HARRIS COUNTY FLOOD CONTROL DISTRICT
PROJECT ID W100-00-00-X043
MEMORIAL PARK DEMONSTRATION
PROJECT
MONITORING PLAN
HARRIS COUNTY, TEXAS

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October 2014
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## Acronyms and Abbreviations

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<th>Description</th>
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<tbody>
<tr>
<td>BEHI</td>
<td>Bank Erosion Hazard Index</td>
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<td>BMP</td>
<td>Best Management Practices</td>
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<td>CMAR</td>
<td>Construction Manager at Risk</td>
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<td>COH</td>
<td>City of Houston</td>
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<td>EPA</td>
<td>Environmental Protection Agency</td>
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<td>HBI</td>
<td>Hilsenhoff Biotic Index</td>
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<td>HCFCFD</td>
<td>Harris County Flood Control District</td>
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<td>HPARD</td>
<td>Houston Parks and Recreation Department</td>
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<td>IBI</td>
<td>Indexes of Biotic Integrity</td>
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<td>LF</td>
<td>Linear Feet</td>
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<td>MPDP</td>
<td>Memorial Park Demonstration Project</td>
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<td>NCD</td>
<td>Natural Channel Design</td>
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<td>NOT</td>
<td>Notice of Termination</td>
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<td>NPDES</td>
<td>National Pollutant Discharge Elimination System</td>
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<td>OHWM</td>
<td>Ordinary High Water Mark</td>
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<td>PVC</td>
<td>Polyvinyl Chloride</td>
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<td>RCI</td>
<td>Reach Condition Index</td>
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<td>ROCC</td>
<td>River Oaks Country Club</td>
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<td>ROW</td>
<td>Right-of-Way</td>
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<td>SCA</td>
<td>Stream Condition Assessment</td>
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<td>SWPPP</td>
<td>Stormwater Pollution Prevention Plan</td>
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<td>SWQM</td>
<td>Surface Water Quality Monitoring</td>
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<td>TCEQ</td>
<td>Texas Commission on Environmental Quality</td>
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<td>TPWD</td>
<td>Texas Parks and Wildlife Department</td>
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<td>USACE</td>
<td>U.S. Army Corps of Engineers</td>
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1.0 Introduction

1.1 Project Overview

Atkins was contracted by Harris County Flood Control District (HCFCD) to provide this Monitoring Plan, which outlines methods to document the establishment and long-term success of restoration measures proposed under the HCFCD Project ID W100-00-00-X043 (Memorial Park Demonstration Project [MPDP]). HCFCD is proposing to restore approximately 5,700 linear feet (LF) of HCFCD Unit W100-00-00 (Buffalo Bayou) and 560 LF of an unnamed tributary to Buffalo Bayou, referred to in the project plans as Hogg Bird Tributary, in Houston, Texas, as described in the U.S. Army Corps of Engineers (USACE) permit application number SWG-2011-00628. Please refer to Appendix A for the project plans. HCFCD will be responsible for implementation of pre- and post-construction monitoring, meeting success criteria, and long-term management and maintenance of the demonstration site as described herein. Although establishing site maintenance is not the objective of this document, a general description of the prescribed maintenance activities to be conducted on the project is included to provide context for the monitoring plan.

The MPDP is a restoration project that will utilize Natural Channel Design (NCD) techniques to minimize erosion, improve natural stream functions, and stabilize banks that have eroded and are threatening the integrity of adjacent properties. Stabilization measures planned include improvements to the dimension, pattern, and profile of the proposed project reach, allowing the stream to convey stormwater and sediment loads more efficiently without aggrading or degrading, and providing improved aquatic habitat.

The project design is based upon the existing site characteristics and needed restoration. HCFCD has developed a planting plan (Appendix B) to be implemented upon completion of construction activities that will be used to reestablish native vegetation, stabilize the banks, and improve the riparian buffer.

The MPDP is located in a non-tidal stream segment in the Buffalo Bayou Basin within the center of the Buffalo-San Jacinto Watershed (Hydrologic Unit Code 12040104). The upstream project limit is 1,450 LF east of the end of Pinehill Lane (2.36 river miles upstream of the Shepherd Drive crossing), and the downstream project limit is 350 LF south-southwest of the southern end of Westcott Street (1.15 river miles upstream of Shepherd Drive). The project is located within the Houston Heights, Texas, U.S. Geological Survey (USGS) 7.5-Minute Quadrangle Map (USGS, 1995); it begins at 29° 45’ 27.45”N, 95° 25’ 19.24”W and ends at 29° 45’ 27.29”N, 95° 26’ 06.42”W.
2.0 Project Objective

HCFCD is proposing to restore approximately 5,700 linear feet (LF) of HCFCD Unit W100-00-00 (Buffalo Bayou) and 560 LF of an unnamed tributary to Buffalo Bayou, referred to in the project plans as Hogg Bird Tributary, in Houston, Texas. The proposed project area is located in Harris County, Texas, within the limits of the City of Houston (COH). As shown on Exhibit A, the proposed project area on Buffalo Bayou flows adjacent to Memorial Park (north side of the stream) and the River Oaks Country Club (ROCC) (south side of the stream). The project will also include areas immediately adjacent to the stream and one access point leading from Memorial Drive down to the bayou. This access point will be located on COH property and has been coordinated with the COH Parks and Recreation Department (HPARD), who is responsible for managing Memorial Park.

The proposed stream restoration project will restore a portion of W100-00-00 channel (Buffalo Bayou) by utilizing NCD techniques to create a stable stream reach that will neither aggrade nor degrade, and will minimize shear stresses on the banks that are causing extensive, active erosion within the proposed project area.

The following measures will be implemented to enhance the stream condition and natural stream functions within the project area:

1. The stream bed and banks will be regraded to establish a pool and riffle system and to restore a natural stream profile. Providing stable riffle/run/pool/glide sequences through the project reach will:
   a. Eliminate degradation or aggradation of the thalweg (as listed above) through the project reach.
   b. Provide improved, stable in-channel features for habitat.
   c. Provide hydraulic benefits for the long-term stabilization of banks.
   d. Remove the anthropogenic rubble from the system.

2. Providing overall channel stability and a stable bankfull bench will reduce the sediment loads to the system by eliminating channel bank and bed erosion.
   - Eroding banks will be regraded to a stable dimension that will reduce erosion and sedimentation within the project area, and allow for the long-term stabilization of the banks with vegetation.
   - Toe wood will be installed as the foundation of the bank stabilization structure to reduce shear stress on the outside of stream bed meanders.
   - The installation of a bankfull bench through the project reach will restore connectivity to the geomorphic floodplain. In areas where bank stabilization is proposed, the bankfull channel banks will be graded to a slope of 3:1 with a slope of 7:1 on point bars.
   - Coir fiber matting, made from coconut fiber, will be placed on graded slopes along with nurse grasses and permanent native vegetation to provide for erosion control and bank stability.
planting plan (Appendix B) for the long-term revegetation of the project area will be implemented to reestablish native vegetation and prevent erosion.

- Vegetated stabilized earthen walls will be installed on slopes above the bankfull bench that require grading steeper than 3:1 due to right-of-way (ROW) constraints.

3. Providing a stable geometry to the channel’s pattern will reduce shear stresses from the outside of meanders by eliminating tortuous curvature and providing stream pattern stability.

- Stream flow training, such as stream pattern adjustment and toewood, will be used to slow and redirect erosive flow velocities to the stream thalweg (or flowline), and a more efficient channel dimension will be constructed to increase the width/depth ratio and improve sediment transport efficiency.

- Moving the stream to a stable pattern will allow for the preservation of mature vegetation in the way of the foreseeable channel migration. Based on a review of historical aerial photos, a tremendous amount of land and vegetation have been lost over the past three quarters of a century due to channel migration as the stream seeks to find a stable pattern.

4. Creating wetlands in the old meander cutoff and within the channel where reestablished hydrological connectivity will promote them. The oxbow wetland plantings will compensate for the loss of existing wetlands required to construct the project. The oxbow wetlands will provide a stable and more protected area for the successful compensation of wetland impacts.

5. Noxious invasive species (Appendix B) will be managed within the riparian corridor and if needed the corridor will be replanted with appropriate riparian floodplain, wetland, and upland grass, sedge, shrub, and tree species. As these new plantings grow to maturity, they will:

   a. Provide additional channel bank stability and riparian habitat.

   b. Provide shade to the restored channel, which will lower water temperatures and potentially increase dissolved oxygen levels.

   c. Increase the overall plant biodiversity of the riparian corridor from its existing condition.

**Summary of Project Goals:**

- Stabilize streambanks that have eroded and are threatening the integrity of adjacent properties.

- Restore a portion of approximately 5,700 LF of Buffalo Bayou and approximately 560 LF of Hogg Bird Tributary using NCD techniques to create a stable stream reach that will neither aggrade nor degrade and will minimize shear stresses on the banks that are causing extensive areas of active erosion within the project area.
• Enhance natural stream functions by establishing a riffle and pool system, installing in-stream structures, such as toe wood, to protect streambanks from erosive flows and provide aquatic habitat.

• Modify the existing stream bed and banks to restore stream dimension, pattern, and profile to a more natural and sustainable configuration.

• Reestablish native vegetation, including trees that will provide shading of aquatic habitats upon establishment within the riparian zone.
3.0 Baseline Information

3.1 Waters of the U.S. Impacts

Based upon the USACE Approved Delineation Verifications SWG-2011-00628 and SWG-2012-01007, approved on February 16, 2012, and January 25, 2013, respectively (Appendix C), the study area, which is a larger delineated area than the project area, contains 7,200 LF of Buffalo Bayou covering 13.97 acres, and 800 LF of an unnamed tributary, referred to as Hogg Bird Tributary, covering 0.50 acre. Please refer to the project plans in Appendix A. Buffalo Bayou within the proposed project area is approximately 5,700 LF and the unnamed tributary is approximately 560 LF. NCD techniques utilized to stabilize the stream through the project area will require temporary impacts to the stream. A stream impacts table is included in the Stream Condition Assessment (SCA) Report (Appendix D). The modifications to the stream will reduce the stream length in some areas in order to address stream pattern instability and reduce shear stresses and severe bank erosion. However, as shown in Table 2 of the SCA Report (Appendix D), the proposed project will result in an overall ecological lift with an average Reach Condition Index (RCI) score increase of 0.64 through improvement of the stream conditions and riparian buffer.

Impacted Wetlands – Baseline Description

Based upon the USACE Approved Delineation Verifications (Appendix C), 28 palustrine emergent wetland sites with an areal extent of 0.78 acre are present within the study area. The wetlands are located above and below the ordinary high water mark (OHWM) of Buffalo Bayou. Most of the wetlands are in-stream wetlands located at or below the OHWM. These in-stream wetlands are generally below the proposed bankfull bench, or existing low banks that are present.

Due to the nature of the proposed project, 18 in-stream wetlands and six depressional wetlands, totaling 0.61 acre, will be impacted by the proposed project. Please refer to Table 2 of the Wetland Delineation Report (Appendix E) for a summary of wetland impacts for the proposed project. Further descriptions of these wetlands are provided in the wetland delineation report (Appendix E). Except for Wetland 4, which will be only partially impacted, these wetlands are individually relatively small. The impacts to these wetlands will be due to regrading that is necessary to stabilize the stream bed and banks, with the exception of Wetland 26, which will be impacted by construction of an access road that is required for construction access to the stream. In addition to the overall ecological uplift anticipated from the proposed project, several bankfull bench areas will be constructed that provide flat surfaces where new in-stream wetlands are anticipated to repopulate, resulting in no anticipated loss of stream functions due to the proposed MPDP.

3.2 Existing Stream Channel Conditions – Baseline Description

Buffalo Bayou within the project area is a large sand-bed stream with a very flat hydraulic slope and low width-depth ratio. The project area is very sinuous with some tortuous meanders shaped through an X-type valley with broad and gentle slopes. Within the project area, the stream is not entrenched but shows a moderate degree of incision. The project area receives a high upstream sediment supply. A
Bank Erosion Hazard Index (BEHI) revealed a low to moderate erodibility rating along a majority of the project area and a moderate to high erodibility rating along the outside bends of tight meanders. In-stream stability is continuously declining as the stream lacks proper dimension, pattern, and profile for the current flow and sediment loading conditions. The riparian buffer has been reduced in some areas and individual spot repairs have increased shear stresses on the banks. The MPDP reach of Buffalo Bayou represents a substantial contribution to the overall total sediment loading to the bayou. An RCI was determined for each stream segment, and based on the assessment, the project area has an overall marginal reach condition. The variable scores and RCI results of each transect can be found in the SCA in Appendix D. A summary of the stream conditions within the project area are discussed below.

**Buffalo Bayou Stream Condition**

According to the SCA report (Appendix D), the overall Visual Channel Condition Variable for the project area was found to be marginal (Score 3). The stream is incised and over-widened at different points with vertically unstable banks. Generally, the stream does not have access to the geomorphic floodplain. The Riparian Buffer Variable for the project area overall was found to be in high suboptimal condition (Score 4.16). A large portion of the north bank is Memorial Park with 60 percent or more native woody vegetation, while other portions owned by homeowners are predominantly lawn. On the southern bank much of the riparian buffer is wooded. The Aquatic Use Variable is poor (Score 2) since the Aquatic Life Use score designated to this segment by Texas Commission on Environmental Quality (TCEQ) under the Texas Water Quality Inventory is limited due in part to bacteria levels. Aquatic Life Use score is based on assessment of dissolved oxygen; toxic substances in water; ambient water and sediment toxicity test results; and indices for habitat, benthic, macroinvertebrate, and fish community.

The overall Channel Alteration Variable is marginal (Score 4) as it has been highly altered with many different types of culverts, riprap, bulk heading, and gabion baskets.

**Hogg Bird Tributary Stream Condition**

According the SCA report (Appendix D), the Hogg Bird Tributary is declining in stream stability in the project area as the stream does not have the proper dimension, pattern, and profile for the current flow conditions. The tributary is actively head-cutting, causing erosion, and structures have been introduced, adding shear stresses to the banks. The stream has a marginal channel condition.
4.0 Project Work Plan

Construction activities required for the MPDP would occur in phases. The following construction sequence of events is general in nature, and subject to adjustment by the Construction Manager at Risk (CMAR) or contractor prior to initiation of on-site work or due to conditions experienced at the work site.

Upon authorization to proceed, work will begin by opening up the access point to the project area. Once access is set up to facilitate movement of equipment, materials, and workers into the project area, clearing activities would begin on the first 1,500-LF segment, followed by installation of best management practices (BMP) for sediment/pollutant control. Grading activities will then proceed as required to establish the appropriate dimension, pattern, and profile portrayed in the construction plans. Vegetation from the bankfull bench elevation down to the water’s edge will be planted by the contractor at the time of construction using coir lifts, live stakes, and native seed mix to facilitate stabilization of soils and establishment of vegetation as quickly as possible following grading activities. Those activities as described above would then be repeated in succession for the next 1,500-LF segment until complete for the entire project length. Removal of construction equipment and cleanup of materials would occur once grading and stabilization is complete for the project, at which time long-term revegetation efforts such as tree plantings would occur.

Activities following the sequence described above would fall under the preliminary Maintenance Plan as described in the following section.
5.0 Preliminary Maintenance Plan

One of the main objectives of the MPDP is for the establishment of a self-sustaining system that requires little to no long-term maintenance. With this goal in mind, scheduled maintenance following the initial construction and stabilization of the project area is to be minimal in order to allow for the natural succession of the site with the ultimate goal of a channel segment that requires no routine maintenance. Planned maintenance for the MPDP includes care for tree and shrub plantings, to include supplemental plantings if needed, and noxious invasive species control. Other non-routine maintenance, such as rehabilitation of natural structures within the channel, may be required if deemed necessary following routine monitoring of the channel. However, such maintenance cannot be predicted and would be part of adaptive management activities. Mowing and/or pruning of woody vegetation within the MPDP project is to be prohibited following planting of trees and shrubs.

Tree and Shrub Plantings

Tree and shrub plantings will be monitored and cared for by HCFCD’s planting contractor for two years to ensure survival of the plantings. Proposed maintenance activities would be limited to watering, mulching, and staking of trees/shrubs during the establishment period. In the event establishment goals are not met as set forth under the metric/success criteria presented in Section 6.0 of this document, supplemental plantings would occur. Upon establishment, no further maintenance is proposed for tree and shrub plantings within the MPDP project area except as identified in Section 8.0, Adaptive Management.

Noxious Invasive Species Control

HCFCD will maintain the MPDP project area to prohibit the establishment of noxious invasive species (Appendix B) including Chinese tallow (*Triadica sebifera*), Chinaberry (*Melia azedarach*), wax-leaf ligustrum (*Ligustrum japonicum*), and/or Chinese privet (*Ligustrum sinense*). Noxious invasive species will be monitored and managed not to exceed 10 percent cover. Removal of noxious species would be carried out through a combination of mechanical methods and herbicide treatment. Noxious invasive species control is anticipated until sufficient canopy closure by native species is achieved to prohibit problematic infestations of these species and as necessary in the future.

Maintenance of Structures

Although HCFCD’s plans call for no routine maintenance within the channel itself, corrective measures may be required to repair or alter natural structures placed within the channel segment. Potential maintenance of such structures would be conducted, if necessary, as outlined in Section 8.0, Adaptive Management.

Prohibited Maintenance

Mowing and/or pruning of woody vegetation within the MPDP project area is to be prohibited following planting of trees and shrubs. Site access for maintenance and/or monitoring of the project area will be limited to rubber-tired vehicles only where needed to facilitate watering and care for tree and shrub plantings. Such traffic would not be allowed during wet periods and must be conducted in a manner that
would not result in creation of ruts and/or the establishment of permanent roadways or trails. Upon successful establishment of tree and shrub plantings, vehicular traffic is to be limited to established roads only, with the remainder of the site to be accessed only by foot. Maintenance determined necessary that does not comply with the prohibitions as outlined above would be conducted only upon approval as outlined in Section 8.0, Adaptive Management.
6.0 Metric/Success Criteria

The extent to which the MPDP effectively satisfies obligations for the restoration of natural stream functions will be determined based on adherence to the performance standards set in place to meet the following objectives for geomorphic stability; benthic macroinvertebrates and fish; tree and shrub planting survival rates; emergent wetland planting coverage; and noxious invasive species management:

Geomorphic Monitoring

The main objective of the MPDP is to provide channel improvements to the stream segment that is experiencing excessive erosion in its current state; therefore, it is critical for HCFCD to document improvements in channel stability with the goal of a restored channel that neither aggrades nor degrades, thus resulting in decreased sediment loads delivered downstream. For this purpose, HCFCD will monitor channel cross-sections, longitudinal profiles, pebble counts, and Bank Erosion Hazard Index (BEHI), and will establish photo stations to provide data for analysis. Observations for Sediment Load and Bacteria would be conducted in conjunction with geomorphic monitoring as specified in the MPDP Sediment Load and Bacteria Monitoring Plan provided in Appendix F.

If HCFCD is able to demonstrate improvements in geomorphic stability from pre-construction levels through the five-year monitoring period, then the project would be determined a success. Expected improvements include:

- Channel cross-sections display increased stability from pre-construction levels.
- Longitudinal profile demonstrates a stable riffle-pool sequence.
- Pebble counts show no indicators of increased erosive activity within the channel from pre-construction levels.
- Assessment of BEHI displays a reduction in erosion hazard from pre-construction levels.
- Photo stations display evidence of increased stability from pre-construction levels and native riparian buffer establishment.
- Reduced sediment load (as measured by MPDP Sediment Load and Bacteria Monitoring Plan, Appendix F).

Bacteria level observations will be tabulated for informational purposes to study potential benefits associated with the channel restoration measures implemented for this project; however, a reduction in bacteria levels associated with the proposed activity is anticipated but is not included as success criterion for the MPDP project.

Benthic Macroinvertebrates and Fish Monitoring

Baseline benthic macroinvertebrates and fish monitoring is being conducted prior to project construction. HCFCD will monitor benthic macroinvertebrates and fish species annually within the channel segment for
two years following completion of construction activities. Success will be determined at the end of the two-year monitoring period based on the following parameters:

- Taxa Richness and the Hilsenhoff Biotic Index (HBI) (Hilsenhoff, 1987; 1988) show no reduction from pre-project levels for benthic macroinvertebrates

- Fish sampling results show no reduction/degradation from pre-project levels for fish species. Parameters that would require continued monitoring would include:
  - Reduction in fish species richness from pre-project levels
  - Reduction in total fish abundance from pre-project levels (excluding non-native species)
  - Increase of individuals with disease or other anomaly

Tree and Shrub Plantings - Survival

HCFCD plans call for planting of approximately 8,000 native trees and shrubs throughout the project area to be planted using a mixture of containerized plants and live stakes. Please refer to the planting plan in Appendix B. HCFCD will be responsible for ensuring adherence to the survival rates as outlined below. This measure will be documented utilizing 10 permanent transects established in the project area. Containerized plantings will occur between October 1 and March 31 following the completion of all earthwork construction. Plantings that do not demonstrate acceptable survival rates (as outlined below) at the end of the second full growing season following planting would require supplemental planting efforts.

- Demonstrate a minimum of 80 percent survival for containerized plants at the conclusion of the second full growing season following planting. Localized areas demonstrating less than 50 percent survival would require supplemental planting regardless of the overall success of plantings throughout the project area.

- Demonstrate a minimum of 50 percent survival for live stakes at the conclusion of the second full growing season. Localized areas that fail to establish woody vegetation from live stakes sufficient to provide for soil stability against erosive forces would require supplemental planting regardless of the overall success of plantings throughout the project area.

Emergent Wetland Plantings - Cover

Emergent wetland plantings should exhibit 70 percent cover by desirable wetland species by the end of the second full growing season following planting, as documented utilizing one transect across the length of the planted area. Planting will occur following the completion of all earthwork construction. Plantings that do not demonstrate the acceptable 70 percent cover at the end of the second full growing season following planting would require supplemental planting efforts. Please refer to Section 7.4 for additional detail on monitoring and management of wetland plantings.
Noxious Invasive Species

Noxious invasive species (Appendix B) would be monitored utilizing 10 permanent transects established in the project area. Noxious invasive species monitoring will continue at least yearly for a minimum of five years to limit establishment and spread of these species. Presence of noxious invasive species (i.e., Chinese tallow, Chinaberry, wax-leaf ligustrum, and Chinese privet) will be managed according to the maintenance plan should areal coverage exceed 10 percent at the time of scheduled monitoring events. Localized areas observed with concentrations of noxious invasive species would be treated regardless of overall composition of the project area.
7.0 Monitoring Requirements/Long-Term Management Plan

The stated purpose of the MPDP is for the establishment of a self-sustaining system that requires little to no long-term maintenance. Pre-construction monitoring will have documented pre-project existing conditions. Post-construction monitoring activities will occur with the appropriate frequency following construction as described in three phases: the Restoration Phase, the Monitoring Phase, and the Stabilization Phase.

Restoration Phase (six months to one year following completion of construction)

Following completion of the proposed construction activities, HCFCD will seed areas that contain exposed soils to establish herbaceous vegetation. In addition, the revegetation plan calls for the planting of approximately 8,000 additional trees and shrubs along the banks of the bayou (Appendix B). Following seeding and planting, HCFCD would monitor bank stabilization measures on a monthly basis and/or immediately following discrete precipitation events resulting in elevated flow of stormwater through the channel. Following inspection of the channel, corrective measures would be prescribed and implemented to correct observed conditions that may contribute to elevated sediment discharge or to erosion/undermining of the recontoured channel. Stormwater inspections and maintenance activities would occur on this schedule until stabilization measures and vegetation are established to thresholds that would allow for closure of the Stormwater Pollution Prevention Plan (SWPPP) under the National Pollutant Discharge Elimination System (NPDES) and filing of the Notice of Termination (NOT) with TCEQ.

Monitoring Phase (two to five years for identified parameters following completion of construction or until closure of USACE Permit)

Upon filing of the NOT with TCEQ, project maintenance would move into the monitoring phase. No scheduled maintenance activities would occur during the monitoring phase outside of supplemental vegetation plantings where needed to replace tree plantings that fail to meet the standards established in the HCFCD planting plan (Appendix B). During the monitoring phase, routine channel inspections would occur bi-annually. Following routine channel inspection, corrective measures would be prescribed and implemented to correct observed conditions that may contribute to elevated sediment discharge or conditions that may contribute to erosion/undermining of the recontoured channel. Conditions that may require corrective action along with conceptual solutions are outlined under the Adaptive Management Plan in Section 8.0 of this document. HCFCD anticipates that the monitoring phase would continue for a period of two to five years as specified below for the prescribed monitoring and will be documented in annual monitoring reports.

Parameters to be evaluated during monitoring and the initial scheduled monitoring period are specified below, with the option to extend the monitoring period for parameters that do not achieve the prescribed performance standard.

- Geomorphic Monitoring – monitored for five years
- Benthic Macroinvertebrates and Fish – monitored for two years
- Tree and Shrub Planting Survival – monitored for two full growing seasons
Emergent Wetland Plantings – monitored for two full growing seasons
Noxious Invasive Species – monitored for a minimum of five years

Stabilization Phase

During the final stabilization phase, routine channel inspections would occur yearly as part of HCFCD's normal channel management schedule. HCFCD anticipates that the final stabilization phase would continue for a period of up to five years. Following routine channel inspection, corrective measures would be prescribed and implemented to correct observed conditions that may contribute to elevated sediment discharge or conditions that may contribute to erosion/undermining of the recontoured channel. Conditions that may require corrective action along with conceptual solutions are outlined under the Adaptive Management Plan in Section 8.0 of this document. Annual monitoring reports will be prepared through the stabilization phase; thereafter, HCFCD would maintain records documenting observed channel conditions internally as part of their annual channel management program.

7.1 Geomorphic Monitoring

HCFCD will conduct geomorphic monitoring, which will include establishing 10 permanent monitoring stations to be surveyed on an annual basis. Monitoring stations will be chosen in a manner that incorporates all major habitat types within the stream channels proposed for restoration, including wadeable portions of the Hogg Bird Tributary. Both straight segments, or riffles, and meander segments, or pools, within the project reach will be monitored to gather performance data for the NCD techniques applied to the MPDP. The following measurements will be made at each monitoring station:

- Channel cross-sections (tied to survey benchmarks identified by HCFCD)
- Pebble counts
- Assessment of BEHI
- Photo stations (upstream, downstream, right bank, and left bank photos at each station)

In addition to the geomorphic measurements collected above at each monitoring station, a longitudinal profile will be monitored along the length of the channel flowline of the Buffalo Bayou project reach and Hogg Bird tributary. Sediment loading and bacteria levels will also be quantified as described in the MPDP Sediment Load and Bacteria Monitoring Plan (Appendix F) in support of the geomorphic monitoring assessments. Pre-Construction Geomorphic monitoring has been completed and post-construction monitoring will be completed following construction of the proposed project annually for five years.

Cross Sections

HCFCD will identify and survey permanently established cross-sections following the methods described in River Stability Field Guide (Rosgen, 2008).
Longitudinal profiles

HCFCD will conduct longitudinal profile surveys following the *River Stability Field Guide* (Rosgen 2008). Geomorphic features that will be collected include left bank and right bank, left edge of water, right edge of water, bankfull bench elevation, water surface, and thalweg (centerline).

**Pebble Counts**

HCFCD will conduct pebble counts following methods established in the *River Stability Field Guide* (Rosgen 2008). When pebble counts may not be safely conducted without requiring field personnel to submerge their head or face, HCFCD will provide survey personnel with sampling devices to safely collect substrate samples. HCFCD previously approved a sampling device that would be constructed using polyvinyl chloride (PVC) pipe sized appropriately for the channel based on information from the longitudinal profile and cross-sectional surveys and with a 45-degree elbow union. The PVC tool may be used by resting the elbow section of the sampling device on the bed of the stream and then moving it sideways in a scooping motion, plugging the top, slowly raising the device, and releasing the sample in either the sampler's hand or sampling tray to be measured and counted.

**Assessment of BEHI**

HCFCD will perform BEHI surveys throughout the project along the right and left banks following methods outlined in *River Stability Field Guide* (Rosgen, 2008).

**Photo Stations**

HCFCD will establish discrete photo stations along Buffalo Bayou to document channel conditions upstream and downstream and along the right and left banks. The selection of photo station locations will be at permanently established monitoring stations with additional locations established within line of sight of previous photo stations or changes in the BEHI, as necessary.

**Sediment Load and Bacteria**

Observations for Sediment Load and Bacteria will be conducted as specified in the MPDP Sediment Load and Bacteria Monitoring Plan provided in Appendix F. Sediment load information will provide documentation to determine the effectiveness of restoration measures aimed at reducing sediment loading. Bacteria level observations will be tabulated for informational purposes to study potential benefits associated with the channel restoration measures implemented for this project. However, a reduction in bacteria levels associated with the proposed activity cannot be predicted and is not included as a success criterion for the MPDP project.

### 7.2 In-stream Macroinvertebrate and Fish Monitoring

Benthic macroinvertebrate and fish communities are useful for determining the biological integrity of streams. Community characteristics are directly related to water chemistry, available habitat, nutrient availability, and level of impairment to a waterbody. Appropriate sampling methods, such as electrofishing, seining, kicknetting, and coarse woody debris picking, will be implemented to ensure all
available habitat types located within the Buffalo Bayou area are represented in baseline and subsequent post-construction monitoring. Benthic macroinvertebrate and fish communities provide measurable data to determine short-term impacts and long-term benefits to aquatic life resulting from the stream restoration activities employed for the demonstration project. Macroinvertebrate and fish monitoring will be completed prior to construction activities and annually for two years following completion of construction.

7.2.1 Transect Establishment

Six 500-foot transects will be established within Buffalo Bayou, one upstream of the project area, four within the project area, and one downstream of the project area, for macroinvertebrate and fish sampling. The Buffalo Bayou survey reach consists of homogenous habitat, primarily sandy bottom runs and glides interspersed with pools and coarse woody debris riffles. The four established transects within the project area will provide approximately 36 percent sampling coverage of the 5,700-foot project area. Based on Atkins' ecologists' professional opinion, this level of coverage will ensure collection of the representative species assemblages located within the bayou. A differentially-corrected global position system receiver will be utilized to ensure sampling replication. It is assumed that transects will remain in similar locations post-construction. Transects established upstream and downstream of the project area will allow for post-construction comparisons in Indexes of Biotic Integrity (IBI) as specified in *Surface Water Quality Monitoring Procedures, Volume 2: Methods of Collecting and Analyzing Biological Assemblage and Habitat Data* (TCEQ, 2014). Sampling will occur between June and September during periods of baseflow. Benthic macroinvertebrate and fish sampling will be sampled concurrently.

7.2.2 Benthic Macroinvertebrates

In-stream macroinvertebrate populations will be sampled at each of the six 500-foot and two 350-foot transects in accordance with *Surface Water Quality Monitoring Procedures, Volume 2: Methods of Collecting and Analyzing Biological Assemblage and Habitat Data* (TCEQ, 2014). Kicknet and sweep netting techniques will be utilized to sample riffles, coarse woody debris, cut banks, in-stream vegetation, roots, and runs. Woody debris will be picked up and attached macroinvertebrates collected. Samples will be placed into a sieve bucket and screened to remove excess sediment. Samples will be placed in jars with a 10 percent formalin solution. Samples will be sorted, identified to appropriate taxon, and enumerated. Data will be evaluated utilizing *Metrics and Scoring for Kick Samples, Rapid Bioassessment Protocol - Benthic Macroinvertebrates* (Harrison, 1996) (Appendix G).

7.2.3 Fish

Fish sampling will be conducted at each of the six 500-foot and two 350-foot transects identified above in accordance with *Surface Water Quality Monitoring Procedures, Volume 2: Methods of Collecting and Analyzing Biological Assemblage and Habitat Data* (TCEQ, 2014). A boat-mounted electrofisher will be the primary sampling method within Buffalo Bayou. Sampling effort per transect will be a minimum of 900 seconds of actual shock time. In wadeable portions of transects, seines will be utilized as a secondary sampling method. For both collection methods, fish will be identified to species, enumerated, and released. A combination of backpack electrofishing and seining will be utilized within the wadeable Hogg Bird Tributary. Fish data will be analyzed using scoring criteria to assess stream fish assemblages in
Western Gulf Coastal Plain streams adapted from *Regionalization of the Index of Biotic Integrity for Texas Streams* (Linam, et al., 2002) (Appendix H).

### 7.3 Riparian Planting

HCFCD’s plans call for planting of approximately 8,000 native trees and shrubs within the project area. Please refer to the planting plan in Appendix B. Following planting, trees and shrubs will be monitored for two years to ensure at least 80 percent survival. Because yearly expected mortality of plantings is greatest in the first year (typically between 10 and 15 percent), tree plantings will be monitored quarterly for the first two years to ensure at least 80 percent survival is achieved with supplemental plantings required should that threshold not be met. Replanting would continue to occur if survival rates are not met. Tree and shrub plantings would continue to be monitored bi-annually after success criteria are met to ensure that project goals are met. This biannual monitoring will continue until the project site demonstrates continued progress toward the desired canopy coverage, which is expected to provide shading benefits to aquatic habitats within the channel segments.

HCFCD will utilize methods described in standard monitoring protocols (Winward, 2000), in addition to pedestrian surveys and photographic logs to determine if performance standards are being met within the project areas.

During the plant establishment period, the planting sites will be managed to control predation from carp, nutria, beaver, feral hogs, and other predators as identified by the HCFCD.

No further supplemental plantings are planned should an 80 percent survival rate of native tree and shrub plantings be experienced within the first two years of monitoring.

### 7.4 Wetland Planting

Wetland plantings will be monitored quarterly for two years to ensure 70 percent cover is achieved. Areas that do not achieve a satisfactory stand will be replanted and maintained until a satisfactory stand is achieved.

HCFCD will utilize methods described in standard monitoring protocols (Winward, 2000), in addition to pedestrian surveys and photographic logs to determine if performance standards are being met within the project areas. HCFCD will monitor the planting areas after 30 days of growth. Determination of satisfactory stand will be made by the HCFCD at the 30-day monitoring event. Quarterly inspections after determination of satisfactory stand will occur during the first year of plant growth. Final inspection will occur one year after initial planting to make a determination of successful stand. Nuisance animal control may include protective netting, fencing, trapping, or other methods as approved. Planting sites will be managed to control the proliferation of noxious invasive species as described below.

### 7.5 Noxious Invasive Species

Site monitoring for noxious invasive species (Appendix B) would be conducted concurrent with monitoring efforts for riparian and wetland plantings as described in Sections 7.3 and 7.4, respectively. The concurrent monitoring would occur on a quarterly schedule for the first year following planting of the site.
and bi-annually following the first year to ensure the site is not negatively affected by noxious invasive species such as Chinese tallow, Chinaberry, Chinese privet, and/or wax-leaf ligustrum. Eradication measures would be evaluated and implemented should noxious invasive species exceed 10 percent cover at any time during site monitoring.
8.0 Adaptive Management Plan

At the end of the two-year monitoring period, HCFCD will document observations about the effect of the demonstration project on benthic macroinvertebrates and fish populations to be used for future projects. Should observations be sufficient to document stabilization of macroinvertebrate and fish populations to at least pre-project levels, no further monitoring would be proposed. Deficiencies resulting in reduced populations of macroinvertebrates and fish, if experienced, would be addressed by corrective actions as necessary and/or continued monitoring may be required beyond the two-year window for those criteria.

HCFCD will monitor channel profiles at established monitoring locations annually for a period of five years. Should portions of the channel be found to be aggrading or degrading in a manner that is not consistent with the project plans, HCFCD would seek to determine the cause, then prescribe and implement corrective measures as deemed necessary. In the event that a stable channel that neither aggrades nor degrades is not achieved as called for in the project design, HCFCD would determine optional measures for corrective action and/or additional monitoring requirements beyond the scheduled five years for geomorphic monitoring.

HCFCD will monitor establishment of tree and shrub plantings for a period of two years. Should the project area fail within the two-year period to achieve the prescribed 80 percent survival rate for container plants and 50 percent survival rate for live-stake plants, HCFCD will take measures to replace trees in the fall following the monitoring event that determined the deficiency. In the event the deficiency is caused by drought conditions, HCFCD may elect to defer supplemental plantings until more favorable conditions occur. For plantings in wetland areas that fail to achieve the prescribed 70 percent cover, HCFCD will replant those areas in the spring following the monitoring event in which the deficiency is identified. For areas in which plantings fail for reasons other than climatic conditions, HCFCD would evaluate those sites to determine the cause of the failure, which may include but would not be limited to, predation by animals or insects, soil deficiencies, vandalism, or storm damage for the specified location. Upon diagnosis of the cause for planting failure, HCFCD would take actions to correct the condition before replanting and would monitor that location for an additional two years.

The maintenance plan calls for no mowing and no pruning of woody vegetation in the project area; however, it is possible that as tree plantings mature on the demonstration site, overcrowding may occur, resulting in closure of the tree canopy to an extent that would not allow light penetration sufficient for the survival of desirable understory, mid-story, and herbaceous vegetation. HCFCD may elect to selectively clear portions of the project area in which an over-crowded canopy is determined to be an issue. Downed trees from selective clearing would either be left in place to provide soil nutrients, cover, and browse for wildlife.

Eradication measures would be evaluated and implemented should noxious invasive species (i.e., Chinese tallow, Chinaberry, Chinese privet, and wax-leaf ligustrum) exceed 10 percent cover at any time during site monitoring. Removal of noxious invasive species will be accomplished through a combination of mechanical (e.g., uprooting, chainsaw) and herbicide (e.g., Garlon 4E and Rodeo w/basal oil and dye and/or other appropriate forms) methods. Monitoring for management of noxious invasive species would be conducted for a minimum of five years and would then continue through HCFCD’s general long-term channel maintenance program.
The proposed project plan calls for restoration of the channel and its surrounding riparian habitat resulting in anticipated improvements to aquatic habitats. As such, the project will result in no net loss of natural stream functions and no mitigation for impacts to wetlands and other potential waters of the U.S. subject to USACE jurisdiction under Section 404 of the Clean Water Act and/or Section 10 of the Rivers and Harbors Act. HCFCD will evaluate the proposed project at the end of the five-year monitoring period to ensure a net increase in function. Should it be determined through the monitoring efforts as described herein that the proposed activities do not result in an increase in the function and value for the restored channel segments and their associated riparian habitats, additional adaptive management and monitoring activities will continue.
9.0 Responsible Parties, Monitoring, and Reporting

HCFCD is responsible for the implementation of the proposed monitoring plan. HCFCD will also establish a self-monitoring program that includes monitoring and reporting that will continue until there is an increase in function.

<table>
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<tr>
<th>Monitoring Activity</th>
<th>Responsible HCFCD Department</th>
<th>Time Period</th>
</tr>
</thead>
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<tr>
<td>Geomorphology</td>
<td>Stormwater Quality</td>
<td>5 years</td>
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<tr>
<td>Benthic and Fish</td>
<td>Regulatory Compliance</td>
<td>2 years</td>
</tr>
<tr>
<td>Riparian Planting</td>
<td>Facilities Maintenance</td>
<td>2 years</td>
</tr>
<tr>
<td>Wetland Planting</td>
<td>Stormwater Quality</td>
<td>2 years</td>
</tr>
<tr>
<td>Noxious Invasive Species</td>
<td>Facilities Maintenance</td>
<td>5 years</td>
</tr>
<tr>
<td>Sediment Load and Bacteria</td>
<td>Stormwater Quality</td>
<td>Pre, Active, and Post-construction (3 events each phase)</td>
</tr>
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10.0 References


Appendix A

Project Maps
Appendix B

MPDP Planting Plan
Noxious Invasive Species List
Appendix C

Approved Delineation Verification
SWG-2011-00628
SWG-2012-01007
Appendix D

Stream Condition Assessment Report
Appendix E

Wetland Delineation Report
Appendix F

MPDP Sediment Load and Bacteria Monitoring Plan
Appendix G

Metrics and Scoring for Kick Samples, Rapid Bioassessment Protocol - Benthic and Macroinvertebrates
Appendix H

Regionalization of the Index of Biotic Integrity for Texas Streams
<table>
<thead>
<tr>
<th>Planting Zone</th>
<th>Area (Ac)</th>
<th>Species</th>
<th>% of Planting</th>
<th>Quantity</th>
<th>Notes</th>
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<tr>
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<td></td>
<td>Will need to find source for American crinum lily</td>
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<td>Live Stakes</td>
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<td>25%</td>
<td>1385</td>
<td>Species planted by construction contractor</td>
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<td>25%</td>
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<tr>
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<td>830</td>
<td>Grass plugs will be included in final numbers</td>
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<td>277</td>
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<td>70</td>
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<td>buttonbush (Cephalanthus occidentalis)</td>
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<td>Virginia sweetsprie (Itea virginica)</td>
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Permanent Native Seed Mix
South Texas Sideoats Grama
Little Bluestem
Dilley Slender Grama
Welder Shortspike Windmillgrass
Mariah Hooded Windmillgrass
Chaparral Hariy Grama
Catrina Bristlgrass
Atascosa Texas Grama
Common Carpet Grass

Application Notes
- Permanent seed mix will be planted at a rate of 87 lbs. per acre.
- Permanent seed mix will be capped off with a high performance erosion control hydromulch called (Pro-Matrix)
- Permanent seed mix planted in the late Fall through early Spring will include as a temporary nurse grass a mixture of durana clover, annual rye grass, and tall fescue.
- Once the seed mixture application is applied to the topsoil, the District will not actively maintain the area. No mowing, herbicide applications, or targeted removal of voluntary species will be undertaken.
<table>
<thead>
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<th>Scientific Name</th>
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<tr>
<td>Chinese tallow</td>
<td>Triadica sebifera</td>
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<tr>
<td>Chinaberry</td>
<td>Melia azedarach</td>
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<td>Wax-leaf ligustrum</td>
<td>Ligustrum japonicum</td>
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</table>
Memorial Park Demonstration Project
Sediment Load and Bacteria Monitoring Plan

Prepared for: Harris County Flood Control District
Prepared by: AECOM
AECOM Project No. 60221290
February 2012
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1.0 INTRODUCTION

The Harris County Flood Control District (HCFCD) is working on several projects to determine the potential bacteria loading to bayou systems from suspended sediment in the water column and from streambed and streambank sediment sources. HCFCD engaged AECOM Technical Services, Inc. (AECOM) to develop a protocol to monitor the effectiveness of streambank stabilization projects in riverine systems. The Sediment and Bacteria Load Monitoring Protocol (Protocol) (HCFCD, 2012) is intended to guide the HCFCD in monitoring bacteria loading from suspended streambed sediment sources and can be applied to a variety of waterways in Harris County where erosion problems occur. The development of the Protocol is consistent with HCFCD’s Storm Water Management Program (SWMP), pursuant to TPDES Permit No. WQ0004685000. In addition, in April of 2009, TCEQ adopted TMDLs for bacteria in the Buffalo and White Oak Bayous and their tributaries. The development of the Protocol supports the Implementation Plan for Seventy-Two TMDLs for Bacteria in the Houston-Galveston Region (Implementation Plan) by conducting research to address bacteria in area waterways.

The Protocol is designed to describe the methodology for assessing streambank erosion on waterways in Harris County and to determine what level of bacteria loading may be associated with that sediment source. The project specific monitoring plan describing the methodology and establishing standard methods for integrating and conducting sediment and water quality studies throughout Harris County waterways should follow the Protocol (HCFCD, 2012). The Monitoring Plan will assist in determining the effectiveness of bank stabilization best management practices (BMPs) and relate sediment load management to bacteria loading. The management of bacteria loading through erosion control is based on the general premise that the reduction of sediment loading achieved through the implementation of erosion control BMPs will result in a reduction of bacteria loading. This premise is consistent with local research which has established correlations between bacteria and sediment particles in Buffalo Bayou (Brinkmeyer, 2010). Ultimately, the Protocol document will serve as a standard procedure and methodology for quantification of the total annual rate of sediment entrainment in area waterways from bank erosion processes in Harris County.

This document serves as the monitoring plan for the Memorial Park Demonstration Project in Buffalo Bayou, Houston, Texas (Figure 1-1).
Figure 1-1: Memorial Park Demonstration Project Location Map

Figure 1-2: Vicinity Map of Memorial Park Demonstration Project
2.0 MONITORING PLAN OBJECTIVES

While determination of bacteria load reduction in Buffalo Bayou from the Memorial Park Demonstration Project may be difficult to ascertain, it is possible to make correlative predictions based on anticipated reduction in total volume of sediment contributed from streambank erosion. The objectives of this Monitoring Plan are to:

- Describe the methodology to perform sediment and water quality sampling and analysis;
- Establish a protocol to determine anticipated bank erosion rates and total annual volume of sediment contributed from bank erosion processes. Application of this method to pre-construction and post-construction conditions will determine potential reduction in sediment loading from the Memorial Park Demonstration Project Reach;
- Allow for comparison between pre-construction, active construction, and post-construction conditions;
- Provide standards, establishing when the project has reached adequate streambank stabilization in order to monitor post-construction sediment and water quality conditions; and
- Establish bacteria load calculations that correlate bacteria concentrations with sediment loading data through estimates of particle size analysis, erosion rate determinations and sediment entrainment.
3.0 MONITORING PLAN OVERVIEW

The primary purpose of this Monitoring Plan is to determine potential bacteria loading to Buffalo Bayou from sediment suspended in the water column and from streambed sources. It will also examine the effectiveness of streambank stabilization projects, or BMPs, in riverine systems by studying the sediment and water quality during three phases of construction; pre-construction, construction, and post-construction activities. The success of this project will be based on the assumed reduced amount of sediment loading.

General considerations for this Monitoring Plan include "construction site" conditions with bank stabilization to control erosion and sedimentation on a 1,000-foot reach of larger/deep stream (5-10 feet deep by 10-20 feet wide).

Additional characteristics to be considered include natural features such as pools, riffles, and meander bends with point bars and cut banks (outer meanders). These characteristics should be considered during the site selection process due to physical factors such as varying water velocities, sedimentation rates, sediment entrainment and scouring effects influencing pollutant concentrations in both the water column and sediment.

The Monitoring Plan addresses the following conditions:
- Pre-Construction (Baseline Conditions)
- Active Construction
- Post-Construction
- Upstream and Downstream and Project Area Assessments

This Monitoring Plan includes standards to determine when the erosion control BMPs employed at the site reach adequate stabilization. Once stabilization and vegetation are established, monitoring of post-construction conditions can be performed to assess the effectiveness of the erosion control BMPs.

This project-specific Monitoring Plan and QAPP must be submitted to HCFCD for review and approval prior to sampling. Sediment and water quality sampling for any project is contingent upon approval of the QAPP. The Quality Assurance Project Plan (QAPP) can be found in Appendix D.

This project will focus on the sediment and water quality in a reach of Buffalo Bayou that is located within a highly urban section of the City of Houston. The stream reach included in this area is approximately 7,800 linear feet in length. It is adjacent to the City of Houston’s Memorial Park, the River Oaks Country Club, and several private residences. The general geomorphology of this reach varies based on observations in the Spring of 2011. It was noted that there were varied changes in width/depth and water surface slope from upstream to downstream. Significant bank erosion was observed along with some attempts to correct or lessen the amount of erosion and sediment deposition. In conclusion, this area
was labeled moderately entrenched and slightly entrenched with a majority of the area moderately entrenched (AECOM, 2011).

This background information has been reviewed, and research has been conducted for the purpose of developing a Sediment and Bacteria Load Monitoring Protocol (HCFCD, 2012). This Protocol establishes methods for measuring the effectiveness of bank stabilization projects in fluvial environments. The methods described in the Protocol will be applied to the MPDP area for evaluating the impacts on sediment and water quality by the bank stabilization BMPs used in this project. The project will focus on bacteria reduction by the management of sediment loading through erosion control. This general premise is supported by local research identifying correlations of bacteria with sediment particles in Buffalo Bayou (Brinkmeyer, 2010).

The streambank stabilization methods to be constructed in the MPDP study area are located in Attachment 1 found in Appendix D. Conceptual design plans (dated July 2011) include the installation of coir lift mats for erosion protection, coir lift woody debris for toe protection, and log-constructed riffles. These BMPs are proposed to assist primarily with bank stabilization and erosion control. These are the BMPs in this Monitoring Plan that will be evaluated to determine their effect on sediment and water quality in the MPDP. The conceptual drawings of the BMPs indicate they will be located at several proposed meanders in the project area. The coir fiber will be placed along the outside of all bends and along both sides of the bayou in riffle areas. Its primary purpose is to protect from erosion and restore the vegetation of the streambank. The woody debris will be located along the bends of the bayou. Placement of the woody debris is to stabilize the streambank and control sediment lost through erosion. It also creates cover and resting areas for local species. The log-constructed riffles will be placed in groups primarily along the bends and curves of the project area. The proposed natural looking log riffles’ main purpose is to establish and maintain the proposed longitudinal profile and thalweg of the channel. It is assumed that since these BMPs assist with bank stabilization and erosion control, that they will also demonstrate the ability to control or reduce the amount of bacteria found in the project area by reducing suspended sediment.
4.0 SAMPLING SITE SELECTION

For the MPDP area, the sampling sites were chosen based on the project boundaries and the length of the stream reach. The total length of the stream reach included in the MPDP area was divided equally, and the stations were distributed evenly to provide coverage of the entire study area. Further refinement of these locations was necessary due to other factors, such as the channel sinuosity and the presence of riffles, runs and pools within the area to be evaluated. Data needs for the Charting Buffalo Bayou Project were also considered during site selection, so the site locations should provide useful sediment data for use in the Charting Buffalo Bayou Model. The sites were chosen in collaboration with the Charting Buffalo Bayou Project team. The sampling sites were labeled based on the existing Charting Buffalo Bayou Project GIS tools. The MPDP area is approximately 7,800 linear feet in length and the total number of sampling sites is seven (7).

The site selection process for the MPDP follows the general premise that sediment load reductions will result in bacteria load reduction due to correlations between bacteria and sediment particles. These dynamics were considered during the sampling site selection process for the MPDP area.

While sites for BMP installation are chosen based on geomorphic assessments, the location and type of BMPs were also considered during the selection of the sampling sites. One sampling site was selected upstream of the project site with the remaining sampling sites selected approximately equidistant in a downstream fashion to provide coverage of the project area. Sites were systematically selected along the project area to represent the various physical stream characteristics within the project area (riffles, pools, meanders, etc). The final site was selected downstream of the overall project area. Sites selected for this project are approximately 1,000 feet apart from each other, including one site upstream of the MPDP and one site downstream of the area. Figure 4-1 is an aerial photograph with locations of the selected sites. Although sampling sites should remain relatively constant between each of the three construction phases, some adjustment may be necessary depending on the BMP installation and bank stabilization techniques implemented.

The sampling sites will be marked for repeated sampling by geo-referencing the points within the stream reach. Through the use of hand held or similar GPS devices, the sampling sites will be accurately located while in the field. The sampling site is typically an existing point mapped in the middle of the stream, where the water and suspended sediment is collected. Sediment core samples will be collected along the banks, which are perpendicular to that point.
Sampling site locations for each of the target conditions or construction phases should remain relatively constant to reduce potential variability in the data results caused by external factors. The same is true with regard to the number and types of samples to produce a comparable dataset. However, some adjustment to sample locations may be necessary due to the BMP installation and stabilization techniques implemented. If sampling site locations need to be adjusted, then the most adequate and characteristically similar location will be chosen to the maximum extent possible.

4.1 Streambank Erosion Assessments

Streambank erosion will be assessed for both pre- and post-construction conditions using the “Bank Assessment for Non-point source Consequences of Sediment” (BANCS) model. The BANCS model was developed as part of the Watershed Assessment of River Stability and Sediment Supply (WARSSSS) method, as a means of predicting bank erosion rates and annual entrainment of streambank sediments into streams and rivers (Rosgen, 2006). This model combines estimates of bank erodibility along a river reach using the Bank Erosion Hazard Index (BEHI) assessment with an erosion rate curve, which is a predictive relationship between BEHI score and erosion rate.
Several investigations have evaluated the existing erosion rates through the MPDP reach. One of these investigations was conducted by AECOM as part of the Charting Buffalo Project. AECOM evaluated the BEHI scores of all of the streambanks on Buffalo Bayou, including MPDP. An image showing the results of this evaluation through the MPDP reach is shown in Figure 4-2. This information was used with a site-specific erosion rate curve (described in more detail below) to estimate erosion rates through this reach. This information can serve as the baseline from which to compare the future erosion and reduction in sediment entrainment expected to occur from restoration/stabilization of Buffalo Bayou through the MPDP reach. Moreover, by combining estimates of total quantity of sediment input from streambank erosion with findings of bacterial concentrations in the bank soils, an estimate can be made of reduction in bacterial colonies, giving a further indication of overall water quality improvement.

Figure 4.2: Results of BEHI Scores on Buffalo Bayou

The following discussion describes the BANCS method and the site-specific erosion rate curve for Buffalo Bayou in more detail.

4.1.1 Methodology

The BANCS model is an integrative method that uses two bank erodibility estimation tools: BEHI and Near Bank Stress (NBS) along with an erosion rate curve to estimate annual bank erosion rates. In the BANCS model, BEHI and NBS values are obtained for the banks in a river reach and then used with an
erosion rate curve. The erosion rate curve is a developed relationship between NBS, BEHI and bank erosion rates made from direct measurement methods such as erosion pins or exposed tree roots.

The advantage of the BANCS model for erosion prediction over direct measurement methods, such as bank pins and bank surveys, is that the erosion rates of all banks within a certain reach can be quickly determined simply by assessing the BEHI and NBS ratings of those banks. BEHI and NBS are semi-quantitative assessments that take minutes to complete per bank, whereas direct measurements of bank erosion may take several years of data to provide meaningful results and require extensive setup and monitoring time. While the BANCS model is further described in the WARSSS methodology, the basic protocol for the key components of this model (BEHI, NBS and the Erosion Rate Curve) are described in more detail below.

4.1.2 BEHI and NBS

The BEHI is a method that evaluates a streambank’s susceptibility to erosion from erosional processes. This method integrates multiple variables that relate to combined erosional processes leading to annual erosion rates. Erosion risk is then established for a variety of BEHI variables and is eventually used to establish corresponding streambank erosion rates. NBS is the evaluation of the potential disproportionate energy distribution in the near-bank region (1/3 of channel cross-section) associated with the bank being evaluated. Increases in NBS can accelerate streambank erosion. There are several methods of determining NBS, some of which are field assessments and others which require evaluation of channel cross sections and aerial photographs. The cross-sections can be developed from available survey data and Harris County LiDAR data. Channel cross sections can be evaluated in any spreadsheet program; however, it is recommended that the fluvial geomorphology program RiverMorph be used, if available. For this Monitoring Plan, the methods of determining BEHI and NBS will follow those described in the WARSSS methodology. The assessor is urged to review the steps outlined in the WARSSS prior to beginning the assessment.

The method of determining changes in BEHI over an entire reach can vary depending on the length of the reach. As described in the WARSSS methodology for long lengths of channel, detailed changes in BEHI and NBS ratings can be determined by evaluating different BEHI types on the channel in detail, then “calibrating” one’s eye to what those BEHI types look like. One can then visually estimate BEHI ratings for the remainder of the reach without the need to fill out BEHI rating forms, thereby saving time and expense. Banks that have extensive areas of armoring are assigned a Very Low BEHI rating provided they are functionally stabilizing the bank.

4.1.3 Erosion Rate Curves

In the BANCS model, the BEHI and NBS rating combinations are input into an erosion rate curve in order to determine corresponding erosion rates. Erosion rate curves have been developed for only a small number of locations throughout the United States, presumably due to the lengthy time requirements of
collecting bank erosion data. The erosion rates used to develop the curves can be obtained from a number of direct measurement methods including: erosion pins installed within the streambank, toe pins, annual surveys of the bank or time-trend aerial photo analysis. However, each of these methods has limitations. Time-trend aerial photo analysis is limited in the level of detail of erosion rates that one can detect from one photo to the next. Erosion pins and bank surveys, while considered the most accurate methods, require multiple years of measurements to obtain meaningful results.

A method of measuring erosion rates which avoids some of these limitations and can yield a large amount of detailed bank erosion rate data in a relatively short period of time is based on using exposed tree roots. Using dendrogeomorphic methods on exposed tree roots to directly measure erosion rates is premised on the fact that the wood structure of a tree root changes when the root becomes exposed through erosional processes. Furthermore, in temperate regions, trees manifest growth rings which represent each year’s growth. Thus, by identifying the specific growth ring associated with a change in morphology from a response to exposure, one can count the number of rings beyond the exposure year to determine the duration of exposure. If this determination is coupled with a measurement from the root’s position to the current streambank location, one can then estimate the erosion rate of that bank. In this way, a relatively large amount of bank erosion data can be collected in a short period of time, when coupled with BEHI and NBS measurements, which are used to develop erosion rate curves. An illustration of the tree root method is provided in Figure 4-3.

![Figure 4-3: Illustration of Method Used to Determine Erosion Rates from Exposed Tree Roots](Source: Dick et al., 2011).

An erosion rate curve was developed for Harris County and published in the study report, *Fluvial Geomorphological Conditions of Harris County, Texas* (AMEC Geomatrix, Inc., 2009). However, as explained in that document, the curves are only suitable for erosion prediction during extreme high-flow events, due to interference with data collection by the extreme flows produced by Hurricane Ike in 2008.
Due to the lack of suitable erosion rate curves within the Harris County region, a detailed erosion rate curve was developed for the Charting Buffalo study using exposed tree roots. This curve will be used in this Monitoring Plan for determining erosion rates. An erosion rate curve is provided in Figure 4-4. This curve will be used to determine erosion rates. Erosion rate curves generally incorporate both BEHI and NBS ratings; however, in developing this curve there were not enough variations in NBS between the locations sampled to produce a functional curve incorporating NBS as well as BEHI. Thus, the erosion rate curve only relates erosion rate to BEHI score. Despite the lack of NBS incorporation, the curve still has a very strong “goodness of fit” and correlation ($R^2=0.82$, $p=0.95$), which suggests that BEHI score, by itself, is statistically a strong predictor of erosion rates on Buffalo Bayou. The erosion rate curves that are already developed for Buffalo Bayou are expected to be transportable to the other fluvial systems within Harris County of similar geomorphic nature (valley type, soils, slope, etc.).

4.1.4 Streambank Erosion Prediction

As the final step in the BANCS analysis, the erosion rate and total annual volume of sediment contributed from bank erosion processes will be determined for post-construction conditions in the MPDP reach. The erosion rate will be determined for each segment of bank using the curve provided above and the NBS and BEHI ratings for that bank. The total annual sediment volume contributed from bank erosion can be determined by multiplying the erosion rate of each segment of bank times that bank’s height and length. Study bank height will be determined from measurements of bank elevations from channel cross section or Harris County LiDAR data, and the bank lengths will be obtained from field mapping. The inputs and final results of BANCS analysis will be recorded on the BANCS analysis worksheet prior to each monitoring phase (included in Appendix A).
5.0 WATER AND SEDIMENT SAMPLING METHODS AND ANALYSIS

Sampling and analysis of sediment and water quality will be performed during the pre-construction, active construction and post-construction phases of erosion control projects. The techniques for sampling and analysis of the sediment and water quality are based in part on work conducted by Dr. Robin Brinkmeyer. Dr. Brinkmeyer’s bacteria research indicates that the highest levels of *Escherichia coli* (*E. coli*) bacteria occur in the top 1 cm of streambed sediment, while highest concentrations of *Enterococcus spp.* bacteria were found in the deeper portions of the sediment (Brinkmeyer, 2010). The highest concentrations of *E. coli* bacteria have also been found attached to sediment particles > 1 \( \mu m \), whereas *Enterococcus spp.* has been shown in higher concentration attached to larger particles > 25 \( \mu m \).

5.1 Sample Collection and Frequency

The sample collection procedures representing pre-construction, active construction and post-construction conditions described in this Monitoring Plan will be standard across each of the three (3) construction phases to be evaluated. The data analysis will include correlation of bacteria to sediment particle size to reinforce the findings of the research described above during the pre-construction analysis. During the active construction phase, correlations will be conducted again to reinforce the relationship described above. The post-construction sampling will evaluate the loading and use the rates of erosion determined by the geomorphic assessments to predict bacteria reductions.

Sampling frequency should be at least twice monthly, for at least three months during each of the three monitoring phases discussed in this Monitoring Plan. During each month, sampling should be conducted at each site at least once during dry weather (low flow conditions) and once during wet weather (high flow conditions), when possible. Dry weather (low flow conditions) should represent normal flow conditions observed in the specific waterway, while wet weather (high flow conditions) will vary by project and waterway. Field sampling activities will be recorded on a field form (Appendix B), identifying the phase during which the samples were collected.

For the MPDP, dry weather or low flow conditions will represent flow conditions observed in Buffalo Bayou below 1,000 cfs at the Piney Point Bridge Crossing (USGS No. 08073700). Wet weather or high flow conditions for this study are conditions observed between 1,500 and 2,000 cfs at the same USGS gauging station (USGS No. 08073700) located at the Piney Point bridge crossing. These conditions will be used to trigger sampling events and define overall hydrologic conditions. However, the flow estimation method using the unsteady state HEC-RAS model described in section 5.2.6 will be used to document flow conditions for the MPDP area during sample collection to be used in bacteria load calculations.

In addition, sampling during the pre-construction phase will occur for at least three months in order to thoroughly document pre-construction conditions. Sampling to assess post-construction conditions will not begin until bank stabilization has been confirmed by the methods described in Section 4.1 of this Monitoring Plan.
5.2 Sample Collection and Methods

Samples of both water and sediment should be collected at the specific sample sites chosen for the project. Flow data will be collected during each sampling event to facilitate pollutant load calculations. Sampling and field measurement procedures should follow the Standard Operating Procedures (SOP) detailed in HCFCD’s *Storm Water Quality Pond Monitoring Protocol, Version 2.0* (HCFCD, 2008) when applicable or the TCEQ’s *Surface Water Quality Monitoring (SWQM) Procedures Manual Volume 1, RG-415* (TCEQ, 2008). For larger/deep streams such as Buffalo Bayou (5-10 ft deep by 10-20 ft wide), it will be necessary to collect the samples from a watercraft or vessel such as kayaks, canoes or Jon boats.

5.2.1 Multi-Parameter Sonde Sampling

When collecting data using a YSI datasonde, the instrument should be placed in the centroid of the flow, and the sensors shall be lowered to a depth of approximately 1 ft. The datasonde should be placed in the centroid of the flow and lowered down the water column at approximately 5 ft intervals in order to obtain a vertical water quality profile. Hence, a 10 ft deep stream will yield three readings to include a bottom reading, a reading at half depth (5 ft) and a surface reading (1 ft).

5.2.2 Secchi Disk Sampling

Secchi disk readings provide a standard measure of water clarity as a point of reference when interpreting water quality data with regards to turbidity, TSS, and suspended sediments. Secchi disk readings will be collected in the centroid of flow and will be recorded as a Secchi depth in meters.

5.2.3 Grab Sampling

Samples to be analyzed in a laboratory will be collected and preserved in containers as designated by the laboratory or in accordance to the corresponding analytical method. The bucket method may be employed in cases where collecting samples directly into the sample container is not possible due to preservatives or other physical impairments preventing collection directly into the sample container. When a bucket is used to collect samples, the bucket will be rinsed three times with ambient water. The rinse water will be dumped outside of the stream and away from the sample area or downstream of the sampling site each time. The water sample should be collected below the surface of the water, which can be accomplished by inverting the collection vessel before submerging it in the water. The collection of samples will be conducted in an order as to prevent contamination (e.g., bacteria samples should always be collected first). When collecting samples, care should be taken to minimize the cross contamination of samples by avoiding the capture of any sediment disturbance caused by wading or wave action. This can be accomplished by collecting samples upstream of the vessel or person. Additionally, sampling
personnel shall allow ample time for the settling of any sediment plumes artificially induced or caused by disturbances other than natural currents before collecting any samples.

All samples will be labeled with the site identification number, preservative, date and time of the sample collection, the analysis requested and the initials of sampling personnel. Containers can be pre-labeled prior to sample collection or immediately following sample collection. Within 15 minutes of sample collection, all water and sediment samples must be preserved using the appropriate preservative corresponding to the analytical method requested. A zip-loc plastic bag will be used to contain the sample jar which will then be stored on ice in an ice chest. The cooler lid must be kept closed to minimize sample exposure to sunlight and to begin the process of cooling to 4°C. Standard sample chain-of-custody (COC) procedures will be followed when submitting water and sediment samples to the laboratory using the appropriate COC form (Appendix B). The sampling personnel will complete the COC form and submit the samples to the laboratory within the time allotted by the analytical method.

5.2.4 Sediment Core Sampling

Sediment core samples will be collected along the streambank/water’s edge following methods used in Dr. Robin Brinkmeyer’s bacteria research for a total of three core samples at each site as described below. Sediment cores will be collected by driving 15 cm, sterile core sleeves into stream beds at 0.5 m above the water line, at the water line, and 0.5 m below the water line (Brinkmeyer, 2010). An additional core sample will be collected in the middle of the stream to provide a cross-sectional dimension at one site. Because E. coli bacteria is the indicator in focus for the MPDP, the various depth horizons in the streambed sediments will not be targeted. Thus, the sediment cores will only be sampled at a depth representative of where E. coli was documented in the streambed sediments in Dr. Brinkmeyer’s research. The significant difference will be that the sediment core samples for the MPDP will be 15 cm deep as opposed to 35 cm. Particle size analysis will include ranges from 1 micron to 200 microns which will represent particles sizes correlating to E. coli. These data will also produce useful results for inclusion in the Charting Buffalo Sediment Model that is being developed. The core samples will be packaged and submitted to the laboratory for bacteria and particle size analyses.

5.2.5 Suspended Sediment Sampling

Samples to be analyzed for suspended sediments will be collected using a depth-integrated sampler, following Field Methods of Fluvial Sediment (Analytical ASTM Method D3977, Test C) included in Appendix C. When collecting the suspended sediment concentration samples with a depth integrated sampler, the device shall be lowered in the centroid of flow, through the water column by using a manual device, such as a winch with a cable or a rope, to effectively lower the sampler vertically through the water column and obtain a representative sample. For larger/deep streams, it is important that the personnel collecting samples position the integrated sampler upstream of the watercraft as to avoid cross-contamination. Samples will be packaged and submitted as discussed previously.
Suspended sediment analyses will provide a representative sample of suspended sediment in the water column using this method and will assist in confirming traditional TSS analyses which can vary due to the variability in particle sizes, densities, sample homogeneity, and physical processing of traditional TSS in water samples. When applicable, analysis of TSS and SSC data can follow the approach described in this section. TSS and SSC concentrations have long been reported in literature to be correlated to turbidity in streams. Due to this correlation between turbidity and TSS/SSC, turbidity sometimes is used as a surrogate in some studies where there is not sufficient TSS data available. A local example of this correlation was found at two USGS Stations along the West Fork San Jacinto River (Bodkin, L. and Oden, J., 2010). At these two locations, both log_{10}(SSC) and log_{10}(TSS) are found to be linearly correlated to log_{10}(turbidity) and log_{10}(streamflow) in a multiple (two independent variables) linear regression model where log_{10}(turbidity) and log_{10}(streamflow) serve as independent variables. The turbidity, stream flow and TSS/SSC data collected in this Buffalo Bayou study can be evaluated to determine if a correlation of TSS/SSC exists for stream flow and turbidity on Buffalo Bayou through a regression analysis. If this correlation exists, the regression model derived from the Buffalo Bayou data can be used to estimate TSS/SSC concentrations and loads using observed streamflow and turbidity data. This correlation can generate TSS/SSC data for any period where TSS/SSC data is lacking, but turbidity and streamflow data are available.

5.2.6 Flow Measurements

Flow measurements should follow procedures outlined in the SWQM Procedures Manual referenced for specific projects and will generally include readings of velocity, depth, and width. Velocities can be measured by instruments such as a Marsh McBirney or Sigma electronic flow meters, Global Flow Probes, or similar instruments. Readings should be taken across the channel at specified depths of designated transects (TCEQ, 2008). Simple flow measurements as described above can be effectively measured in wadeable streams. For non-wadeable streams, use of an Acoustic Doppler Velocimeter may be necessary as described in the SWQM Procedures Manual Volume 1, RG-415 (TCEQ, 2008). In cases where physical limitations, such as depth, impede effective and simple flow measurements, the data from the closest USGS gauging stations along the project area should be obtained and interpolations used to calculate a flow value applicable to the specific area. Flow may also be modeled if cross-sectional data or site-specific hydrograph curves exist for a particular project area, such as described below for the MPDP.

For the MPDP, water surface elevation will be measured at the foot bridge that is located just downstream of the River Oaks Country Club Golf Course. The foot bridge provides connection between the Bayou Bend Collection and Gardens, located on the south side of Buffalo Bayou, and a parking lot located at the terminus of Westcott Street, on the north side of Buffalo Bayou.
The stage will be estimated by measuring the depth of the water below the foot bridge (low chord elevation) as presented in the FEMA effective model of Buffalo Bayou. Comparing this measured stage to a stage vs. flow hydrograph, as computed using an unsteady state HEC-RAS model, the corresponding flow rate will be estimated. For this study, the model can be used to represent the entire 7,800 linear feet of stream. The elevation change within the MPDP boundary is negligible, and the resolution of the modeled flows is not sensitive enough to recognize negligible differences. Additionally, there is an absence of additional discharges within the project area, which further supports the concept of a low percent error in the estimated flow value.

5.3 Sample Analysis

The sample collection, field measurement, and laboratory analytical procedures for the MPDP are detailed in a project-specific Quality Assurance Project Plan (QAPP), included in Appendix D of this Monitoring Plan.

Standard conventional water quality and sediment parameters included in this study are listed in Table 5-1.
Table 5-1: Standard Parameters for the MPDP Study

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Matrix</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Field Parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conductivity</td>
<td>uS/cm</td>
<td>water</td>
<td>EPA 120.1</td>
</tr>
<tr>
<td>Dissolved Oxygen (DO)</td>
<td>mg/L</td>
<td>water</td>
<td>SM 4500-OG</td>
</tr>
<tr>
<td>pH</td>
<td>pH/ units</td>
<td>water</td>
<td>EPA 150.1</td>
</tr>
<tr>
<td>Temperature</td>
<td>°C</td>
<td>water</td>
<td>SM 2550B</td>
</tr>
<tr>
<td>Turbidity</td>
<td>mg/L</td>
<td>water</td>
<td>SM 2130 / EPA 180.1</td>
</tr>
<tr>
<td>Salinity</td>
<td>pp&lt;sup&gt;th&lt;/sup&gt;</td>
<td>water</td>
<td>SM 2520B</td>
</tr>
<tr>
<td>Water Clarity</td>
<td>M</td>
<td>water</td>
<td>Secchi Disk</td>
</tr>
<tr>
<td><strong>Conventional and Nutrient Parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonia-N, total</td>
<td>mg/L</td>
<td>water</td>
<td>SM 4500 NH3 C / EPA 350.1</td>
</tr>
<tr>
<td>Biochemical Oxygen Demand (BOD)</td>
<td>mg/L</td>
<td>water</td>
<td>SM 5210B</td>
</tr>
<tr>
<td><em>E. coli</em></td>
<td>mpn/100mL</td>
<td>water</td>
<td>SM 9223B</td>
</tr>
<tr>
<td><em>E. coli</em></td>
<td>mpn/100mL</td>
<td>sediment</td>
<td>SM 9223 / MPN</td>
</tr>
<tr>
<td>Enterococcus spp.</td>
<td>mpn/100mL</td>
<td>water</td>
<td>SM 9230C</td>
</tr>
<tr>
<td>Enterococcus spp.</td>
<td>mpn/100mL</td>
<td>sediment</td>
<td>SM 9230C</td>
</tr>
<tr>
<td>Hardness, total (as CaC03)</td>
<td>mg/L</td>
<td>water</td>
<td>EPA 200.7 / SM 2540C</td>
</tr>
<tr>
<td>Nitrate/Nitrite-N, total</td>
<td>mg/L</td>
<td>water</td>
<td>EPA 300.0</td>
</tr>
<tr>
<td>Nitrogen – N, total</td>
<td>mg/L</td>
<td>water</td>
<td>TKN + NOX (CALC)</td>
</tr>
<tr>
<td>O-phosphate-P filter &gt;15 min.</td>
<td>mg/L</td>
<td>water</td>
<td>EPA 300.0 / EPA 365.1</td>
</tr>
<tr>
<td>Particle Size Distribution</td>
<td>1-200 microns</td>
<td>sediment</td>
<td>SM 2560</td>
</tr>
<tr>
<td>Phosphorus-P, total</td>
<td>mg/L</td>
<td>water</td>
<td>EPA 365.3 / 365.1</td>
</tr>
<tr>
<td>Suspended Sediment Concentration (SSC)</td>
<td>mg/L</td>
<td>water</td>
<td>ASTM D3977-97</td>
</tr>
<tr>
<td>Total Dissolved Solids (TDS)</td>
<td>mg/L</td>
<td>water</td>
<td>SM 2540C</td>
</tr>
<tr>
<td>Total Kjeldahl Nitrogen (TKN)</td>
<td>mg/L</td>
<td>water</td>
<td>EPA 351.2</td>
</tr>
<tr>
<td>Total Suspended Solids (TSS)</td>
<td>mg/L</td>
<td>water</td>
<td>SM 2540D</td>
</tr>
</tbody>
</table>
The use of YSI Sondes (6920 V2), Secchi disks, and turbidimeters (LaMotte 2020) will be dependent on the method of sampling. Calibration and post-calibration procedures for YSI multi-probe instruments will follow the manufacturers’ recommendations and should be conducted as detailed in HCFCD’s *Storm Water Quality Pond Monitoring Protocol, Version 2.0* (HCFCD, 2008).

5.4 Monitoring Phases

The sample collection procedures for pre-construction, active construction and post-construction conditions described in this Monitoring Plan should be standard across each of the three (3) monitoring phases to be evaluated. The data analysis will include correlation of bacteria to sediment particle size to reinforce the findings of the research described above during the pre-construction, and active construction phases. The post-construction sampling will evaluate the loading and use the rates of erosion determined by the geomorphic assessments to predict bacteria reductions.

For the MPDP area, the seven (7) sites selected included locations upstream and downstream of the project area, and the sites were equidistantly distributed along the 7,800 linear feet of stream reach defining the project area. One sampling site is located upstream of the proposed project area, and the remaining sampling sites are systematically located in a downstream fashion providing spatial coverage of the entire project area. The sampling sites were selected considering the various physical stream characteristics within the project area (riffles, pools, meanders, etc.) and preliminary geomorphic data. The last downstream site is located outside of the 7,800 linear feet of stream reach. Each site will be sampled during the three (3) monitoring phases described below.

5.4.1 Pre-Construction (Baseline) Phase

To establish baseline conditions, sampling should be performed prior to the installation of proposed streambank stabilization methods, which may include in-stream structures or other erosion control Best Management Practices (BMPs). Field sampling activities will be recorded on the field form in *Appendix B*, identifying the samples as representative of “pre-construction conditions.” Standard sample COC procedures will be followed when submitting water and sediment samples to the laboratory using the appropriate COC form in *Appendix B*.

The water samples to be collected at each site in the centroid of flow include the following:

- One (1) *E. coli* and *Enterococcus spp.* water sample
- One (1) suspended sediment sample collected with an integrated depth sampler
- One (1) water column profile measurement of the physio-chemical parameters with the YSI sonde
- One (1) Secchi disk measurement
- One (1) BOD water sample
- One (1) hardness water sample
One (1) TDS, TSS and nutrients water sample

The streambed/streambank sediment samples at one bank within each sample site include the following:

- One (1) core sample collected 0.5 m above the water line
- One (1) core sample collected at the water line
- One (1) core sample collected 0.5 m below the water line
- An additional core sample will be collected in the middle of the stream to provide a cross-sectional dimension at one sample site.

The sediment core samples will be tested for *E. coli* and *Enterococcus spp.* and will include particle size analysis. Particle size analysis will include ranges from 1 micron to 200 microns.

### 5.4.2 Construction Phase

Sampling during the active construction phase will use the same techniques as the sampling conducted during the pre-construction phase. The test parameters and schedule of the sampling plan will follow the pre-construction activities. Although the sampling frequency may be modified, it typically will not be in excess of the pre- or post-construction frequency. Field sampling activities will be recorded on the field form in *Appendix B*, identifying the samples as representative of “active construction conditions.”

Standard sample COC procedures will be followed when submitting water and sediment samples to the laboratory using the appropriate COC form in *Appendix B*.

For the MPDP area, sampling site locations for each of the target conditions or construction phases, should remain relatively constant to reduce potential variability in the data results caused by external factors. The same is true with regard to the number and types of samples to produce a comparable dataset. However, some adjustment to sample locations may be necessary due to BMP installation and stabilization techniques implemented.

The water samples to be collected at each site in the centroid of flow include the following:

- One (1) *E. coli* and *Enterococcus spp.* water sample
- One (1) suspended sediment sample collected with an integrated depth sampler
- One (1) water column profile measurement of the physio-chemical parameters with the YSI sonde
- One (1) Secchi disk measurement
- One (1) BOD water sample
- One (1) hardness water sample
- One (1) TDS, TSS and nutrients water sample

The streambed/streambank sediment samples at one bank within each sample site include the following:

- One (1) core sample collected 0.5 m above the water line
• One (1) core sample collected at the water line
• One (1) core sample collected 0.5 m below the water line
• An additional core sample will be collected in the middle of the stream to provide a cross-sectional dimension at one sample site.

The sediment core samples will be tested for *E. coli* and *Enterococcus spp.* and will include particle size analysis. Particle size analysis will include ranges from 1 micron to 200 microns.

### 5.4.3 Post-Construction Phase

It is important to note that post-construction sampling of water and sediment for quality analysis should not begin until the project site has reached stability. Bank stabilization is established and/or erosion control BMPs will be deemed stable through the geomorphic assessments described above using the Streambank Erosion Assessment Protocol. Post-construction monitoring of bank stabilization strategies includes comparisons of geomorphic data obtained over time, as discussed in Section 4 of this Monitoring Plan.

Post-construction sampling can begin when final stabilization has been achieved for the project area. According to the EPA, final stabilization means that at least 70% of the permanent vegetative cover has been established. Alternatively, final stabilization is also achieved when permanent measures such as rip rap, gabions, or other structural BMPs have been employed. It will be at the discretion of the Project Engineer and HCFCD to state when final stabilization has occurred for a given project area prior to commencement of post-construction sampling events.

Sampling to evaluate post-construction conditions will be performed following the pre-construction procedures outlined above. The sampling site location for each of the target conditions or construction phases should remain relatively constant to reduce potential variability in the data results caused by external factors. The same is true with regard to the number and types of samples to produce a comparable dataset. However, some adjustment to sample locations may be necessary due to BMP installation and stabilization techniques implemented. The parameters to be tested and the schedule of the Monitoring Plan will follow the pre-construction activities. Field sampling activities will be recorded on the field form in *Appendix B*, identifying the samples as "post-construction samples." Standard sample COC procedures outlined in the QAPP will be followed when submitting water and sediment samples to the laboratory using the appropriate COC form in *Appendix B*.

The water samples to be collected at each site in the centroid of flow include the following:

• One (1) *E. coli* and *Enterococcus spp.* water sample
• One (1) suspended sediment sample collected with an integrated depth sampler
• One (1) water column profile measurement of the physio-chemical parameters with the YSI sonde
- One (1) Secchi disk measurement
- One (1) BOD water sample
- One (1) hardness water sample
- One (1) TDS, TSS and nutrients water sample

The streambed/streambank sediment samples at one bank within each sample site include the following:

- One (1) core sample collected 0.5 m above the water line
- One (1) core sample collected at the water line
- One (1) core sample collected 0.5 m below the water line
- An additional core sample will be collected in the middle of the stream to provide a cross-sectional dimension at one sample site.

The sediment core samples will be tested for *E. coli* and *Enterococcus spp.* and will include particle size analysis. Particle size analysis will include ranges from 1 micron to 200 microns.
6.0 DATA ANALYSIS AND INTERPRETATION

The sample results from the pre-construction monitoring establish baseline conditions for sediment and water quality in the project area. The sample results for “active construction” conditions represent sediment and water quality during active soil disturbance. The post-construction results represent sediment and water quality after stabilization of BMPs used in the bank stabilization project. Post-construction monitoring results will be compared to the results obtained during the pre-construction and active construction phases of the project. This comparison will help determine the effectiveness of the erosion control BMPs and will assist in identifying any pollutant load reductions achieved through bank stabilization practices.

The standard assumption is to expect the pollutant concentrations observed during construction activities to be higher than those observed during pre-construction (baseline) conditions due to the sediment disturbance. However, the physical characteristics of the sampling site, such as site-specific construction BMPs used, sediment entrainment dynamics, particle size distribution, water velocity, depth, and erosion rates will affect the pollutant concentrations in the samples. To reduce variability in any of the results, the sampling site locations and number of samples should remain the same during each of the conditions assessed to the maximum extent practicable.

6.1 Bacteria and Sediment Loading

The primary purpose of this Monitoring Plan is to determine potential bacteria loading to Buffalo Bayou from sediment suspended in the water column and from streambed sources. The hypothesis for this monitoring plan is that a reduction in sediment will link to a reduction in bacteria. The success of this project will be based on the reduced amount of sediment loading. Correlation of bacteria with sediment data will be used to calculate loading. This Monitoring Plan includes standards to determine when the erosion control BMPs employed at the site reach adequate stabilization. Once stabilization is established, monitoring of post-construction conditions can be performed to assess the effectiveness of the erosion control BMPs.

Flow data, sediment particle size distribution, streambank erosion rates and sediment entrainment will be used to calculate bacteria loading from bank sediment erosion and will assist in identifying areas potentially contributing significant bacteria loads via sediment particles. These data will be used to evaluate the effectiveness of BMPs used for erosion control and therefore achieving bacteria reductions. The assessment will serve as a planning tool for better managing bacteria loading, where possible, and will assist in identifying potential sediment and water quality benefits obtained through streambank stabilization projects. Streambed bacteria data from instream sediment core samples will be used to calculate the contribution of bacteria from resuspension of bottom sediments. Two separate approaches for bacteria loading data analysis may be used and applied as appropriate and as detailed below.
The first approach entails estimating bacteria loads contributed within a reach which is served by a specific BMP. The estimate will be based on the difference of in-stream loading between the downstream boundary and the upstream boundary in dry weather. In wet weather, the bacteria load can be estimated as the downstream in-stream loading minus the upstream loading. Instream loading is the product of flow and bacteria concentration. Bacteria concentrations measured at upstream and downstream boundaries, coupled with the flow data obtained for the MPDP area, will allow a bacteria load estimate to be calculated.

The second approach may be necessary depending on variability observed in the sample results. Significant variability may affect the estimation of the bacteria load. For example, the measured bacteria level at the upstream boundary may be higher than that at the downstream boundary. If this is the case, the bacteria load has to be estimated using the correlation between sediment and bacteria data. A regressed correlation of bacteria with sediment data will be established using the samples collected. This correlation will give the ratio of bacteria to sediment (number of bacteria per gram of sediment). It is assumed that this ratio applies to eroded sediment from streambank. Applying this ratio to the amount of streambank sediment eroded as quantified by the model, the bacteria associated with the sediment from the eroded streambank can be estimated as the product of this ratio and the amount of streambank eroded.

6.2 Reporting

Regular progress reports and technical reports will be prepared under this Monitoring Plan, each serving different purposes while meeting project specific requirements. Below are descriptions of these reports.

6.2.1 Progress Reports

Regular progress reports to HCFCD will be made at a frequency meeting the requirements in the project-specific scope. The format for the progress reports will be approved by HCFCD.

6.2.2 Technical Reports

A technical report using a standard report format approved by HCFCD will be used to describe and summarize the results of sediment and water quality sampling activities conducted for projects under this Monitoring Plan. These will summarize the methods used, analytical results, and conclusions from the sampling. Comparisons between the results obtained during the various stages of the bank stabilization projects, including pre- and post-construction, will be used to evaluate the impact of the project on water quality and the effectiveness of installed BMPs on erosion control. Modifications to any procedures or methodology and data quality objectives will be discussed in the report and reference the appropriate QAPP revision. Data reporting will include spreadsheets, tables, figures, graphs, statistical results, and load calculation results as applicable. Populated copies of the field forms included in the appendices of this Monitoring Plan will be provided in the appendices of the technical reports.
7.0 QUALITY ASSURANCE

For Quality Assurance, a project-specific QAPP will be developed or a regional QAPP may be referenced, as applicable. The QAPP for the MPDP is included in Appendix D of this Monitoring Plan. The QAPP establishes the quality control procedures for all field and analytical work to be performed during the project. The QAPP defines and establishes the project organization, data quality objectives, required constituents, field methods, and laboratory performance standards and addresses the roles and activities of all project participants. The QAPP essentially establishes project-specific data quality objectives (DQOs) and defines data validation procedures. The following sub-sections describe significant elements included in the QAPP.

7.1 Project Organization

The QAPP should address the roles and activities of all individuals and organizations involved in the field sampling activities including the name of the organizations and the analytical laboratories working on the project. The organization conducting the field sampling has primary responsibility for project execution in accordance with QAPP requirements with regard to sampling and analytical testing. The organization must have a clear understanding of the QAPP and DQOs of the sampling plan.

7.1.1 Data Quality Objectives

During QAPP development, it is important to maintain consistency with the ultimate goals of the Monitoring Plan to meet the DQOs of the Monitoring Plan. The DQOs for this Monitoring Plan are specified below. The QAPP should define the project limits for precision and accuracy of data by requiring specific sample splits, duplicate, and spike samples.

7.1.2 Precision

Precision is a measure of the reproducibility of a measurement when the procedure is repeated. It is defined as the degree to which a set of observations or measurements of the same property, obtained under similar conditions, conform to themselves. It is an indication of random error and used to assess field splits or variability between two samples. When the relative percent difference between two duplicate samples exceeds 30%, the data is considered excessively variable. This condition would require documentation of corrective action under the QAPP guidelines.

Relative percent difference (RPD) is calculated as follows:

\[ \text{RPD} = \left| \frac{(X1 - X2)}{(X1+X2)/2} \right| \times 100 \]

7.1.3 Accuracy

A result is considered accurate when the value reported does not differ from the true value. Accuracy is verified through the analysis of matrix spikes and calibration control standards determined by the
laboratory for specific analytical methods and matrices. Accuracy should be addressed in the laboratory measurement performance standards included in the QAPP.

7.1.4 Comparability

Comparability of data sets for water quality assessments is based on the standardization and consistency of methods approved for sampling and analysis used during a project. These are defined in the QAPP. Confidence in data sets is also increased by using standard units in reporting data, by using accepted rules for rounding values, and by standardizing reporting format.

7.1.5 Completeness

The completeness of the data is basically a relationship of how much of the data is available for use compared to the total potential data. Ideally, 100% of the data should be available. However, the possibility of unavailable data due to accidents, insufficient sample volume, broken or lost samples, etc. is to be expected. Therefore, it will be a general goal of the project(s) that 90% data completion is achieved.

7.1.6 Required Parameters

The QAPP should list the project-specific parameters required for sampling at specific project sites. In some cases, the parameters may vary between project areas depending on the goal of the project.

Under this Sediment Load and Bacteria Monitoring Plan, sediment and erosion control, using the geomorphic assessment methods described previously, are of primary concern for water quality projects in Harris County. Therefore, suspended sediment concentration, TSS, and streambed sediment core samples are required parameters under this Monitoring Plan. However, information in this quality section pertains to other types of analysis to cover potential future projects that may include additional parameters.

7.1.7 Field Methods

The QAPP will describe the appropriate field sampling methods, including sample collection, field QA/QC procedures, collection of field split samples, sample preservation methods, and approved sample containers.

7.1.8 Laboratory Performance Standards

The QAPP shall describe laboratory performance standards, including minimum detection levels (MDLs), reporting limits (RLs), minimum analytical levels (MALs), and objectives for precision, accuracy, and completeness. The QAPP for the MPDP references the laboratory’s Standard Operating Procedures (SOPs).
7.1.9 Field Quality Control

Processes to prevent contamination in the field include procedures outlined in the TCEQ Surface Water Quality Monitoring Procedures Manual which outlines the necessary steps to prevent contamination of samples. These include: direct collection into sample containers, when possible; clean sampling techniques for metals; and certified containers for organics. Field QC samples are collected to verify that contamination has not occurred.

7.1.10 Sampling Quality Control Requirements and Acceptability Criteria

The minimum field QC requirements for specific analysis are outlined in the TCEQ Surface Water Quality Monitoring Procedures Manual. General descriptions of field sample QC follows below and should be considered on a project specific basis under this Monitoring Plan:

**Field Split** - A field split is a single sample subdivided by field staff immediately following collection and submitted to the laboratory as two separately identified samples according to procedures specified in the SWQM Procedures. Split samples are preserved, handled, shipped, and analyzed identically and are used to assess variability in all of these processes. Field splits apply to conventional samples only. To the maximum extent possible, field splits prepared and analyzed over the course of the project should be performed on samples from different sites. The QAPP should define the frequency in which these samples will be collected for specific projects and should be no less than the standard 10%.

7.1.11 Standards Traceability

All standards used in the field and laboratory are traceable to certified reference materials. Standards preparation is fully documented and maintained in a standards log book. Each documentation includes information concerning the standard identification; starting materials, including concentration; amount used and lot number; date prepared; expiration date; and preparer’s initials/signature. The reagent bottle is labeled in a way that will trace the reagent back to preparation.

7.1.12 Laboratory Measurement Quality Control Requirements and Acceptability Criteria

The performance criteria addresses: method specific QC requirements, Limits of Quantitation (LOQs), LOQ check sample, laboratory control samples (LCS), duplicates, matrix spikes, method blanks, and percent recovery definitions, which are explained in detail in laboratory SOPs and quality manual (QMs). For the MPDP, Hygeia Laboratories Inc, and Xenco Laboratories will be performing the analyses, and copies of the QMs can be found in Attachment 4 of the QAPP.

7.1.13 Chain-of-Custody

The QAPP will describe the proper chain-of-custody (COC) procedures. Field personnel will follow the COC guidelines described in the QAPP for all water and sediment samples collected. All samples must be documented on a COC form and samples must remain under the custody of field personnel until they
are formally relinquished to another individual for transport or to their final destination for analysis (laboratory). A sample is defined as being under an individual’s custody when any of the following conditions exist: (1) it is physically in their possession, (2) it is within their view after physically being in their possession, (3) it was in their possession and then stored in a secure area under key and lock, or (4) it is in a designated secure area. During transport, samples are under the custody of the transporter until they are relinquished to the laboratory for sample log in, and preparation for analysis. As samples are relinquished from person-to-person, from collection to arrival at the laboratory, each individual must sign and date the COCs when a transfer of sample custody occurs.

Documentation of sample possession must include the following:

- Unique sample identification
- Date and time of sample collection
- Source of sample (including name, location, and sample type)
- Designation of Matrix Spike/Matrix Spike Duplicate
- Preservative used
- Sample container type
- Analyses required
- Name of collector(s)
- Custody transfer signatures, dates and times sample was relinquished
- Bill of lading or shipping tracking number (when applicable)

Preprinted COC forms should be provided by the laboratory and used to document the transfer of samples from collection to final destination. A copy of the chain-of-custody standard form should be included in the QAPP for specific projects. A sample COC form is provided in Appendix B of this Monitoring Plan.

7.1.14 Data Validation

The QAPP in Appendix D addresses data validation procedures to be implemented for the MPDP study. Analytical data validation procedures are detailed in laboratory QMs.
8.0 REFERENCES


AMEC Geomatrix, Inc. 2009. Fluvial Geomorphological Conditions of Harris County, Texas.


Harris County Flood Control District, 2012. Harris County Sediment Load and Bacteria Monitoring Protocol.


9.0 ACRONYMS AND TERMS

Bank Assessment for Non-point source Consequences of Sediment (BANCS) Model: The BANCS model is an integrative method that uses two bank erodibility estimation tools: Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS).

Bank Erosion Hazard Index (BEHI): Bank Erosion Hazard Index is a bank erodibility estimation tool used in geomorphic assessments.

BMP: Best Management Practice

Chain-of-Custody (COC): Standard procedures to document sample handling and transport used to minimize the possibility of tampering with samples.

Channel: A natural or man-made water conveyance.

DQO: Data Quality Objective

Light Detection and Ranging (LiDAR): Light Detection and Ranging (LiDAR) is a technology similar to RADAR that can be used to create high-resolution digital elevation models (DEMs) with vertical accuracy as good as 10 cm. LIDAR equipment, which includes a laser scanner, a Global Positioning System (GPS), and an Inertial Navigation System (INS), is generally mounted on a small aircraft.

MPDP: Memorial Park Demonstration Project

Monitoring Protocol: Specific instructions and guidance contained within a sampling plan describing methodology used during monitoring activities.

Near Bank Stress (NBS): Near Bank Stress is a bank erodibility estimation tool used in geomorphic assessments.

Pollutant: Any agent introduced to the environment through human activity that may cause or contribute to the degradation of environmental (water) quality.

Sampling Plan: A document prepared by an organization describing project specific or site-specific sampling, analysis, QA/QC, and data management procedures to be used during a given project.

Structural BMP: Constructed device to reduce or prevent pollutants from entering the environment.

APPENDIX A

Streambank Assessment Forms
# Worksheet 20. BEHI variable worksheet

<table>
<thead>
<tr>
<th>Stream:</th>
<th>Cross Section:</th>
<th>Date:</th>
<th>Observers:</th>
</tr>
</thead>
</table>

## Bank Height/Max Depth Bankfull (C)

<table>
<thead>
<tr>
<th>Study Bank Height (ft)</th>
<th>Bankfull Height (ft)</th>
<th>A/B =</th>
</tr>
</thead>
</table>

## Root Depth/Bank Height (E)

<table>
<thead>
<tr>
<th>Root Depth (ft)</th>
<th>Study Bank Height (ft)</th>
<th>D/A =</th>
</tr>
</thead>
</table>

## Weighted Root Density (G)

<table>
<thead>
<tr>
<th>Root Density (%)</th>
<th>F*E =</th>
</tr>
</thead>
</table>

## Bank Angle (H)

<table>
<thead>
<tr>
<th>Bank Angle (Degrees)</th>
<th>H</th>
</tr>
</thead>
</table>

## Surface Protection (I)

<table>
<thead>
<tr>
<th>Surface Protection %</th>
<th>I</th>
</tr>
</thead>
</table>

### Bank Sketch

**Horizontal Distance (ft)**

- 0
- 2
- 4
- 6
- 8
- 10
- 12

**Vertical Distance (ft)**

- 0
- 1
- 2
- 3
- 4

- Bankfull Height
- Root Depth
- Bank Angle
- Surface Protection
- Start of Bank

- Bank Sketch Diagram
## Worksheet 21. Summary of bank erosion hazard index (BEHI)

### Bank Erosion Hazard Rating Guide

<table>
<thead>
<tr>
<th>Bank Erosion Potential</th>
<th>Bank Height/ Bankfull Ht</th>
<th>Root Depth/ Bank Height</th>
<th>Root Density %</th>
<th>Bank Angle (Degrees)</th>
<th>Surface Protection%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VERY LOW</strong></td>
<td>1.0-1.1</td>
<td>1.0-0.9</td>
<td>100-80</td>
<td>0-20</td>
<td>100-80</td>
</tr>
<tr>
<td><strong>LOW</strong></td>
<td>1.1-1.19</td>
<td>0.89-0.5</td>
<td>79-55</td>
<td>21-60</td>
<td>79-55</td>
</tr>
<tr>
<td><strong>MODERATE</strong></td>
<td>1.2-1.5</td>
<td>0.49-0.3</td>
<td>54-30</td>
<td>61-80</td>
<td>54-30</td>
</tr>
<tr>
<td><strong>HIGH</strong></td>
<td>1.6-2.0</td>
<td>0.29-0.15</td>
<td>29-15</td>
<td>81-90</td>
<td>29-15</td>
</tr>
<tr>
<td><strong>VERY HIGH</strong></td>
<td>2.1-2.8</td>
<td>0.14-0.05</td>
<td>14-5.0</td>
<td>91-119</td>
<td>14-10</td>
</tr>
<tr>
<td><strong>EXTREME</strong></td>
<td>&gt;2.8</td>
<td>&lt;0.05</td>
<td>&lt;5</td>
<td>&gt;119</td>
<td>&lt;10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>V = value, I = index</th>
</tr>
</thead>
</table>

| Bank Material Description: |

Bank Materials:
- **Bedrock** (Bedrock banks have very low bank erosion potential)
- **Boulders** (Banks composed of boulders have low bank erosion potential)
- **Cobble** (Subtract 10 points. If sand/gravel matrix greater than 50% of bank material, then do not adjust)
- **Gravel** (Add 5-10 points depending percentage of bank material that is composed of sand)
- **Sand** (Add 10 points)
- **Silt Clay** (+ 0: no adjustment)

**BANK MATERIAL ADJUSTMENT**

| Stratification Comments: |

Stratification:
- Add 5-10 points depending on position of unstable layers in relation to bankfull stage

**STRATIFICATION ADJUSTMENT**

| Bank location description (circle one) |

| Straight Reach | Outside of Bend |

**GRAND TOTAL**

<table>
<thead>
<tr>
<th>VERY LOW</th>
<th>LOW</th>
<th>MODERATE</th>
<th>HIGH</th>
<th>VERY HIGH</th>
<th>EXTREME</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-9.5</td>
<td>10-19.5</td>
<td>20-29.5</td>
<td>30-39.5</td>
<td>40-45</td>
<td>46-50</td>
</tr>
</tbody>
</table>

**BEHI RATING**
Worksheet 22A. Various field methods of estimating Near-Bank Stress risk ratings for the calculation of erosion rate.

**Estimating Near-Bank Stress (NBS)**

<table>
<thead>
<tr>
<th>Stream:</th>
<th>Location:</th>
<th>Date:</th>
<th>Crew:</th>
</tr>
</thead>
</table>

**Methods for Estimating Near-Bank Stress**

1. **Transverse bar or split channel/central bar creating NBS/high velocity gradient:** Level I - Reconnaissance.
2. **Channel pattern (Rc/W):** Level II - General Prediction.
3. **Ratio of pool slope to average water surface slope (Sp/S):** Level II - General Prediction.
4. **Ratio of pool slope to riffle slope (Sp/Srif):** Level II - General Prediction.
5. **Ratio of near-bank maximum depth to bankfull mean depth (dnb/dbkf):** Level III - Detailed Prediction.
7. **Velocity profiles/Isovels/Velocity gradient:** Level IV - Validation.

**Converting Values to a Near-Bank Stress Rating**

<table>
<thead>
<tr>
<th>Near-Bank Stress Rating</th>
<th>Method Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Low</td>
<td>N/A</td>
</tr>
<tr>
<td>Low</td>
<td>2.01 - 2.2</td>
</tr>
<tr>
<td>Moderate</td>
<td>2.21 - 3.0</td>
</tr>
<tr>
<td>High</td>
<td>1.81 - 2.0</td>
</tr>
<tr>
<td>Very High</td>
<td>1.5 - 1.8</td>
</tr>
<tr>
<td>Extreme</td>
<td>&lt; 1.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Overall Near-Bank Stress Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
</tr>
</tbody>
</table>
## Worksheet 23. Total Bank Erosion Calculation

<table>
<thead>
<tr>
<th>Station (ft)</th>
<th>BEHI (adjective)*</th>
<th>Near Bank Stress (adjective)</th>
<th>Erosion Rate (ft/yr)*</th>
<th>Length of Bank (ft)</th>
<th>Bank Height (ft)</th>
<th>Erosion Sub-Total (ft³/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
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<td>2</td>
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<td>15</td>
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</tbody>
</table>

I. Sum erosion sub-totals for each BEHI/NBS combination

II. Divide total erosion (feet³) by 27 feet³/yard³

III. Multiply Total Erosion (yard³) by 1.3 (conversion of yd³ to tons for average material type)

IV. Calculate erosion per unit length: divide total erosion (ton/year) by total length (ft) surveyed

*Use numerical category spread to predict rates. (i.e. 21 = Moderate but at start of category, where as 28 is on upper end of relation - use prediction values appropriate to numerical rating).
APPENDIX B

Sediment and Water Quality Monitoring Forms
### Field Data Sheet

**Project Name:**

**Monitoring Personnel:**

**Date / Time:**

**Site ID:**

**BMP Description:**

<table>
<thead>
<tr>
<th>Circle One:</th>
<th>High Flow Conditions</th>
<th>Low Flow Conditions</th>
<th>Stream Height (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circle One:</td>
<td>Pre-Construction</td>
<td>Active Construction</td>
<td>Post-Construction</td>
</tr>
</tbody>
</table>

**Total Depth (M):**

**Secchi Depth (M):**

**Weather Observations:**

**Notes:**

<table>
<thead>
<tr>
<th>Depth Measurement</th>
<th>Temperature (°C)</th>
<th>DO (mg/L)</th>
<th>pH (s.u.)</th>
<th>Conductivity (µS/cm)</th>
<th>Turbidity (mg/L)</th>
<th>Salinity (PP'Th)</th>
</tr>
</thead>
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</tbody>
</table>
APPENDIX C

Field Methods of Fluvial Sediment (ASTM Method D3977, Test C)
APPENDIX D

Quality Assurance Project Plan (QAPP)
Memorial Park Demonstration Project (MPDP) Sediment Load and Bacteria Monitoring Plan and Quality Assurance Project Plan

Harris County Flood Control District
c/o AECOM
5757 Woodway, Suite 101W
Houston, Texas 77057

Prepared By: AECOM
AECOM Project No. 60221290

Effective Period: February 2012 to February 2014

Questions concerning this quality assurance project plan should be directed to:

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Senior Project Manager
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Houston, TX 77057
713.267.2956
ralph.calvino@aecom.com
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Attachment 2: Xenco Chain of Custody Form
Attachment 3: Field Data Sheet
Attachment 4: Laboratory Quality Assurance Manuals (QMs)
Attachment 5: Example Letter to Document Adherence to the QAPP
I. APPROVAL PAGE

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Carlos Castro  Date
Laboratory Director

Hygeia Laboratories, Inc.

Anita Shauer  Date  Crystal Enloe  Date
Laboratory Project Manager  Laboratory Quality Assurance Officer and Lab Director

February 2012
II. LIST OF ACRONYMS

BIG    Bacteria Implementation Group
BMP    Best Management Practices
CAP    Corrective Action Plan
COC    Chain of Custody
DQO    Data Quality Objective
EPA    United States Environmental Protection Agency
FY     Fiscal Year
HCFCD  Harris County Flood Control District
I-Plan Implementation Plan
MPDP   Memorial Park Demonstration Project
LCS    Laboratory Control Sample
LCSD   Laboratory Control Sample Duplicate
LIMS   Laboratory Information Management System
LOD    Limit of Detection
LOQ    Limit of Quantitation
NELAP  National Environmental Lab Accreditation Program
QA     Quality Assurance
QM     Quality Manual
QAO    Quality Assurance Officer
QAPP   Quality Assurance Project Plan
QC     Quality Control
QMP    Quality Management Plan
SLOC   Station Location
SOP    Standard Operating Procedure
SWQM   Surface Water Quality Monitoring
TMDL   Total Maximum Daily Load
TCEQ   Texas Commission on Environmental Quality
TNI    The NELAC Institute
TSWQS  Texas Surface Water Quality Standards
III DISTRIBUTION LIST

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1.0 INTRODUCTION

In April of 2009, TCEQ adopted TMDLs for bacteria in the Buffalo and White Oak bayous and their tributaries. The sources of bacteria include wastewater treatment facilities, sanitary sewer systems, onsite sewage facilities, stormwater runoff, illicit discharges, agriculture, livestock, wildlife, pets, sediment resuspension, and bacterial regrowth. Through the stakeholder process, the Bacteria Implementation Group (BIG), developed the Implementation Plan (I-Plan) describing the implementation activities and schedule for addressing bacteria levels in these watersheds. The I-Plan lists implementation measures aimed at achieving bacteria load reduction within these waterways and is intended to be a dynamic process which will evolve based on new research findings. One of the strategies discussed in the I-Plan (Implementation Strategy 4.0) is the introduction of bacteria into waterways via stormwater, which may correlate the increase in population growth (land development) and instream bacteria levels. It is suggested that certain BMPs directed towards stormwater will reduce bacteria loading from runoff and in turn, lower instream bacteria levels.

Harris County Flood Control District (HCFCD) has been a major stakeholder in this process and is currently working on several projects in cooperation with several other major stakeholders in the implementation of activities to address bacteria loading into local waterways. One of these projects is the development of the Sediment Load and Bacteria Monitoring Plan for the Memorial Park Demonstration Project (MPDP).

The primary purpose of the Sediment Load and Bacteria Monitoring Plan for the Memorial Park Demonstration Project (MPDP) is to determine potential bacteria loading to Buffalo Bayou from sediment suspended in the water column and from streambed sources. It will also examine the effectiveness of streambank stabilization projects, or BMPs, in riverine systems by studying the sediment and water quality during three phases of construction; pre-construction, construction, and post-construction activities.

2.0 PLAN OBJECTIVES

The objectives of this study are:

- Describe the methodology to perform sediment and water quality study in MPDP;
- Allow for comparison between pre-construction, construction, and post-construction conditions;
- Provide standards establishing when a project has reached adequate stabilization in order to monitor post-construction water and sediment quality conditions;
- Establish bacteria load calculations that correlate with sediment loading data through estimates of particle size analysis, erosion rate determinations and sediment entrainment.

In addition, this study supports several research goals listed in the TMDL I-Plan to support research for bacteria reduction as listed below:

1. Research Priority 10.2: Further Evaluate Bacteria Persistence and Regrowth - To evaluate the bacteria loading from human sources by first examining the background bacteria levels that are naturally occurring. In addition, the instream bacteriological cycle, including the ability for bacteria regrowth, requires further evaluation in order to more accurately determine the impact of bacteria on a waterway over time.

2. Research Priority 10.4:
   a. Land Use - The correlation of land use, turbidity and bacteria levels as it is suggested that increased turbidity may be associated with increased bacteria levels in the waterway.
   b. Nutrients and Other Constituents - The evaluation of certain constituents within the waterway, such as nutrients, sediment and other fine particles, and their influences on instream bacteria levels.
3.0 SAMPLING SITE SELECTION

The general premise of the protocol is based on current research which suggests strong correlations between bacteria levels and sediment particles. Logically, it can be deduced that by reducing the sediment load, a reduction of bacteria loading can be expected. Achieving sediment load reductions by the implementation of erosion control BMPs will result in bacteria load reductions from both streambed and suspended sediments. These dynamics should be considered during the site selection process since areas of high erosion potential would be expected to contribute high loads of bacteria.

Site selection should follow project objectives and target areas of high erosion potential with planned bank stabilization projects. While considering secondary factors such as scope and budget, the site selection process should include as many sites as possible to provide a representative segment of the stream to be evaluated, the type of BMPs to be implemented, and provide sufficient data to effectively evaluate sediment and bacteria load reductions. Sampling site location for each of the target conditions or construction phases, should remain relatively constant to reduce potential variability in the data results caused by external factors. The same is true with regards to the number and types of samples to produce a comparable dataset. However, some adjustment to sample locations may be necessary due to BMP installation and stabilization techniques implemented. A sampling site will be a point within the stream reach to be evaluated, which will be geo-referenced and where all water and sediment sampling will occur. Thus, a sampling site is typically an existing point mapped in the middle of the stream, where the water and suspended sediment is collected. Sediment core samples will be collected along the banks perpendicular to that point.

The site selection process will depend highly on geomorphic data collected identifying areas with greater erosion potential and/or areas selected for the implementation of erosion control BMPs. While sites for BMP installation are chosen based on geomorphic assessments, monitoring sites for the collection of water and sediment samples will be determined by the location of the specific BMPs used and other data project specific data needs.

Physical characteristics to be considered when selecting the water quality and sediment quality sites include natural features such as pools, riffles, meander bends with point bars and cut banks (outer meanders). Channel sinuosity is an essential characteristic which typically ranks high on the priority list for bank stabilization projects. These characteristics should be considered during the monitoring site selection process due to physical factors such as varying water velocities, sedimentation rates, sediment entrainment and scouring effects influencing pollutant concentration in the stream.

Sampling sites should generally include locations both upstream and downstream of the project area to allow data to be used in future evaluations of the effectiveness of the BMPs implemented after construction. At least one sampling site should be located upstream of the proposed BMP site and at least one site should be located downstream of the proposed BMP area. Additional sampling sites should be chosen systematically to represent the various physical stream characteristics within the project area or stream reach (riffles, pools, meanders, etc).

For the MPDP area, the sites where chosen based on the project boundaries and the length of the stream reach was taken into account. Please see Figure 3.1 for an aerial photograph of the project area. The total length of the stream reach included in the MPDP area was divided equally and the stations were distributed evenly to provide coverage of the entire stream reach. Further refinement of these locations was necessary due to other factors, such as the channel sinuosity, presence of riffles, runs and pools within the stream reach to be evaluated. Data needs for the Charting Buffalo Bayou Project was also considered during site selection and the locations should provide useful sediment data for use in the Buffalo Bayou Model. The MPDP area is approximately 7,800 linear feet in length and the total number of sampling sites is seven (7).

As discussed earlier, the site selection process for the MPDP follows the general premise that sediment load reductions will result in bacteria load reduction due to correlations between bacteria and sediment particles. These dynamics were considered during the site selection process for the MPDP area.
While sites for BMP installation are chosen based on geomorphic assessments, the location and type of BMPs were also considered during the selection of the sampling sites. One sampling site was selected upstream of the project site with the remaining sampling sites selected approximately equidistant in a downstream fashion to provide coverage of the project area or systematically selected along the project area to represent the various physical stream characteristics within the project area (riffles, pools, meanders, etc). The final site will be located downstream of the overall project area. Sites selected for this project are approximately 1,000 feet apart from each other, including one site upstream of the Memorial Park Demonstration Project (MPDP) and one site downstream of the area. See Figure 3.2 for an aerial photograph with locations of the selected sites. Although sampling sites should remain relatively constant between each of the three construction phases, some adjustment may be necessary depending on the BMP installation and bank stabilization techniques implemented.

Figure 3.1: Memorial Park Demonstration Project Location Map
4.0 WATER AND SEDIMENT SAMPLING METHODS AND ANALYSIS

4.1 Sampling Conditions and Frequency

Sampling and analysis of sediment and water quality will be performed at pre-construction, construction and post-construction phases of erosion control projects. During each phase, sampling will be conducted at least twice a month at each site when possible; once during dry weather (low flows) and once during wet weather (high flows). Sampling will be conducted for three months during each of the construction phases discussed. For the purposes of this project, dry weather or low flow conditions should represent normal flow conditions observed in the specific waterway. Wet weather or high flow conditions for this study are between 1,500 and 2,000 cfs. Flow data used to determine high flow conditions will be obtained from the USGS gauging station located at the Sheperd Drive Bridge. In addition, sampling during the pre-construction phase will occur for at least three months in order to document pre-construction conditions. Sampling during the active construction phase will follow the same methodology as the pre-construction sampling however; some adjustment to sample locations may be necessary due to BMP installation and stabilization techniques implemented.

Sampling to assess post-construction conditions will not begin until bank stabilization has been confirmed by the methods described in Section 4.1 of the protocol.

4.2 Sampling Equipment and Methods

Sampling methodology will follow the Sediment Load and Bacteria Monitoring Protocol. Large/deep streams will necessitate the use of a watercraft or vessel such as kayaks, canoes or a Jon Boat to collect the samples. Table 5.1 details the equipment and supplies needed to collect the samples.

Table 4.1: Equipment and Supplies:

<table>
<thead>
<tr>
<th>Equipment Checklist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bucket with rope</td>
</tr>
<tr>
<td>YSI Multi-probe</td>
</tr>
<tr>
<td>Integrated Depth Sampler</td>
</tr>
<tr>
<td>Secchi Disk</td>
</tr>
<tr>
<td>Core Sampling Device</td>
</tr>
<tr>
<td>Sterile Core Sleeves</td>
</tr>
<tr>
<td>Tape measure (reel tape)</td>
</tr>
<tr>
<td>Sample containers</td>
</tr>
<tr>
<td>Latex gloves (powder free)</td>
</tr>
<tr>
<td>Cooler</td>
</tr>
<tr>
<td>Ice</td>
</tr>
<tr>
<td>1-gallon Ziploc bags</td>
</tr>
<tr>
<td>First aid kit</td>
</tr>
<tr>
<td>Chain of custody forms</td>
</tr>
<tr>
<td>Field data sheets</td>
</tr>
<tr>
<td>Sharpie pen</td>
</tr>
<tr>
<td>Boat (large streams)</td>
</tr>
<tr>
<td>PPE (life jackets, etc)</td>
</tr>
<tr>
<td>Winch</td>
</tr>
<tr>
<td>Rope/Cable</td>
</tr>
</tbody>
</table>
Sampling Methods:

4.2.1 Multi-Parameter Sonde Sampling

When collecting data using a YSI data sonde, the instrument should be placed in the centroid of the flow, and the sensors shall be lowered to a depth of approximately 1 ft. so as to avoid influence from the surface of the water, and avoiding contact with the stream bed. Additionally, when using a YSI multi-probe data sonde, a water quality profile should be collected vertically through the water column at approximately 5ft intervals hence; a 10ft deep stream will yield 3 readings to include a bottom reading, a reading at half depth (5ft) and a surface reading (1ft).

4.2.2 Secchi Disk Sampling

Secchi disk readings will be collected in the centroid of flow and will be recorded on the field form as a Secchi depth in meters. Secchi disk readings provide a standard measure of water clarity as a point of reference when interpreting water quality data with regards to turbidity, TSS, and suspended sediments. Secchi disk readings will be collected in the centroid of flow and will be recorded as a Secchi depth in meters.

4.2.3 Grab Sampling

A bucket may be employed in cases where collecting samples directly into the sample container is not possible due to preservatives or other physical impairments preventing collection directly into the sample container. When using a bucket to collect samples, rinse the bucket three times with ambient water, dumping the rinse water outside of the stream, away from the area sampled, or downstream of the sampling site each time. The water sample should be collected below the surface of the water, which can be accomplished by inverting the collection vessel before submerging it in the water. The collection of samples will be conducted in an order as to prevent contamination (e.g.: bacteria samples should always be collected first). When wading in the stream to collect samples, care should be taken in collecting samples upstream of any sediment disturbance caused by wading through the water. Additionally, sampling personnel will allow ample time for the settling of any sediment plumes caused by disturbances other than natural currents or artificially induced before collecting any samples. All samples will be labeled with the site identification number, preservative, date and time of the sample collection, the analysis requested and the initials of sampling personnel. Containers can be pre-labeled prior to sample collection or immediately following sample collection. Within 15 minutes of sample collection, all water and sediment samples must be preserved using the appropriate preservative corresponding to the analytical method requested. A zip-loc plastic bag will be used to contain the sample jar which will then be stored on ice in an ice chest. The cooler lid must be kept closed to minimize sample exposure to sunlight and to begin the process of cooling to 4°C. Standard sample chain of custody (COC) procedures will be followed when submitting water and sediment samples to the laboratory using the appropriate COC form (Attachment 2). The sampling personnel will complete the chain of custody form and submit the samples to the laboratory within the time allotted by the analytical method.

4.2.4 Sediment Core Sampling

Sediment cores will be collected by driving 15 cm, sterile core sleeves into stream beds 0.5 m above the water line, at the water line, and 0.5 m below the water line on one bank for a total of three sediment core samples at each site. An additional sample will also be taken in the center of the stream at one sample site. The sediment core samples will be tested for Escherichia coli (E. coli) bacteria and will include particle size analysis. Particle size analysis will include ranges from 1 micron to 200 microns. The core samples will be packaged, stored and transported to the laboratory described above for all samples.

4.2.5 Suspended Sediment Sampling

When collecting the suspended sediment concentration samples with the depth integrated sampler, the device will have to be lowered through the water column by using a manual device such as a winch with a cable or a rope to effectively lower the sampler vertically through the water column and obtain a representative sample. It is important that personnel collecting samples do so by positioning the integrated sampler facing upstream of the vessel so as to reduce any disturbed sediment from entering
the sample and avoiding cross-contamination of the sample. Samples will be packaged and submitted as discussed previously.

4.2.6 Flow Measurements

For the MPDP, water surface elevation will be measured at the foot bridge that is located just downstream of the River Oaks Country Club Golf Course. The foot bridge provides connection between the Museum of Fine Arts, located on the south side of Buffalo Bayou, and a parking lot located at the terminus of Weston Street on the north side of Buffalo Bayou.

The stage will be estimated by measuring the depth of water below the foot bridge low chord elevation as presented in the FEMA effective model of Buffalo Bayou. Comparing this measured stage to a stage vs. flow hydrograph, as computed using an unsteady state HEC-RAS model, the corresponding flow rate will be estimated.

4.3 Sample Analysis

Table 4.2 lists the parameters to be analyzed in the study.
Table 4.2: Analytical Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Matrix</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Field Parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conductivity</td>
<td>uS/cm</td>
<td>water</td>
<td>EPA 120.1</td>
</tr>
<tr>
<td>Dissolved Oxygen (DO)</td>
<td>mg/L</td>
<td>water</td>
<td>SM 4500-OG</td>
</tr>
<tr>
<td>pH</td>
<td>pH/units</td>
<td>water</td>
<td>EPA 150.1</td>
</tr>
<tr>
<td>Temperature</td>
<td>°C</td>
<td>water</td>
<td>SM 2550B</td>
</tr>
<tr>
<td>Turbidity</td>
<td>mg/L</td>
<td>water</td>
<td>SM 2130/EPA 180.1</td>
</tr>
<tr>
<td>Salinity</td>
<td>pp${}^{th}$</td>
<td>water</td>
<td>SM 2520B</td>
</tr>
<tr>
<td>Water Clarity</td>
<td>M</td>
<td>water</td>
<td>Secchi Disk</td>
</tr>
<tr>
<td><strong>Conventional and Nutrient Parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonia-N, total</td>
<td>mg/L</td>
<td>water</td>
<td>SM 4500 NH3 C/EPA 350.1</td>
</tr>
<tr>
<td>Biochemical Oxygen Demand (BOD)</td>
<td>mg/L</td>
<td>water</td>
<td>SM 5210B</td>
</tr>
<tr>
<td><em>E. coli</em></td>
<td>mpn/100mL</td>
<td>water</td>
<td>SM 9223B</td>
</tr>
<tr>
<td><em>E. coli</em></td>
<td>mpn/100mL</td>
<td>sediment</td>
<td>SM 9223/MPN</td>
</tr>
<tr>
<td>Enterococcus spp.</td>
<td>mpn/100mL</td>
<td>water</td>
<td>SM 9230C</td>
</tr>
<tr>
<td>Enterococcus spp.</td>
<td>mpn/100mL</td>
<td>sediment</td>
<td>SM 9230C</td>
</tr>
<tr>
<td>Hardness, total (as CaCO3)</td>
<td>mg/L</td>
<td>water</td>
<td>EPA 200.7/SN 2540C</td>
</tr>
<tr>
<td>Nitrate/Nitrite-N, total</td>
<td>mg/L</td>
<td>water</td>
<td>EPA 300.0</td>
</tr>
<tr>
<td>Nitrogen – N, total</td>
<td>mg/L</td>
<td>water</td>
<td>TKN + NOX (CALC)</td>
</tr>
<tr>
<td>O-phosphate-P filter &gt;15 min.</td>
<td>mg/L</td>
<td>water</td>
<td>EPA 300.0/EPA 365.1</td>
</tr>
<tr>
<td>Particle Size Distribution</td>
<td>1-200 microns</td>
<td>sediment</td>
<td>SM 2560</td>
</tr>
<tr>
<td>Phosphorus-P, total</td>
<td>mg/L</td>
<td>water</td>
<td>EPA 365.3/365.1</td>
</tr>
<tr>
<td>Suspended Sediment Concentration (SSC)</td>
<td>mg/L</td>
<td>water</td>
<td>ASTM D3977-97</td>
</tr>
<tr>
<td>Total Dissolved Solids (TDS)</td>
<td>mg/L</td>
<td>water</td>
<td>SM 2540C</td>
</tr>
<tr>
<td>Total Kjeldahl Nitrogen (TKN)</td>
<td>mg/L</td>
<td>water</td>
<td>EPA 351.2</td>
</tr>
<tr>
<td>Total Suspended Solids (TSS)</td>
<td>mg/L</td>
<td>water</td>
<td>SM 2540D</td>
</tr>
</tbody>
</table>
4.4 Sampling QA/QC

QA/QC samples will be collected on a 10% basis. When samples are collected so infrequently that significant amounts of time (> 20 days) pass by in between sampling events, then a QA/QC sample will be submitted with each batch. The sample must be labeled with an arbitrary name that will not indicate to the laboratory that it is a QA/QC sample. The Chain of Custody should be treated the same. The only document that may indicate the identity of a QA/QC field sample is the field form where the “notes” section can be used to record that a duplicate sample was collected. For the MPDP, one duplicate sample will be collected during each month for each of the construction phases of the project. Analysis of the duplicate samples only apply to the conventional parameters so for the MPDP, only the TSS, TDS, and the suspended sediment concentration.

4.5 Field Monitoring Recordkeeping

The following list of forms includes directions on recording information.
- **Field Form** - Fill in all the blanks and record additional observations in the “notes” section.
- **Chain of Custody Form** - Fill in the required fields. A copy of the COC attached to this QAPP (Attachment 2).
  The chain of custody is a legally binding document and it is used to track the sample during transport from the time of collection to its final destination. Ensure all required fields are filled in.

4.6 Submitting Samples to Laboratory

All samples will be submitted to Xenco Laboratories, Inc. located at 4143 Greenbriar Dr., Stafford, TX 77447 (P) 281-240-4200.

5.0 DATA ANALYSIS AND INTERPRETATION

The sample results from the pre-construction monitoring establish baseline conditions for sediment and water quality in the project area. The sample results for “active construction” conditions represent water and sediment quality during active soil disturbance and are expected to indicate temporary degradation of water and sediment quality. The post-construction results represent water and sediment quality after stabilization of BMPs used in the bank stabilization project. Post-construction monitoring results will be compared to the results obtained during the pre-construction and construction phases of the project for determining the effects of the erosion control BMPs evaluated, and to assist in identifying any pollutant load reductions achieved through bank stabilization practices.

Correlation of bacteria with sediment data will be used to calculate loading. Flow data, sediment particle size distribution, streambank erosion rates and sediment entrainment, will be used to calculate bacteria loading from bank sediment erosion and will assist in identifying areas potentially contributing significant bacteria loads via sediment particles. These data will be used to evaluate the effectiveness of BMPs used for erosion control and in achieving bacteria reductions. The assessment will serve as a planning tool for better managing bacteria loading where possible and will assist in identifying any potential water/sediment quality benefits obtained through streambank stabilization projects. Streambed bacteria data from instream sediment core samples will be used to calculate contribution of bacteria from resuspension of bottom sediments. Two separate approaches for bacteria loading data analysis, may be used and applied as appropriate and as detailed below.

The first approach entails estimating bacteria loads contributed within a reach which is served by a specific BMP, which would be estimated as the difference of in-stream loading between the downstream boundary and the upstream boundary in dry weather. In wet weather, the bacteria load can be estimated as the downstream in-stream loading minus the upstream loading. Instream loading is the product of flow and bacteria concentration. Bacteria concentrations measured at upstream and downstream boundaries coupled with the flow data obtained for the MPDP area, will allow a bacteria load estimate to be calculated.

The second approach, may be necessary, depending on variability observed in sample results. Significant variability may affect the estimation of the bacteria load. For example, the measured bacteria
level at upstream boundary may be higher than that at the downstream boundary. If this is the case, the bacteria load has to be estimated using the correlation between sediment and bacteria data. A regressed correlation of bacteria with sediment data will be established using the samples collected. This correlation will give the ratio of bacteria to sediment (number of bacteria per gram of sediment). It is assumed that this ratio applies to eroded sediment from streambank. Applying this ratio to the amount of streambank sediment eroded as quantified by the model, the bacteria associated with the sediment from the eroded streambank can be estimated as the product of this ratio and the amount of streambank eroded.

For analysis of TSS and SSC data, the following approach may be used if applicable. TSS and SSC concentrations have been long reported in literature to be correlated to turbidity in streams. Due to this correlation between turbidity and TSS/SSC, turbidity sometimes is used as a surrogate in some studies where there is not sufficient TSS data available. A local example of this correlation was found at two USGS Stations along the West Fork San Jacinto River (Bodkin, L. and Oden, J. 2010). At these two locations, both log_{10}(SSC) and log_{10}(TSS) are found to be linearly correlated to log_{10}(turbidity) and log_{10}(streamflow) in a multiple (two independent variables) linear regression model where log_{10}(turbidity) and log_{10}(streamflow) serve as independent variables. The turbidity, stream flow and TSS/SSC data collected in this Buffalo Bayou study can be evaluated to determine if a correlation of TSS/SSC exists to stream flow and turbidity on Buffalo Bayou through a regression analysis. If this correlation exists, the regression model derived from the Buffalo Bayou data can be used to estimate TSS/SSC concentrations and loads using observed streamflow and turbidity data. This correlation can generate TSS/SSC data for any period where there are no TSS/SSC data, but turbidity and streamflow data are available.

5.1 Reporting

5.1.1 Progress Reports

Regular progress reports to HCFCD will be made at a frequency meeting the requirements in the project-specific scope. The format for the progress reports will be approved by HCFCD.

5.1.2 Technical Reports

A technical report will be used to summarize the methods used, analytical results, and conclusions from the sampling. Comparisons between the results obtained during the various stages of the bank stabilization projects including pre- and post-construction will be used to evaluate the impact of the project on water quality and the effectiveness of installed BMPs on erosion control. Modifications to any procedures or methodology and data quality objectives will be discussed in the report and reference the appropriate QAPP revision. Data reporting will include spreadsheets, tables, figures, graphs, statistical results, and load calculation results as applicable. Populated copies of the field forms will also be provided in the appendices of the technical reports.

6.0 QUALITY ASSURANCE

6.1 Project Organization

Description of Responsibilities and Organizational Chart (Figure 7.1)

Carolyn White
Harris County Flood Control District, Project Manager
Responsible for overall Project Management and execution on behalf of HCFCD.

Patricia A. Matthews, PE
AECOM, Project Director
Responsible for overall management on behalf of AECOM.
Ralph Calvino, REM  
AECOM, Senior Project Manager  
Responsible for management and execution of the project including: project design, sampling plan development, and coordination of work efforts.

Liz Stone  
AECOM, Project Manager  
Responsible for supporting day-to-day management of overall project including scope, schedule, and budget planning.

Stephen Lienhart, PE  
AECOM, Quality Assurance Officer  
Responsible for QA review in preparation for reporting/releasing to HCFCD.

Mary L. Purzer, PE  
AECOM, QC Officer  
Responsible for QC - technical reviews, and assisting with project design, sampling plans, and making recommendations as necessary.

Karen Kottke  
AECOM, Environmental Scientist  
Responsible for leading field sampling efforts, assisting in field data collection efforts, data documentation and project compliance and execution.

Lyndsay Massey  
AECOM, Environmental Specialist  
Responsible for project design and sampling plan development, leading field sampling efforts, assisting in field data collection efforts, data documentation and project compliance and execution.

Mike Kimmel  
Xenco, Project Manager  
Responsible for laboratory operations including; preparation, analysis, data reporting, coordination, laboratory QA/QC.

Robert Ramnarine  
Xenco, Quality Assurance Officer  
Responsible for QA review in preparation for reporting/releasing to AECOM and HCFCD.

Carlos Castro  
Xenco, Laboratory Director  
Responsible for overall program management.

Anita Shauer  
Hygeia, Project Manager  
Responsible for laboratory operations including; preparation, analysis, data reporting, coordination, laboratory QA/QC.

Crystal Enloe  
Hygeia, Quality Assurance Officer and Laboratory Director  
Responsible for QA review in preparation for reporting/releasing to Xenco and Responsible for overall program management.
6.2 Amendments to the QAPP

Revisions to the QAPP may be necessary to reflect changes in project organization, tasks, schedules, objectives, and methods. Requests for amendments will be directed from the Senior Project Manager electronically. Amendments are effective immediately upon approval by the Senior Project Manager. They will be incorporated into the QAPP by way of attachment and distributed to personnel on the distribution list by the Senior Project Manager.

6.3 Special Training and Certification

New field personnel receive training in proper sampling and field analysis from qualified personnel, approved by the Project Manager in charge of field sampling. Before actual sampling or field analysis occurs, they will demonstrate to the appropriate Project Manager their ability to properly perform field sampling procedures.

6.4 Data Quality Objectives

During QAPP development, it is important to maintain consistency with the ultimate goals of the Sampling Plan to meet the Data Quality Objectives (DQOs) of the protocol. The DQOs for the protocol are
specified below. The QAPP should define the project limits for precision and accuracy of data by requiring specific sample splits, duplicate, and spike samples and/or incorporating by reference, the SOP’s of the specific laboratory used for the project. The following sections discuss some of the major performance measurement standards for meeting project specific DQOs.

6.5 Precision

Precision is the degree to which a set of observations or measurements of the same property, obtained under similar conditions, conform to themselves. It is a measure of agreement among replicate measurements of the same property, under prescribed similar conditions, and is an indication of random error.

Field splits are used to assess the variability of sample handling, preservation, and storage, as well as the analytical process, and are prepared by splitting samples in the field. However, for this study, field splits will not be used.

Laboratory precision is assessed by comparing replicate analyses of laboratory control samples in the sample matrix (e.g., deionized water, sand, commercially available tissue) or sample/duplicate pairs in the case of bacterial analysis. Precision results are compared against measurement performance specifications and used during evaluation of analytical performance.

6.6 Accuracy

A result is considered accurate when the value reported does not differ from the true value. Accuracy is verified through the analysis of matrix spikes and calibration control standards determined by the laboratory for specific analytical methods and matrices.

6.7 Comparability

Confidence in the comparability of routine data sets for this project and for water quality assessments is based on the commitment of project staff to use only approved sampling and analysis methods and QA/QC protocols in accordance with quality system requirements and as described in this QAPP. Comparability is also guaranteed by reporting data in standard units, by using accepted rules for rounding figures, and by reporting data in a standard format as specified in the Data Management Section 7.24.

6.8 Completeness

The completeness of the data is basically a relationship of how much of the data is available for use compared to the total potential data. Ideally, 100% of the data should be available. However, the possibility of unavailable data due to accidents, insufficient sample volume, broken or lost samples, etc. is to be expected. Therefore, it will be a general goal of the project(s) that 90% data completion is achieved.

6.9 Required Parameters

The measurement performance specifications to support the project purpose for a minimum data set are specified in Table 7.1 and in the following text.
### Table 6.1: Measurement Performance Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Matrix</th>
<th>Method</th>
<th>Parameter Code</th>
<th>Limit of Quantitation (LOQ)</th>
<th>LOQ Check Standard %Rec</th>
<th>Precision (RPD of LCS/LCSD)</th>
<th>Bias % Rec. of LCS</th>
<th>Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Field Parameters</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conductivity</td>
<td>uS/cm</td>
<td>water</td>
<td>YSI Sonde, EPA 120.1</td>
<td>94</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>Field</td>
</tr>
<tr>
<td>Dissolved Oxygen (DO)</td>
<td>mg/L</td>
<td>water</td>
<td>YSI Sonde, SM 4500-O G</td>
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<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>Field</td>
</tr>
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<td>pH</td>
<td>pH/units</td>
<td>water</td>
<td>YSI Sonde, EPA 150.1</td>
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<td>NA</td>
<td>Field</td>
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<td>Temperature</td>
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<td>water</td>
<td>YSI Sonde, SM 2550 B</td>
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<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>Field</td>
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<td>Turbidity</td>
<td>NTU</td>
<td>water</td>
<td>Turbidimeter (LaMotte 2020) or SM2130B or EPA 180.1</td>
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<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>Field</td>
</tr>
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<td>Secchi Depth</td>
<td>m</td>
<td>water</td>
<td>Secchi Disk</td>
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<td>NA</td>
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<td>NA</td>
<td>Field</td>
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<td>cfs</td>
<td>N/A</td>
<td>Calculated using stream depth and HEC-RAS Hydrograph</td>
<td></td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Field</td>
</tr>
<tr>
<td><strong>Conventional Parameters</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. coli</td>
<td>mpn/100mL</td>
<td>water</td>
<td>SM 9223 B</td>
<td>31699</td>
<td>1</td>
<td>**</td>
<td>0.5</td>
<td>**</td>
<td>Xenco</td>
</tr>
<tr>
<td>E. coli</td>
<td>mpn/100mL</td>
<td>sediment</td>
<td>SM 9222 G</td>
<td>1</td>
<td>**</td>
<td>0.5</td>
<td>**</td>
<td>Xenco</td>
<td></td>
</tr>
<tr>
<td>Particle Size Distribution or Malvern Grain Size Analysis</td>
<td>1-200 microns</td>
<td>sediment</td>
<td>ASTM D422 63</td>
<td>49900, 49906</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>Xenco</td>
</tr>
<tr>
<td>Suspended Sediment Concentration (SSC)</td>
<td>mg/L</td>
<td>water</td>
<td>ASTM D3977-97 C</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>80-120</td>
<td>Xenco</td>
</tr>
<tr>
<td>Total Dissolved Solids (TDS)</td>
<td>mg/L</td>
<td>water</td>
<td>SM 2540 C or EPA 160.1</td>
<td>70300</td>
<td>0.1%</td>
<td>**</td>
<td>20 RPD</td>
<td>**</td>
<td>Xenco</td>
</tr>
<tr>
<td>TSS</td>
<td>mg/L</td>
<td>water</td>
<td>SM 2540 D or EPA 160.2</td>
<td>530</td>
<td>2</td>
<td>NA</td>
<td>20</td>
<td>80-120</td>
<td>Xenco</td>
</tr>
</tbody>
</table>

**References for Table 7.1:**
- United States Environmental Protection Agency (USEPA) Methods for Chemical Analysis of Water and Wastes, Manual #EPA-600/4-79-020
- American Society for Testing and Materials (ASTM) Annual Book of Standards, Vol. 11.02

### 6.10 Field Methods

Field sampling will be conducted according to procedures documented in HCFCD’s *Stormwater Quality Pond Monitoring Protocol (HCFCD, 2008)*. Table 7.2 lists the sample volume, container types, minimum sample volume, preservation requirements, and holding time requirements for the parameters to be analyzed in this study.
Table 6.2: Sample Volume, Storage, Preservation and Handling Requirements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Matrix</th>
<th>Container</th>
<th>Preservation</th>
<th>Sample Volume</th>
<th>Holding Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductivity</td>
<td>water</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Dissolved Oxygen (DO)</td>
<td>water</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>pH</td>
<td>water</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Temperature</td>
<td>water</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Turbidity</td>
<td>water</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Secchi Depth</td>
<td>water</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Total Dissolved Solids (TDS)</td>
<td>water</td>
<td>cubitainer</td>
<td>ice</td>
<td>1 gallon</td>
<td>48 hours</td>
</tr>
<tr>
<td>TSS</td>
<td>water</td>
<td>sterile plastic</td>
<td>Na₂S₂O₃</td>
<td>250 ml</td>
<td>6 hours</td>
</tr>
<tr>
<td>E. coli</td>
<td>water</td>
<td>sterile plastic</td>
<td>Na₂S₂O₃</td>
<td>250 ml</td>
<td>6 hours</td>
</tr>
<tr>
<td>Particle Size Distribution</td>
<td>sediment</td>
<td>sterile plastic</td>
<td>NA</td>
<td>500 ml</td>
<td>48 hours</td>
</tr>
<tr>
<td>Suspended Sediment Concentration (SSC)</td>
<td>water</td>
<td>sterile plastic</td>
<td>NA</td>
<td>500 ml</td>
<td>48 hours</td>
</tr>
</tbody>
</table>

Sample Containers

All sample containers are received from the laboratory. Samples will be preserved in the field by placing in ice chest. Any chemical preservative will be added to the containers at the lab before the samples are collected. No sample containers will be reused for sample collection.

Processes to Prevent Contamination

Procedures outlined in HCFCD’s Stormwater Quality Pond Monitoring Protocol list the necessary steps to prevent contamination of samples. These include: direct collection into sample containers, when possible. Field QC samples (identified in Section 7.12) are collected to assess potential contamination.

Documentation of Field Sampling Activities

Field sampling activities are documented on field data sheets (or actual name of the documents used to record field data) as presented in Attachment 3.

The following will be recorded for all visits:

1. Station ID
2. Sampling Date
3. Location
4. Sampling depth
5. Sampling time
6. Sample collector’s name/signature
7. Values for all field parameters
8. Flow method and measurement
9. Detailed observational data, including:
   - water appearance
   - weather
   - biological activity
   - unusual odors
   - pertinent observations related to water quality or stream uses (e.g., exceptionally poor water quality conditions/standards not met; stream uses such as swimming, boating, fishing, irrigation pumps, etc.)
• Watershed or instream activities (events impacting water quality, e.g., bridge construction, livestock watering upstream, etc.)
• Specific sample information (number of sediments grabs, type/number of fish in a tissue sample, etc.)
• missing parameters (i.e., when a scheduled parameter or group of parameters is not collected)

Recording Data
For the purposes of this section and subsequent sections, all field and laboratory personnel follow the basic rules for recording information as documented below:
1. Write legibly in indelible ink
2. Changes should be made by crossing out original entries with a single line, entering the changes, and initialing and dating the corrections.
3. Close-out incomplete pages with an initialed and dated diagonal line.

Sampling Method Requirements or Sampling Process Design Deficiencies, and Corrective Action
Examples of sampling method requirements or sample design deficiencies include but are not limited to such things as inadequate sample volume due to spillage or container leaks, failure to preserve samples appropriately, contamination of a sample bottle during collection, storage temperature and holding time exceedence, sampling at the wrong site, etc. Any deviations from the QAPP and appropriate sampling procedures may invalidate resulting data and may require corrective action. Corrective action may include for samples to be discarded and re-collected. It is the responsibility of the Project Manager, in consultation with the QAO, to ensure that the actions and resolutions to the problems are documented and that records are maintained in accordance with this QAPP.

6.11 Laboratory Performance Standards
Laboratory performance standards, including MDLs, RLs, MALs, and objectives for precision, accuracy, and completeness can be found in the laboratory QMs in Attachment 4.

6.12 Field Quality Control
Processes to prevent contamination in the field include procedures outlined in HCFCD’s Stormwater Quality Pond Monitoring Protocol, which outline the necessary steps to prevent contamination of samples. These include: direct collection into sample containers, when possible. Field QC samples are collected to verify that contamination has not occurred. Field QC samples are collected to assess potential contamination.

6.13 Sampling Quality Control Requirements and Acceptability Criteria
The minimum field QC requirements for specific analysis are outlined in HCFCD’s Stormwater Quality Pond Monitoring Protocol. A general description of field sample QC as applicable to the MPDP follows below. Additional criteria should be considered on a project-specific basis under the protocol.

Field Split - A field split is a single sample subdivided by field staff immediately following collection and submitted to the laboratory as two separately identified samples. Split samples are preserved, handled, shipped, and analyzed identically and are used to assess variability in all of these processes. Field splits apply to conventional samples only. To the extent possible, field splits prepared and analyzed over the course of the project should be performed on samples from different sites. The QAPP should define the frequency in which these samples will be collected for specific projects and should be no less than the standard 10%. For the MPDP, the only conventional samples requiring a field split are the TDS, TSS and suspended sediment concentration samples.

6.14 Standards Traceability
All standards used in the field and laboratory are traceable to certified reference materials. Standards preparation is fully documented and maintained in a standards log book. Each documentation includes information concerning the standard identification, starting materials, including concentration, amount used and lot number, date prepared, expiration date and preparer’s initials/signature. The reagent bottle
is labeled in a way that will trace the reagent back to preparation. For the MPDP, refer to the laboratory QMs for analytical standards.

### 6.15 Sample Handling and Custody

Proper sample handling and custody procedures ensure the custody and integrity of samples beginning at the time of sampling and continuing through transport, sample receipt, preparation, and analysis.

A sample is in custody if it is in actual physical possession or in a secured area that is restricted to authorized personnel. The Chain of Custody (COC) form is a record that documents the possession of the samples from the time of collection to receipt in the laboratory. The following information concerning the sample is recorded on the COC form (see Attachment 2). The following items are to be filled out on the COC:

1. Date and time of collection
2. Site identification
3. Sample matrix
4. Number of containers
5. Preservative used
6. Analyses required
7. Name of collector
8. Custody transfer signatures and dates and time of transfer
9. Bill of lading (if applicable)

Samples that are sent out to sub-contracted labs will follow the same procedure with the appropriate COC.

**Sample Labeling**

Samples from the field are labeled on the container (or on a label; please specify) with an indelible marker. Label information includes:

1. Site identification
2. Date and time of collection
3. Preservative added, if applicable
4. Indication of field-filtration (for metals) as applicable
5. Sample type (i.e., analysis(es)) to be performed

**Sample Handling**

From the time of collection to the moment of laboratory drop-off, all samples are handled in accordance with HCFCD’s *Stormwater Quality Pond Monitoring Protocol*.

**Sample Tracking Procedure Deficiencies and Corrective Action**

All deficiencies associated with chain-of-custody procedures as described in this QAPP are immediately reported to the Project Manager. These include such items as delays in transfer, resulting in holding time violations; violations of sample preservation requirements; incomplete documentation, including signatures; possible tampering of samples; broken or spilled samples, etc. The Laboratory Senior Analyst in consultation with the Project Manager will determine if the procedural violation may have compromised the validity of the resulting data. Any failures that have reasonable potential to compromise data validity will invalidate data, and the sampling event should be repeated.

The definition of and process for handling deficiencies and corrective action are defined in Section 7.23.

### 6.16 Analytical Methods

The analytical methods, associated matrices, and performing laboratories are listed in Table 7.1 of Section 7.9. Laboratories collecting data under this QAPP are compliant with the NELAC standards. Copies of laboratory QMs are located in Attachment 4.
6.17 Analytical Method Deficiencies and Corrective Actions

Deficiencies in field and laboratory measurement systems involve, but are not limited to such things as instrument malfunctions, failures in calibration, blank contamination, quality control samples outside QAPP defined limits, etc. In many cases, the field technician or lab analyst will be able to correct the problem. If the problem is resolvable by the field technician or lab analyst, then they will document the problem on the field data sheet or laboratory record and complete the analysis. If the problem is not resolvable, then it is conveyed to the Laboratory Senior Analyst, who will make the determination and notify the Senior Project Manager. The nature and disposition of the problem is reported on the data report which is sent to the Senior Project Manager. The definition of and process for handling deficiencies and corrective action are defined in Section 7.23.

6.18 Data Validation

Sampling Quality Control Requirements and Acceptability Criteria

Specific requirements are outlined below. Field QC sample results are submitted with the laboratory data report (see Section 7.22). Quality Management manuals for Xenco and Hygeia Laboratories are located in Attachment 4.

Field split – A field split is a single sample subdivided by field staff immediately following collection and submitted to the laboratory as two separately identified samples according to procedures. Split samples are preserved, handled, shipped, and analyzed identically and are used to assess variability in all of these processes. Field splits apply to conventional samples only and for this project include TDS, TSS, and suspended sediment concentration samples only.

The precision of field split results is calculated by relative percent difference (RPD) using the following equation:

\[ RPD = \left| \frac{(X1 - X2)}{\left(\frac{X1+X2}{2}\right)} \right| \times 100 \]

A 30% RPD criteria will be used to screen field split results as a possible indicator of excessive variability in the sample handling and analytical system. If it is determined that elevated quantities of analyte (i.e., > 5 times the LOQ) were measured and analytical variability can be eliminated as a factor, than variability in field split results will primarily be used as a trigger for discussion with field staff to ensure samples are being handled in the field correctly. Some individual sample results may be invalidated based on the examination of all extenuating information. The information derived from field splits is generally considered to be event specific and would not normally be used to determine the validity of an entire batch; however, some batches of samples may be invalidated depending on the situation. Professional judgment during data validation will be relied upon to interpret the results and take appropriate action. The qualification (i.e., invalidation) of data will be documented on the Data Summary. Deficiencies will be addressed as specified in this section under Quality Control or Acceptability Requirements Deficiencies and Corrective Actions.

Laboratory Measurement Quality Control Requirements and Acceptability Criteria

Batch – A batch is defined as environmental samples that are prepared and/or analyzed together with the same process and personnel, using the same lot(s) of reagents. A preparation batch is composed of one to 20 environmental samples of the same NELAP-defined matrix, meeting the above mentioned criteria and with a maximum time between the start of processing of the first and last sample in the batch to be 25 hours. An analytical batch is composed of prepared environmental samples (extract, digestates or concentrates) which are analyzed together as a group. An analytical batch can include prepared samples originating from various environmental matrices and can exceed 20 samples.

Method Specific QC requirements – QC samples, other than those specified later this section, are run (e.g., sample duplicates, surrogates, internal standards, continuing calibration samples, interference check samples, positive control, negative control, and media blank) as specified in the methods. The requirements for these samples, their acceptance criteria or instructions for establishing criteria, and corrective actions are method-specific.
Detailed laboratory QC requirements and corrective action procedures are contained within the individual laboratory quality manuals (QMs), located in Attachment 4. The minimum requirements that all participants abide by are stated below.

**Limit of Quantitation (LOQ)** – The laboratory will analyze a calibration standard (if applicable) at the LOQ listed in Table 7.1, on each day calibrations are performed. In addition, an LOQ check sample will be analyzed with each analytical batch. Calibrations including the standard at the LOQ listed in Table 7.1 will meet the calibration requirements of the analytical method or corrective action will be implemented.

**LOQ Sediment Samples** – When considering LOQs for solid samples and how they apply to results, two aspects of the analysis are considered: (1) the LOQ of the sample, based on the real-world in which moisture content and interferences affect the result and (2) the LOQ in the QAPP based on an idealized sample with zero % moisture.

The LOQ for a solid sample is based on the lowest non-zero calibration standard (as are those for water samples), the moisture content of the solid sample, and any sample concentration or dilution factors resulting from sample preparation or clean-up.

To establish solid-phase LOQs to be listed in Table 7.1 of the QAPP, the laboratory will adjust the concentration of the lowest non-zero calibration standard for the amount of sample extracted, the final extract volume, and moisture content (assumed to be zero % moisture). When data are reviewed for consistency with the QAPP, they are evaluated based on this requirement.

**LOQ Check Sample** – An LOQ check sample consists of a sample matrix (e.g., deionized water, sand, commercially available tissue) free from the analytes of interest spiked with verified known amounts of analytes or a material containing known and verified amounts of analytes. It is used to establish intralaboratory bias to assess the performance of the measurement system at the lower limits of analysis. The LOQ check sample is spiked into the sample matrix at a level less than or near the LOQ published in Table 7.1, for each analyte for each analytical batch of CRP samples run. If it is determined that samples have exceeded the high range of the calibration curve, samples should be diluted or run on another curve. For samples run on batches with calibration curves that do not include the LOQ listed in Table 7.1, a check sample will be run at the low end of the calibration curve.

The LOQ check sample is carried through the complete preparation and analytical process. LOQ Check Samples are run at a rate of one per analytical batch.

The percent recovery of the LOQ check sample is calculated using the following equation in which %R is percent recovery, SR is the sample result, and SA is the reference concentration for the check sample:

\[
%R = \frac{SR}{SA} \times 100
\]

Measurement performance specifications are used to determine the acceptability of LOQ Check Sample analyses as specified in Table 7.1.

**Laboratory Control Sample (LCS)** - An LCS consists of a sample matrix (e.g., deionized water, sand, commercially available tissue) free from the analytes of interest spiked with verified known amounts of analytes or a material containing known and verified amounts of analytes. It is used to establish intralaboratory bias to assess the performance of the measurement system. The LCS is spiked into the sample matrix at a level less than or near the midpoint of the calibration for each analyte. In cases of test methods with very long lists of analytes, LCSs are prepared with all the target analytes and not just a representative number, except in cases of organic analytes with multipeak responses.

The LCS is carried through the complete preparation and analytical process. LCSs are run at a rate of one per preparation batch.

Results of LCSs are calculated by percent recovery (%R), which is defined as 100 times the measured concentration, divided by the true concentration of the spiked sample.
The following formula is used to calculate percent recovery, where %R is percent recovery; SR is the measured result; and SA is the true result:

\[ %R = \frac{SR}{SA} \times 100 \]

Measurement performance specifications are used to determine the acceptability of LCS analyses as specified in Table 7.1.

**Laboratory Duplicates** – A laboratory duplicate is an aliquot taken from the same container as an original sample under laboratory conditions and processed and analyzed independently. A laboratory control sample duplicate (LCSD) is prepared in the laboratory by splitting aliquots of an LCS. Both samples are carried through the entire preparation and analytical process. LCSDs are used to assess precision and are performed at a rate of one per preparation batch.

For most parameters, precision is calculated by the relative percent difference (RPD) of LCS duplicate results as defined by 100 times the difference (range) of each duplicate set, divided by the average value (mean) of the set. For duplicate results, X1 and X2, the RPD is calculated from the following equation: *(If other formulas apply, adjust appropriately.)*

\[ \text{RPD} = \left| \frac{(X1 - X2)}{\left(\frac{(X1+X2)}{2}\right)} \right| \times 100 \]

A bacteriological duplicate is considered to be a special type of laboratory duplicate and applies when bacteriological samples are run in the lab. Bacteriological duplicate analyses are performed on samples from the sample bottle on a 10% basis. Results of bacteriological duplicates are evaluated by calculating the logarithm of each result and determining the range of each pair.

Measurement performance specifications are used to determine the acceptability of duplicate analyses as specified in Table 7.1. The specifications for bacteriological duplicates in Table 7.1 apply to samples with concentrations > 10 org./100mL.

**Laboratory equipment blank** - Laboratory equipment blanks are prepared at the laboratory where collection materials for metals sampling equipment are cleaned between uses. These blanks document that the materials provided by the laboratory are free of contamination. The QC check is performed before the metals sampling equipment is sent to the field. The analysis of laboratory equipment blanks should yield values less than the LOQ. Otherwise, the equipment should not be used.

**Matrix spike (MS)** – Matrix spikes are prepared by adding a known mass of target analyte to a specified amount of matrix sample for which an independent estimate of target analyte concentration is available. Matrix spikes are used, for example, to determine the effect of the matrix on a method’s recovery efficiency.

Percent recovery of the known concentration of added analyte is used to assess accuracy of the analytical process. The spiking occurs prior to sample preparation and analysis. Spiked samples are routinely prepared and analyzed at a rate of 10% of samples processed, or one per preparation batch whichever is greater. The information from these controls is sample/matrix specific and is not used to determine the validity of the entire batch. To the extent possible, matrix spikes prepared and analyzed over the course of the project should be performed on samples from different sites. The MS is spiked at a level less than or equal to the midpoint of the calibration or analysis range for each analyte. Percent recovery (%R) is defined as 100 times the observed concentration, minus the sample concentration, divided by the true concentration of the spike.

The results from matrix spikes are primarily designed to assess the validity of analytical results in a given matrix and are expressed as percent recovery (%R). The laboratory shall document the calculation for %R. The percent recovery of the matrix spike is calculated using the following equation in which %R is percent recovery, SSR is the observed spiked sample concentration, SR is the sample result, and SA is the reference concentration of the spike added:

\[ %R = \frac{(SSR - SR)}{SA} \times 100 \]

Measurement performance specifications for matrix spikes are not specified in this document.
The results are compared to the acceptance criteria as published in the mandated test method. Where there are no established criteria, the laboratory shall determine the internal criteria and document the method used to establish the limits. For matrix spike results outside established criteria, corrective action shall be documented and the data should not be reported.

**Method blank** – A method blank is a sample of matrix similar to the batch of associated samples (when available) that is free from the analytes of interest and is processed simultaneously with and under the same conditions as the samples through all steps of the analytical procedures, and in which no target analytes or interferences are present at concentrations that impact the analytical results for sample analyses. The method blanks are performed at a rate of once per preparation batch. The method blank is used to document contamination from the analytical process. The analysis of method blanks should yield values less than the LOQ. For very high-level analyses, the blank value should be less than 5% of the lowest value of the batch, or corrective action will be implemented. Samples associated with a contaminated blank shall be evaluated as to the best corrective action for the samples (e.g. reprocessing or data qualifying codes). In all cases the corrective action must be documented.

The method blank shall be analyzed at a minimum of one per preparation batch. In those instances for which no separate preparation method is used (example: volatiles in water) the batch shall be defined as environmental samples that are analyzed together with the same method and personnel, using the same lots of reagents, not to exceed the analysis of 20 environmental samples.

**Quality Control or Acceptability Requirements Deficiencies and Corrective Actions**

Sampling QC excursions are evaluated by the Lead Organization Project Manager, in consultation with the Lead Organization QAO. In that differences in sample results are used to assess the entire sampling process, including environmental variability, the arbitrary rejection of results based on pre-determined limits is not practical. Therefore, the professional judgment of the Project Manager and QAO will be relied upon in evaluating results. Rejecting sample results based on wide variability is a possibility.

Laboratory measurement quality control failures are evaluated by the laboratory staff. The disposition of such failures and the nature and disposition of the problem is reported to the Laboratory QAO. The Laboratory QAO will discuss with the Project Manager.

The definition of and process for handling deficiencies and corrective action are defined in Section 7.23.

**6.19 Instrument/Equipment Testing, Inspection and Maintenance**

All sampling equipment testing and maintenance requirements are detailed in HCFCD’s *Stormwater Quality Pond Monitoring Protocol*. Sampling equipment is inspected and tested upon receipt and is assured appropriate for use. Equipment records are kept on all field equipment and a supply of critical spare parts is maintained.

All laboratory tools, gauges, instrument, and equipment testing and maintenance requirements are contained within laboratory QMs, located in Attachment 4.

**6.20 Instrument Calibration and Frequency**

Field equipment calibration requirements are contained in the HCFCD’s *Stormwater Quality Pond Monitoring Protocol*. Post-calibration error limits and the disposition resulting from error are adhered to. Data not meeting post-error limit requirements invalidate associated data collected subsequent to the pre-calibration. Detailed laboratory calibrations are contained within the QMs, located in Attachment 4.

**6.21 Inspection/Acceptance of Supplies and Consumables**

No special requirements for acceptance are specified for field sampling supplies and consumables. For laboratory-related supplies and consumables, see laboratory QMs in Attachment 4.
6.22 Documents and Records

The documents and records that describe, specify, report, or certify activities are listed.

<table>
<thead>
<tr>
<th>Document/Record</th>
<th>Location</th>
<th>Retention (yrs)</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>QAPPs, amendments and appendices</td>
<td>AECOM</td>
<td>7 years</td>
<td>Electronic and paper</td>
</tr>
<tr>
<td>Field SOPs</td>
<td>AECOM</td>
<td>7 years</td>
<td>Electronic and paper</td>
</tr>
<tr>
<td>Laboratory Quality Manuals</td>
<td>Xenco, Hygeia</td>
<td>NELAC standards</td>
<td>NELAC standards</td>
</tr>
<tr>
<td>Laboratory QMs</td>
<td>Xenco, Hygeia</td>
<td>NELAC standards</td>
<td>NELAC standards</td>
</tr>
<tr>
<td>QAPP distribution documentation</td>
<td>AECOM</td>
<td>7 years</td>
<td>Electronic</td>
</tr>
<tr>
<td>Field staff training records</td>
<td>AECOM</td>
<td>7 years</td>
<td>Electronic</td>
</tr>
<tr>
<td>Field equipment calibration/maintenance logs</td>
<td>AECOM</td>
<td>7 years</td>
<td>Electronic and paper</td>
</tr>
<tr>
<td>Field instrument printouts</td>
<td>AECOM</td>
<td>7 years</td>
<td>Electronic</td>
</tr>
<tr>
<td>Field notebooks or data sheets</td>
<td>AECOM</td>
<td>7 years</td>
<td>Electronic</td>
</tr>
<tr>
<td>Chain of custody records</td>
<td>AECOM, Xenco, Hygeia</td>
<td>7 years</td>
<td>Electronic and paper</td>
</tr>
<tr>
<td>Laboratory calibration records</td>
<td>Xenco, Hygeia</td>
<td>NELAC standards</td>
<td>NELAC standards</td>
</tr>
<tr>
<td>Laboratory instrument printouts</td>
<td>Xenco, Hygeia</td>
<td>NELAC standards</td>
<td>NELAC standards</td>
</tr>
<tr>
<td>Laboratory data reports/results</td>
<td>AECOM, Xenco, Hygeia</td>
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</tr>
<tr>
<td>Laboratory equipment maintenance logs</td>
<td>Xenco, Hygeia</td>
<td>NELAC standards</td>
<td>NELAC standards</td>
</tr>
<tr>
<td>Corrective Action Documentation</td>
<td>AECOM, Xenco, Hygeia</td>
<td>7 years</td>
<td>Electronic</td>
</tr>
</tbody>
</table>

**Laboratory Test Reports**

Test/data reports from the laboratory must document the test results clearly and accurately. Routine data reports should be consistent with the TNI Volume 1, Module 2, Section 5.10 and include the information necessary for the interpretation and validation of data. The requirements for reporting data and the procedures are provided.

*Note:* The NELAC Standard provides for some flexibility in regard to the elements required in a test report. It is important that data are reported unambiguously, are accurate, and that the necessary information for the review, verification, validation, and interpretation of data is included. If reports are only generated upon request, please state this explicitly. At the very minimum, test reports (regardless of whether they are hard copy or electronic) should include the following:

- Sample results
- Units of measurement
- Sample matrix
- Dry weight or wet weight (as applicable)
- Station ID or name
- Date and time of collection
- Sample depth (as applicable)
- LOQ and LOD (formerly referred to as the reporting limit and the method detection limit, respectively), and qualification of results outside the working range (if applicable)

Certification of NELAC compliance on a result-by-result basis.
6.23 Assessments and Response Actions

The following table presents the types of assessments and response actions for data collection activities applicable to the QAPP.

<table>
<thead>
<tr>
<th>Assessment Activity</th>
<th>Approximate Schedule</th>
<th>Responsible Party</th>
<th>Scope</th>
<th>Response Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Status Monitoring Oversight, etc.</td>
<td>Continuous</td>
<td>AECOM</td>
<td>Monitoring of the project status and records to ensure requirements are being fulfilled</td>
<td>Internal QA/QC, PM oversight</td>
</tr>
<tr>
<td>Laboratory Inspection</td>
<td>Lab to provide date of last inspection</td>
<td>TCEQ/NELAC</td>
<td>Analytical and quality control procedures employed at the laboratory and the contract laboratory</td>
<td>30 days to respond in writing to the TCEQ to address corrective actions</td>
</tr>
</tbody>
</table>

Corrective Action Process for Deficiencies

It is the responsibility of the Lead Organization Project Manager, in consultation with the Lead Organization QAO, to ensure that the actions and resolutions to the problems are documented and that records are maintained in accordance with this QAPP.

Corrective Action

Corrective Action Plans (CAPs) should:

- Identify the problem, nonconformity, or undesirable situation
- Identify immediate remedial actions if possible
- Identify the underlying cause(s) of the problem
- Identify whether the problem is likely to recur, or occur in other areas
- Evaluate the need for Corrective Action
- Use problem-solving techniques to verify causes, determine solution, and develop an action plan
- Identify personnel responsible for action
- Establish timelines and provide a schedule
- Document the corrective action

To facilitate the process a flow chart has been developed, and is shown in Figure 7.2.
Status of Corrective Action Plans will be included in the regular progress reports. In addition, significant conditions (i.e., situations which, if uncorrected, could have a serious effect on safety or on the validity or integrity of data) will be reported to HCFCD immediately.

The Project Manager is responsible for implementing and tracking corrective actions. Records of audit findings and corrective actions are maintained by the Project Manager. Audit reports and corrective action documentation will be submitted to the HCFCD with the progress report.

If audit findings and corrective actions cannot be resolved, then the authority and responsibility for terminating work are specified in agreements in contracts between participating organizations.
6.24 Data Management

Data Management Process
Laboratory results will be sent via email to the AECOM Project Manager. Attachment 5 includes a sample letter to document adherence to this QAPP and should be signed by all participants before field sampling begins.

Data Errors and Loss
Data error or loss will be reported, noted or flagged with an explanation in case narrative form describing the errors.

Recordkeeping and Data Storage
Data will be stored electronically and reported on tables.

Specific details on laboratory data management can be found in the QMs located in Attachment 4.

6.25 Reports to Management

<table>
<thead>
<tr>
<th>Table 6.5: QA Management Reports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Report</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>Data Reports</td>
</tr>
</tbody>
</table>

6.26 Data Review, Verification and Validation

All field and laboratory data will be reviewed and verified for integrity and continuity, reasonableness, and conformance to project requirements, and then validated against the project objectives and measurement performance specifications which are listed in Section 7. Only those data which are supported by appropriate quality control data and meet the measurement performance specifications defined for this project will be considered acceptable.

6.27 Verification and Validation Methods

All field and laboratory data will be reviewed, verified and validated to ensure they conform to project specifications and meet the conditions of end use as described in Section 7 of this document.

Data review, verification, and validation will be performed using self-assessments and peer and management review as appropriate to the project task. The data review tasks to be performed by field and laboratory staff is listed in the first column of Table 7.6, respectively. Potential errors are identified by examination of documentation and by manual (or computer-assisted) examination of corollary or unreasonable data. If a question arises or an error is identified, the manager of the task responsible for generating the data is contacted to resolve the issue. Issues which can be corrected are corrected and documented. Field and laboratory reviews, verifications, and validations are documented.

The Data Review Checklist, Table 7.6, covers three main types of review: data format and structure, data quality review, and documentation review.
## Table 6.6: Data Review Tasks

<table>
<thead>
<tr>
<th>Data to be Verified</th>
<th>Field Task</th>
<th>Laboratory Task</th>
<th>Lead Organization Data Manager Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample documentation complete; samples labeled, sites identified</td>
<td>X</td>
<td></td>
<td>Karen Kottke, Lyndsay Massey</td>
</tr>
<tr>
<td>Field QC samples collected for all analytes as prescribed in HCFCD’s Stormwater Quality Pond Monitoring Protocol</td>
<td>X</td>
<td></td>
<td>Karen Kottke, Lyndsay Massey</td>
</tr>
<tr>
<td>Standards and reagents traceable</td>
<td>X</td>
<td>Laboratory Manager</td>
<td>Laboratory Manager</td>
</tr>
<tr>
<td>Chain of custody complete/acceptable</td>
<td>X</td>
<td>Laboratory Manager</td>
<td>Laboratory Manager</td>
</tr>
<tr>
<td>NELAP Accreditation is current</td>
<td>X</td>
<td>Laboratory Manager</td>
<td>Laboratory Manager</td>
</tr>
<tr>
<td>Sample preservation and handling acceptable</td>
<td>X</td>
<td>Laboratory Manager</td>
<td>Laboratory Manager</td>
</tr>
<tr>
<td>Holding times not exceeded</td>
<td>X</td>
<td>Laboratory Manager</td>
<td>Laboratory Manager</td>
</tr>
<tr>
<td>Collection, preparation, and analysis consistent with SOPs and QAPP</td>
<td>X</td>
<td>Laboratory Manager</td>
<td>Laboratory Manager</td>
</tr>
<tr>
<td>Field documentation complete</td>
<td>X</td>
<td>Laboratory Manager</td>
<td>Laboratory Manager</td>
</tr>
<tr>
<td>Instrument calibration data complete</td>
<td>X</td>
<td>Laboratory Manager</td>
<td>Laboratory Manager</td>
</tr>
<tr>
<td>Bacteriological records complete</td>
<td>X</td>
<td>Laboratory Manager</td>
<td>Laboratory Manager</td>
</tr>
<tr>
<td>QC samples analyzed at required frequency</td>
<td>X</td>
<td>Laboratory Manager</td>
<td>Laboratory Manager</td>
</tr>
<tr>
<td>QC results meet performance and program specifications</td>
<td>X</td>
<td>Laboratory Manager</td>
<td>Laboratory Manager</td>
</tr>
<tr>
<td>Analytical sensitivity consistent with QAPP</td>
<td>X</td>
<td>Laboratory Manager</td>
<td>Laboratory Manager</td>
</tr>
<tr>
<td>Results, calculations, transcriptions checked</td>
<td>X</td>
<td>Laboratory Manager</td>
<td>Laboratory Manager</td>
</tr>
<tr>
<td>Laboratory bench-level review performed</td>
<td>X</td>
<td>Laboratory Manager</td>
<td>Laboratory Manager</td>
</tr>
<tr>
<td>All laboratory samples analyzed for all scheduled parameters</td>
<td>X</td>
<td>Laboratory Manager</td>
<td>Laboratory Manager</td>
</tr>
<tr>
<td>Corollary data agree</td>
<td>X</td>
<td>Laboratory Manager</td>
<td>Laboratory Manager</td>
</tr>
<tr>
<td>Nonconforming activities documented</td>
<td>X</td>
<td>Laboratory Manager</td>
<td>Laboratory Manager</td>
</tr>
<tr>
<td>Outliers confirmed and documented; reasonableness check performed</td>
<td>X</td>
<td>Laboratory Manager</td>
<td>Laboratory Manager</td>
</tr>
<tr>
<td>Dates formatted correctly</td>
<td>X</td>
<td>Laboratory Manager</td>
<td>Laboratory Manager</td>
</tr>
<tr>
<td>Depth reported correctly and in correct units</td>
<td>X</td>
<td>Laboratory Manager</td>
<td>Laboratory Manager</td>
</tr>
<tr>
<td>TAG IDs correct</td>
<td>X</td>
<td>Laboratory Manager</td>
<td>Laboratory Manager</td>
</tr>
<tr>
<td>TCEQ Station ID number assigned</td>
<td>X</td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>Valid parameter codes</td>
<td>X</td>
<td>Laboratory Manager</td>
<td>Karen Kottke, Lyndsay Massey</td>
</tr>
<tr>
<td>Codes for submitting entity(ies), collecting entity(ies), and monitoring type(s) used correctly</td>
<td>X</td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>Time based on 24-hour clock</td>
<td>X</td>
<td></td>
<td>Karen Kottke, Lyndsay Massey</td>
</tr>
<tr>
<td>Absence of transcription error confirmed</td>
<td>X</td>
<td>Laboratory Manager</td>
<td>Karen Kottke, Lyndsay Massey</td>
</tr>
<tr>
<td>Absence of electronic errors confirmed</td>
<td>X</td>
<td>Laboratory Manager</td>
<td>Laboratory Manager</td>
</tr>
<tr>
<td>Sampling and analytical data gaps checked (e.g., all sites for which data are reported are on the coordinated monitoring schedule)</td>
<td>X</td>
<td></td>
<td>Karen Kottke, Lyndsay Massey</td>
</tr>
<tr>
<td>Field QC results attached to data review checklist</td>
<td>X</td>
<td></td>
<td>Karen Kottke, Lyndsay Massey</td>
</tr>
<tr>
<td>Verified data log submitted</td>
<td>X</td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>10% of data manually reviewed</td>
<td>X</td>
<td></td>
<td>Karen Kottke, Lyndsay Massey</td>
</tr>
</tbody>
</table>
### 6.28 Data Review Checklist

This checklist is to be used by HCFCD and other entities handling the monitoring data in order to review final data. This table may not contain all of the data review tasks being conducted.

#### Table 6.7: Data Review Checklist

<table>
<thead>
<tr>
<th>Data Format and Structure</th>
<th>☐, ☑, or N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Are there any duplicate Tag Id numbers in the Events file?</td>
<td>☐, ☑, or N/A</td>
</tr>
<tr>
<td>B. Do the Tag prefixes correctly represent the entity providing the data?</td>
<td>☐, ☑, or N/A</td>
</tr>
<tr>
<td>C. Have any Tag Id numbers been used in previous data submissions?</td>
<td>☐, ☑, or N/A</td>
</tr>
<tr>
<td>D. Are TCEQ station location (SLOC) numbers assigned?</td>
<td>☐, ☑, or N/A</td>
</tr>
<tr>
<td>E. Are sampling Dates in the correct format, MM/DD/YYYY with leading zeros?</td>
<td>☐, ☑, or N/A</td>
</tr>
<tr>
<td>F. Are sampling Times based on the 24 hr clock (e.g. 09:04) with leading zeros?</td>
<td>☐, ☑, or N/A</td>
</tr>
<tr>
<td>G. Is the Comments field filled in where appropriate (e.g. unusual occurrence, sampling problems, unrepresentative of ambient water quality)?</td>
<td>☐, ☑, or N/A</td>
</tr>
<tr>
<td>H. Are submitting Entity, Collecting Entity, and Monitoring Type codes used correctly?</td>
<td>☐, ☑, or N/A</td>
</tr>
<tr>
<td>I. Do sampling dates in the Results file match those in the Events file for each Tag Id?</td>
<td>☐, ☑, or N/A</td>
</tr>
<tr>
<td>J. Are values represented by a valid parameter code with the correct units?</td>
<td>☐, ☑, or N/A</td>
</tr>
<tr>
<td>K. Are there any duplicate parameter codes for the same Tag Id?</td>
<td>☐, ☑, or N/A</td>
</tr>
<tr>
<td>L. Are there any invalid symbols in the Greater Than/Lesser Than (GT/LT) field?</td>
<td>☐, ☑, or N/A</td>
</tr>
<tr>
<td>M. Are there any Tag Ids in the Results file that are not in the Events file or vice versa?</td>
<td>☐, ☑, or N/A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data Quality Review</th>
<th>☐, ☑, or N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Are “less-than” values reported at the LOQ? If no, explain in Data Summary.</td>
<td>☐, ☑, or N/A</td>
</tr>
<tr>
<td>B. Have the outliers been verified and a “1” placed in the Verify_flg field?</td>
<td>☐, ☑, or N/A</td>
</tr>
<tr>
<td>C. Have checks on correctness of analysis or data reasonableness been performed? e.g., Is ortho-phosphorus less than total phosphorus? Are dissolved metal concentrations less than or equal to total metals? Is the minimum 24 hour DO less than the maximum 24 hour DO? Do the values appear to be consistent with what is expected for site?</td>
<td>☐, ☑, or N/A</td>
</tr>
<tr>
<td>D. Have at least 10% of the data in the data set been reviewed against the field and laboratory data sheets?</td>
<td>☐, ☑, or N/A</td>
</tr>
<tr>
<td>E. Are all parameter codes in the data set listed in the QAPP?</td>
<td>☐, ☑, or N/A</td>
</tr>
<tr>
<td>F. Are all stations in the data set listed in the QAPP?</td>
<td>☐, ☑, or N/A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Documentation Review</th>
<th>☐, ☑, or N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Are blank results acceptable as specified in the QAPP?</td>
<td>☐, ☑, or N/A</td>
</tr>
<tr>
<td>B. Were control charts used to determine the acceptability of duplicates?</td>
<td>☐, ☑, or N/A</td>
</tr>
<tr>
<td>C. Was documentation of any unusual occurrences that may affect water quality included in the Event files ’s Comments field?</td>
<td>☐, ☑, or N/A</td>
</tr>
<tr>
<td>D. Were there any failures in sampling methods and/or deviations from sample design requirements that resulted in unreportable data? If yes, explain in Data Summary.</td>
<td>☐, ☑, or N/A</td>
</tr>
<tr>
<td>E. Were there any failures in field and/or laboratory measurement systems that were not resolvable and resulted in unreportable data? If yes, explain in Data Summary.</td>
<td>☐, ☑, or N/A</td>
</tr>
<tr>
<td>F. Was the laboratory’s NELAP Accreditation current for analysis conducted?</td>
<td>☐, ☑, or N/A</td>
</tr>
</tbody>
</table>
7.0 REFERENCES


H-GAC. 2011. Implementation Plan (I-Plan) for Total Maximum Daily Loads for Bacteria in the Houston-Galveston Region.

ATTACHMENT 1

Conceptual Design Plans for the Memorial Park Demonstration Project
ATTACHMENT 2

Xenco Chain of Custody Form
## Analysis Request & Chain of Custody Record

**Company-City**

**Phone**

**Project Name:**
- Previously performed at Xenco
- Site: Texas City

**Project ID**

**TAT:**
- 5h 12h 24h 48h 5d 7d 10d 21d

**Standard TAT is project specific.**

- It is typically 5-7 Working Days for level II and 10+ Working days for level III and IV data.

---

**Sample Name**

**Signature**

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Sampling Date</th>
<th>Time</th>
<th>Depth</th>
<th>Matrix</th>
<th>Cont. Type</th>
<th>4 Containers</th>
<th>4 Containers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**Remarks**

**Instructions:**

- All Xenco Standard Terms and Conditions Apply.

---

**Preservatives:**
- Various (V), HCl pH<2 (H), H2SO4 pH<2 (S), HNO3 pH<2 (N), Asbc AcidNaOH (A), ZnAxNaOH (Z), (Cos<4C) (C), None (NA), See Label (L), Other (O)

**Cont. Size:**
- 4oz (4), 8oz (8), 32oz (32), 40ml VOAV (V), 1L (1), 500ml (5), Tedlar Bag (B), Wipe (W), Other (O)

**Cont. Type:**
- Glass Amb (A), Glass Clear (C), Plastic (P), Other (O)

---

**Matrix:**
- Air (A), Product (P), Solid (S), Water (W)

**SDBE Committed to Excellence in Service and Quality since 1990**

www.xenko.com
ATTACHMENT 3

Field Data Sheet
## Field Data Sheet

<table>
<thead>
<tr>
<th>Project Name:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitoring Personnel:</td>
</tr>
<tr>
<td>Date / Time:</td>
</tr>
<tr>
<td>Site ID:</td>
</tr>
<tr>
<td>BMP Description:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Circle One:</th>
<th>High Flow Conditions</th>
<th>Low Flow Conditions</th>
<th>Stream Height (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circle One:</td>
<td>Pre-Construction</td>
<td>Active Construction</td>
<td>Post-Construction</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Depth (M):</th>
<th>Secchi Depth (M):</th>
</tr>
</thead>
</table>

**Weather Observations:**

**Notes:**

<table>
<thead>
<tr>
<th>Depth Measurement</th>
<th>Temperature (°C)</th>
<th>DO (mg/L)</th>
<th>pH (s.u.)</th>
<th>Conductivity (uS/cm)</th>
<th>Turbidity (mg/L)</th>
<th>Salinity (PP₅⁰)</th>
</tr>
</thead>
</table>
ATTACHMENT 4

Laboratory Quality Assurance Manuals
Hygeia Quality Assurance Manual
ATTACHMENT 5

Example Letter to Document Adherence to the QAPP
Example Letter to Document Adherence to the QAPP

TO: (name)  
(organization) 

FROM: (name)  
(organization) 

RE: Buffalo Bayou - MPDP QAPP 

Please sign and return this form by (date) to:  

(address) 

I acknowledge receipt of the “Memorial Park Demonstration Project Bayou Sediment and Water Quality Study QAPP”. I understand the document(s) describe quality assurance, quality control, data management and reporting, and other technical activities that must be implemented to ensure the results of work performed will satisfy stated performance criteria. My signature on this document signifies that I have read and approved the document contents pertaining to my project. Furthermore, I will ensure that all staff members participating in sampling activities will be required to familiarize themselves with the document contents and adhere to them as well. 

Signature Date

<table>
<thead>
<tr>
<th>METRIC</th>
<th>SCORING</th>
<th>CRITERIA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Taxa richness</td>
<td>&gt; 21</td>
<td>15-21</td>
</tr>
<tr>
<td>EPT taxa abundance</td>
<td>&gt; 9</td>
<td>7-9</td>
</tr>
<tr>
<td>Biotic index (HBI)</td>
<td>&lt; 3.77</td>
<td>3.77-4.52</td>
</tr>
<tr>
<td>% Chironomidae</td>
<td>0.79-4.10</td>
<td>4.11-9.48</td>
</tr>
<tr>
<td>% Dominant taxon</td>
<td>&lt; 22.15</td>
<td>22.15-31.01</td>
</tr>
<tr>
<td>% Dominant FFG</td>
<td>&lt; 36.50</td>
<td>36.50-45.30</td>
</tr>
<tr>
<td>% Predators</td>
<td>4.73-15.20</td>
<td>15.21-25.67</td>
</tr>
<tr>
<td>Ratio of intolerant:tolerant taxa</td>
<td>&gt; 4.79</td>
<td>3.21-4.79</td>
</tr>
<tr>
<td>% of total Trichoptera as Hydropsychidae</td>
<td>&lt; 25.50</td>
<td>25.51-50.50</td>
</tr>
<tr>
<td># of non-insect taxa</td>
<td>&gt; 5</td>
<td>4-5</td>
</tr>
<tr>
<td>% Collector-gatherers</td>
<td>8.00-19.23</td>
<td>19.24-30.46</td>
</tr>
<tr>
<td>% of total number as Elmidae</td>
<td>0.88-10.04</td>
<td>10.05-20.08</td>
</tr>
</tbody>
</table>

Aquatic life use point score ranges:

- Exceptional: > 36
- High: 29-36
- Intermediate: 22-28
- Limited: < 22

Reference Materials & Criteria B-17 06/2007
Table B-9. Ecoregion 34 Metrics

<table>
<thead>
<tr>
<th>Metric</th>
<th>Scoring Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Total number of fish species</td>
<td>See Figure B-7</td>
</tr>
<tr>
<td>2 Number of native cyprinid species</td>
<td>&gt;2 2 &lt;2</td>
</tr>
<tr>
<td>3 Number of benthic invertivore species</td>
<td>&gt;1 1 0</td>
</tr>
<tr>
<td>4 Number of sunfish species</td>
<td>&gt;3 2-3 &lt;2</td>
</tr>
<tr>
<td>5 Number of intolerant species</td>
<td>≥1 - 0</td>
</tr>
<tr>
<td>6 % of individuals as tolerant species (excluding western mosquitofish)</td>
<td>&lt;26% 26-50% &gt;50%</td>
</tr>
<tr>
<td>7 % of individuals as omnivores</td>
<td>&lt;9% 9-16% &gt;16%</td>
</tr>
<tr>
<td>8 % of individuals as invertivores</td>
<td>&gt;65% 33-65% &lt;33%</td>
</tr>
<tr>
<td>9 Number of individuals in sample</td>
<td></td>
</tr>
<tr>
<td>10 % of individuals as non-native species</td>
<td>&lt;1.4% 1.4-2.7% &gt;2.7%</td>
</tr>
<tr>
<td>11 % of individuals with disease or other anomaly</td>
<td>&lt;0.6% 0.6-1.0% &gt;1.0%</td>
</tr>
</tbody>
</table>

Aquatic life use: ≥49 Exceptional; 39-48 High; 31-38 Intermediate; <31 Limited

Figure B-7.