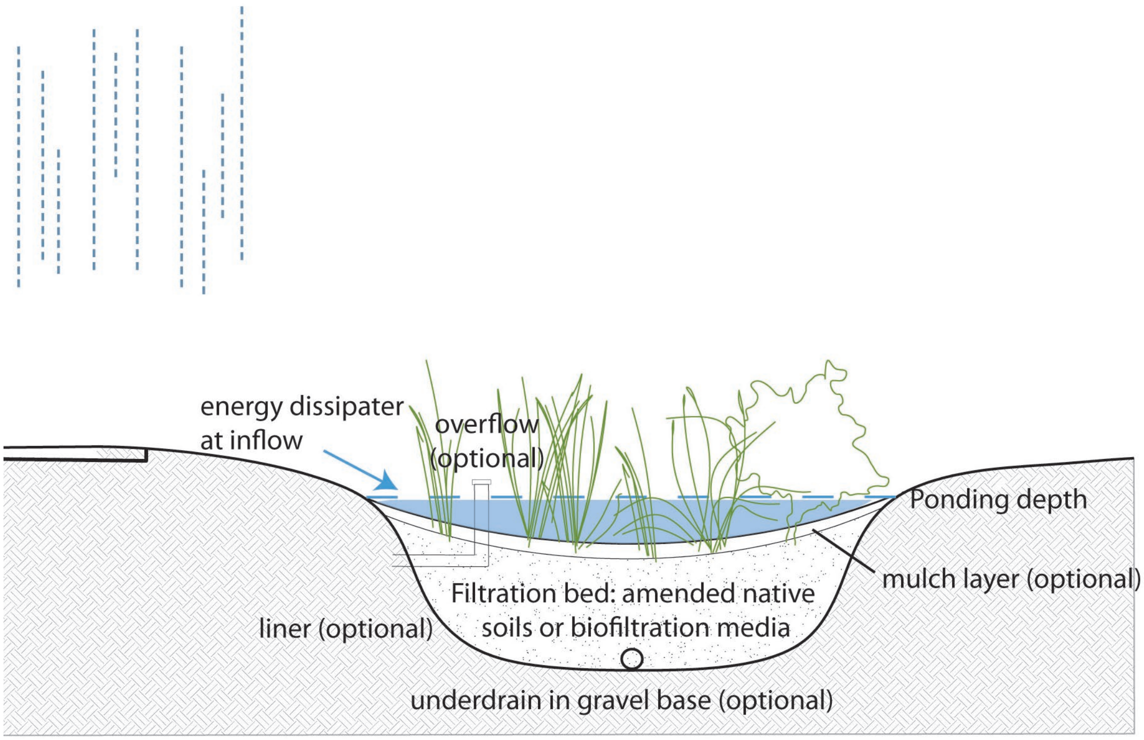

Figure 1. A diagram of the basic rain garden / bioretention system components, including optional components (Blackland Collaborative)

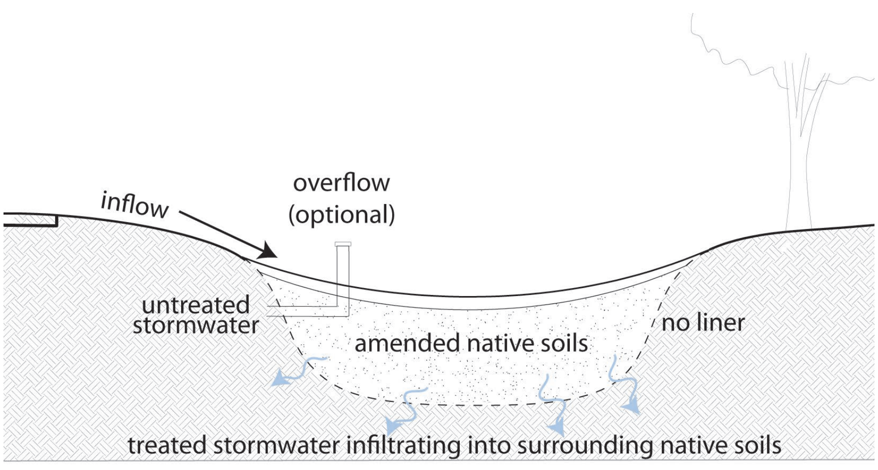

Figure 2: Rain garden schematic with no underdrain (Blackland Collaborative)

Bioswales

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.

C. Value and ecosystem services

Ecosystem Services

Ecosystem services are services that nature provides for free that humans rely on to live such as cleaning air and water, providing food, regulating temperatures, and improving mental health and wellness.

Wetlands are some of the most productive ecosystems in the world[4]. They are highly biodiverse systems and provide critical habitat for fish and wildlife. Wetland benefits include storing floodwaters, maintaining surface water flow during dry periods, protecting, and improving water quality and providing fish and wildlife habitat[5]. Wetlands are an important part of the watershed ecology. Wetlands are also excellent at carbon sequestration which helps to regulate thermal temperatures.

LID reduces the volume and rate of stormwater runoff and attempts to restore the predevelopment hydrograph. Similar to wetlands, LID allows water to infiltrate and be cleansed as well. Depending upon its structure, LID allows water to recharge groundwater that was previously being piped into streams and channels causing erosion and significant habitat damage. LID can help reduce the impacts of flooding and associated property damage[6]. Total suspended solids (TSS) reduction of 85-90% is readily achievable with LID practices. Treatment systems that rely on infiltration as the primary process for removing solids in stormwater typically achieve a reduction of approximately 90%. Wetlands also achieve this level of performance. Pollutant removal and abatement is more readily achievable when LID practices include both media and robust vegetation, rather than just media (such as sand) or a singular plant species. Recent, local research demonstrated that removal of TSS, phosphorous, nitrogen, and fecal coliform from vegetated columns was consistently greatly than from columns with no vegetation (LBJWC 2011).

Additionally, all green spaces provide valuable ecosystem services such as reducing the heat island effect and improving air quality (Bellaire 2019). It is additionally important to not consider these habitats in isolation and understand that they function most optimally when connected and implemented in a holistic way. The management BMPs outlined in this manual are designed to protect, enhance, or rebuild the ability of wetlands and LID to provide these and other services.

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[4] https://www.epa.gov/wetlands/how-do-wetlands-function-and-why-are-they-valuable
[5] https://tcwp.tamu.edu/wetland-education/
[6] https://www.nrcs.usda.gov/wps/portal/nrcs/detail//?cid=nrcs142p2_008519

D. Sustainable development

Sustainable development protects and enhances ecological function while integrating it with human use. The following process (Figure 3) illustrates sustainable development and ecological restoration principles as pertains to wetland restoration and LID implementation and integration into HPB projects. As mentioned previously, success requires a holistic approach. The sequencing timeline below outlines the general progression of activities for a project from consideration for acquisition through the initial stages of maintenance.

E. Project Sequencing

Restoration as a practice is a trajectory, which lacks a defined end point since the restoration process revolves around restoring ecosystem function and natural systems that have cycles of activity. It is always possible to lose a restoration no matter how long it has been established. Maintenance begins with site preparation and never ends as it evolves from establishment to an iterative process of adaptive management. Establishing the monitoring program as early as possible will also benefit the project flow and capacity to gather valuable information that will inform management decisions.

Adaptive management

Adaptive management is a management approach that acknowledges uncertainty in ecological systems and reduces uncertainty by using a problem-solving management approach. The focus is on learning about the system and how to best change the system. The process for adaptive management is circular in nature starting with assessment, design, implementation, monitoring, evaluation, and adjusting. Adaptive management is a hybrid of management and research (Murrary and Marmorek 2003).

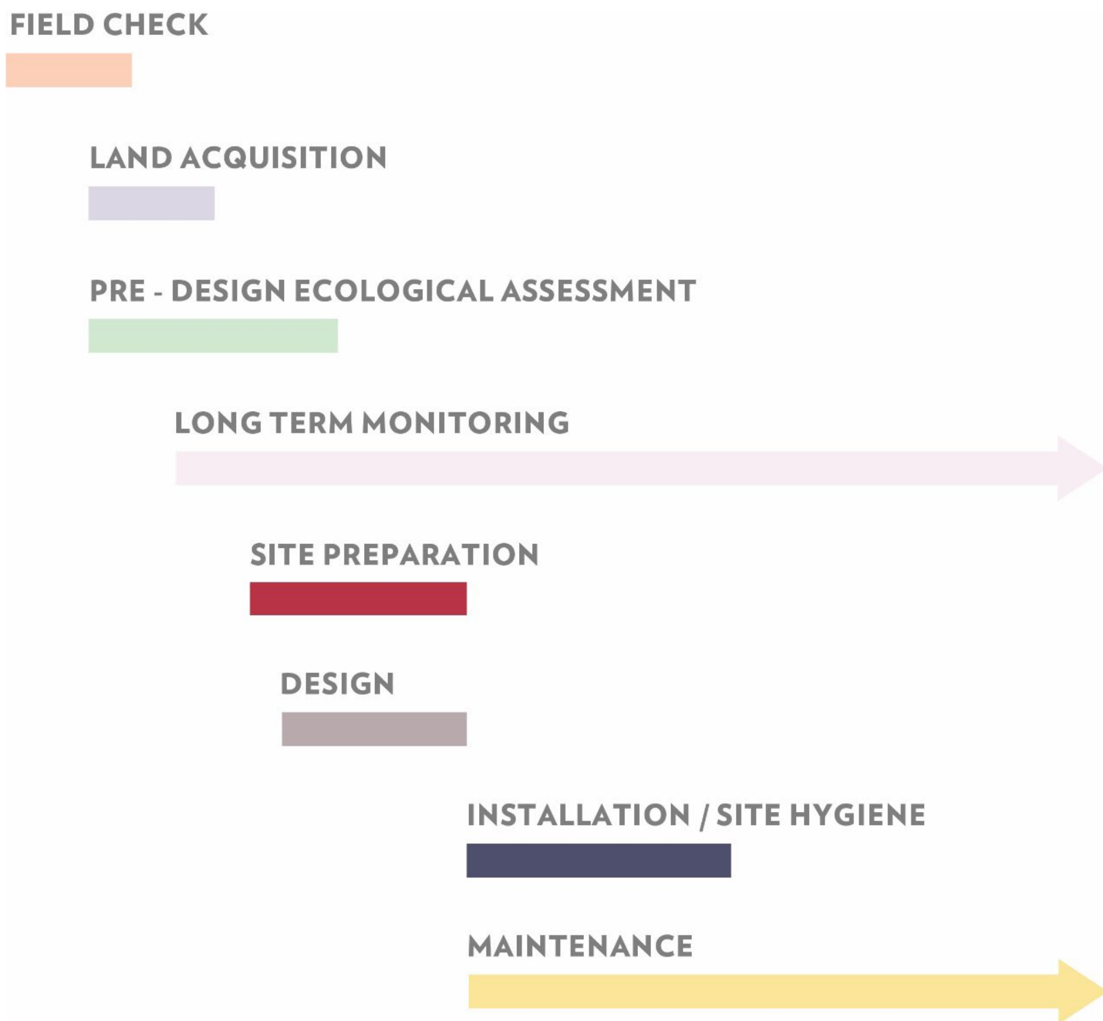

Figure 3 Project Sequencing and Major Milestones

Major questions and actions for each phase:

Pre-design

- What are the habitat types and what condition is it in?
- What are the opportunities and performance goals?
- Are there special considerations for this site that would shape our planning?

Metrics and Monitoring

- Set the program up early to get baseline data and have as long of data collection as possible.

Design

- Where is the optimal placement and layout for optimal ecosystem function and maintenance success.

Site Preparation and Installation

- **Scheduling enough time to prepare the site soils and gather plant materials.** Installing in an ideal sequence to vegetate as soon as possible.

- Maintain good site hygiene during installation.

Maintenance and Management

- Maintenance, especially controlling invasive species, start once site preparation begins and continues through maintenance and adaptive management.
- Monitoring of performance will inform management activities which is part of the adaptive management process.

F. Restoring landscapes

The restoration techniques mentioned in this BMP are designed to guide conservation staff in the process of repairing land or converting resource-intensive landscapes into areas that are both beautiful and best suited to perform ecosystem services. The species listed in this document evolved in disturbance-driven ecosystems that included wildfire and floods and are best adapted to contribute towards the recovery of ecosystem services. Houston Parks Board staff should note that the transition of a site from a degraded state dominated by invasive plant growth or severe erosion will be challenging and take a concerted effort that involves biotic and abiotic manipulation. 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 of 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).

During the restoration process. it is very likely that the best laid plans will face setbacks and that multiple efforts will be required to achieve success. Ecosystems are dynamic entities consisting of complicated networks of interconnected biotic and abiotic components. By slowing water and keeping 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, conservation staff will make a major difference over time and help mitigate damage from future climatic events. This is not to say that restoration will completely prevent damage, but by embracing these measures, the residents of Houston will be able to enjoy a more diverse, healthy, and functional urban landscape and contribute towards an overall improvement of their urban habitats.

II. Site Assessment

When evaluating the site to determine the appropriate ecosystem, it is important to look at the historical ecological condition of the greater Houston area as a reference. Understanding the ecological condition at a regional scale informs the restoration target at a project level. The Houston region is one of the most diverse urban areas in the United States. According to Houston Wilderness ecological classifications in the Gulf-Houston Region are composed of ten ecoregions. Seven of the ecoregions are land-based and three are water-based (Figure 4). [Houston Wilderness] defines ecoregions as large areas of land or water that contain geographically distinct assemblages of species, natural communities, and environmental conditions.

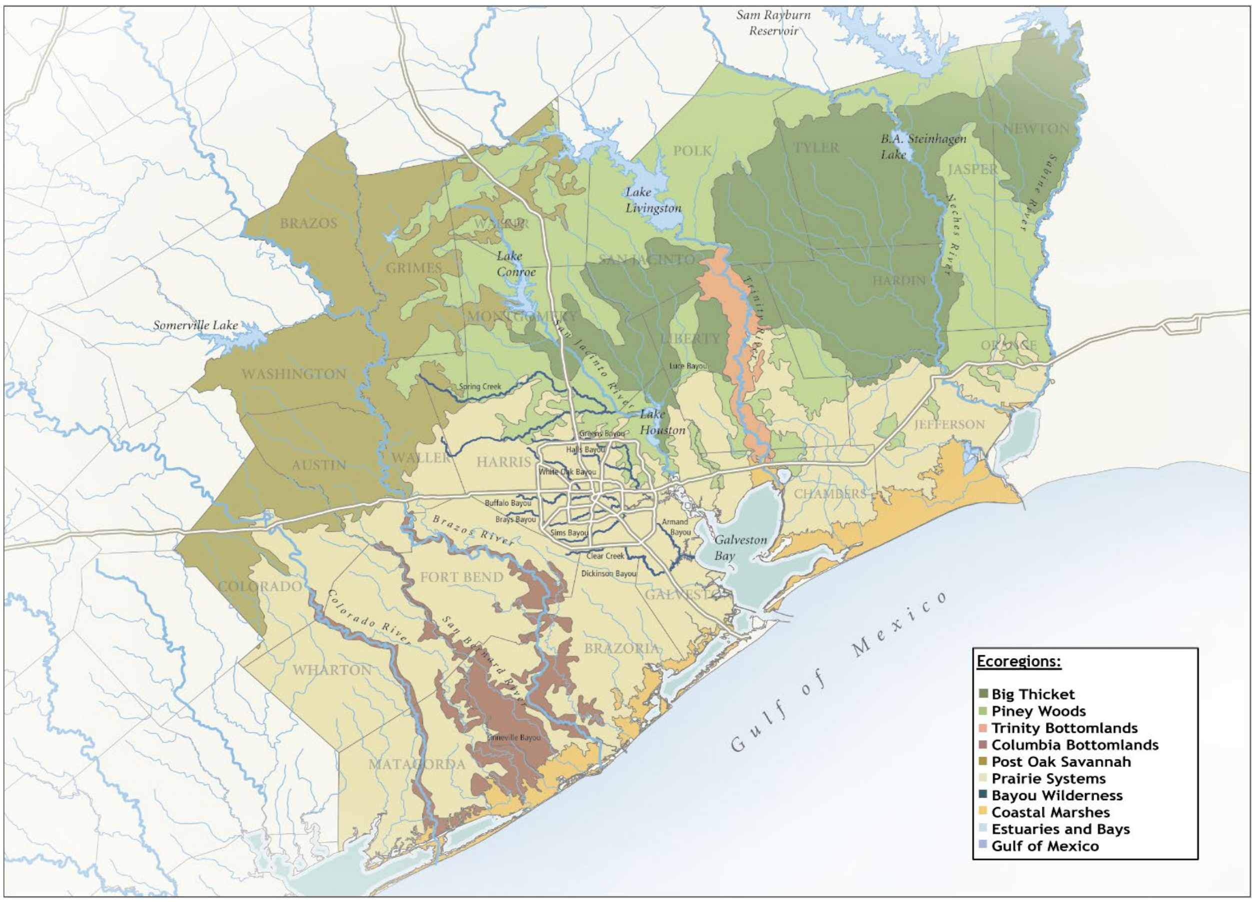

Figure 4. Houston area ecoregion map.

Based on the regional information, HPB conservation program is restoring and managing for 5 different habitat types that provide critical ecosystem services. *Ecosystem services are services that nature provides for free that we rely on to live such as cleaning air and water, providing food, regulating temperatures, and improving mental health and wellness.* These habitat types are prairie, woodland/forest, wetland, riparian, and native landscapes. Prairies were once the dominant ecosystem of the greater Houston region. Woodland to the northeast, northwest, and along lower lying riparian areas is the second most significant ecosystem. Wetlands and riparian habitats (especially along the bayous) are dispersed throughout the landscape and play critical roles in mitigating flooding and improving water quality. Lastly native landscapes are planted areas that are more horticulturally based but use native and adapted plant communities to help provide needed ecosystem services.

Protecting, restoring and building ecological health requires a detailed understanding of the site's condition, its processes and how it is changing over time. Several types of site assessment are needed for different phases in a project from acquisition through maintenance. Three types of site assessment are needed for basic operations (field check, predesign ecological assessment, maintenance assessments). These assessments inform operational and maintenance decisions and track project status. Additionally, a long-term monitoring program is needed to track how the program is reaching conservation and HPB goals. The long-term monitoring program can also provide practical information to inform future restoration efforts within HPB and efforts of other conservation organizations. Table II.1 below summarizes the assessment types.

The field check, pre-design ecological assessment, and maintenance rapid assessment will be discussed in this Site Assessment section. The Monitoring Protocol will be discussed in its own section.

Table 1. Site assessment types

Name	Project Phase	Purpose	Data gathered
Field Check	Pre-acquisition	Gather preliminary data on habitat value to be considered during purchase decisions	Community type, basic structure, dominant species, presence/absence of ecological assets/liabilities
Pre-design ecological assessment	Pre-design	Evaluate current ecological condition and identify opportunities and issues to be considered during design	Ecological context, vegetation community structure and composition, soil condition, hydrologic condition.
Maintenance rapid assessment	Post installation, ongoing	Monitor project condition and identify maintenance needs	Plant health, invasive species presence/expansion, soil condition including erosional features
Monitoring protocol	Initiate prior to installation, repeat periodically for life of project	Evaluate contribution to Ecological goals, provide data on restoration evolution	Species use as habitat, soil condition, community complexity, species diversity, connectivity, heat.

I. Field check

The Field Check occurs during the acquisition process. This is a high-level check intended to be performed during initial consideration of a property, in coordination with Capital's initial assessment. The goal is to obtain a high-level understanding of the site's existing condition, possible value, and liabilities from an ecological perspective. This is a windshield survey identifying the following parameters:

- Community Structure: Woodland, Savanna, Prairie, Wetland, Urban condition (% canopy)
- Dominant species in each layer
- Approximate percentage of invasive species, native species
- Presence of rare or valuable species/communities
- Presence of factors that will complicate restoration/management efforts such as severe erosion, substantial presence of invasive species, problematic adjacent properties etc.
- Presence of factors that will assist restoration/management efforts
- Presence/extent/severity of soil erosion

An example data sheet for a rapid assessment and erosion assessment is found in Appendix A: Data Sheets.

B. Pre-design ecological assessment

The predesign ecological assessment evaluates the site's current ecological condition and identifies opportunities for improving ecological health, sensitive features, and liabilities such as damaged soil and invasive species. It is important that this assessment occurs before design to ensure that planned restorations, as well as features such as paths and other amenities, are optimally placed within the landscape.

One of the main reasons for doing a Pre-Design Site Assessment is to assess the ecological condition of the site to determine challenges and opportunities. The diagram below illustrates how ecological function exists on a spectrum (Figure 5). To the left is a fully functional condition and to the right is a nonfunctional system such as a parking lot. Understanding where the project is on this spectrum during all phases of the project's life is valuable to informing management decisions. The goal is to continually move the project up the spectrum towards the left. However, a variety of scenarios could impact the site's function such as a delay in construction leaving areas unvegetated, an extreme weather event, or an insect infestation. Being able to assess where the project is on this spectrum pre-design through the life space of the project will help inform necessary steps for improving the site's ecological function through adaptive management.

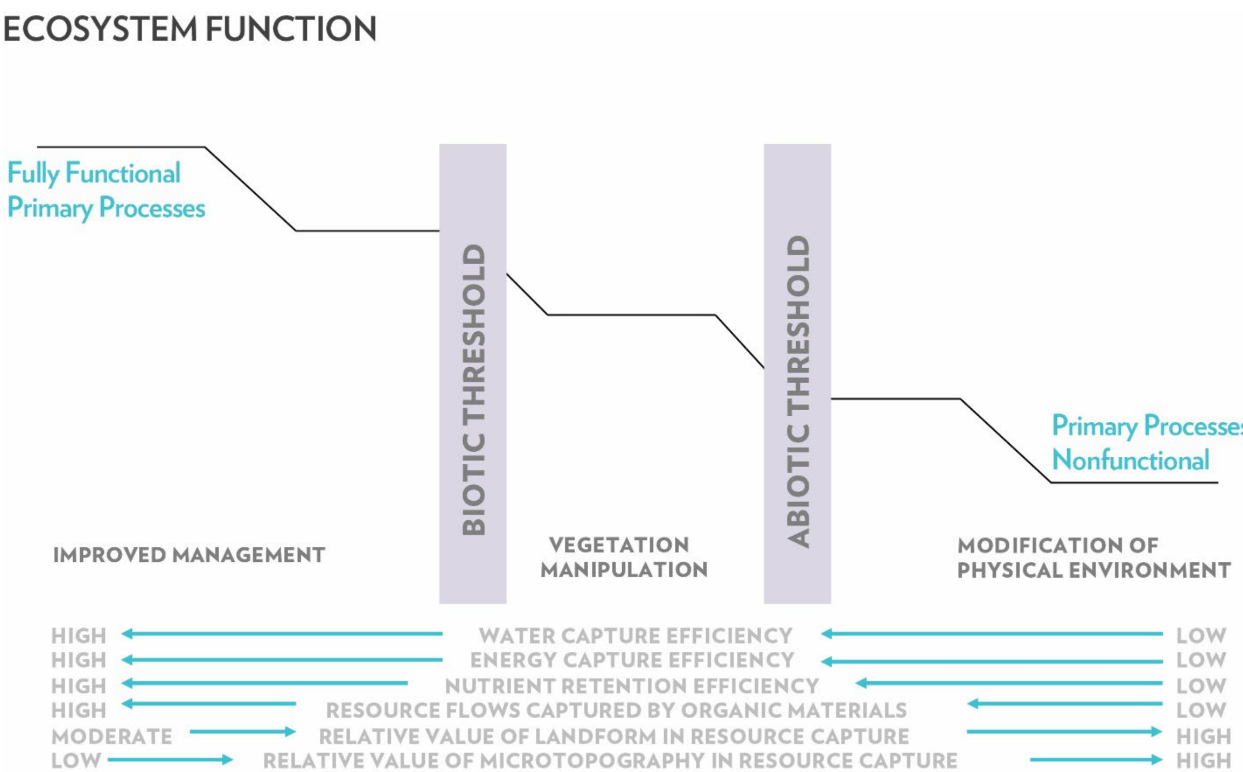

Figure 5. Ecological function. (Whisenant 2002)

Prior to the on-site portion of the assessment, the EPA Level III ecoregion, soils, ecological sites, flood plain, and stream network should be mapped. The Level III ecoregion provides an overview of the types of communities that would naturally occur for the area. Soils can be gathered from the USDA-NRCS soil survey. Soil information within the soil survey contains expected attributes for the soils on-site, which include texture, erodibility, and several classifications. One of the most important classifications from a restoration perspective is the Ecological Site. The ecological site description outlines the vegetative communities the site can support, including the historic or reference community, and provides a discussion of the ecological dynamics that shifts composition between these communities. It is one of the few nationally available resources that discusses ecological dynamics for a particular site. Soil survey information is available online at the Web Soil Survey[7]. More information on referencing the Ecological Site for restoration and long-term management can be found in the **HPB Habitat Maintenance and Management Guidelines** document. Once these elements have been mapped, the on-site portion of the site assessment can begin.

Once these elements have been mapped the on-site portion of the site assessment can begin. The on-site assessment can be divided into several parameters: Hydrology, Soils, Vegetation, and Site Context. These are specifically important when assessing a site in relationship to wetlands and LID placement.

Hydrology

- Map stream, wetland, shoreline, (Desktop exercise/field confirmation)
- Current overland flow direction (Desktop exercise/field confirmation). For wetlands, evaluating topography will inform where the water ponds. This, in addition with assessing the vegetation and soils, will indicate a wetland condition.
- Existing and potential pollution sources & and health hazards, on site and adjacent sites
- 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 is important to determine the water quality volume, the storage needed to capture and treat the runoff (based on local conditions), the sensitivity of the receiving body, and the desired performance goals of the BMP.

Soils

Reference regional soil maps and the USDA-NRCS soil survey and compare to existing conditions. Map healthy soils and disturbed soils to allow development of a soil management plan. An interpretation of soil sample findings is included below in the Installation section.

- Take composite soil samples within each soil type and vegetative community type. Obtain agricultural soil analysis of: organic matter, texture, macronutrients, micronutrients. The Texas A&M Agrilife Extension Soil Lab can perform testing. Soil sampling methodology is found in Appendix A: Data sheets and linked here: http://soiltesting.tamu.edu/files/websoilunified2021.pdf.

[7] USDA-NRCS Web Soil Survey. https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

- Soil samples are generally not needed for wetland assessments however it is important to note the soils texture. Sandy soils will not hold water sufficiently to create a wetland habitat. The soil needs to have high clay content so that water ponds for long enough time to have hydric soils and water loving vegetation. Soil type will also influence the LID design. LID features often have modified or engineered soils to increase infiltration though it is also possible to use native soils for some features. Soil infiltration rates will influence the features size to ensure it can capture the required water quality volume.
- Reviewing geo-tech reports when available is helpful information to find out where the water table is located and also what material is below the soil profile for LID features that will be infiltrating into native soil.
- Assess soil compaction through bulk density or soil cone penetrometer measurements. Penetrometer measurements are quick, but results will vary with soil moisture. Bulk density testing provides more robust measurements, but takes a bit more processing. This will be less important for wetlands but will impact infiltration. For LID features, it is important to make sure the soils are not compacted so that infiltration is able to occur.
- Bulk Density sampling methodology found in Appendix A: Data sheets, and is available here: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_019165.pdf
- Penetrometers test the pressure required to penetrate soil, providing quick, in situ information on soil compaction. Penetrometers are particularly useful during and after construction to assess compaction.
- Test soil infiltration. Infiltration testing methodology from NRCS USDA is found in Appendix A; Data sheets and is available here: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_052494.pdf Infiltration rates is important for both wetland and LID features.
- Assess % bare ground and compare to acceptable amount for Ecological Site in the Soil Survey
- Erosion: Assess extent, severity and type. Erosion evaluation datasheet found in Appendix A.
- Soil evaluations for wetlands includes looking for evidence of hydric soils.
- Pull a sample of the soil and look at the soil profile.
- Use a Munsell soil color chart to classify the soils based on the soil color[8]. Soils that are gray, or bluish to greenish-gray are indicators of anaerobic conditions.

Vegetation

Map:

- Threatened or endangered species habitat
- Zones of land cover/vegetation types. Note invasive species, native communities, special status plants and relative abundance classification (Abundant, common, frequent, occasional, rare). Take diameter breast height (DBH) for significant trees.
- Vegetative structure: % cover for overstory, mid-story, understory/herbaceous layer, litter cover, bare soil. Identify dominant species in each layer.

[8] https://munsell.com/color-blog/wetland-mitigation-soils/

- Identify wetland indicator species. A few common plants for HPB projects are *Phyla nodiflora* Texas frogfruit, *Cyperus entrerianus* Deep-rooted sedge, *Carex spp*, *Eleocharis spp*, and *Alternanthera philoxeroides* Alligator weed[9].

Site context

Take note of elements surrounding the site that will influence it. For example, a parking lot adjacent to the site that is channeling water into the site, or a dense stand of invasive species. These elements will need to be considered during design and maintenance planning.

The following equipment can facilitate the necessary data collection and determinations:

- Infiltrometor or Amoozemeter
- Slide-hammer or rings for bulk density
- Soil sampling bags/equipment (permanent marker, plastic bags, shovels)
- GPS
- Camera
- DBF tape
- Meter tape

[9] http://www.tsusinvasives.org/home/database/plants.html

C. Maintenance Rapid Assessment

The Maintenance Rapid Assessment follows the protocols of the Existing Prairie and Wetland Habitat Assessment Protocol (updated Feb 2020), with the addition of these parameters: Bare patches, failing planted species, erosion, human or maintenance factors impacting the community (social trails, offroading etc).

HPB Maintenance Rapid Assessment is included in Appendix A: Data sheets

III. Long-term Monitoring

For an ecological monitoring program to be successful over the long term, the benefits of the information must justify the cost. The most value will be provided by a monitoring program that allows HPB to track progress toward organizational goals, allows improvements to restoration and maintenance operations over time, and provides information to the larger conservation community to facilitate efforts across the greater Houston area. The largest single cost is data collection. However, the cost of data management, quality assurance, and analysis are equally important and are often neglected during monitoring program design (Caughlan & Oakley 2001). The ideal monitoring protocol is often cost prohibitive, and the quality and depth of data collected must be balanced with the time and effort required to collect it. In some Cases, easily measured parameters can be used as surrogates for more costly parameters.

It is unrealistic to monitor everything of interest, so statistical sampling should be included as part of the design. The HPB properties should be seen as a system, and sampling points should be selected to represent the system, not necessarily individual sites. A stratified sampling design ensuring each habitat type has adequate coverage is recommended. Replication over time is equally important. The correct sampling interval will detect changes over time but avoid oversampling. The appropriate interval depends on the parameter being sampled. Long-term changes in vegetation can be detected with yearly, or twice-yearly sampling soil changes occur more slowly and can be sampled every other year. Use of sites by target faunal species will be documented on a schedule timed to the life history of that species, or within an interval that will capture use by multiple species of interest. The framework for data collection is being created and established at this time. The earlier the framework is established the better the data will be overtime. Gathering baseline data is highly recommended whenever possible to have a comparison and reference point for ecosystem improvement.

In addition to formal observations and monitoring methods used by staff or partner organizations, less formal methods of citizen science data collection can be used to supplement these data.

- Photo monitoring points in which visitors take photos and link to a database, can provide ongoing monitoring as well as help tell the story of the site. An example of a photo-point protocol is the USGS Tidal Marsh Monitoring Program[10]. Another protocol example is the Photo-Point Standard Operating Procedures developed by USGS[11]. The Conservation Team should look at these examples in addition to other to create a photo monitoring program that suites their specific needs. More detailed information regarding the USGS method is included in the HPB BMP Management and Maintenance document.

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[10] http://www.tidalmarshmonitoring.net/pdf/USGS_WERC_Photo-Point_SOP.pdf

[11] US Geological Survey. 2012.

- Creation of a project within an application like iNaturalist can provide an informal, but quite useful, index of species present. “Friends” groups of trained volunteers can assist in monitoring for invasive species and other maintenance concerns.

Turnover in personnel is a constraint to long-term monitoring that can be mediated by selection of techniques that are less sensitive to differences in observers, and that are easily communicated to new staff/volunteers. Training observers is an important mechanism to reduce variability in observation.

Two critical components of a monitoring program are scientific oversight by a qualified person, ideally attached to the program for the long-term, and quality assessment (QA). For an ecological monitoring program QA means that the data are of known quality and meet the program’s needs. Quality controls (QCs) are an important part of QA and should be designed along with the monitoring protocol. This is especially true for HBP because multiple researchers, methodologies, and data types will be used. Using a QA plan can increase the cost effectiveness of the monitoring program.

Reporting of monitoring data is especially important. The audience for the HPB monitoring data is varied, including field staff making management decisions, managers reviewing budgets and making investment decisions, conservation organizations such as the Nature Conservancy looking to improve their own programs, as well as the general public. A basic reporting plan and budget should be developed during the creation of the monitoring program.

Possible models exist. One such model is the Waller Creek Biodiversity & Ecosystem Monitoring Project conducted by The Nature Conservancy (Belaire et al. 2018). This study demonstrates a straightforward way to monitor biodiversity and ecosystem services across a large area. The methods used could be modified to fit the needs of HPB.

I. Monitoring parameters

It is of utmost importance that each of the monitoring protocols outlined below support the Conservation Program’s Vision as well as HPB’s conservation messaging and outreach. Also of significance, is that the monitoring below aligns with the work and messaging of HPB’s partners. Partners can also benefit from HPB’s monitoring data as well as contribute to HPB’s data collection. Ultimately, the monitoring must feed into habitat conservation practices and inform adaptive management decisions. The main performance criteria the Conservation Team would like to monitor have been identified over a series of meetings with Blackland Collaborative. These are:

- Stormwater capture
- Biodiversity
- Habitat Connectivity
- Habitat Quality
- Heat Island Mitigation

Below the areas of research are described for their purpose, a proposed method for measurement, as well as potential issues. The Conservation Team will then take these frameworks and further develop the methods into a research framework that works best for the needs of the Conservation Team. The Conservation Team should consider the time of the year, data collection frequency, and general achievability based on staff availability in addition to getting the needed data to be able to make valuable conclusions regarding their management strategies.

Stormwater capture

Summary and purpose

The stormwater capture metric is about monitoring the site's capacity to slow down, hold, and infiltrate water. Since the majority of the Bayou Greenway locations are adjacent to bayou systems, having a performance goal focused on water movement and quality is a benefit to improving bayou ecosystem function. Furthermore, locating and designing all HPB's restoration projects with a watershed approach that aims to slow and capture stormwater as much as possible could have a positive impact on the Houston region that has high rainfall, is prone to flooding, and continues to increase impervious cover. As identified as one of City of Houston's Resilient Houston goals to complete 100 new green stormwater infrastructure projects by 2025, HPB projects are being recorded to help meet this goal. To be able to contribute performance data to the City of Houston, will help further inform future planning and initiatives to better improve ecosystem function in urban environments.

Measuring water quality most likely means following the City of Houston Code of Ordinances chapters 9 and 13[12] as well as Harris County's Low Impact Development and Green Infrastructure Design Criteria for Stormwater Management.

How we measure

Estimate the combined capacity of restored communities, green infrastructure practices such as rain gardens and infiltration basins, and traditional parkland. Tools are available such as the National Stormwater Calculator and the calculations available within the Sustainable Sites Initiative[13] to assist with this effort. Reasonable estimations of capture capacity for each habitat type will need to be assembled from existing literature or new experimental results[14].

Potential issues with this metric

These calculations are normally done by an engineer and sometimes with special software.

Biodiversity

Summary and purpose

[12] https://www.houstontx.gov/codes/
[13] https://sustainablesites.org/resources
[14] https://www.epa.gov/water-research/national-stormwater-calculator

In general, a more diverse ecosystem is a healthier ecosystem. Species diversity means more robust ecosystem services are provided and offered, and there is more resilience in the face of disaster.

The purpose of measuring biodiversity is to evaluate and hopefully show that HPB restoration projects are increasing wildlife and vegetation biodiversity, therefore creating a healthier urban habitat.

Formally sampling vegetation over time (to represent flora) and pollinators (to represent fauna) should be the priority. Organized bird observations with volunteers and other groups such as Houston Audubon and Master Naturalist to tally species are also high priority though data collection will not be as formalized.

Other wildlife monitoring would be supplemental to vegetation, pollinators, and birds. Though important, it seems challenging to collect this data without partnerships or more staff. Wildlife cameras wherever possible would be extremely beneficial.

<u>How we measure</u>

HPB conservation team is developing methods for assessing flora and fauna biodiversity and those methods should be referenced once fully developed. Below is a working methodology.

- Vegetation- a suggested framework has been proposed
    - Use the 9 bayous and their watersheds to organize the data collection.
    - A bayou as a sample area. If a project is not right on the bayou it can be included in the sample area of the closest bayou.
    - 3 bayous per year on a 3-year rotation to capture all the bayous and associated greenspaces.
    - 6 points per habitat type (4) = 24 points per bayou= 108 collection points per year.
    - Data collection can be done at organized times throughout the year- ie fall and spring and with interns/volunteers.
    - If a site is big enough and distinct from the bayou system, use the same structure as above- The site itself becomes a sample area and then sampled by habitat type (six samples of 4 habitat types) within that area- i.e. Cool-green.
    - As much as possible wildlife, vegetation, and pollinators data collection should be in the same area.
    - Establishing a control would be beneficial to the analysis of the data and for telling the performance story. An example control site could be sampling turf areas to compare performance.
    - Before beginning, reference maps and assign habitat types on them then establish sampling locations that you return to on a yearly basis.
    - Once the sample locations are established, put something physical in the ground to mark them such as orange forestry stake markers in addition to GPS points. It is recommended to locate the center of the sampling point in the middle of the habitat type- not randomly located.

    - Assign a central point and follow the radial methods defined in Houston Arboretum vegetation methods (Appendix B), which is based on the US Forestry methods. To get more data for the herbaceous layer, it is recommended to add more quadrats, specifically either define 4 other quads based on that central point or do a random scatter of quads around the point each time.

- Birds and pollinators
    - Pollinator and wildlife data should be collected in the same locations, if possible.
    - A pollinator method could be layered on the radial/quadrat method. Blackland can assist with developing a method.
    - Another option is following a pollinator-transect example titled Streamlined Bee Monitoring Protocol for Assessing Pollinator Habitat provided in (Appendix B). Other organizations in Houston are following this method. It is easy and fast. Since the method was established not in Texas, it is recommended to go out earlier in the day than what is specified.

<u>Potential Issues with this Metric</u>

Data on flora and fauna changes over time is useful information for storytelling and reaching out to the public about restoration improvements. The data collection can take time and needs to be replicated consistently.

Habitat Connectivity

<u>Summary and Purpose</u>

Connectivity can be defined as the capacity of the landscape to facilitate movement of species, resources, seed etc. between larger habitat patches. Connectivity supports migration and allows some species to effectively increase their habitat area. To continue the example from above, most wild bees need a patch size of 48 to 198 acres to fully support a population. However, much smaller patches are valuable as long as they are close enough that the bees can move between them, stepping-stone style. This metric is focused more on connectivity within the different projects rather than project wide.

The purpose of habitat connectivity metric is to increase connectivity within each HPB conservation project so that the layout, design, and maintenance considers wildlife movement through the different ecosystems.

<u>How we Measure</u>

- Pollinators – A body of research exists outlining the distances and floristic richness needed between patches of habitat to elevate the value of an area for pollinators. Key species can be selected, and connectivity evaluated based on the requirements of those species.
- Other species such as bats, reptiles, and select bird species can be included over time if there is capacity

<u>Potential Issues with this Metric</u>

Selecting the appropriate scale can be challenging. This metric would most likely be program-wide, and a summary would be done every few years. Partnering with professors would be the ideal way to do this.

Habitat Quality

Summary and Purpose

Habitat Quality is an important part of assessing ecological function.

Creating a Habitat quality index for the greater Houston region as mentioned in HPB high level metrics, is a need for multiple professionals to evaluate habitat function. Gathering habitat quality data at the project level could help contribute to this data need. Collaboration with other like-minded organizations and stakeholders is recommended to coordinate the collection of highest priority data, and organization and distribution of the data. A Nature Conservancy Biodiversity and Ecosystem Monitoring program conducted in Austin (Belaire et al. 2017, provided in Appendix B: Resources) provides a possible model.

How we measure

- Species diversity
- Community diversity
- % native
- Structural diversity, when appropriate
- Utilization by target species
- Soil quality

Potential issues with this metric

Habitat quality is defined by species and settling on an overall metric is challenging.

Heat Island Mitigation

Summary and Purpose

Greenspaces help mitigate heat island effect by reflecting more solar radiation than human made surfaces such as buildings and roads. Urban environments typically are warmer than surrounding rural areas. The number one weather related deaths are caused by heat, and Houston's temperatures on a whole are getting hotter and hotter.[15]

How we measure

- Temperature measurements adjacent to and within project boundaries
- Can follow Nature Conservancy methods of Houston Heat Mapping | The Nature Conservancy [16]

Potential issues with this metric

Finding the time to organize staff and volunteers to get enough data points.

[15] https://weather.com/safety/heat/news/2021-06-03-heat-america-fatalities

[16] https://www.nature.org/en-us/newsroom/houston-heat-mapping/

IV. Design

Several elements during overall park design should be considered to increase the success of included conservation projects.

A. Placement and selection of elements

The results of the ecological site assessment should be used to help place both conservation projects as well as other elements such as trails. Focus elements such as trails, ballfields and parking lots in areas identified as damaged, or in low ecological health, during the ecological site assessment. Restoration will be prioritized in more healthy areas, in areas in which the soils or existing vegetation would best support the planned restoration, and in areas damaged by construction. All elements should be coordinated to ensure optimum ecosystem services. For example, prairie restorations can be placed to help capture and clean water flowing from parking lots. Wetlands can be placed to help with flood mitigation and to reduce storm pulses to the bayou. Green infrastructure, native landscaping, and restoration areas can be placed in such a way that they create a series of refugia for pollinators making their way through the park, and all elements can be organized into a cohesive system for capturing and cleaning water.

B. Design for maintenance

Maintenance capacity and logistics should be a design parameter. Elements like pathways can be used to simplify maintenance and delineation of different types of areas.

C. Wetland placement

As discussed in the site assessment section; topography, soils, and vegetation are three determinates for a wetland. When placing a wetland in a design it is best to be informed by site conditions. Understanding where water ponds on the site and where there are existing indications of wetland conditions is the ideal place to either enhance what is on-site or create a more defined feature.

Some ideal wetland locations for the HPB are near stormwater drains. By doing minimal grading, a wetland zone can be created at these locations where the water will stand for longer times and the plants will benefit from the additional water. The water will be further filtered before it enters the drain, the soil profile, or is evaporated.

D. Wetland design

The most common wetlands that are part of HPB projects are normally shallow mid-sized depressions with a subtle dip ranging from 6” to 2’ in depth. These wetlands are not meant to be a larger detention or retention basins. This type of wetland is ephemeral. It will pond for periods of time and then will also go dry for periods of time, yet the soils remain moist to sustain the anerobic conditions. Wetlands differ from raingardens in the fact that the soils remain moist and water ponds for longer times. Due to the water retention differences, vegetation is also different in wetland and LID features. Identified wetland areas will either require scraping existing turf to deepen low spots for sections of obligate wetland plants to grow in pockets. Unlike LID, the size of the wetland is based on site conditions to maintain wetland hydrology and is not based on a water quantity or quality sizing requirements.

Wetland planting is based on moisture conditions and water level. Different planting zones have been defined and the included plant list in the following section is based on those zones.

E. LID placement

The LID toolbox is extensive with different types of BMP features such as porous pavement, greenroofs, rainwater harvesting, and filter strips but for the purpose of this BMP and HPB projects, LID is referring to rain gardens or bioretention basins and bioswales. Placement of these LID features also requires understanding the site topography and water movement across the site. Engineers often define water drainage areas during site design. LID requires that the site is broken into even smaller micro-watersheds to be able to calculate the amount of water volume the feature will be holding and treating.

F. LID design and guidance

LID design is informed by the City of Houston Code of Ordinances chapters 9 and 13[17] as well as Harris County's Low Impact Development and Green Infrastructure Design Criteria for Stormwater Management. In general, the size of a LID feature will depend upon the size of the micro-watershed, amount of impervious cover, and rate of infiltration of the soil or design media. For example, a faster infiltrating media will mean a smaller LID footprint.

G. Rain garden design guidelines

Timing & Installation – All sediment control devices need to be in place before starting main construction as fine sediment from construction can significantly compromise the rain garden. If possible, rain gardens can be constructed last to avoid sediment entering the rain garden. If this is not possible, the rain gardens should be protected from all construction activities, especially from receiving any construction runoff, and only begin service when the contributing drainage area has been stabilized. Alternatively, the areas identified to become rain gardens can be used as temporary construction ponds so long as the areas are excavated with all fine sediment removed before the rain gardens are filled with appropriate soil or filtration media.

Entry Point – The entry point to a rain garden, whether via curb cut or other method, can contain several design modifications to act as catchment areas for trash or large amounts of debris as shown in Figure 6 below. Further, when siting these facilities to intercept drainage, the designer should attempt to use the preferred "off-line" facility design. Off-line facilities are defined by the flow path through the facility. Any facility that utilizes the same entrance and exit flow path upon reaching pooling capacity is considered an off-line facility.

Subgrade – The subgrade should not be compacted. The area below the native or amended native soil media should be undisturbed, non-compacted native soils. To avoid compaction of native soils beneath the rain garden, do not put any heavy equipment or machinery in the rain

[17] https://www.houstontx.gov/codes/

garden. If using heavy equipment to construct the rain garden, keep the machinery outside of the area. Soils can be protected in a designated vegetation and soil protection zone (VSPZ). If compaction does occur, soil should be restored to bulk density prior to construction (if using this approach, bulk density analysis should take place before any activity) or improved according to the designed infiltration rate. One common method to restore soils post-compaction is to rip or roughen the soils.

Media – In a rain garden, the media should be 18" at minimum. The rain garden media may be composed of either native soil where infiltration rates are sufficient or amended native soils where existing soils have low infiltration rates. After placing the planting media, lightly water to allow for natural compaction and settlement. The media is expected to naturally compact by about 20%. Rake the soil as needed to level the soil out. Due to settlement, the invert area should be overfilled. When leveling the media, it is easier to remove overfilled media than to add new media.

Ponding Depth – Rain gardens should have 6" of ponding depth. The ponding depth can be greater in higher permeability soils if the facility is designed to infiltrate within 48 hours.

Underdrains – Underdrains are not required, nor necessary in homeowner applications. However, they are recommended if the system is installed in soils with infiltration rates of less than 0.5 in/hr. Some designers are replacing the geotextile fabric between the planting media and gravel layer with a bridging layer of pea gravel, since clogging of the textile has occasionally been shown to be a cause of failure. This option is also acceptable.

Mulch – Rain gardens may have mulch topdressing to help reduce erosion and provide preliminary pollutant removal capabilities in addition to the horticultural benefits. Mulch is not required, but if used, a recommended mulch layer can be anywhere from 1-3". Conventional mulch material includes shredded bark, but additional options provide similar function such as rock, pecan shells or other locally sourced material. Mulch topdressing is optional and should be carefully considered as softer materials (e.g., wood) can either float or be pushed out of the system during larger rainfall events. A hybrid mulching approach might include using rock on the bottom of the garden and a secondary material on the higher side slopes.

H. Bioretention design guidelines

Water Quality Volume – The water quality volume of the facility should be calculated according to any existing local regulations.

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

Curb Cut Inlet – There are several design options for curb cuts, where curbs are used or modified, to allow runoff to enter the bioretention or rain garden system. Several of these (non-exclusive) options are diagramed below (Figure 6). Figure 7 demonstrates two types of inlets where a sediment / debris catchment area is included. These types of modifications can provide places to catch larger items such as soda cans or other floatables and can be designed with grates where water flows through the 'box' and into the rain garden, or be designed to be level with the base of the bioretention system. In either method, they should be designed to be shovel-width for easy maintenance.

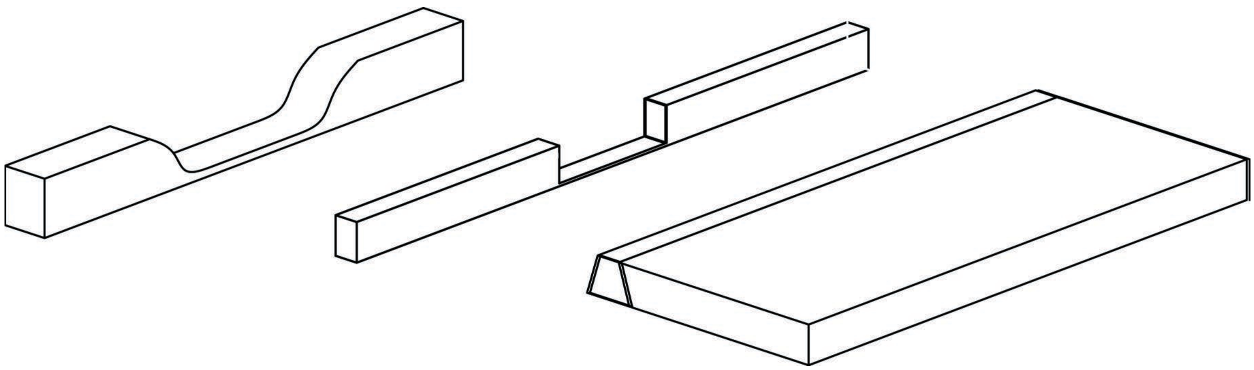

Figure 6: Curb cut options: smooth cut, hard cut and flush curb

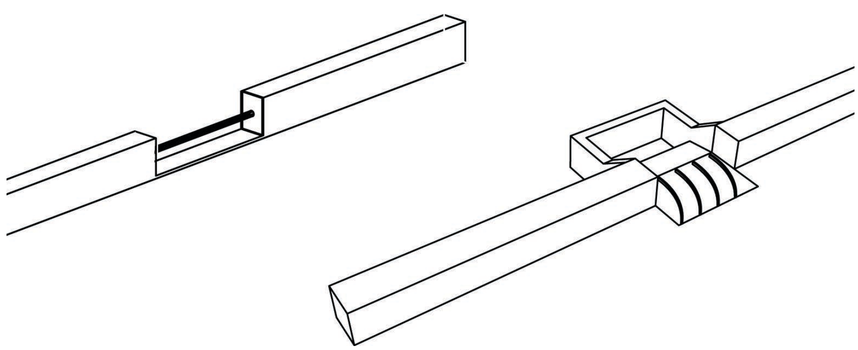

Figure 7: Curb cuts with optional sediment / trash screens

Filtration Area – The footprint of the media should be sufficiently large that it underlies the entire flooded area for the design water quality volume. A common requirement for the water depth over the media for the design storm is recommended not to exceed 6 inches unless pretreatment with a 6 foot wide grass filter strip is provided. In that case, water depths as great as 12 inches are allowed. Even without a pretreatment area, the allowable water depth over the media could be greater with higher permeability soils if the facility is designed to infiltrate within 48 hours.

Media Properties – The filtration media should have a minimum thickness of 18 inches. If planting trees in the bioretention system, additional media may be needed, up to 30", but is not required. The media should have a maximum clay content of less than 5%. The soil mixture should be 75-90% sand; 0-4% organic matter; and 10-25% screened bulk topsoil. The soil should be a uniform mix, free of stones, stumps, roots, or other similar objects larger than two inches. No other materials or substances should be mixed or dumped within the bioretention that may be harmful to plant growth or prove a hindrance to the planting or maintenance operations. Provide clean sand, free of deleterious materials. Sand may be composed of either ASTM C-33 (concrete sand) or ASTM C-144 (masonry sand).

Several alternative media design options exist and are acceptable to use aside from sand as the filtration component. These include crushed limestone, crushed (and recycled) glass, or manufactured sand. These additional options are acceptable to use as they function similar to sand and provide a more sustainable media as they are locally sourced, and often recycled, materials that are not mined. However, if using one of these media types such as crushed glass, it is important to include a small amount of organic matter for the vegetation.

The organic matter listed above should be carefully selected. Traditional options for organic matter include peat moss or shredded bark mulch. Additional options include rice hulls or shredded paper. Compost can be an acceptable organic matter in bioretention systems but it must be used with caution. There have been some issues with using compost and resulting water quality leaving the system. However, this is often due to compost that is high in nutrients or immature compost. Only low-nutrient compost should be used, and preferable compost that is very mature (processed for at least 6 months).

Underdrains – Underdrains are recommended where infiltration rates are lower than 0.5 in/hr. While there is some flexibility here, the idea is to make sure the system does not remain saturated for an extended period of time. The underdrain piping should consist of a main collector pipe and two or more lateral branch pipes, each with a minimum diameter of 4 inches. Underdrains should be perforated with ¼ - ½ inch openings, 6 inches center to center. The pipes should have a minimum slope of 1% (1/8 inch per foot) and the laterals should be spaced at intervals of no more than 10 feet. Each individual underdrain pipe should have a cleanout access location. Ideally the cleanout access will be located in the facility embankment to reduce the possibility of bypass if the cleanout is damaged (see Figure 8 for example). All piping is to be Schedule 40 PVC.

A configuration like that shown in Figure 9 is preferred. In this configuration, the underdrain is installed above the invert of the excavation to promote infiltration. The filter fabric does not need to extend to the side walls. The filter fabric may be installed horizontally above the gravel blanket-extending just 1-2 feet on either side of the underdrain pipe below. Do ***not*** wrap the underdrain with filter fabric. Some designers are replacing the geotextile fabric between the planting media and gravel layer with a bridging layer of pea gravel, since clogging of the textile has occasionally been shown to be a cause of failure. This option is also acceptable.

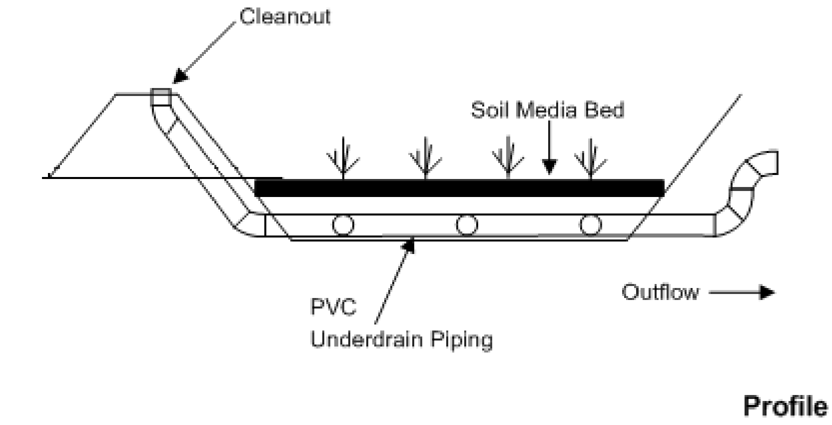

Figure 8: Detail of cleanout location

Liners – Liners must be used in facilities in areas with the potential for groundwater contamination. Impermeable liners may be clay, concrete or geomembrane. Use of any of these three liners must meet local specifications. Installation methods for liners will vary according to site requirements.

Outlet – A raised outlet as illustrated in Figure 9 is optional. It has the potential advantage of reducing the headloss across the facility and providing a permanent pool that will provide additional water for the plants during long dry periods.

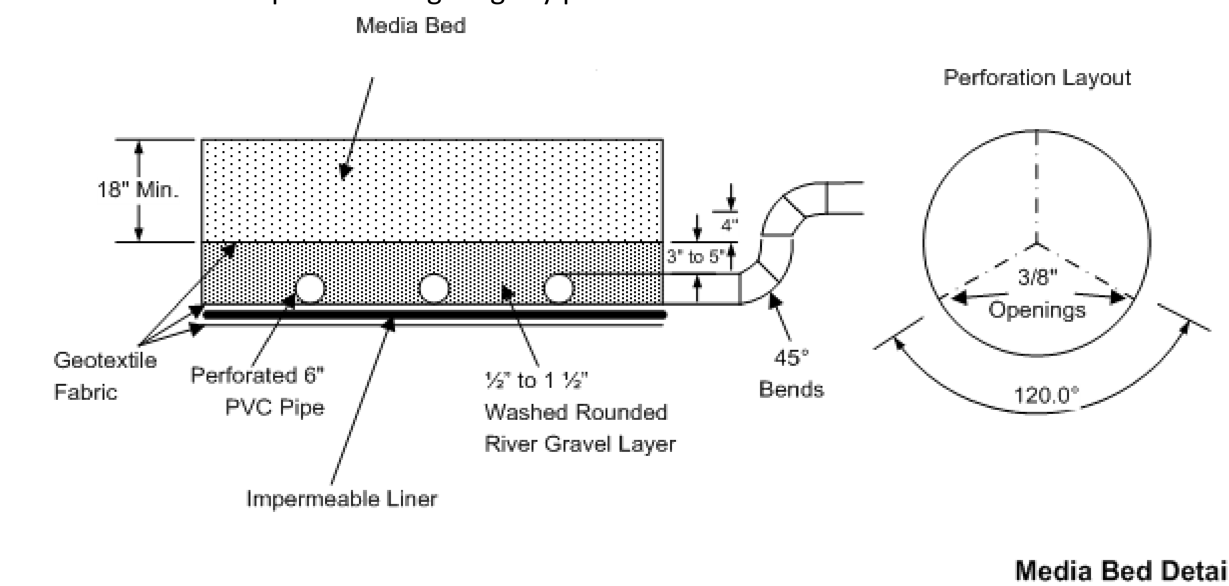

Figure 9: Illustration of optional outlet design

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

Vegetation – Vegetation selected for the bioretention system should be both tolerant of frequent inundation during extended periods of wet weather and drought tolerant for extended dry periods. Buffalograss (*bouteloua dactyloides*) and big muhly (*muhlenbergia lindheimeri*) have both been shown to provide enhanced nutrient removal.

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

I. Soil protection

Vegetation and soil protection zones (VSPZs) should be delineated early in the design, based on the results of the ecological site assessment and the design requirements of the site. These zones should be protected in the final design as well as during the installation process.

V. Installation & Maintenance

A. Soil Sampling

Before starting any work, it will be imperative to understand the basic conditions of the soils to see if they align with soil survey data or have been altered significantly as drastic changes might necessitate a plant mix that is not representative of the historical climax plant community.

Submitting a soil sample for wetlands is not as critical as it is for the other habitat types. Though a soil sample could provide information regarding texture which is important for both wetlands and LID features. LID feature will want to look at any Geotech information that might be available to understand infiltration at deeper soil locations.

As mentioned in the site assessment section, for wetlands it is important to look at the soil profile in the field to assess if it is anerobic. Using a munsell color chart will provide critical information.

Information regarding submitting soil samples is included below:

Houston Parks Board will submit soil samples for each restoration site to the Texas A&M Agrilife Extension office. Samples should follow these steps as laid out by Texas A&M's T.L. Provin and J.L. Pratt in their document, *Testing Your Soil: How to Collect and Send Samples*. The conservation department will utilize the *Urban Homeowner Soil Sample Information Form SU12 (*this form also has sampling guidelines at the end of the document for guidance). Sample information is as follows:

- Sample ID (name of specific restoration site)
- Square footage
- Last time fertilized (not applicable)
- Previously used fertilizers/organics (not applicable)
- I am growing -> Enter J. Buffalograss (or other native species if this category changes)
- Choose test 12 – Routine I +

TEXAS A&M AGRILIFE EXTENSION

Soil, Water and Forage Testing Laboratory
Department of Soil and Crop Sciences
Texas AgriLife Extension Service

SU21

Urban and Homeowner Soil Sample Information Form

Please submit this completed form and payment with samples. Mark each sample bag with your sample identification and ensure that It corresponds with the sample identification written on this form. *See sampling and mailing instructions on the back of this form.
(PLEASE DO NOT SEND CASH)

SUBMITTAL AND INVOICE INFORMATION: This information will be used for all official invoicing and communication. **Sheet ___ of ____**

Name ________________________________ County where sampled ______________________

Mailing Address ________________________________ Phone ______________________

City ____________________State______ Zip ______ Email* ______________________

CLIENT NAME: Client name will only be included with information above on result reports.

Name ________________________________

Lab Use only

Payment (DO NOT SEND CASH)
☐ Check/ Money Order (keep your M.O. receipt)
Amount Paid $_______________
Make Checks Payable to: **Soil Testing Laboratory**
☐ Prepayment on Aggie Marketplace Payment
Order Number_________________ $ amount _____
☐ Extension of Credit-Bill, AG-257 on file
Samples will not be processed if payment is not received or a valid AG-257 is not on file with Texas A&M AgriLife Extension Service. See website for more information on Form AG-257

SAMPLE INFORMATION (Required) (see options listed below)

Laboratory # For Lab Use)	My Sample ID	Square feet of sampled area	Last Time Fertilized	I previously used fertilizers/organics	I am growing (see below*)	Requested Analyses
Example	Front Yard	2000	5/30/14	5 lbs 21-0-5 per 1000 sqft	F	Select only one box
						☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12
						☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12

***A $2.00 mail fee will be charged for all invoice and sample results mailed via USPS. Results and invoice can be emailed in PDF form for free.** ☐**email results** ☐**Charge $2 for mailing**

We strongly suggest emailing the laboratory at soiltesting@tamu.edu prior to shipping your samples. This will provide the laboratory a valid email address for returning your results and invoice. Bounced emails will be billed $2 and a hardcopy will be mailed to the address listed above.

Annual, Flowers and Gardens
A. Azaleas and Camelias
B. Roses
C. Annuals
D. Vegetable Garden
E. Other

Turfgrass
F. Common Bermudagrass
G. Hybrid Bermudagrass
H. St. Augustinegrass
I. Centipedegrass
J. Buffalograss
K. Tall Fescue
L. Kentucky Bluegrass
M. Zoysiagrass

Trees and Woody Ornamentals
N. Pecan trees
O. Fruit trees
P. Shrubs and Ornamentals
Q. Shade trees
R. Other trees

1. Routine Analysis (R) (1) **$12 per sample**
(pH, NO_3-N, P, K, Ca, Mg, Na, S and Conductivity)
(This test is a base test for basic fertilizer recommendations.)
2. R + Micronutrients (Micro) (2) **$19 per sample**
(Adds Zn, Fe, Cu, and Mn to test 1.)
3. R + Micro + Boron (B) (3) **$26 per sample**
(Includes Test 2 plus boron)
(Recommended for individuals applying compost and manures.)
4. R + Detailed Salinity (4) **$34 per sample**
(Includes Test 1 plus detailed salinity analysis)
(Recommended for individuals using lower quality irrigation water.)
5. R + Micro + Detailed Salinity (5) **$41 per sample**
(Includes Test 2 plus detailed salinity analysis)
6. Routine Analysis + Organic Matter (8) **$32 per sample**
(Includes Test 1 plus organic matter analysis)
7. R + Micro + Organic Matter (10) **$39 per sample**
(Includes Test 2 plus organic matter analysis)
8. R + Micro + B + Organic Matter (13) **$46 per sample**
(Includes Test 3 plus organic matter analysis)
9. R + Texture (determines % sand, silt, and clay)(7) **$32 per sample**
(Includes Test 1 plus textural analysis)
10. R + Micro + Texture (11) **$39 per sample**
(Includes Test 2 plus textural analysis)
11. R + Micro + B + Organic Matter + Detailed Salinity(14) **$68 per sample**
(Includes Test 8 plus detailed salinity)
12. R + Micro + B + Org. Matter + Detailed Sal. + Texture (15) **$88 per sample**
(Includes Test 8 plus textural analysis and detailed salinity and provides the most comprehensive data needed for troubleshooting most plant/soil growing issues (does not address pathogen, pesticide or hydrocarbon issues)).
Hardcopy mailed to address listed above **$2 per invoice**

Pricing valid until 12-31-2021.

The latest form can be downloaded at the laboratory's website: soiltesting.tamu.edu Form S4-21

Figure 10. Texas AM Soil Sample information form

The main objective of carrying out these soil tests is to:

- Understand if soil web results align with actual soil conditions

- Understand current textural condition
- Understand if any macro (Nitrogen-N, Phosphorus-P, Potassium-K) levels are at 0
- Understand current organic matter (OM) level

For wetland and LID features the most important information that would be gathered from a soil sample would be texture. Soil samples are probably not necessary for a wetland as texture can be assessed in the field through touch and observation; however a soil sample is needed for LID features that plan to drain into the native soil profile.

TEXAS A&M AGRILIFE EXTENSION

Soil Analysis Report

Soil, Water and Forage Testing Laboratory
Department of Soil and Crop Sciences
2478 TAMU
College Station, TX 77843-2478
979-845-4816 (phone)
979-845-5958 (FAX)
Visit our website: http://soiltesting.tamu.edu

Report generated for:

Sample received on: 1/4/2021
Printed on: 1/14/2021
Area Represented: 17800 acres
SWFTL recommends <40 acres/sample

Travis County
Laboratory Number:
Customer Sample ID: Middle West
Crop Grown: MINIMUM REQUIREMENT: WARM SEASON PERENNIAL GRASS

Analysis	Results	CL*	Units	ExLow VLow Low Mod High VHigh Excess.	Fertilizer Recommended
pH	7.5	(5.8)	-	Slightly Alkaline	
Conductivity	144	(-)	umho/cm	None	
Nitrate-N	14	(-)	ppm**		10 lbs N/acre
Phosphorus	17	(50)	ppm		35 lbs P2O5/acre
Potassium	100	(130)	ppm		5 lbs K20/acre
Calcium	17,603	(180)	ppm		0 lbs Ca/acre
Magnesium	148	(50)	ppm		0 lbs Mg/acre
Sulfur	18	(13)	ppm		0 lbs S/acre
Sodium	8	(-)	ppm		
Iron	4.51	(4.25)	ppm		
Zinc	3.71	(0.27)	ppm		0 lbs Zn/acre
Manganese	8.63	(1.00)	ppm		0 lbs Mn/acre
Copper	0.19	(0.16)	ppm		0 lbs Cu/acre
Boron	0.43	(0.60)	ppm		0.5 lbs B/acre
Limestone Requirement					0.00 tons 100ECCE/acre
Limestone Requirement (Chemical Test)					0.0 tons 100ECCE/acre

Detailed Salinity Test (Saturated Paste Extract)

pH	7.5		
Conductivity	0.53	mmhos/cm	
Sodium	18	ppm	0.786 meq/L
Potassium	16	ppm	0.410 meq/L
Calcium	124	ppm	6.200 meq/L
Magnesium	8	ppm	0.636 meq/L
SAR	0.43		
SSP	9.78		

Organic Matter 2.43 %

*CL=Critical level is the point which no additional nutrient (excluding nitrate-N, sodium and conductivity) is recommended. **ppm=mg/kg

pH - Important to know what plant community you need to aim for. Houston will have acidic and alkaline communities.

N/P/K (Macros) - vital for plant growth. If applying fertilizer make sure you can reference "available" N,P,K as they are immediately availabe to plants. Regarding soil report, you are mainly determining if there is no available macro. Native plants DO NOT NEED excessive nutrients. Many evolved on soils that agronomists would consider nutrient poor soils. Adding excessive nutrients will result in invasive plant explosion.

CL - "Critical Level" is the amount that agronomists aim for, but is not as important for native plants. Again, you can add organic fertilizer if chlorosis becomes an issue, but the soil report should verify that there is no lack of any macro.

Fertilizer Recommended - these recommendations are from a crop perspective. No need to follow the recommendation. HPB staff just need to understand if there is a complete lack of a major nutrient.

Conductivity - Indicates the amount of salts present in the soil. (K,Ca, Mg, Na, CL, HCO3). Excessive salts will hinder or prevent plant growth and can affect infiltration. 1 mmhos/cm = 1 dS/m. Adverse impacts will start at .75 dS/m.

Organic Matter - prairie soil organic matter varied upon the specific soil type, but acceptable percentage range is 2-5% with 2-3% being common. Even if OM falls within acceptable ranges, compost should be added as a soil amendment to help address soil structure and inoculate with beneficial microorganisms.

Figure 11. Soil sample results and interpretation

B. Site Preparation

Ecological restoration is a trajectory, not an intervention. The amount of time you place on site preparation will determine your rate of success. While it is true that conservation staff could take a minimalist approach in site prep and save money up front, it is very likely that species diversity and richness will never be achieved, and a massive amount of sweat equity will be involved trying to "right the ship" by dueling with invasive species within the interior space of the restoration plots over the life of the plot. It cannot be overstated how much work will be saved if the Houston Parks Board understands that each step of the process of identifying acquisitions, prepping chosen sites once acquired, and installing during the optimal installation windows must be given adequate time to ensure success. Trying to flip a portion of land in a limited amount of time will yield poor results.

The first part of this BMP reviews all the steps recommended for site selection and assessment. This portion will focus on ensuring a solid foundation, installing sites correctly, and establishing these plots:

- Invasive removal
- Soil preparation
- Compaction rates
- Soil Amendments
- Live planting
- Establishment
- Post installation monitoring first year

C. Vegetation and Soil Protection

A vegetation and soil management plan is needed at this phase. The plan should identify areas of healthy vegetation and soils to protect with vegetation and soil protection zones (VSPZ). Healthy soils are identified through a combination of vegetation community assessment, agricultural soil testing, and comparison to reference soils either in the soil survey or from identified reference sites nearby. These areas should be clearly marked for contractors and communicated through maps and in the field to reduce damage and compaction. In addition, laydown areas and construction access and circulation should be identified. Limits of construction should be well defined to reduce site disturbance as much as possible. Though the site is a greenspace and seems like it has ample space for moving around, it should be treated as an urban downtown project with tight constraints. Protecting healthy areas will reduce work in the future and increase project success.

D. Site Hygiene

Once site activity begins, the site should be considered a construction zone and maintenance begins. Site hygiene should be a high priority as much as possible for HPB and its contractors. Maintaining site hygiene practices, means protecting the site from invasive species encroachment or preventing damage such as soil loss or compaction. Site hygiene practices include:

- Washing equipment
- Properly stockpiling soils
- Managing invasive species during construction
- Stormwater protection measures such as silt fences and erosion control mats

Timing between site preparation and installation is critical to sequencing in the most effective and efficient manner. Communication between all involved parties should occur regularly so that the project is well coordinated, and adjustments do not significantly alter the forward process.

E. Invasive removal

It is highly likely that most urban sites will be dominated by undesirable invasive vegetation. Each site should be evaluated during the site assessment to determine appropriate restoration activities. While the focus of long-term pest management should focus on least toxic means, often the best option when starting on invasive dominated sites is to completely start over with the goal of eliminating all vegetative growth. Site preparation should include integrating herbicides, tillage, adequate depth mulching, and, depending upon timeline/approval, prescribed fire. Invasive species will be removed for wetlands and LID features primarily by grading the site, scaping off the vegetation, and digging deeper into the soil profile.

Wetland sites, that will not be graded or have vegetation removed, with pre-existing stands of competitive or dominant invasive plants such as

- Hydrilla *(Hydrilla verticillate)*
- Itchgrass *(Rottboellia cochinchinensis)*
- Alligator weed *(Alternathera philoxeroides)*
- Giant salvinia *(Salvinia molesta)*
- Parrotfeather milfoil *(Myriophyllum aquaticum)*
- Deep-rooted sedge *(Cyperus entrerianus)*
- Elephant ears *(Colocasia esculenta)*[18]
- Cattail *(Typha)*[19]
- Giant ragweed *(Ambrosia trifida)*

or many others, will require multiple treatments with herbicide to suppress vigorous stands.

Unlike other habitat types, controlling wetland invasive species with herbicide will be primarily done through contractors. Because of aquatic specific herbicides are needed with specialized surfactants, more precautions are needed to treat invasive wetland plants.

<u>It is recommended that the conservation team develop an Integrated Pest Management (IPM) plan specifically for the Conservation Program's invasive species needs.</u> Best Management

[18] https://www.texasinvasives.org/plant_database/detail.php?symbol=COES
[19] https://www.usgs.gov/news/cattail-typha-invasion-north-american-wetlands

Practices for control of problematic vegetation are based on IPM principles that will maintain the desired site conditions using a combination of available methods (cultural, manual, mechanical, chemical), while minimizing risk to people, property, and the environment. Employing the least toxic, yet effective, treatment is desired. Managers use current information on pest life cycles and control methods to select the least toxic control method that is effective and economical. IPM principles identify current infestations, set action thresholds for treatment, and prescribe control and prevention methods.

All pesticide applicators must follow all label requirements and read the material safety data sheets (MSDS), including dilution, application and disposal of containers. Equipment must be maintained to ensure cost effectiveness and safety. Do not apply herbicide when rain is expected within 48 hours. Use directed or individual plant treatment, rather than broadcast, application methods.

For more information regarding IPM management please refer to the ***HPB BMP Maintenance and Management Manual*****.**

F. Soil preparation

After grading and any needed herbicide treatments, the clay dominated wetland soil will be ready for planting. There may be a need to add a small layer of compost if grading was significantly deeper into nutrient-poor clays. However, this practice is not common. If compost is used, it should be a modest amount as adding organic matter will encourage invasive species such as cattails.

LID soil will be prepared based on City and County design guidelines. If a native soil is used there may also be a need to add topsoil and compost. It is recommended to source material from Natures Way Resources. Compaction will need to be tested to ensure infiltration rates meet the designed criteria. Soil and media recommendations are mentioned above in **Section IV Design**

Conservation staff will need to use a cone scale penetrometer (Figure 12) to gauge the level of compaction to assess how much manipulation will be required to address compaction conditions. A general guide to acceptable compaction ranges for multiple soil types comes from James Urban's *Up by Roots: Healthy Soils and Trees in the Built Environment*. Soil scientists and ecologists tend to describe soil compaction by using bulk density, while engineers utilize Standard Proctor Density. There was no good translation correlating these two metrics until Urban's text. His table below shows that regardless of soil type (albeit with some variation), **Standard Proctor Density should not exceed 80 – 85%** to ensure deep root penetration (Figure 13). This language will allow conservation staff to communicate with HPB Capital projects on desired finished compaction levels once projects are handed over to conservation. Conservation should know that these levels are well below the typical compaction levels specified by engineers because they use compaction as a means to prevent erosion. However, this strategy is problematic because vegetation is the most effective means of erosion control and if soils are compacted beyond optimal ranges, vegetation will be limited to taproot plants and annuals that are able to take hold under extreme compaction. Often, these over-compacted sites will require erosion matting that remains until invasive plants can get a hold and start to spread over several years. This approach is fundamentally opposed to restoration work goals of vegetation quality, focusing instead on total coverage with no assessment of species or growth type (e.g., annual, tap root, invasive). Monitoring compaction on construction sites also inhibits contractors' abilities to drive heavy equipment all over the site. This restriction might not be a factor for work occurring in existing greenways but will need to be considered for HPB Capital projects where major grading and construction occurs.

Figure 12. Cone scale penetrometer image

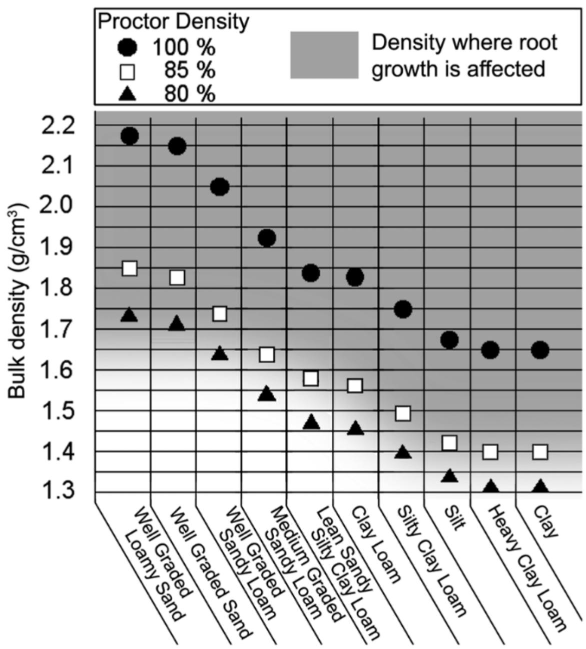

Figure 13. Bulk Density to Standard Proctor Density graph. James Urban, Up By Roots, Healthy Soils and Trees in the Built Environment.

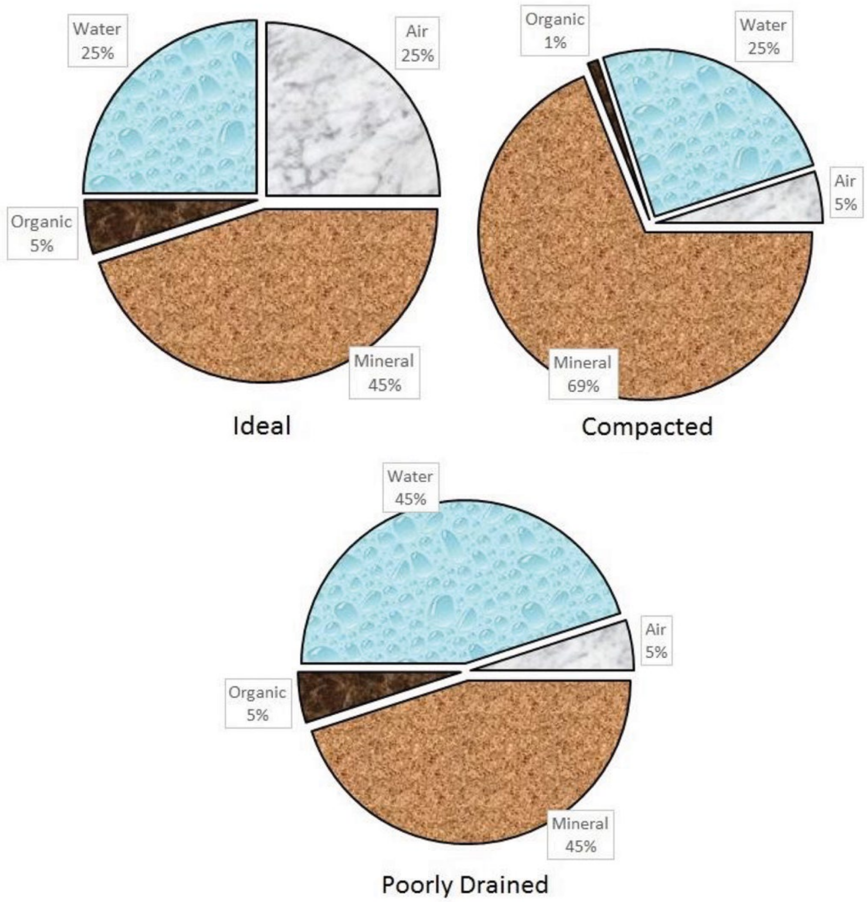

Figure 14. Image of soil particles, Luke Gatiboni, Extension Soil Fertility Specialist and Assistant Professor, NC State Department of Crop & Soil Sciences, North Carolina State University Extension.

The cone scale penetrometer will not provide hyper accurate data though it will provide conservation staff with an immediate answer as to whether the soil compaction rates are suitable, bordering compacted, or beyond acceptable compaction ranges. It is a very useful tool when dealing with contractors and helps provide instant feedback so that unsatisfactory work can be controlled and corrected.

Only utilize deep tilling to loosen soil if it is absolutely necessary based on compaction test results (e.g., cone scale penetrometer, bulk density testing). As mentioned before, deep tilling or cultivation will pull up dormant invasive seed bank.

To address soil compaction in LID features, the conservation team will need to alert the installer and have them prove infiltration rates meet specifications. If it does not, the media will need to be corrected to provide appropriate infiltration rates. Enforcement of VSPZ will help reduce unnecessary compaction. Once a soil is compacted it is generally not going to perform as well as an undisturbed area for quite some time even if amended.

G. Seeding

Seeding is not the primary planting application given the amount of moisture in both wetlands and LID features, where seeds have difficulty germinating. If seeding is done it will be hand collected by the HPB conservation team, not stored for a long period of time, and will be seeded in the intermittent shelf at the edge of the inundation zone to upland edge. Species that would be used are species that recruit heavily such as:

- Southern Cutgrass *leersia hexandra*
- Bushy bluestem *Andropogon glomeratus*
- Longspike tridesn *Tridens strictus*
- Nealley's sprangletop *Leptochloa nealleyi*

Wild collected seed from remnant wetlands are important for genetic diversity and ensures the most local sources available. Seasonal seed collection outings could be part of the conservation teams regular duties for yearly supplemental diversity seedings. This might be more infrequent for wetlands but the concept still applies. Additionally, considering seeing in ideal planting windows is important for optimal outcomes.

H. Live planting

Live planting is the primary way to establish wetlands and LID features due to moist conditions that restrict seed germination. While native plants are important for all the habitat types HPB restores and manages, using local plants for wetlands is even more critical given the aggressive capacity for invasive wetland species to establish and cause restoration failure. Below is an extensive list of plants for wetland planting. Green Star Wetland Plant Farm's plant available for May 2022 is cross-referenced as a starting point for securing material. HPB already has a strong relationship with Green Star and it has been successful for planting efforts.

Planting window- Ideal planting for wetlands is February through November. If planting occurs in the summer or warmer months, more grass species should be use because the grasses are more drought tolerant.

Planting zones- Plants in wetlands are group by their moisture requirements. The plants listed below in Table 2 has grouped the plants into the Transition Zone which is the pond edge to a permanent pool level of 3" below. This has some range from mostly dry to often wet therefore there are more species in this group. The second group is the Marsh Zone 3"-12" below and the third zone is the Deep Water Zone 12"-36" below.

Planting densities -When planting wetlands, it is recommended to use a clustering method where one plant species is tightly planted in a cluster of 10 to 20 sprigs. Then about 5' from the previous cluster another species should be planted in a grouping of 10 to 20 sprigs. Continue this cluster method throughout the wetland area. Dense plantings are beneficial in restoration projects, and this is even more true in wetland projects to help compete against invasive species establishing in any voids.

Rescuing valuable plant material from projects pre-construction is an excellent way to then replant the site with conserved material. The conservation team needs to have the capacity to pot and maintain the plants until they are ready to be planted. Salvaging plants from other sites beyond HPB in areas that will be disturbed due to construction or other impacts is another best management practice to preserve plant material and provide benefits to the soil biology. Plant salvage events should also be a regular practice.

Table 2. Wetland Live Planting List

WETLAND LIVE PLANTING LIST		
Pond Edge Zone 6" above permanent pool level to 3" below		
Scientific Name	**Common Name**	**Green Star Availability May 2022**
Andropogon glomeratus	Bushy bluestem	
Bacopa caroliniana	Lemon bacopa	*1 gal*
Bacopa monnieri	Waterhyssop	*1 gal*
Carex cherokeensis	Cherokee sedge	
Carex emoryii	Emory sedge	
Carex frankii (hystricina cherokeensis)	Caric-sedge	
Carex levenworthii	Texas sedge	
Cephalanthus occidentalis	Buttonbush	*1 gal*
Chasmanthium latifolium	Inland sea oats	*1 gal*
Cyperus odoratus (ochraceus, alternifolius, pseudovegetus)	Flatsedge	
Cyperus virens	Green Flatsedge	
Echinodorus berteroi	Tall burhead	*1 gal*
Echinodorus cordifolius	Burhead	*1 gal*
Eleocharis cellulosa	Gulf spikerush	*1 gal*
Eleocharis macrostachya (palustris, montevidensis)	Spikerush (short)	*1 gal*
Eleocharis quadrangulata	Squastem spikrush	*1 gal*
Fuirena simplex	Umbrella sedge	
Helianthus angustfolius	Swamp sunflower	*1 gal*
Hibiscus laevis	Halberd-leaf hibiscus	*1 gal*
Hibiscus lasiocarpos	Wooley rosemallow	*1 gal*
Hydrocotyl umbellata	Marsh pennywort	
Hygrophila lacustris	Gulf swampweed	*bare root*
Juncus effusus	Common or Soft rush	
Juncus diffusissimus	Slimpod rush	
Juncus tenuis	Poverty rush	
Juncus interior	Inland rush	
Juncus validus	Roundhead rush	
Liaeopsis caroliniana	Carolina grasswort	*4" pots*
Lobelia cardinalis	Cardinal flower	
Marsilea macropoda	Water clover	*bare root*
Muhlenbergia lindheimeri	Big muhly	

Phyla lanceolata	Lanceleaf frogfruit	
Phyla nodiflora	Texas frogfruit	
Physostegia angustifolia	Obedient plant	
Pluchea odorata	Marsh fleabane	*1 gal*
Rhynchospora caduca	Anglestem beaksedge	
Rhynchospora colorata	Whitetop sedge	
Rhynchospora corniculata	Horned beaksedge	
Rhynchospora glomerata	Clustered beaksedge	
Sabal minor	Palmetto	
Spilanthes americana	Water daisy	
Tripsacum dactyloides	Easterngama grass	

Marsh Zone 3"below-12" below		
Latin Name	**Common Name**	**Green Star**
Canna glauca	Canna lily (native)	
Crinum americanum	Crinum lily	*1 gal*
Eleocharis acicularis	Slender spikerush	
Eleocharis macrostachya	Flatstem spikerush	
Eleocharis montevidensis	Spikerush	
Eleocharis (rostellata, quadrangulata, cellulos)	Spikerush (tall)	
Heteranthera limosa	Mudplantain	
Hibiscus laevis	Halberdleaf rosemallow	
Hibiscus moscheutos	Crimsoneyed rosemallow	
Iris virginica	Blue flag	
Justicia americana	American waterwillow	
Peltandra virginica	Arrow arum	
Pontederia cordata (purple and white)	Pickerelweed	*1 gal*
Sagittaria platyphylla	Arrowhead	*1 gal*
Sagittaria graminea	Bulltongue	
Schoenoplectus acutus	Hard-stem bulrush	
Schoenoplectus americanus	Three-square bulrush	
Schoenoplectus pungens	Three-square rush	*1 gal*
Zanichellia palustris	Horned pondweed	

Deep Water Zone 12" below-36" below		
Latin Name	**Common Name**	**Green Star**
Cabomba caroliniana	Fanwort	
Ceratophyllum demersum	Coontail	*bunch*

Chara spp	Stonewort/Muskgrass	*bunch*
Heteranthera dubia	Water stargrass	
Heteranthera dubia (Liebmannii)	Water star grass	
Limnobium spongia	American frog's bit	
Nymphaea (odorata, elegans, mexicana)	Water lily	*1 gal*
Potamogeton nodosus	American pondweed	*1 gal*
Potamogeton pectinatus (nodosus, diversifolia, illinoensis)	Pondweed	
Potamogeton pusillus	Slender pondweed	
Schoenoplectus americanus	Giant bulrush	
Stuckenia pectinata	Sago pondweed	
Thalia dealbata	Powdery Thalia	
Utricularia gibba	Floating blatterwort	
Utricularia radiata	Little floating blatterwort	
Vallisneria americana	Wild celery	

I. Planting for LID features

Plant Density: Vegetated cover with herbaceous material should be at least 70% coverage within the rain garden or bioretention area once established. If the project desires a more immediate finished aesthetic it might be best to plant more densely and then remove plants as needed. Research has indicated that as the plant density increases so does the functioning of the system. At the establishment phase, at least 50% of the system's area should be planted. While this planting density may seem high, it takes into consideration many factors for successful establishment and longevity of the system. Lastly, the denser the planting strategy, the less mulch will be required.

Soil Modifications: It is important to consider soil modifications when choosing plant species for various LID BMPs. For instance, plants that survive well in clay soils will not be appropriate for a modified sandy media.

Biological activity: It is important to plant a mix of cold and warm season plants so the bioretention system maintains biological activity year-round.

Installation: Soils should be used in a manner that will ensure adequate filtration. Thus, it is important to scarify the sides and invert areas of the excavated feature (not required for features that require liners). Place soil in eight to twelve inch (8" – 12") lifts in order to reduce the possibility of excessive settlement. Lifts are not to be compacted, but may be slightly watered to encourage natural compaction. Rake soil to level condition. Overfill above the proposed surface grade to accommodate natural settlement.

Accessibility: Bioretention areas should be designed to allow for access and aid in the maneuverability of maintenance equipment. If areas of the bioretention system are designed to be mowed, acute angles should be avoided in turf areas; wide angles, gentle, sweeping curves, and straight lines are easier to mow.

Grasses: Prairie grasses have a high biomass and a deep rooted system that can penetrate into the clay soils and increase water infiltration. Additionally, the plants help reduce drawn-down time by drawing the water up allowing for more water storage capacity in the soil before the next rain event.

Trees: When using trees in bioretention, consideration should be given to their placement in the right-of-way or other areas where existing utilities may exist, both underground and overhead.

Establishment: Vegetation should be allowed time to establish before the system is active. One option is to protect the inlet from receiving any runoff until plants are established to avoid plant mortality, complete submergence of young plants in high rainfall events, or lack of sufficient plant cover during these early storms. The inlet can be protected with the use of sand bags and a liner, or other similar methods. There may be certain instances where this is not necessary, for example, if the system has sufficient rock mulch to diffuse velocity.

Planting windows:

a. The ideal establishment period for grasses and forbs is in the spring and fall window. Late September-May are ideal planting times. Ideal planting windows for shrubs and trees is mid-fall through early-spring.

a. Replant areas which did not establish if coverage is less than 70% of the system area.

Design: Plants species can be chosen and planted based on the zone of the bioretention system. For instance, species that can handle longer periods of inundation should be planted on the bottom while species that prefer drier conditions should be placed on the top.

Underdrain and liners: For bioretention systems with underdrains or liners which drain water rapidly and do not allow for significant infiltration, use plants accustomed to well-drained conditions. In addition, large trees or other plants with root systems that might penetrate the liner should not be used.

Table 3. LID recommended plants

Grasses	**Forbs**	**Shrubs & Trees***
Eastern gamagrass *Tripsacum dactyloides*	Frogfruit *Phyla Nodiora*	Sycamore *Platanus occidentalis*

Seep muhly *Muhlenbergia reverchonii*	Blue mistflower *Conoclinium coelestinum*	Bald cypress *Taxodium distichum*
Bushy bluestem *Andropogon glomeratus*	Baldwin's ironweed *Vernonia baldwinii*	Cedar elm *Ulmus crassifolia*
Upland switchgrass *Panicum virgatum*	Canada germander *Teucrium canadense*	Possum-haw *Ilex decidua*
Inland sea oats *Chasmanthium latifolium*	Horseherb *Calyptocarpus*	Red mulberry *Morus rubra*
Indiangrass *Sorghastrum nutans*		
Cherokee sedge *Carex cherokeensis*		

J. Watering for Establishment

Watering wetlands is done by filling up the wetland pond initially and then filling as needed. Generally, the wetlands need to be filled every couple of months during establishment. Also, watering during times of drought will be needed- especially if the wetland was established within 6 to 8 months prior to the drought.

Watering guidelines for LID features

The newly planted bioretention or rain garden needs to be watered regularly, though temporarily, to ensure proper plant establishment. Watering should begin immediately after installation. A temporary above-ground drip irrigation line is a preferred method for irrigation post-installation, though other methods are acceptable. Watering for establishment should follow the schedule provided below.

Establishment Watering Schedule for seed establishment

- First 10 days seed is not allowed to dry out – watering event replicating 1” rain event every day
- Next 3 weeks – watering event replicating 1” event every other day
- Next 2 weeks – watering event replicating 1” event twice a week

*This schedule can be adjusted, and days skipped if rainfall occurs.

Drench all trees and shrubs with water twice, during the first 24 hours after installation. This will ensure the root zone is well saturated. Maintenance of soil moisture at or greater than 6” below grade during early (3-6) months is critical for tree establishment. Young saplings should be watered twice a week (saturating the critical root zone) for 2-3 months. At each watering, thoroughly saturate the soil around each tree and ensure proper soil moisture at least 6” below grade. Over the next four months, the root depth should not be allowed to dry out, watering every other week or as necessary depending on local weather conditions. After this initial establishment period, stormwater runoff should provide sufficient irrigation needs. However, if there is a long drought period or no significant precipitation for any 4-6 week period over the first two growing seasons, the trees will need supplemental watering. Trees should be maintained for two years and inspected at least once a month during this two-year establishment period.

K. Monitoring for establishment

Each project will establish differently over time, but if done right conservation staff should see verdant growth and filling in within the first three weeks. Staff will need to become familiar with each native species and seedlings of invasive plants. They will also need to know each of these plants as they advance in their life cycle. Each project should have regular establishment monitoring for the first two years with the first year having a minimum of a site visit every two weeks.

Hand removal can occur, and regular sweeps should be made during inspections to make sure undesired plants are not allowed to go to seed. Any plants that are setting seed should be treated or pulled, seedheads or plants bagged, and then bags discarded. Herbicide treatment of Wetland plant material will be need further approval by HPB and will most likely be done by contractors. If invasive spot treatment occurs and results in dead patches, conservation staff should remove dead material and then replant with fast growing plants. It is imperative to not leave the void unattended because urban areas are vectors for invasive species and could potentially fill the space if native seed or live plugs are not planted as soon as possible.

Undesired woody growth should be removed as it presents with a weed wrench (Figure 15). Nature prevented sapling establishment with wildfire and high intensity grazing. The absence of these disturbance events means that conservation staff will have to take up that function and serve as bison surrogates where appropriate.

Figure 15. Image of weed wrench

L. Management and Maintenance

The goal of restoration is to restore ecosystem process, not simply to replace components. Ecosystem processes allow natural systems to repair themselves and to remain relatively stable. The restoration principles help make connections between site context and site-specific information and help relate to future restoration projects and maintenance. Developing a restoration and maintenance plan that incorporates a well-supported interpretive plan reinforces a successful implementation, maintenance, and education impact.

The restoration invasive species toolbox is composed primarily of prescribe fire, mowing, physical removal, and chemical treatments. Often it is not one tool or another, it is a combined use of these tools and practices. Physical hand removal of invasive species and spot treatments of invasive species provided by contractors will most likely be the main disturbance for HPB's Wetland's and LID features.

Management of new habitat types requires frequent monitoring and recording of management activities and performance results. Adaptive management practices should be applied following and adaptive management framework. (Williams and Brown 2016)

Adaptive management

Adaptive management is a management approach that acknowledges uncertainty in ecological systems and reduces uncertainty by using a problem-solving management approach. The focus is on learning about the system and how to best change the system. The process for adaptive management is circular in nature starting with assessment, design, implementation, monitoring, evaluation, and adjusting. Adaptive management is a hybrid of management and research (Murrary and Marmorek 2003).

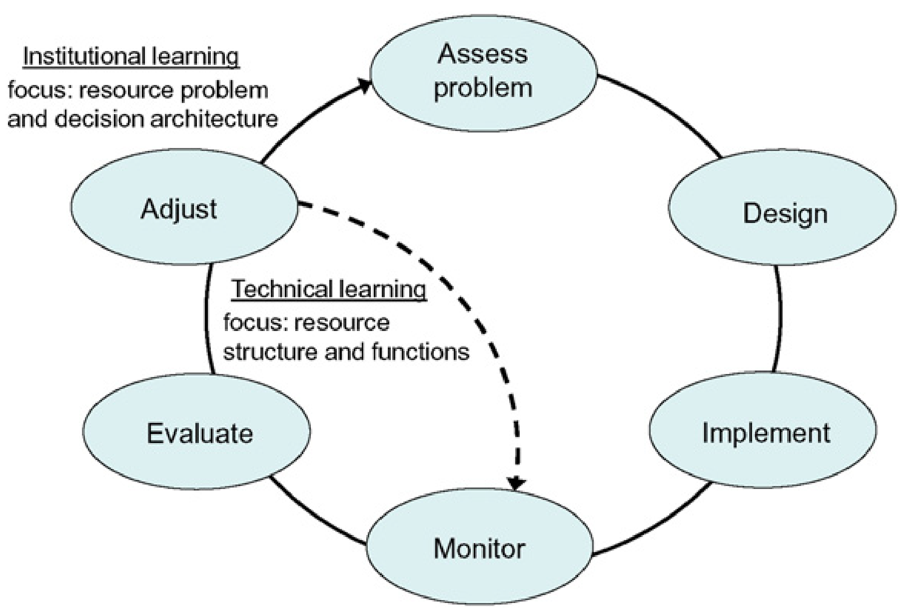

Figure 16. Diagram of the Adaptive Management process. (Williams and Brown 2016).

Figure 16 provides a diagram of adaptive managements circular process starting with assessing the problem and then moving from there to design, implement, monitor, evaluate, and adjust. The diagram also highlights that there is a smaller circle within the larger framework where learning regarding the methods can be adjusted while maintaining the larger process. Managing complex living systems in urban environments with relatively new science requires flexibility, adaptability, as well as a method and process. More information regarding adaptive management and maintenance recommendations are included in the associated *HPB BMP Management and Maintenance Guidelines.*

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VII. Appendix

Appendix A. Data Sheets (also provided as an excel document)

1. Field Check

Date: Surveyor: Rapid assessment-vegetation

Point/ location	Dominant communities	Soil surface condition overall (1-5)	Erosion class (1-5)	Erosion extent (% cover)	Invasive (% cover)	Valuable species (% cover)	Invasives - other	High value - other
					total	total		
					Dominant spp.	heritage tree (>60.96 cm)		
					Ligustrum sp.	protected tree (>48.26 cm)		
Overall diversity	**Woody age** diversity	**Dominants** overstory	**Dominants** midstory	**Dominants** Herb	bermudagrass	Reference community spp.		

Riparian buffer (width-ft)	Connection to floodplain (high/med/low)	Bottomland/ riparian diversity (high/med/low)			Challenges	Assets	Additioaal challenge/ asset	Boundary/ adjacent property
Comments					Social trails	Reference species		
					Damaged soil	Healthy soil		
					Boundary influences	Microtopography		
					Poor access	Water availability		
					Invasive dominance	Existing work		

Cover classes	Soil surface condition	Erosion classes
Class 1: None Class 2: trace Class 3: 1-25% Class 4: 26-50% Class 5: 51-75% Class 6: 75-100%	Class 5-**High**: developed organic layer, good structure, low/no disturbance **Class 3: Medium** Class 1-**Low**: thin, damaged, rocky, construction debirs present	**Class 1: severe**, subsoil exposed, most rocks/plants pedestaled and roots exposed **Class 3: moderate** movement of soil, surface rock/ or litter, pedestalling in flow patterns **Class 5**: no visual evidence of soil movement

2. Pre-design assessment

Date: Surveyor: Rapid assessment-vegetation

Point/ location	Ecological site / Community name	Overstory (% cover / diversity (1-5))	Midstory (% cover / diversity (1-5))	Ground (% cover / diversity (1-5))	Invasive (% cover)	Valuable species (% cover)	Invasives - other	High value - other
		% cover	% cover	% cover	total	total		
		Diversity	Diversity	Diversity	Dominant spp.	heritage tree (>60.96 cm)		
		Dominants	Dominants	Dominants	Ligustrum sp.	protected tree (>48.26 cm)		
Overall diversity	Woody age diversity				bermudagrass	Reference community spp.		

Soil surface condition	Erosion severity	Erosion extent	Connection to floodplain (high/med/low)	Bottomland/ riparian diversity (high/med/low)	Challenges	Assets	Additioaal challenge/ asset	Boundary/ adjacent property
Comments					Social trails	Reference species		
					Damaged soil	Healthy soil		
					Boundary influences	Microtopography		
					Poor access	Water availability		
					Invasive dominance	Existing work		

Cover classes	Soil surface condition	Erosion classes
Class 1: None Class 2: trace Class 3: 1-25% Class 4: 26-50% Class 5: 51-75% Class 6: 75-100%	Class 5-**High**: developed organic layer, good structure, low/no disturbance **Class 3: Medium** Class 1-**Low**: thin, damaged, rocky, construction debris present	**Class 1: severe**, subsoil exposed, most rocks/plants pedestaled and roots exposed **Class 3: moderate** movement of soil, surface rock/ or litter, pedestalling in flow patterns **Class 5**: no visual evidence of soil movement

3. Soil condition classes

Characteristic	Class 1	Class 2	Class 3	Class 4	Class 5
Soil movement	Subsoil exposed on much of the area; may have embryonic dunes an/or wind scoured depressions	Soil and debris deposited against minor obstructions	Moderate movement of soil particles has occurred	Some movement of soil particles has occurred	No visual evidence of soil movement
Surface rock and/or litter	Very little remaining; if present, surface rock or fragments exhibit some movement and accumulation of smaller fragments behind obstacles	Extreme movement; many large deposits against obstacles; surface rocks exhibit movement; smaller fragments accumulate behind obstacles	Moderate movement; fragments deposited against obstacles, fragments have a poorly developed distribution pattern	May show slight movement; if present, coarse fragments have truncated appearance or spotty distribution caused by wind or water	Accumulation in place; if present, the distribution of fragments shows no movement caused by wind or water
Pedestaling	Most rocks and plants pedestaled and roots are exposed	Many rocks and plants pedestaled and roots are exposed	Rocks and plants pedestaled in flow patterns	Slight pedestalling in flow patterns	No visual evidence of pedestaling
Flow patterns	Flow patterns numerous, readily noticeable; may have large barren fan deposits	Flow patterns contain silt, sand deposits and alluvial fans	Well defined, small and few with intermittent deposits	Deposition of particles may be in evidence	No visual evidence of flow patterns
Rills and gullies	May be present at depths of 8--15 cm and at intervals of less than 13 cm; sharply incised gullies cover most of the area, with 50% actively eroding	Rills 1-15 cm deep at 150 cm intervals; gullies numerous and well developed; active erosion on 10-50% of their lengths or a few well-developed gullies with active erosion along more than 50% of their length	Rills 1-15 cm deep in exposed places at about 300 cm intervals; gullies well developed, with active erosion along less than 10% of their length with vegetation present	Few infrequent rills in evidence at distances of over 300 cm; evidence of gullies with little bed or slope erosion; some vegetation is present on slopes	No visual evidence of rills; may be present in stable condition, but with vegetation on channel bed and side slopes

Appendix B. Methods

1. Vegetation Monitoring

Houston Arboretum & Nature Center's Vegetation Monitoring Plots

Chris Garza

Introduction

In 2015, a total of 88 permanent vegetation monitoring plots were created across the property of the Houston Arboretum & Nature Center. ArcMap software was used to generate these plots by placing a two acre grid across the site and randomly placing a plot center within each cell (Figure 1). When located with a Garmin GPS (each plot center is entered in the GPS as "RP##' with #'s denoting the plot number), each plot center is permanently established in the field with a stake. Vegetation monitoring consists of assessing trees, shrubs, and herbaceous plants (Figure 2). All trees with a diameter at breast height (dbh) greater than 6 inches within a circular 0.1 acre plot around the plot center have their dbh measured and the species are recorded. All trees and shrubs with a dbh between 3 and 6 inches are recorded the same way within a 0.05 acre subplot. All trees and shrubs with a dbh less than 3 inches are counted by species within the same 0.05 acre subplot. Grasses, forbs, vines, and tree/shrub seedlings are measured within a square meter quadrat around the plot center. Percent cover is recorded for each species. The percent cover of bare soil and leaf litter is also noted. Each year, a variable number of plots are sampled so that all 88 plots are sampled within 5 years. Plots can then be resampled and compared 5 years from when they were previously sampled. Refer to Figure 3 to see the plots when plots are to be sampled.

Methods

Materials used included a ½ meter by ½ meter square pipe, a compass, a GPS, eight pin flags, a DBH tape measure, and the data sheets. The location of each vegetation plot was determined with a GPS and a compass. An orange stake was placed in the ground at the center of the plot. Starting from the orange stake, two pin flags were placed in each cardinal direction, one 26 feet away and one 37 feet away from the orange stake. A DBH tape was used to measure the distance from the orange stake to the 26 and 37 feet marks in each direction. This effectively makes a big circle with a radius of 37 feet, and a smaller circle with a radius of 26 feet, both with the orange stake serving as the central point. One person stood at the orange stake holding the end of the tape measure while the other person measured and placed the pin flags. Once all of the pin flags were set up, a 1 meter vegetation sampling with the orange stake as the center point was completed. A compass was utilized to determine the northwest direction, and the ½ meter by ½ meter square pipe was placed in the northwest quadrant. Percentage of leaf litter and bare ground were recorded, as well as the species of any plant growing in the quadrant. This was repeated for the northeast, southeast, and southwest directions, effectively making a 1 meter square plot with the orange stake in the middle.

After the 1 meter square plot survey, trees were measured and counted. The DBH and species of any trees with a DBH over 6 inches and located within the bigger circle (radius of 37 inches) were recorded. Any trees with a DBH between 3 and 6 inches and located only within the smaller circle (radius of 26 inches) were measured. The DBH and species were recorded. After that, any trees with a DBH below 3 inches and taller than hip height (around 3 feet) in the smaller circle were simply counted. The species and number of individuals of each tree were recorded.

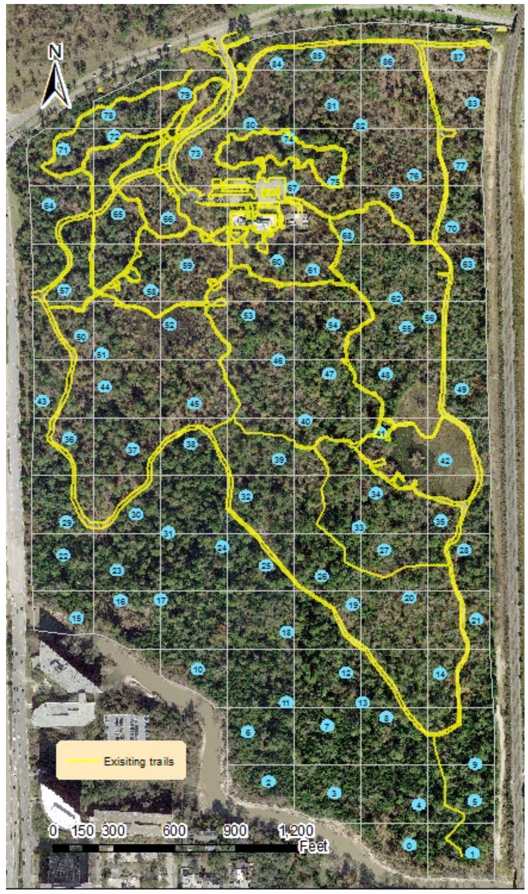

Figure 1: In 2015, the 88 permanent vegetation monitoring plots were placed randomly within a two acre grid. Trees, shrubs, and herbaceous plants are monitored in these plots.

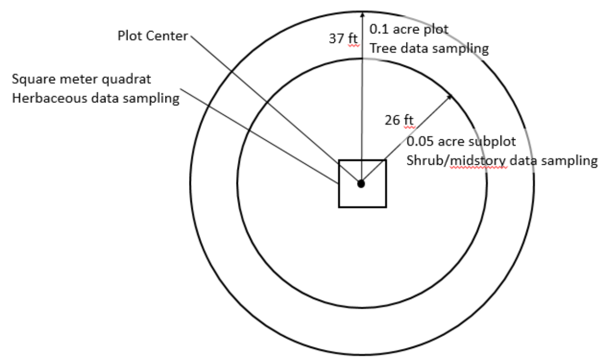

Figure 2: The vegetation monitoring plots were designed to sample trees, shrubs, and herbaceous plants.

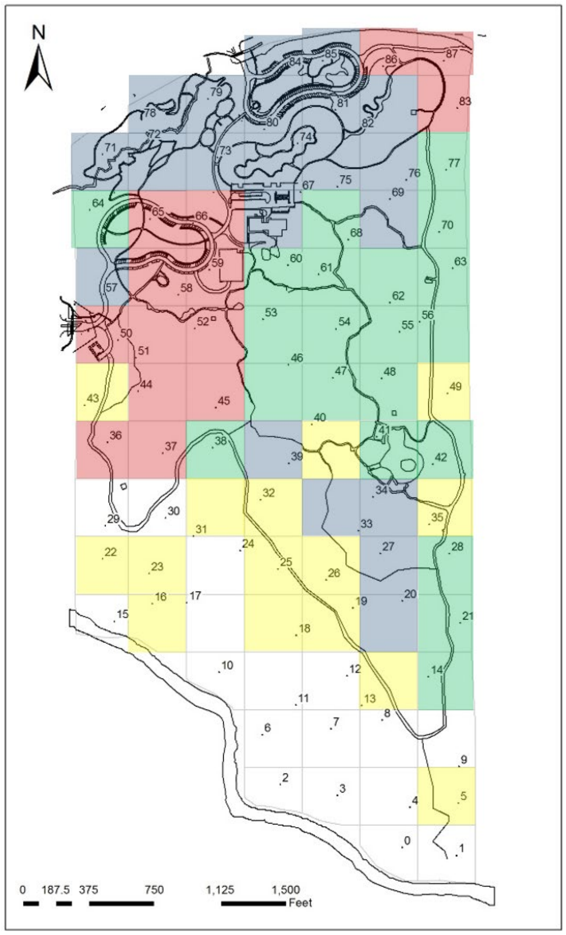

Figure 3: The staggered plot sampling system over five years. Red plots (14 total) were sampled in 2015 and will be resampled in 2020. Yellow plots (15 total) were sampled in 2016 and will be resampled in 2021. Blue plots (21 total) were sampled in 2018 and will be resampled in 2023. Green plots (21 total) are to be sampled in 2019 and will be resampled in 2024. Note that no plots were sampled in 2017. The uncolored plots (17 total) can be sampled for the first time in 2022.

Plot #		Date		%Canopy cover	

Overstory trees with dbh > 6" within 1/10th acre plot (37' radius)

Species	*Dbh*	*Height*	*Notes*

Midstory trees with 3-6" dbh within 1/20th acre plot (26' radius)

Species	*Dbh*	*Height*	*Notes*

Understory trees with dbh < 3" within 1/20th acre plot (26' radius)

Species	*Count*	*Notes*

Herbaceous - NW

Species	*% Cov*	*Notes*	*Species*	*% Cov*	*Notes*
Bare					
Litter					

Herbaceous - NE

Species	*% Cov*	*Notes*	*Species*	*% Cov*	*Notes*
Bare					
Litter					

Herbaceous - SE

Species	*% Cov*	*Notes*	*Species*	*% Cov*	*Notes*
Bare					
Litter					

Herbaceous - SW

Species	*% Cov*	*Notes*	*Species*	*% Cov*	*Notes*
Bare					
Litter					

Figure 4: The template of the data sheets to be used in the field

2. Pollinator Monitoring

Houston Arboretum Pollinator Methods- Chris Garza

In 2015, 88 vegetation monitoring sites were chosen across the 155-acre HANC using ArcMap software, located with GPS coordinates, and permanently marked with a stake. 30 of these sites were randomly selected for pollinator community monitoring in addition to vegetation surveys to record changes in pollinator diversity with vegetation changes as the site undergoes continued restoration and development.

Materials used included a ½ meter by ½ meter square pipe, a compass, a GPS, a pin flag, a DBH tape measure, and the data sheets. A GPS device and compass were used to locate the pollinator plot locations marked with an orange stake. Once at the orange stake, the cardinal directions were determined with a compass. Then, one person stood over the orange stake holding one end of the tape measure while the other person walked with the tape measure in one cardinal direction until a distance of 26 feet was reached. A pin flag was placed in the ground at the 26 feet mark, and vegetation sampling around the flag was completed. With the pin flag serving as the center of a 1 meter square plot, the square pipe was placed in the northwest direction first, which was determined with a compass. The percentage of bare ground versus percentage of ground covered in leaf litter was recorded on the data sheets. Then any vegetation found within the square pipe was classified and its species and percent cover were recorded. The square pipe was then moved to the northeast quadrant of the 1 meter square plot and the percent cover and species present were again recorded. This was repeated for the southeast and southwest quadrants. If any flowers were present in or directly above the 1 meter square plot, the flowers were observed for 15 minutes and any pollinator activity was recorded along with the species of the pollinator. Then, the pin flag was taken back to the orange stake, the center of the big plot. Once a second cardinal direction was determined, one person held the end of the tape measure and the other walked 26 feet in the cardinal direction. As before, the pin flag was placed at the 26 feet mark and a 1 square meter vegetation survey was performed around the pin flag. This whole process was repeated for the two remaining cardinal directions. The relative humidity, temperature, and wind speed were determined with an iPhone and recorded on the data sheets as well.