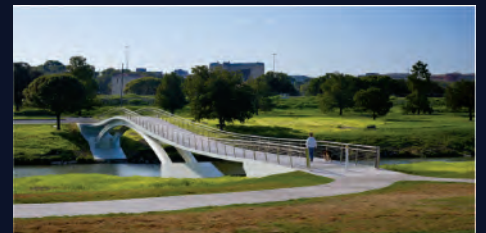
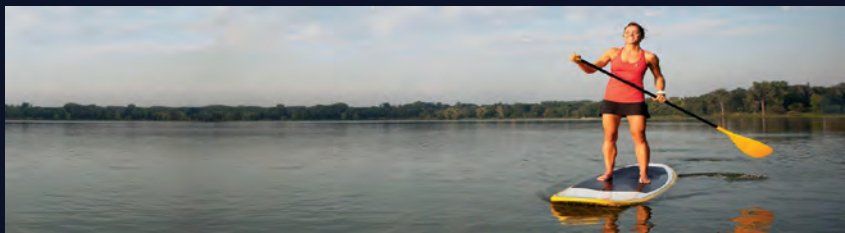


WATER QUALITY GUIDANCE MANUAL

Planning and Implementing Stormwater Quality Practices

April 2021





WATER QUALITY GUIDANCE MANUAL

Planning and Implementing Stormwater Quality Practices
April 2021

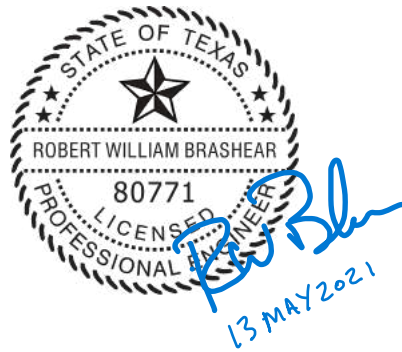


Version	Date	Notes
1.0	June 2018	Initial version of guidance manual
2.0	April 2021	Addition of Appendix G (example specifications) and Appendix H (example details)



WATER QUALITY GUIDANCE MANUAL

Planning and Implementing Stormwater Quality Practices
April 2021





WATER QUALITY GUIDANCE MANUAL

Planning and Implementing Stormwater Quality Practices

June 2018



Prepared by:



in association with



ACKNOWLEDGMENTS

The project team would like to thank the many individuals who contributed to the development of this inaugural water quality manual for the Tarrant Regional Water District to assist in implementing cost-effective storm drainage infrastructure that benefits quality as well as quantity. This manual is the result of three years of extensive study on the long-term water quality impact of untreated urban runoff on the Clear and West Forks of the Trinity.

Storm drainage infrastructure that provides water quality as well as flood protection benefits is critical to maintaining the outstanding water resource that now exists in the Trinity River as it flows through Fort Worth. These waters are enjoyed not only by Fort Worth citizens, but also by many out-of-town visitors who come to enjoy the nearly 100-miles of trails, swimming, water skiing, fishing, canoeing, kayaking, paddle-boarding, parks and nature areas, and just enjoying the aesthetics of this great resource – a resource no other major North Texas community can claim.

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Appendices

Appendix A – Design Review Resources

Appendix B – BMP Fact Sheets

Appendix C – Planting Palettes

Appendix D – Design Component Inspection and Maintenance

Appendix E – BMP Spreadsheets

Appendix F – Zone Maps

Appendix G – Example Specifications

Appendix H – Example Typical Details

List of Acronyms

BMP	best management practice
CFW	City of Fort Worth
CGP	Construction General Permit
cm/s	centimeters per second
ft/sec	feet per second
GSi	green stormwater infrastructure
HDPE	high density polyethylene
iSWM™	integrated Stormwater Management
lbs.	pounds
lbs/sq yd	pounds per square yard
LID	low impact development
NOI	notice of intent
NRCS	Natural Resources Conservation Service
O&M	operation and maintenance
oz/cm ³	ounces per cubic centimeter
PCB	polychlorinated biphenyl
PVC	polyvinyl chloride
STD	standard
SWPPP	Storm Water Pollution Prevention Plan
TCEQ	Texas Commission on Environmental Quality
TPDES	Texas Pollutant Discharge Elimination System
TRWD	Tarrant Regional Water District
TxDOT	Texas Department of Transportation
USCS	Unified Soil Classification System
UWRI	Urban Water Resources Institute

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TRWD WATER QUALITY MANUAL

PLANNING AND IMPLEMENTING STORMWATER QUALITY PRACTICES

SECTION 1

The TRWD Water Quality Manual

The Trinity River is one of the greatest assets of the City of Fort Worth. Management of the river is an important goal of the Tarrant Regional Water District (TRWD) to protect water supply, reduce the risk of flooding, and enhance the quality of life by creating recreation opportunities and enabling active lifestyles. Water quality protection plays an important role in this mission by ensuring water is suitable for swimming, fishing, and recreation. Part of TRWD's mission is to continually assess the current water quality conditions in the Trinity River. Because of the importance of water quality to the users of the Trinity River and the citizens of area, TRWD has spent the past three years analyzing in detail what the impact to the water quality of the river will be as the population continues to grow and land use changes (TRWD 2018). These studies have shown that without changes to how stormwater runoff is handled, the current quality of the Trinity River in Fort Worth could degrade significantly to the point contact recreation activities, such as swimming, will be impacted due to elevated amounts of bacteria. Without intervention, the aesthetics of the river will decline as well due to increasing amounts of trash in the river and unsightly algae growth from increases in nutrients which also impact aquatic life. These studies have also shown that, over time as changes occur in watersheds draining to the river, the implementation of appropriate stormwater quality infrastructure that captures and treats stormwater before discharge to waterways can mitigate much of this undesired impact to the Trinity River. Where this has been done in other locations in the country, it has often not only had the desired effect of protecting water quality, but it has also improved the aesthetic quality of the land surface, raised property values, and made communities more desirable.

The waterways of the Trinity River flowing through the City of Fort Worth are currently and will continue to be influenced by growth. This growth impacts hydrology and sediment transport in watersheds as well as the quality of receiving waters. This manual is part of a larger effort by TRWD to implement actions to protect water quality.

1.1 PURPOSE AND INTRODUCTION

The goal of this manual is to promote effective, useful guidance in cost-effectively planning, designing, and implementing stormwater water quality infrastructure that will protect the water quality of the Trinity River and its tributaries from the negative impacts of urban runoff.

The primary objectives of this document are to:

- Define the water quality requirements for both new and re-development projects,

- Provide planning, design, and implementation guidance for structural best management practices (BMPs) to protect water quality downstream of new development and re-development projects, and
- Outline the review process and roles and provide support materials for meeting water quality requirements for development projects.

Four zones are designated within the region shown in Figure 1.1 (additional maps with more detail are provided in Appendix F). BMP requirements vary based on the zone in which development or re-development occurs. This manual focuses on the requirements for Zones 1 and 2 (the requirements are discussed in Section 1.5).

The BMPs and designs identified in this manual are intended to foster the use of beneficial green stormwater infrastructure (GSI) features and provide mitigation of the water quality impacts of development and redevelopment activities. The BMPs may also provide flood control management, (e.g., extended (dry) detention basins); however, this manual is focused on mitigating water quality impacts of land draining to the Trinity River. Seven types of structural BMPs are discussed in this manual that if designed, constructed, and maintained as described in this manual and with proper documentation (see Section 1.6), meet the required level of water quality treatment. These are:

- Bioretention basin
- Constructed wetland
- Sand or media filter
- Wet (pond) basin
- Extended (dry) detention basin
- Retention and irrigation basin
- Permeable or porous pavers (Note that there are limitations to the drainage areas that can be treated using pavers).

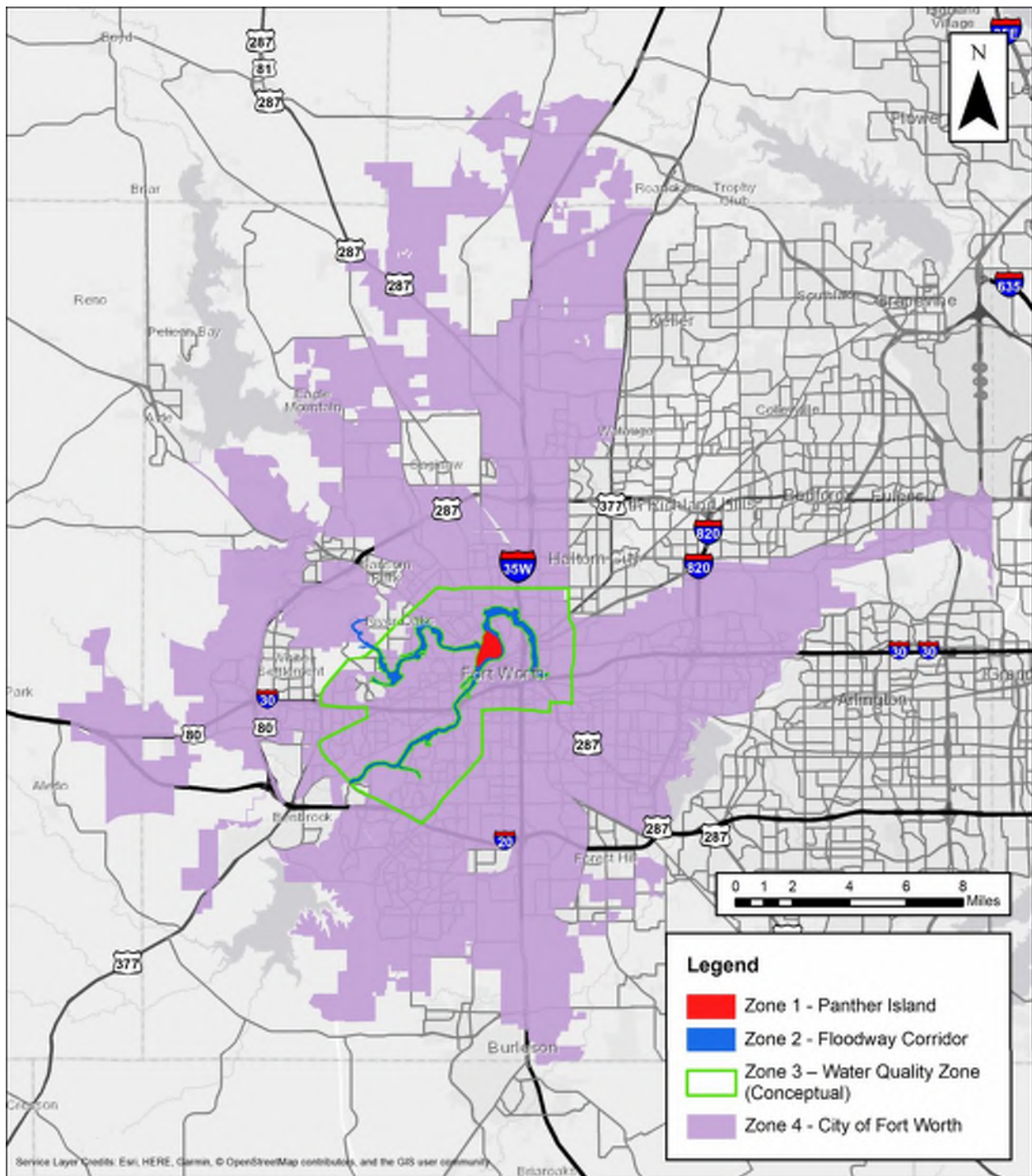
In addition to these seven types of BMPs, there are two BMPs described in this manual that can be used for small drainage areas, where appropriate, to reduce the overall required treatment volume for a site or in conjunction with the seven BMPs listed above. These BMPs are:

- Vegetative filter strip and
- Grass swale

Some of the BMPs listed above are commonly referred to as low impact development (LID) or green stormwater infrastructure (GSI) facilities.

Compliance requires the proper sizing, design, site layout, construction and appropriate maintenance for the BMP(s) chosen for any given site.

Figure 1.1 Water Quality Zones for the Trinity River



Note: new developments and re-developments in or across Zone 2 will be required to incorporate water quality BMPs to treat the water quality protection volume as described in this manual.

1.2 HOW TO USE THIS MANUAL

The intended audience for the TRWD Water Quality Manual includes developers, engineers, landscape architects, designers, and reviewers for governing authorities. An understanding of the local ordinances, BMPs, and design alternatives will be beneficial to all. This manual is intended to be a living document. The relevant items in the manual for each of the intended audiences is outlined below.

- § Developers – This manual summarizes requirements and siting considerations (Section 2) and includes BMP descriptions and fact sheets (Appendix B). These sections are intended to provide the information relevant to developers to meet water quality requirements.
- § Engineers, Landscape Architects, and Designers – This manual provides sizing information and guidance (Sections 3 and 4) for BMPs for professionals performing the calculations and design for BMPs. In addition, several other sections provide relevant information, including planting palettes (Appendix C), and BMP spreadsheets (Appendix E).
- § TRWD and Adjacent Jurisdictions – This manual provides an outline of the key jurisdictions and responsibilities (Section 2) and provides design review resources (Appendix A) as well as inspection and maintenance resources (Appendix D).

The manual contains the following sections:

Section 1 – The Water Quality Manual – Provides an introduction to the manual, including the objectives, the intended users, and background information.

Section 2 – BMP Process and Plan Development – Describes the initial steps of evaluating the need and options for BMPs at a site. It provides information about locating BMP devices and estimating the water quality protection volume to be treated. This section provides an overview of the TRWD review process for BMPs and highlights major steps in the process. Section 2 provides a description of the items required for submittal for review and graphical examples and templates that can be used by the developer and TRWD.

Section 3 – Post-Construction BMP Practices – Provides an introduction to the BMPs covered in the manual and a description of each BMP, graphical examples, the benefits of each BMP, and inspection and maintenance requirements.

Section 4 – Post-Construction BMP Practice Design Components – Provides an explanation of the design elements that can be integrated into each BMP. The design components are the fundamental elements required for a BMP to function adequately. Section 4 provides details and specifications for components, including inlets, pretreatment, energy dissipation, area protection, storage media, media barriers, planting media, landscaping, and outlets/piping.

Section 5 – Water Quality Requirements Specific to Panther Island (Zone 1) – The application of this manual varies somewhat for Zone 1 (Panther Island). For consistency with the Panther Island Form-Based Code, to leverage the associated Public Improvement District planned for Panther Island, and to allow redevelopment the maximum amount of footprint to work with, Zone 1 is restricted smaller set of available practices and they will be predominantly sited in the public right of way. This greatly increases the efficiency and lowers the cost of stormwater quality management for developers.

APPENDICES

Appendix A – Design Review Resources – Provides tools to develop and review project submittals, a summary of the required design details to be provided with submittals, and checklists the reviewer can use to evaluate the submittals. Appendix A should be filled out and submitted to TRWD with the other required project submittals.

Appendix B – BMP Fact Sheets – Provides a quick overview of the BMPs discussed in this manual and include:

1. Introduction and applicability
2. Major design elements
3. Operation and maintenance (O&M)
4. Constructability
5. Basic sizing guidelines
6. Submittal requirements

Appendix C – Planting Palettes – Provides an overview of the plants that should be used for BMP projects.

Appendix D – Design Component Inspection and Maintenance – Provides guidance for inspection and maintenance of BMP design components.

Appendix E – BMP Spreadsheets – Provides spreadsheet tools that can be used to help design and review BMPs.

Appendix F –Zone Maps

1.3 WATER QUALITY IMPACTS FROM DEVELOPMENT

Increasing urbanization in watersheds draining to the Trinity River in Fort Worth threatens to reduce or eliminate the ability of the river to support contact recreation activities and other designated uses. Development has significant impacts on hydrology and stormwater runoff. Development also can lead to alteration of hydrology, hydraulics, and sediment transport.

The manual is intended to reference, build off of, and be consistent with extensive studies and resources on the effect of new development and re-development on this important water resource for TRWD, the City of Fort Worth, and other adjacent municipalities, specifically with regard to water quality.

The primary water quality parameters of concern for the Trinity River and its tributaries are:

- Bacterial indicators
- Nutrients
- Sediment
- Floatables

1.4 APPLICABLE WATER QUALITY PROTECTION ZONES

TRWD provides protection to the Trinity River. Figure 1.1 shows four water quality zones defined by TRWD where water quality requirements are being adopted or recommended. These are:

- Zone 1 Panther Island
- Zone 2 Floodway Corridor
- Zone 3 Water Quality Zone
- Zone 4 City of Fort Worth (outside of Zones 1-3)

New developments and re-developments in or across Zones 1 and 2 will be required to incorporate water quality BMPs to treat the water quality protection volume as described in this manual. The specifics of requirements for development in Zone 1 are described in Section 5 – Water Quality Requirements Specific to Panther Island (Zone 1).

1.5 AUTHORITIES AND JURISDICTIONS

This section discusses the authorities and jurisdictions that are involved with the water quality program. For new developments and re-developments in or across Zone 1 and Zone 2, TRWD will review water quality BMPs associated with the project. The required submittals are outlined in Section 2.5 of this manual.

For activities within the City of Fort Worth, the City of Fort Worth will be given the opportunity to review the water quality impacts and plans. The City of Fort Worth has flood control, drainage, tree preservation and other requirements which are not discussed in this manual. These requirements must be followed. Any conflicts between guidance in this manual with City of Fort Worth requirements should be discussed with TRWD. More information about the requirements for projects within the City of Fort Worth is provided in the City of Fort Worth's Stormwater Criteria manual (2015 or the most recent adopted version of the manual).

All applicable state and federal regulatory requirements must be met. Compliance with this manual does not imply compliance with state and federal requirements. These may include National Pollutant Discharge Elimination System (NPDES) and Texas Pollutant Discharge Elimination System (TPDES) permit requirements or coverage under the Construction General Permit (CGP) authorized by the Texas Commission on Environmental Quality (TCEQ).

1.6 BMP SUBMITTAL REQUIREMENTS

The BMP requirements outlined in this manual must be followed for new developments and re-developments in or across Zones 1 and 2 with Zone 1 (Panther Island) having specific requirements discussed in Section 5. The BMP must be certified as meeting the water quality performance specifications and must be submitted to TRWD for review. The BMP submittals will need to be certified by a Professional Engineer licensed in the State of Texas.

The applicant must submit the following for review:

- 1) The plans and details for all water quality BMPs. These and any variances must be certified by a licensed Professional Engineer to verify they meet the water quality goals of the guidance manual (*see design submittal requirements checklists in Section 4 for more detail by component*),**
- 2) Calculation summary sheets for WQv and for BMP structures (*see Section 4 for detail on the necessary calculations for different components and Appendix E for design spreadsheets*),**
- 3) Supporting information, including test results, manufacturer information or specific details and assumptions where there is variation from the guidance manual, and**
- 4) Facility maintenance plan with guarantee that the maintenance will occur.**

After construction of the BMP, Certification from the Design Engineer or other Professional Engineer licensed in the State of Texas must be submitted to TRWD to verify that the BMP was built in accordance with the submitted plan information.

Drainage and BMP reviews are required at several stages of the overall development review process. However, some of the specifics of the review depend on the types of development activities proposed and the location of the project. The contractor or developer should provide advance notice to TRWD of pre-construction meetings for new and re-development.

As noted above, the developer must provide a certificate of completion that states that the BMP was installed in accordance with the design submittals and BMP construction requirements. In addition, as-builts must be submitted within six weeks of construction completion that are sealed by a currently registered Professional Engineer licensed in the State of Texas. The as-builts must show that the BMPs were built in accordance with the design submittals and the Zones 1 and 2 requirements.

For developments within the Zones 3 and 4, the engineer shall provide the City information as per their requirements. For projects in or across Zones 1 and 2, the calculations must also be consistent with the Water Quality Volume estimation guidance provided in Section 2.3 of this manual.

The BMP should be identified, and relevant information provided in required submittals, that may include grading plans, concept plans, and platting. The drainage calculations should be provided for existing, proposed, and fully developed conditions. The water quality features of the site plan and temporary and post-construction water quality BMPs should be detailed in the documents.

Proper maintenance of the BMP is critical to maintain effective stormwater treatment. To ensure that maintenance will be performed as necessary, a maintenance plan and agreement must be submitted as part of the required BMP documentation using the *Stormwater Facility Maintenance Agreement – Water Quality Devices* (available through the City of Fort Worth). The agreement must outline the actions that will be taken to maintain the facility (including frequency and schedule) and the repercussions if the facility is not maintained.

1.7 ALTERNATIVE APPROACHES

The applicant may propose alternative approaches to achieving compliance. *Note that TRWD will NOT entertain requests to use alternatives approaches based solely because the applicant considers it more convenient to do so or to avoid the stormwater pollutant reduction goals intended in this manual.*

Should an applicant desire TRWD to consider one or more alternative approaches to compliance with requirements in this manual or a variance from full compliance from requirements, the following steps must be taken:

- 1) Apply the processes as set forth in this manual and a currently registered Professional Engineer in the State of Texas (Texas PE) shall document the results including results that show one or more compelling reasons why alternatives should be considered.
- 2) Submit this documentation along with a request in writing to TRWD, notifying the District of the applicant's desire to request one or more alternatives for compliance.
- 3) After review and discussion with applicant, TRWD will issue a determination that compelling reasons either do or do not exist to consider deviations to the processes outlined in this manual.
- 5) If TRWD determines that compelling reasons do not exist, applicant will be notified in writing and applicant should continue their submittals to TRWD based on the processes outlined in this manual.
- 6) If TRWD determines that compelling reasons do exist for deviating from the processes outlined in this manual, applicant should submit alternative approaches and technologies applied to their property under the seal of a Texas PE to TRWD for review and approval. As a part of this submittal applicant must document that these alternatives can meet the pollutant reduction goals established in step 6. TRWD will then approve, reject, or request revision and resubmittal of alternative approaches.

1.8 PROJECT REVIEW PROCESS

As part of the review process for the local municipality, TRWD will review compliance with water quality requirements for projects within their jurisdiction. TRWD will review compliance with the process established by TRWD and outlined in this manual, the required submittals, and with water quality goals. The review process will include verification that the applicant is following this manual, including the WQv estimates, design criteria, details, and specifications.

The applicant must follow the process established for submittal and review of development by the local jurisdiction.

As an administrative procedures toolkit to the review process, this manual includes a submittal checklist (see Appendix A) and the digital spreadsheet for calculation and review comparison (see Appendix E).

REFERENCES

TRWD, "Hydrodynamic and Water Quality Modeling of The Trinity River and Its Watersheds Through Downtown Fort Worth – Model Documentation, developed and prepared by CDM Smith, Tarrant Regional Water District, Fort Worth, Texas, March 2018

ADDITIONAL RESOURCES

- ¹ City of Fort Worth. December 20, 2012. Standard Construction Specification Documents.
- ² Federal Interagency Stream Restoration Working Group (FISRWG). 1998. Stream Corridor Restoration: Principles, Processes, and Practices. GPO Item No. 0120-A; SuDocs No. A 57.6/2:EN 3/PT.653. ISBN-0-934213-59-3.
- ³ North Central Texas Council of Governments (NCTCOG). September 2014. "iSWM Technical Manual: Water Quality: 1.0 Water Quality Protection Volume and Peak Flow", Arlington, Texas, April 2010, Revised September 2014,
http://iswm.nctcog.org/Documents/technical_manual/Water%20Quality_9-2014.pdf
- ⁴ Texas Commission on Environmental Quality (TCEQ). November 2015. Rules and Regulations for Public Water Systems.
- ⁵ Urban Watershed Research Institute (UWRI). October 5, 2015. Comparison of Water Quality Capture Volume Needs for Ft. Worth, TX Region to Capture of 85th Percentile Runoff Volume and Runoff Events
- ⁶ U.S. Environmental Protection Agency (EPA). 2005. National Management Measures to Control Nonpoint Source Pollution from Urban Areas.,
<http://water.epa.gov/polwaste/nps/urban/index.cfm>. Accessed June 20, 2013.



TRWD WATER QUALITY MANUAL

PLANNING AND IMPLEMENTING STORMWATER QUALITY PRACTICES

SECTION 2

BMP Process and Plan Development

Proper planning for development projects and implementation of BMPs is important for the mitigation of impacts to water quality and protection of receiving water bodies. Implementing a plan that considers the existing hydrology of the site and protects pervious areas and existing vegetation can help minimize both the cost and the footprint of structural drainage practices.

This section provides a brief overview of the BMP planning processes and outlines the plan submittal requirements for new development and re-development projects. This includes a discussion to support integration of water quality BMPs into site development and recommendations to help determine the type and layout of BMPs for a specific site layout. Additional detail is provided in Sections 3 and 4.

2.1 BMP AND SITE PLANNING

Proper BMP planning includes consideration of site layout and BMP placement early in the process. These steps can help to provide important water quality benefits. The recommended steps for the planning of the site and BMPs are:

1. Identify protected and sensitive features and opportunities to protect these. This may include development of a setback for impervious areas from creeks, wetlands, riparian areas, and dense and / or desirable vegetation. Other planning practices include:
 - Locate the development in less sensitive areas of the site
 - Fit the design to the terrain
2. Define the areas that are most suitable for development, areas to be landscaped, and areas to be conserved. Conform site layout along natural landforms and avoid excessive grading and soil disturbance. Avoid construction on steep slopes, in floodplains, and on erodible soils.
3. Assess opportunities to minimize overall impervious coverage on the site.
4. Locate BMPs with consideration for capturing stormwater runoff from areas with a high potential for pollutant loading, such as parking lots.

2.1.1 SITE LAYOUT

Careful consideration of the site layout can help mitigate the water quality impact of the development and, as a result, reduce the water quality volume (WQV) that must be treated and the required BMP footprint.

The existing site conditions that serve important hydrologic functions such as reducing runoff or pollutant loads downstream should be identified for protection early in the site assessment process. Natural and sensitive features that should be protected include:

- Bodies of water such as streams, rivers, ponds, and lakes
- Natural drainage paths
- Riparian areas
- Floodplains
- Wetlands
- Aquifer recharge areas
- Steep slopes
- Erodible soils
- Areas of dense vegetation
- Areas with seasonal high groundwater
- Other site-specific features that may impact hydrology

The developer should take steps during planning and construction to protect these features. It is important to consider that the disturbance of soil during construction can enable large quantities of sediment to be mobilized during stormwater events. These sediment loads can harm natural features and clog or otherwise damage BMPs. Temporary construction controls should be implemented as per City of Fort Worth and TCEQ requirements to prevent erosion and sediment transport.

2.1.2 IMPERVIOUS SURFACES

The developer should minimize the amount of impervious cover in the site design where possible to help reduce the size and cost of structural BMPs. WQ_v and BMP size are calculated based on the impervious cover for new and re-development sites. Therefore, reducing the amount of impervious cover can reduce the volume, cost, and land required for BMPs. Approaches might include using more vertical construction (reducing building footprints), utilizing pervious pavement, and designing the site for efficient vehicle circulation, reducing pavement area.

Disconnecting impervious surfaces can also be an effective way to reduce the required WQ_v treated by structural BMPs. This can be performed at an individual lot level and at the larger development site level. At an individual lot or property, impervious surfaces can be disconnected by directing gutter downspouts to pervious areas, installing rain gardens, and implementing other small scale BMPs or pre-treatment devices. Similar strategies can be implemented at the larger development scale by draining runoff to pervious areas. Other examples of this may include using stable grass swales instead of curb and gutters and natural channel paths instead of storm sewers. Both of these alternatives could function as pre-treatment based on compliance with the design standards outlined in this manual.

2.1.3 SITING BMPs

The developer should consider potential sources of high pollutant loading and locate BMPs to capture stormwater runoff from these areas. Roof runoff and parking lots will require pre-treatment before treatment by approved BMPs. Section 4 of this manual outlines the options for pre-treatment.

2.2 BMP SELECTION

The planning for the types and locations of BMPs to be implemented on a site should be performed with consideration of the pollutants of concern, available right-of-way, existing soil types and infiltration rates, pollutants of concern, and the development goals that impact aesthetics of the development. Table 2.1 summarizes the level of treatment that each type of BMP provides for pollutants of concern.

Table 2.1 Pollutant Reductions by BMP

	Sand and Media Filters*	Bioretention Basins*	Constructed Wetlands	Wet Basins	Retention and Irrigation Basin	Detention Basin	Vegetated Filter Strips/ Grass Swales*	Permeable Surfaces
Sediment	High	High	High	High	High	Moderate	Moderate to High	High
Nutrients	Low to Moderate	Moderate	Moderate to High**	Moderate to High**	Moderate to High	Low to Moderate	Low to Moderate	Low
Trash	High	High	High	High	High	High	Low to Moderate	High
Metals	Moderate to High	Moderate to High	Moderate	Moderate	High	Moderate	Low to Moderate	Moderate
Bacteria	Moderate to High	High	High**	High**	High	Moderate to High	Low	High
Oil and Grease	High	High	High	High	No Data	No Data	Moderate to High	Moderate
Organics	Moderate to High	Moderate	High**	High**	No Data	Low	Moderate to High	Low

Source: SARA, 2013; NCTCOG, 2014; TCEQ, 2005; ISWBD, 2017

* Removal effectiveness varies dependent on infiltration capacity and design

** Wetlands, Wet Basins, and other BMPs with wildlife habitat can have high internal loads of bacterial indicators, nutrients, and organics

Section 3 of this manual outlines the requirements and benefits of the post-construction BMPs that can be implemented to comply with the water quality requirements for areas covered in this manual. The fact sheets (Appendix B) summarize the effectiveness of the BMPs for removal of different pollutants.

2.3 CALCULATION OF WATER QUALITY VOLUME

The required WQ_v to be treated is calculated based on the runoff volume from the 85th percentile runoff event. A continuous hydrologic simulation model assessment was performed to define the WQ_v . The model assessment considered routing through the capture basin, infiltration in the tributary drainage area, and the recapture of infiltration and other losses during dry periods in the Trinity River watershed.

For a development within Zones 1 and 2, the water quality volume can be estimated using Figure 2.1 or Table 2.2. The process to estimate is also summarized in the callout on this page.

First, the developer should define the drainage areas within the project site and calculate the size of each of the drainage areas (step 1). Note that the project area may have more than one drainage area, and one or more BMPs should be used for each drainage area where there will be new impervious or redevelopment. Only the portion of each drainage area within the site boundaries will need to be treated.

Next, the developer should estimate the amount of impervious cover and the percentage of impervious cover within each drainage area (step 2). This should be done for each drainage area within the site. The developer should then identify the BMP type(s) that may be used to treat stormwater runoff on the site and evaluate the drainage time and components for the BMP(s) (step 3 and step 4).

Figure 2.1 provides a graphical representation of the Water Quality Depth (WQ_D) expressed in inches as a function of the percent impervious area of a development and the design drain time for the selected BMPs. Equations to estimate the WQ_D are also provided in Table 2.2. To calculate the total water quality volume for each drainage area within the project site, use the percent impervious for that drainage area and the drain time for the selected BMP to estimate the WQ_D (step 5). Multiply the WQ_D by the drainage area to calculate the total WQ_v for that drainage area (step 6). The WQ_D and WQ_v should be estimated for each drainage area separately.

How to Estimate WQ_v

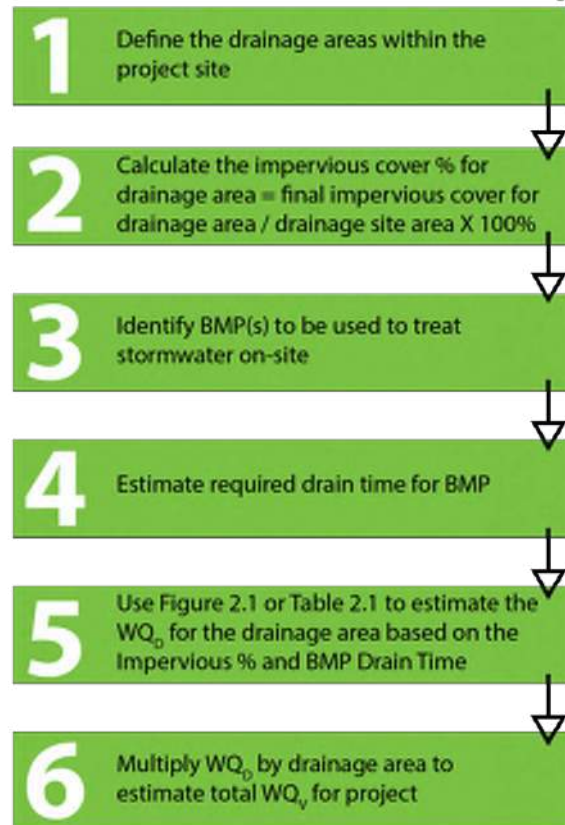
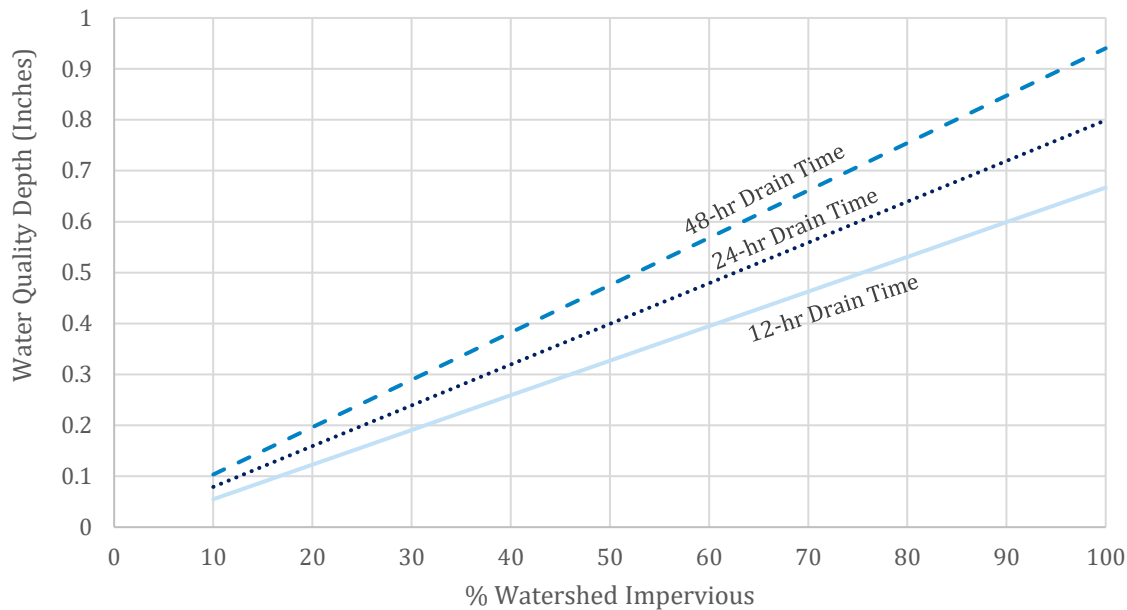


Figure 2.1 Water Quality Depth (in watershed inches) for the 85th Percentile Capture of Runoff Volume

As noted, the equations provided in Table 2.2 can also be used to calculate the WQ_D for BMPs based on the amount of impervious in the drainage area and the drain time of the BMP. As described for Figure 2.1, multiply the WQ_D by the drainage area to calculate the WQ_V .

Table 2.2 Equations for Required Water Quality Depth

Drain Time	Water Quality Depth
48 hour	$y = 0.0093x + 0.0104$
24 hour	$y = 0.0080x - 0.0009$
12 hour	$y = 0.0068x - 0.0132$

Where:

x = percent impervious (%) for drainage area to BMP

y = water quality volume in inches

Section 3 and the design spreadsheets included in Appendix E also include guidance for these estimates. The WQ_V is based on the percent of the drainage area with impervious cover. By reducing the amount of impervious cover, a new development or re-development project can reduce the required footprint of BMPs.

2.4 BMP DESIGN

The design guidance in this manual is based on components. The components for each BMP are the critical elements required for that BMP to meet the water quality goals. Based on the type of BMP, components may include inlets, pretreatment, energy dissipation, area protection, storage media, media barriers, planting media, landscaping, and outlets/piping. To allow flexibility for specific sites, this manual provides alternatives for components that meet the design criteria. The required design specifications and components for each BMP are outlined in Section 3. Design sheets and conceptual layouts for the components are provided in Section 4.

ADDITIONAL RESOURCES

- ¹ City of Fort Worth. December 20, 2012. Standard Construction Specification Documents.
- ² North Central Texas Council of Governments (NCTCOG). September 2014. "iSWM Technical Manual: Water Quality: 1.0 Water Quality Protection Volume and Peak Flow", Arlington, Texas, April 2010, Revised September 2014, http://iswm.nctcog.org/Documents/technical_manual/Water%20Quality_9-2014.pdf
- ⁴ San Antonio River Authority (SARA). 2013. San Antonio River Basin Low Impact Development Technical Guidance Manual.
- ⁵ Texas Commission on Environmental Quality (TCEQ). July 2005. Complying with the Edwards Aquifer Rules: Technical Guidance on Best Management Practices.
- ⁶ International Stormwater BMP Database. Accessed September 2017. BMP Database Tool: Texas BMPs. <http://bmpdatabase.org/retrieveBMPs.asp>



TRWD WATER QUALITY MANUAL

PLANNING AND IMPLEMENTING STORMWATER QUALITY PRACTICES

SECTION 3

Post-Construction Storm Water Quality Control Measures

This section provides information about the Best Management Practices (BMPs) that can be implemented to comply with the water quality requirements for Zones 1 and 2 (as presented in Section 1.4). The BMPs included in this section, if sized for the Water Quality Volume (WQ_v) (defined in Section 2) and designed in compliance with this manual, meet the water quality requirements for new and re-development projects in Zones 1 and 2, with two exceptions: grass swales and vegetated filter strips. These two BMPs are intended to treat only small impervious areas or act as pre-treatment or post-treatment for other BMPs. Specific requirements unique to Zone 1 (Panther Island) are discussed in Section 5. The following sections provide 1) a short description of each BMP, 2) information about the application of the BMP, 3) design criteria, and 4) maintenance considerations for design and construction. The design criteria describe the required components for each type of BMP and criteria for the components.

The general approach to identifying and designing appropriate BMPs includes the following steps:

- 1) Review the descriptions and applicability information provided in this section to determine what BMPs are most appropriate for the development.
- 2) Review the design criteria in this section to determine the necessary components and design elements for compliance with water quality requirements. The design criteria include references to applicable design details and specifications in Section 4. Review the maintenance considerations for design in this section to make any design adjustments that would simplify maintenance.
- 3) Identify the component details and specifications in Section 4 based on the components and references described in this Section. See Table 4.1 for major components.

Additional support included in Appendix E will assist in performing design calculations, sizing BMP structures and developing project submittal support information. The BMP design plan sheets and calculations, inspection and maintenance plans, as-builts, and other supporting information for projects in Zones 1 and 2 with WQ_v treatment requirements must be submitted for review to TRWD.

3.1 SAND FILTERS

3.1.1 DESCRIPTION OF BMP

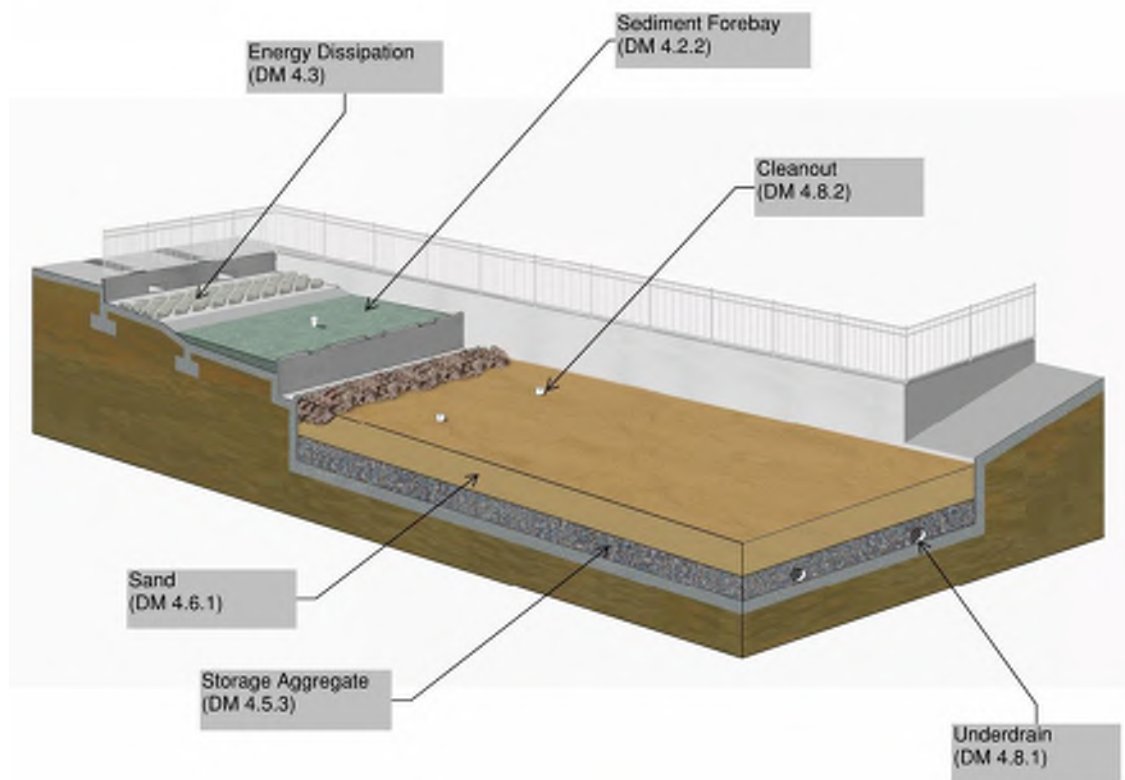
Sand filters and other types of media filters filter stormwater through sand or other media to remove pollutants. These BMPs can be implemented to treat a relatively large (generally up to 10-

acres) drainage area. This manual focuses on sand as the filtration media; other types of media may be considered on a case by case basis but are not specifically detailed in this section.

Two of the primary components are the sediment forebay (also referred to as sedimentation chamber) and the filtration chamber. The sediment forebay should be included for sand filters with drainage areas over 2-acres and can be included in smaller sand filters to remove floatables, large materials, and sediment before storm water is filtered through the sand or other media. The volume of water conveyed to the treatment system must be controlled by a diversion structure to prevent inflow rates that exceed the capacity of the BMP.

Component details and specifications are provided in Section 4. Figure 3.1 provides a conceptual rendering of a Concrete Sand Filter with major components identified for reference. The components may depend on the size and type of sand filter; these are described further in Section 3.1.3.

Figure 3.1 Conceptual Rendering of a Concrete Sand Filter



Due to the inherent dangers associated with confined spaces, which complicates routine inspections and maintenance, as well as the out-of-sight nature and inherent potential for neglect, underground structures/vaults are not discussed. Developers wishing to propose buried structures must provide conclusive supporting documentation regarding maintenance access and equivalent performance compared to above grade filters. These sand filters must be in compliance with all applicable confined space rules and regulations.

3.1.2 APPLICABILITY

The layout of sand filters is highly flexible. They can be incorporated within new development or as retrofits in re-development sites and can be used at locations with limited space or where other BMPs would be difficult to fit². Although versatile in their potential application, sand filters are best suited for areas with highly impervious drainage areas. However, sites that produce heavy sediment loads will clog filtration media and without frequent maintenance, will render this BMP ineffective².

3.1.3 DESIGN CRITERIA

This section provides the design criteria for sand filters. The structural criteria provide information about the necessary components and include references to the component design section of this manual (Section 4). The details and specifications for the components are provided in that section. The design/review spreadsheet in Appendix E outlines the design steps and calculations for the BMPs.

1) General Criteria

- a. Runoff from all impervious surfaces should be directed to a BMP.
- b. The maintenance plan for sand filters must include, as a minimum, trash removal, accumulated sediment removal, inspection for standing water, and inspection for 24-hour drawdown in accordance with the *Stormwater Facility Maintenance Agreement – Water Quality Devices* and outlined in Appendix D.

2) Site Conditions

- a. Drainage area – Sand filters are recommended for drainage areas less than 10-acres in size. Larger areas should be subdivided and treated by multiple devices.
- b. Depth to water table – A minimum of 2-feet are required between the bottom of the sand filter and the elevation of the seasonally high-water table.
- c. Soils – An underdrain is required for soils that do not allow sufficient infiltration.
- d. Floodplain – Where feasible, the BMP should be located outside of the 100-year floodplain. Where not feasible, the top of walls / embankments for the BMP should be above the 100-year floodplain and the BMP should be designed to protect against surcharge from downstream waters.
- e. Space required to achieve WQ_v – Function of available head at the site, the holding time, WQ_v , and the surface area of the sand layer for the BMP (see design calculation procedures in Appendix E).

3) Structural Criteria

- a. Emptying / drain time – Design to drain within 24-hours.
- b. Minimum head – The elevation difference needed at a site between the inflow and the outflow is generally 5-feet.

- c. Pre-treatment - A sediment forebay must be used for all sand filters treating over 2-acres and is recommended for all sand filters.
 - i. The forebay should be designed to hold at least 25% of the WQv.
 - ii. The sediment forebay should have a length-to-width ratio of at least 2:1.
 - iii. Inlet and outlet structures should be located at opposite ends of the chamber to prevent short-circuiting (see Section 4.1 for additional information on inlet structures, Section 4.2 on the design of the sediment forebay, and Section 4.8 on outlet structures).
 - iv. A vegetated filter strip or grass swale can be implemented in lieu of a sediment forebay where the drainage area is less than 2-acres.
- d. Energy dissipation – Required to dissipate energy and prevent erosion at the inlet to the BMP (*see Section 4.3*).
- e. Sand filter chamber – The structure of a surface sand filter may be constructed of impermeable material such as concrete or using earthen embankments and slopes.
 - i. Size – The filtration chamber must be designed to hold 100% of the WQv (*see Sections 4.5 and 4.6 for additional information on layout criteria*).
 - ii. Depth – Maximum design depth of WQv within filtration basin shall not exceed 5-feet. Note that surface area and depth of captured stormwater impacts maintenance requirements; a larger surface area (and resulting reduced stormwater depth) increases the ability of the sand filter to store sediment without clogging. Therefore, a depth greater than 3-feet may increase the frequency of required maintenance to keep the BMP effective.
 - iii. BMP media – Primary BMP media used is sand consisting of 18-inch (minimum) to 24-inch layer of clean washed medium sand. A storage aggregate layer shall be placed at the bottom of the sand filter chamber for additional water storage capacity. (*see Section 4.5 for material, gradation, and design criteria*). Filter fabric can be used between the sand and gravel to prevent migration of fines; however, the material can clog and require additional maintenance. Alternatively, an aggregate layer is not required if a slotted underdrain is used to prevent sand from flowing into the underdrain pipe.
 - iv. Media barrier – A geomembrane liner should be used to line the bottom and side slopes of the structure before installation for sand filters with earthen embankments (*see Section 4.6*). An impermeable liner must be used for installations adjacent to streets to prevent water from getting under the pavement into the base material.
 - v. Underdrain - If the system includes an underdrain, the BMP media shall be located above the underdrain system and the underdrain shall be located within the storage aggregate layer (*see Section 4.8*).

- vi. Note - Texas Commission on Environmental Quality (TCEQ) Dam Safety requirements shall be accounted for as required with higher depth structures.
- f. Diversion structure – The diversion structure must be capable of passing the peak flow rate of the ten (10) year annual chance storm into the stormwater quality BMP and passing excess runoff, including up to the 100-year storm, through the diversion structure without overtopping the sidewalls of the pond. (*see Section 4.1 for additional information on diversion structures*).

3.1.4 MAINTENANCE CONSIDERATIONS FOR DESIGN AND CONSTRUCTION

Routine inspection and maintenance of sand filters is critical to their performance. The activities, schedule, and additional maintenance considerations and requirements are attached in Appendix D, the “BMP Inspection and Maintenance” section of this manual. The following should be considered during design and construction of the BMP:

- Access – Adequate access must be provided for all sand filter systems for inspection and maintenance, including the appropriate equipment and vehicles. An access ramp with a minimum width of 10-feet and a maximum slope of 25% shall be provided.
- Fencing – To prevent risk to the public, it is recommended that sand filter facilities be fenced in accordance with the City of Fort Worth requirements.
- Include cleanouts as discussed in Section 4.8. These can be used for inspection to make sure that the underdrain is intact, and for ongoing maintenance during and after construction.
- For earthen systems, include vegetated side slopes to pre-treat runoff and reduce the frequency of maintenance².
- The BMP should be kept offline until the construction activities are completed. However, the BMP excavation can be used as a sediment trap during construction before filtration or other media are placed in the basin. In that case, the bottom of the basin should not be excavated below 2-feet of the final grade. Temporary BMPs should be in place as detailed in the project Sediment and Erosion Control Plan to protect receiving waters during construction activities (the Sediment and Erosion Control Plan requirements are not discussed in this manual). Sediment discharged during construction can clog the system and would require additional maintenance.

City of Austin. (2017). Design Guidelines for Water Quality Controls. Environmental Criteria Manual.

² Urban Drainage and Flood Control District (UDFCD). (2010). Urban Storm Drainage Criteria Manual (USDCM): Volume 3 Stormwater Quality.

3.2 BIORETENTION BASINS

3.2.1 DESCRIPTION OF BMP

Bioretention basins (also referred to as rain gardens, biofiltration basins, or biofilters) use the chemical, biological, and physical properties of plants, microbes, and soils to remove pollutants from stormwater runoff via a system of distributed micro-scale storm water treatment devices.¹ The filter medium is an engineered mix of highly-permeable natural media, which are usually mixtures of soil, sand and organic matter, that facilitate pollutant removal via sedimentation, filtration, sorption, and precipitation.¹ The defining characteristic of a bioretention system is the integration of plants and microorganisms that are rooted in the filter medium and can provide more treatment of runoff, directly and by uptake by the filter medium². Plants help sustain the permeability of the medium for longer periods and enhance removal of pollutants^{1,2}. The composition of the BMP media is key to the system's overall effectiveness.¹

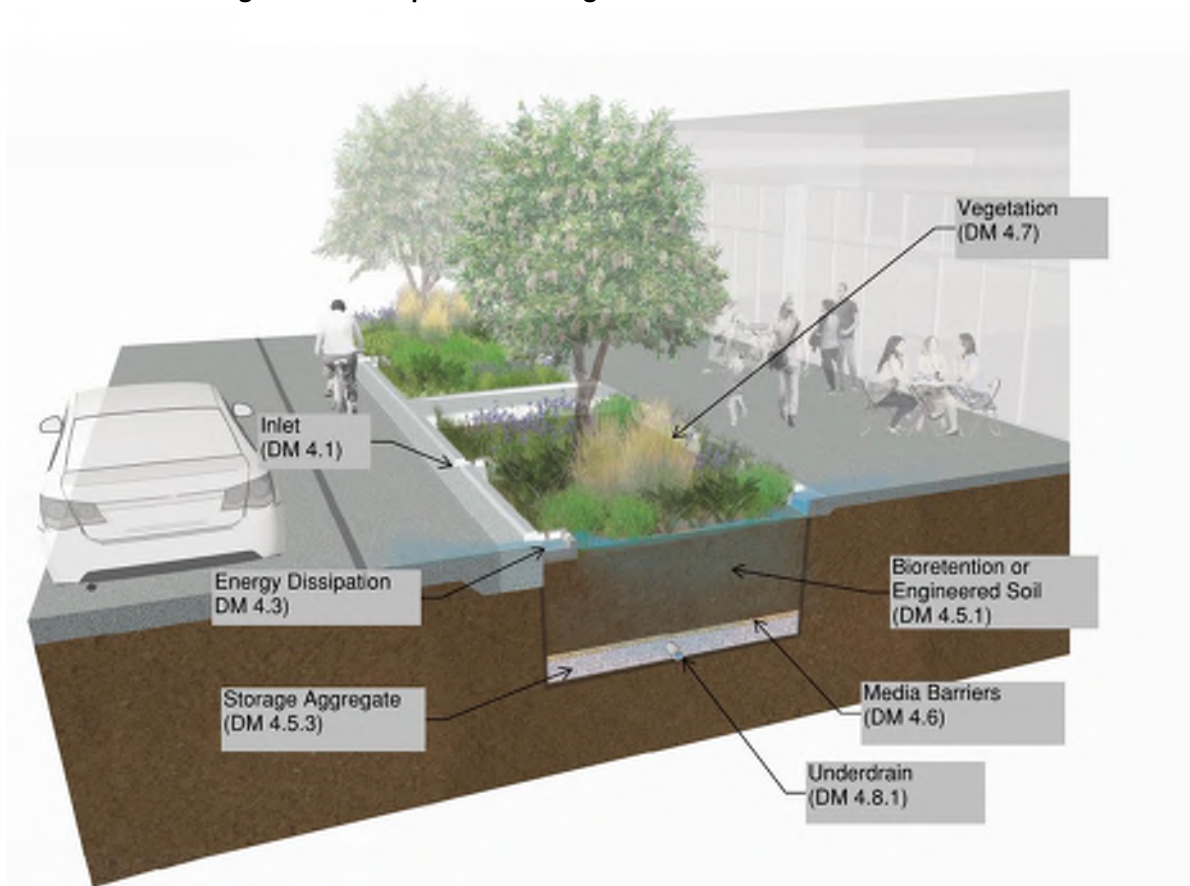
More information on the components for bioretention basins can be found in the design criteria discussion in Section 3.2.3 and the component details and specifications are provided in Section 4.

There are two types of bioretention basins that are addressed as part of this handbook – centralized and distributed bioretention basins. Centralized bioretention basins must be implemented for larger drainage areas and have additional elements as detailed below. These include a two-cell system. Distributive bioretention basins (i.e., rain gardens or green street infrastructure) can be implemented for drainage areas of 1-acre or less. These are smaller and shallower than the centralized systems and are often placed adjacent to the impervious cover runoff source. The primary components for these are different. Figure 3.2 provides a conceptual rendering of a distributive bioretention basin with the components identified. The components that are fundamental for distributive bioretention basins are shown in the figure. For larger centralized bioretention facilities, pre-treatment should be included. Additional area protection may also be considered.

3.2.2 APPLICABILITY

Given the variability of design as it relates to the drainage area and allowable ponding depth within the system, the selection of a bioretention basin design depends largely on the size of the contributing drainage area. Large centralized bioretention basins are well suited to service large residential subdivisions. However, these may also be used to treat commercial and industrial sites, although pretreatment should be considered, especially if there are high sediment loads anticipated. Bioretention basins are not recommended to treat drainage areas greater than 5-acres. Small bioretention basins (rain gardens) may serve these land use types; however, they are limited to sites that are less than an acre. Therefore, on large sites, the developer should consider distributing smaller systems throughout the site. Given the ability of a rain garden to be incorporated into the landscape, its use is extremely flexible and makes it ideal for roadway median strips and curb bump outs, parking lot islands, and roof downspout catchment areas³.

Figure 3.2 Conceptual Rendering of Distributive Bioretention Basin



3.2.3 DESIGN CRITERIA

The following sections provide design criteria for both centralized and distributed bioretention basins. As noted above, the primary differences between the two are the allowable drainage area size and inclusion of the sediment forebay.

3.2.3.1 CENTRALIZED BIORETENTION BASINS

This section provides the design criteria for large centralized bioretention basins (those serving drainage areas up to 5-acres). Note that some of the primary differences between sand filters and the centralized bioretention basin described in this section are the bioretention media and landscaping.

1) General Criteria

- a. Runoff from all impervious surfaces should be directed to a BMP.
- b. Maintenance plans – Maintenance plan contains a guarantee of maintenance in accordance with the *Stormwater Facility Maintenance Agreement – Water Quality Devices* and confirms with requirements in Appendix D.

2) Site Conditions

- a. Drainage Area – Not recommended for drainage areas greater than 5-acres; there is no minimum drainage area limitation. If proposed for drainage areas greater than 5-acres, additional information must be provided to ensure that the basin will perform effectively, and additional maintenance and inspections may be required to verify.
- b. Depth to Water Table – Consider depth of 4-feet to groundwater table when identifying appropriate locations for bioretention. A high groundwater level could damage the bioretention basin or limit the treatment by infiltration.
- c. Soils – the characteristics of the native soils will determine if infiltration would occur naturally outside of the bioretention basin.
- d. Floodplain – Where feasible, the BMP should be located outside of the 100-year floodplain. Where not feasible, the top of walls / embankments for the BMP should be above the 100-year floodplain and the BMP should be designed to protect against surcharge from downstream waters.
- e. Space Required – The BMP footprint is a function of the available head at the site, the size of the drainage area, and the designed surface area for the BMP.

3) Structural criteria

- a. Emptying / drain time – The optimal drain time for the BMP is 12-hours, but the drain time should be not be greater than 24-hours.
- b. Minimum Head – The elevation difference required at a site from the inflow to the outflow is generally 3 to 5-feet.
- c. Pre-treatment – For inlets where there is concentrated flow, the centralized bioretention cells should have a sediment forebay. The sediment forebay should be designed to hold 10% of the bioretention volume. For areas with sheet flow, the bioretention system should have vegetated filter strips or gravel to dissipate energy, minimize erosion, and capture sediment (*see Section 4.2*).
- d. Bioretention cell - The structure of the bioretention cell is constructed through the use of excavations and earthen embankments.
 - i. Size – The bioretention cell must hold 100% of the WQ_v (*see Sections 4.5 and 4.6 for additional information on layout criteria*).
 - ii. Length to width – The bioretention cell should maximize the length-to-width ratio (*see Section 4.1 for additional information on inlet structures and Section 4.8 on outlet structures*).
 - iii. Maximum depth – The maximum depth for captured WQ_v within the basin is 12-inches.
 - iv. Area Protection – Curbing is advised in locations with pedestrian traffic and vehicular traffic. Bollards are advised in locations with vehicular traffic (*see Section 4.4*).

- v. BMP Media – Centralized bioretention basins require a 30-inch (minimum) to 48-inch (maximum) layer of bioretention or engineered soil medium. A storage aggregate layer shall be placed below the centralized bioretention for additional water storage capacity (*see Sections 4.5*).
- vi. Media barrier – Depending on site conditions, a permeable geotextile or geomembrane liner should be used to line the bottom and sides of the BMP before installation of the underdrain system and BMP media. A media barrier is also recommended between the bioretention or engineered soil and the storage aggregate layer to reduce sediment migration into the storage aggregate layer; permeable geotextile is not recommended because of the tendency for the material to clog and thus prevent water migration into the storage layer (*see Section 4.6*). An impermeable liner must be used for installations adjacent to streets to prevent water from getting under the pavement into the base material.
- vii. Vegetation – Vegetation must be provided, and mulch used for areas where there is bare soil. Organic enhancers may be added to promote vegetation growth and use of heavy tackifier with hydro mulch and erosion mats staked to the soil can be used to help vegetation establish and stabilize the site (*see Section 4.7*). Appendix C provides planting palettes for BMP facilities. These areas should not receive any fertilizers, pesticides, or herbicides. Vegetation on the pond embankments should be mowed as appropriate to prevent the establishment of woody vegetation.
- viii. Underdrains - If the system includes an underdrain, the bioretention medium shall be located above the underdrain system and the underdrain shall be located within the storage aggregate layer (*see Section 4.8*).
- e. The diversion structure must be capable of passing the peak flow rate of the ten (10)-year storm into the stormwater quality BMP and bypassing excess runoff, including up to the 100-year storm, away from the BMP (*see Section 4.1 for additional information on diversion structures*).
- f. Note – Texas Commission on Environmental Quality (TCEQ) Dam Safety requirements shall be accounted for as required with higher depth structures.

3.2.3.2 DISTRIBUTIVE BIORETENTION BASINS (RAIN GARDENS)

This section provides the design criteria for distributive bioretention basins (hereafter referred to as rain gardens).

1) General criteria

- a. Runoff from all impervious surfaces should be directed to a BMP.
- b. Maintenance plans – Maintenance plan contains a guarantee of maintenance in accordance with the *Stormwater Facility Maintenance Agreement – Water Quality Devices* and confirms with requirements in Appendix D.

2) Site conditions

- a. Drainage Area – Maximum drainage area of 1-acre.
- b. Depth to Water Table – Consider depth of 4-feet to groundwater table when identifying appropriate locations for bioretention. A high groundwater level could damage the bioretention basin or limit the treatment by infiltration.
- c. Soils – the characteristics of the native soils will determine if infiltration would occur from the bioretention basin. Engineered media is required for the bioretention filtration media to perform effectively.
- d. Floodplain – Where feasible, the BMP should be located outside of the 100-year floodplain. Where not feasible, the top of walls / embankments for the BMP should be above the 100-year floodplain and the BMP should be designed to protect against surcharge from downstream waters.
- e. Space Required – The BMP footprint is a function of the available head at the site, the size of the drainage area, and the designed surface area for the BMP.

3) Structural criteria

- a. Emptying / drain time – The optimal drain time for the BMP is 12-hours, but the drain time should be not be greater than 24-hours.
- b. Minimum Head – The elevation difference needed at a site from the inflow to the outflow is generally 3 to 5-feet.
- c. Energy dissipation – Energy dissipation is recommended, especially for areas with concentrated flow. Gravel or vegetated filter strips can be used to dissipate energy (*see Section 4.3*).
- d. Bioretention cell – The structure of the bioretention cell is constructed through excavation and the construction of earthen embankments.
 - i. Size – The entire treatment system must be designed for 100% of the WQv (*see Sections 4.5 and 4.6 for additional information on layout criteria*).
 - ii. Maximum depth – The maximum depth of water within the rain garden bioretention cell is 12-inches.
 - iii. Area Protection – Curbing is advised in locations with pedestrian traffic and vehicular traffic. Bollards are advised in locations with vehicular traffic (*see Section 4.4*).
 - iv. BMP Media – The BMP media consists of 30-inch (minimum) to 48-inch layer of bioretention or engineered soil medium. A storage aggregate layer shall be placed at the bottom of the distributive bioretention for additional water storage capacity (*see Sections 4.5*).
 - v. Media barrier – Depending on site conditions, a permeable geotextile or geomembrane liner should be used to line the bottom and sides of the BMP before installation of the underdrain system and BMP media. A media barrier is also recommended between the bioretention or engineered soil

and the storage aggregate layer to reduce sediment migration into the storage aggregate layer; permeable geotextile is not recommended because of the tendency for the material to clog and thus prevent water migration into the storage layer (*see Section 4.6*). An impermeable liner must be used for installations adjacent to streets to prevent water from getting under the pavement into the base material.

- vi. Vegetation – Vegetation must be provided, and mulch used for areas where there is bare soil. Organic enhancers may be added to promote vegetation growth and use of heavy tackifier with hydro mulch and erosion mats staked to the soil can be used to help vegetation establish and stabilize the site (*see Section 4.7*). Appendix C provides planting palettes for BMP facilities. These areas should not receive any fertilizers, pesticides, or herbicides. Vegetation on the pond embankments should be mowed as appropriate to prevent the establishment of woody vegetation.
- vii. Underdrains - If the system includes an underdrain, the underdrain shall be located within the storage aggregate layer below the bioretention soil media (*see Section 4.8*).

3.2.4 MAINTENANCE CONSIDERATIONS DURING DESIGN AND CONSTRUCTION

Inspection and maintenance are critical to the performance of bioretention systems. The activities, schedule, and additional maintenance considerations and requirements are attached in Appendix D “BMP Inspection and Maintenance” of this manual. The following should be considered during design and construction of the BMP:

- Access – For centralized bioretention, adequate access must be provided for inspection and maintenance, including the appropriate equipment and vehicles. For larger facilities where access may be an issue, an access ramp with a minimum width of 10-feet and a maximum slope of 25% shall be provided. Distributive bioretention should be accessible for inspection and maintenance including the appropriate equipment; however, due to the smaller facilities, no access ramp is necessary.
- Fencing (optional) – To prevent access and damage to vegetation, it is recommended that centralized bioretention facilities be fenced to prevent public access and in accordance with City of Fort Worth requirements.
- The use of vegetation is preferred to mulch. Mulch can float and clog outlets. However, there must be effort taken to ensure successful implementation of the vegetation³.
- Maintenance should be considered during the design and layout. For example, pruning and mowing of vegetation and accessibility to features that will need to be maintained³.
- Include cleanouts as discussed in Section 4.8. These can be used for inspection to make sure that the underdrain is intact, and for ongoing maintenance during and after construction.
- Keep the BMP offline until the construction activities are completed. Temporary BMPs should be in place as detailed in the project Sediment and Erosion Control Plan to protect receiving waters during construction activities (the Sediment and Erosion Control Plan requirements

are not discussed in this manual). Sediment discharged during construction can clog the system and would require additional maintenance.

- Consider making the bioretention basin shallower, to make maintenance easier³.

¹ Hsieh, C.-h., & Davis, A. P. November 2005. Evaluation and Optimization of Bioretention Media for Treatment of Urban Storm Water Runoff. *Journal of Environmental Engineering*, 1521-1531.

² City of Austin. (2017). Design Guidelines for Water Quality Controls. *Environmental Criteria Manual*.

³ Urban Drainage and Flood Control District (UDFCD). (2010). *Urban Storm Drainage Criteria Manual (USDCM): Volume 3 Stormwater Quality*.

3.3 CONSTRUCTED WETLANDS

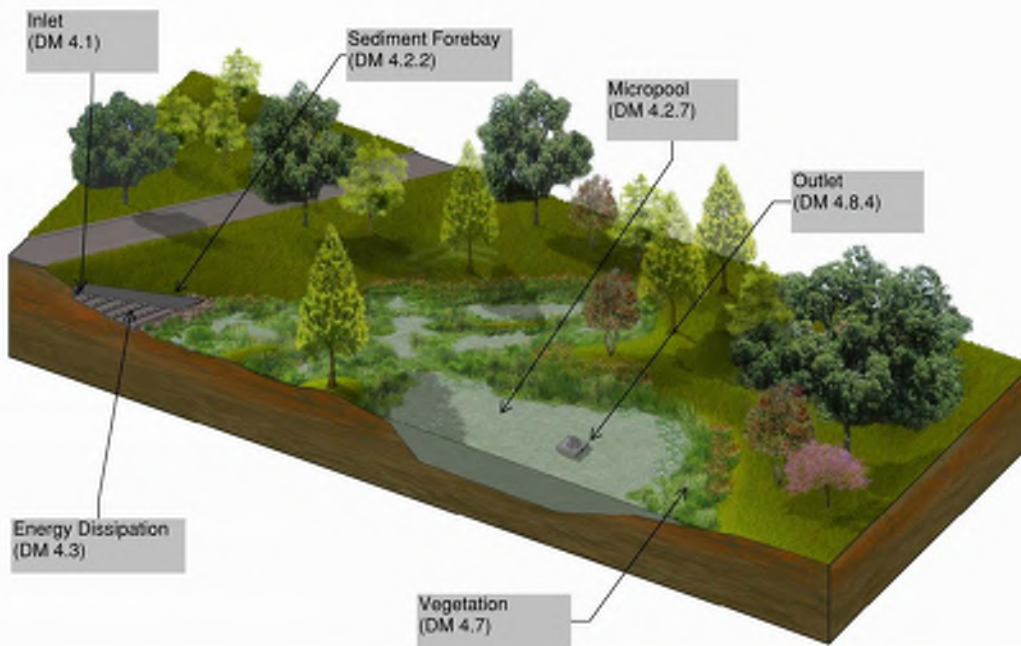
3.3.1 DESCRIPTION OF BMP

Constructed wetlands generally serve large drainage areas where the WQv is both stored and treated in the wetland facility. They may also provide additional capacity for flood control management. For water quality, these practices are often referred to as stormwater wetlands. The purpose of the constructed wetland is to provide treatment by way of a functional pool resulting in the settlement, filtration, and uptake of pollutants by a viable wetland ecosystem. Constructed wetlands sized for the WQv and designed in compliance with this manual meet the water quality requirements for new and re-development in Zone 2.

A Design/Review spreadsheet has been developed specifically for use with this document and is included in Appendix E. Figure 3.3 provides a conceptual rendering of a constructed wetland with major components identified. As will all detention facilities, constructed wetlands need to be designed such that public safety is maintained (such as using benching to keep deeper water further from shore and/or barriers on lookouts, walkways and the like, or where benching can't be accomplished cost-effectively).

3.3.2 APPLICABILITY

The selection of a constructed wetland depends largely on the ability to make sure the system is viable as a wetland ecosystem, performs the key functions of stormwater treatment, and minimizes potential vectors to protect human health. As such, considerable design expertise beyond hydrology, hydraulics, and water quality needs to be engaged to provide a sustainable wetland ecosystem that meets these criteria. Constructed wetlands are best suited for large areas often where flood control detention is also required and where the wetland can contribute additional value to the setting (e.g., such as a park system with trails where birdwatching, environmental education, and the like could occur). Therefore, the final condition of the developed site and the availability of a perennial source of water (and whether a wetland system can be viable with interruptions in water supply) should be considered before choosing constructed wetlands. Poorly designed constructed wetlands can become public nuisances because they lack the natural ability to mitigate mosquito populations. As such, other practices (such as extended dry detention) should be considered before constructed wetlands where wetland viability is questionable. Practices like extended dry detention can be designed with attractive landscape elements as well for inclusion in open spaces, park systems, etc.

Figure 3.3 Conceptual Rendering of a Constructed Wetland

3.3.3 DESIGN CRITERIA

This section provides the design criteria for constructed wetlands. The structural criteria provide information about the components and include references to the component design section of this manual (Section 4). The details and specifications for the components are provided in that section. The design/review spreadsheet in Appendix E outlines the design steps and calculations for the BMPs.

1) General Criteria

- a. Runoff from all impervious surfaces should be directed to a BMP.
- b. Maintenance plans – Maintenance plan for constructed wetlands must contain a guarantee of maintenance in accordance with the Stormwater Facility Maintenance Agreement for Water Quality Devices and be in conformance with the requirements outlined in Appendix D. The plan must be submitted for review by TRWD.

2) Site Conditions

- a. Drainage area – Constructed wetlands should be implemented at locations where there is a larger drainage area or where a wetland system is viable.
- b. Depth to water table – 2-feet are required between the bottom of the constructed wetland and the elevation of the seasonally high-water table.
- c. Soils – Infiltration into soils is not recommended to maintain a permanent pool. Permeable soils are not ideal for maintaining water levels within the constructed wetlands. An impermeable barrier may be needed to minimize water loss from the

permanent pool (*See Section 4.6 for additional information on media barriers*). A geomembrane liner must be used for installations adjacent to streets to prevent water from getting under the pavement into the base material.

- d. Floodplain – Where feasible, the BMP should be located outside of the 100-year floodplain. Where not feasible, the top of walls / embankments for the BMP should be above the 100-year floodplain and the BMP should be designed to protect against surcharge from downstream waters.
- e. Space – The space required for the BMP is a function of available head at the site, treatment WQv, and availability of make-up water.

3) Structural Criteria

- a. Energy dissipation – The constructed wetland must be designed with energy dissipation structures at the inlet if the entrance velocities exceed the erosive velocity requirement of the BMP surface material (*See Section 4.3*).
- b. Diversion structure – The diversion structure should be sized to bypass flows from the 10-year annual probability storm and the channel should be able to convey flows from the 100-year annual probability storm without overtopping.
- c. Sediment forebay – The constructed wetland must have a sediment forebay to prevent sediment accumulation in the wetland.
 - i. Size – The forebay volume should be sized to contain 0.1-inches of runoff from the impervious portion of the contributing drainage area. For example, for a two-acre drainage basin with 60% impervious cover, the forebay should be designed to hold 0.1 inches of runoff from 1.2 acres.
 - ii. The length to width ratio of the forebay should be at least 2:1 (length:width) and have a side slope ratio no steeper than 3:1 (horizontal:vertical).
 - iii. Drawdown – The forebay outlet should be sized such that the forebay drains within 24-hours.
- d. Constructed wetland basin
 - i. Size – The basin should be sized to contain a permanent pool volume equal to 100% of the WQv and a surcharge volume sized to contain 120% of the WQv. The purpose of the additional storage volume is to account for the total volume lost through sediment accumulation over time. Ideally, constructed wetlands should have sinuous flow paths, a length to width ratio of 4:1, and side slopes no steeper than 3:1 (horizontal: vertical) (*See Section 4.4 for additional information on area protection*). It is recommended that the basin be lined with a filter fabric if constructed with earthen embankments.
 - ii. Depth – The permanent pool depth of the constructed wetland should have varying depths as outlined below, ending with a micropool before the outlet that is no more than 6-feet in depth. The surcharge depth should be 2-feet or less. Below are the different permanent pool depth zones that should be included in a constructed wetland.

1. Semi-Wet Zone – This zone lies at or above the permanent pool and is only inundated following storm events. *(See Section 4.7 for Plant List 4 through 8).*
 2. Aquatic Bench Zone – This zone has a depth of 18-inches below the permanent pool elevation. *(See Section 4.7 for Plant List 3).*
 3. Deep Water Zone – This zone has a depth from 18-inches to 6-feet below the permanent pool elevation. *(See Section 4.7 for Plant List 2).*
- iii. Vegetation – appropriate vegetation is a critical component of the effectiveness of the wetland system. The different zones must be planted with the appropriate vegetation for the depth of inundation *(see Section 4.7)*. Appendix C provides planting palettes for BMP facilities. These areas should not receive any fertilizers, pesticides, or herbicides. Vegetation on the pond embankments should be mowed as appropriate to prevent the establishment of woody vegetation.
 - iv. Outlet – Design the outlet properly with the fine trash rack in front of the outlet orifices and is submerged the full depth of the micropool. This allows flow under the clogged portions of the trash rack.
 - v. Emptying / drain time – The surcharge of the wetland above the permanent pool volume should drain within 24-hours. *(See Section 4.8 for additional information on outlets/piping).*

3.3.4 MAINTENANCE CONSIDERATIONS DURING DESIGN AND CONSTRUCTION

Inspection and maintenance are critical to the performance of constructed wetlands. The activities, schedule, and additional maintenance considerations and requirements are attached in Appendix D “BMP Inspection and Maintenance” of this manual. The following should be considered during design and construction of the BMP:

- Maintenance requirements should be considered during the design and layout. For example, pruning and mowing of vegetation and accessibility to features that will need to be maintained. Access should be provided to the constructed wetland, particularly to the sediment forebay. A maintenance ramp should be a minimum of 10-feet in width and have a maximum slope of 25%. For mowing, it is recommended to keep side slopes at a maximum of 3:1 (horizontal:vertical). Sediment accumulation in the forebay should be monitored using vertical depth markers indicating when sediment accumulation equals 20% of the forebay volume.
- The BMP should be kept offline until the construction activities are completed. However, the BMP excavation can be used as a sediment trap during construction before filtration or other media are placed in the basin. In that case, the bottom of the basin should not be excavated below 2-feet of the final grade. Temporary BMPs should be in place as detailed in the project Sediment and Erosion Control Plan to protect receiving waters during construction activities (the Sediment and Erosion Control Plan requirements are not discussed in this manual). Sediment discharged during construction can clog the system and would require additional maintenance.

- Monitor and minimize use of fertilizers that can increase nutrient concentrations in discharge and cause algal blooms¹.

¹ Urban Drainage and Flood Control District (UDFCD). (2010). Urban Storm Drainage Criteria Manual (USDCM): Volume 3 Stormwater Quality.

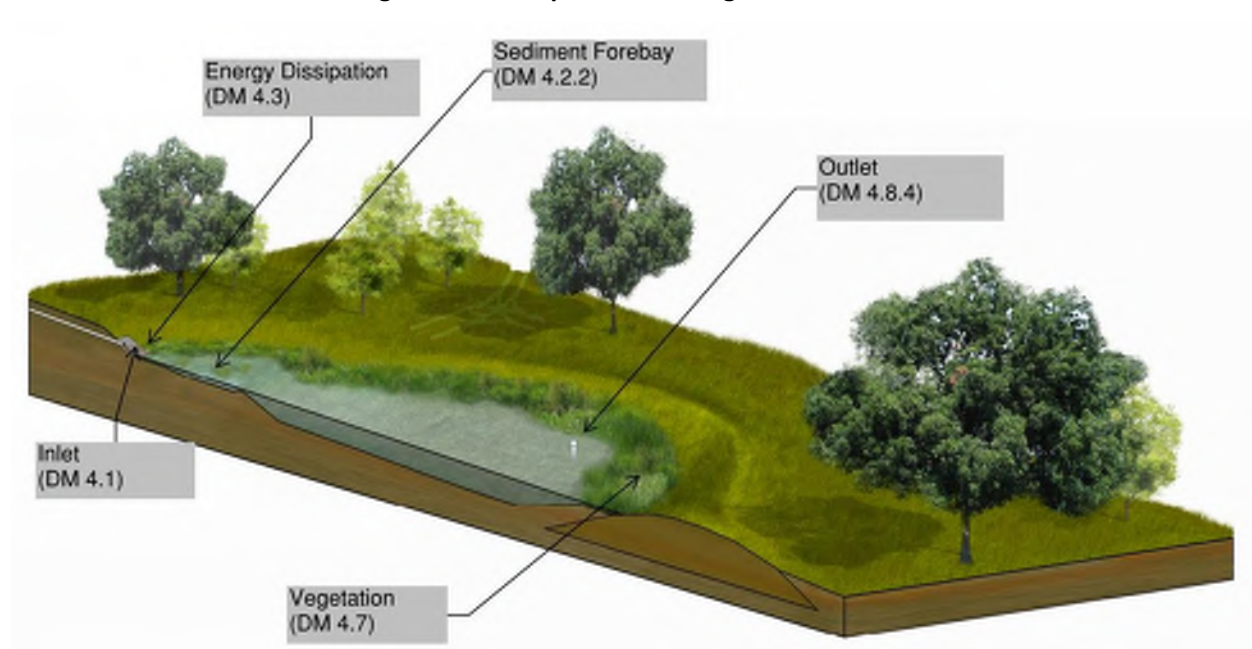
3.4 WET BASINS

3.4.1 DESCRIPTION OF BMP

Wet basins are designed to retain stormwater in ponds between runoff events to allow the retained volume to be treated for an extended period. These BMPs are also referred to as wet ponds, stormwater ponds, or retention ponds. They are best suited to treat large drainage areas and require a source of water to maintain the permanent pool. Wet basins sized for the WQv and designed in compliance with this manual meet the water quality requirements for new and re-development in Zone 2.

Wet basins remove pollutants by retaining stormwater and allowing for settling and plant uptake during that period. A design/review spreadsheet has been developed specifically for use with this document and is included in Appendix E. Figure 3.4 provides a conceptual rendering of a wet basin with major components identified. Area protection should also be considered.

Figure 3.4 Conceptual Rendering of a Wet Basin



3.4.2 APPLICABILITY

The selection of a wet basin depends largely on the availability of space, a large contributing drainage area, and the availability of a water source to ensure a permanent pool throughout the entire year. Having a source of water available to maintain a permanent pool is an important consideration when considering the use of wet basin as a BMP.

3.4.3 DESIGN CRITERIA

This section provides the design criteria for wet basins. The structural criteria provide information about the components and include references to the component design section of this manual (Section 4). The details and specifications for the components are provided in that section. The design/review spreadsheet in Appendix E outlines the design steps and calculations for the BMPs.

1) General Criteria

- a. Runoff from all impervious surfaces should be directed to a BMP.
- b. Maintenance plans – Maintenance plan for wet basins must contain a guarantee of maintenance in accordance with the Stormwater Facility Maintenance Agreement for Water Quality Devices and be in conformance with Appendix D. The plan must be submitted for review by TRWD.

2) Site Conditions

- a. Drainage area – Wet basins should be implemented at locations where there is a larger drainage area or a potential source of baseflow to maintain the water level.
- b. Depth to water table – 2-feet are required between the bottom of the wet basin and the elevation of the seasonally high-water table.
- c. Soils – Infiltration into soils is not recommended to maintain a permanent pool. Permeable soils are not ideal for maintaining water levels within the wet basins. An impermeable barrier may be needed to minimize water loss from the permanent pool. *(See Section 4.6 for additional information on media barriers)*. A geomembrane liner must be used for installations adjacent to streets to prevent water from getting under the pavement into the base material.
- d. Floodplain – Where feasible, the BMP should be located outside of the 100-year floodplain. Where not feasible, the top of walls / embankments for the BMP should be above the 100-year floodplain and the BMP should be designed to protect against surcharge from downstream waters.
- e. Space – The space required for the BMP is a function of available head at the site, required treatment WQv, and availability of make-up water.

3) Structural criteria

- a. Energy dissipation – The wet basin must be designed with energy dissipation structures at the inlet if the entrance velocities exceed the erosive velocity requirement of the BMP surface material *(see Section 4.3)*.

- b. Diversion structure – The diversion structure should be sized to bypass flows from the 10-year annual probability storm and the channel should be able to convey flows from the 100-year annual probability storm without overtopping.
- c. Sediment forebay – The wet basin must have a sediment forebay to prevent sediment accumulation in the basin.
 - i. Size – The forebay volume should be sized to hold 0.1-inches of runoff depth from the impervious portion of the contributing drainage area. For example, for a two-acre drainage basin with 60% impervious cover, the forebay should be designed to hold 0.1 inches of runoff from 1.2 acres.
 - ii. The recommended length to width ratio is no less than 2:1 (length:width), and side slopes no steeper than 3:1 (horizontal:vertical).
 - iii. Drawdown – The forebay outlet should be sized such that the forebay drains within less than 24-hours.
- d. Wet Basin
 - iv. Size – The wet basin should be designed to contain a permanent pool volume equal to or greater than the WQv and a surcharge volume of 120% of the WQv (*See Section 4.4 for additional information on area protection*). The purpose of the additional storage volume is to account for the total volume lost through sediment accumulation over time. The basin should be lined with a filter fabric if constructed with earthen embankments.
 - v. Depth – The wet basin surcharge should have no more than 5-feet of depth. The wet basin should have a safety bench, or littoral zone, which makes up 15% of the total surface area of the basin.
 - vi. Vegetation – Appropriate vegetation is a critical component of the effectiveness of the wetland system. The different zones must be planted with the appropriate vegetation for the depth (*See Section 4.7*). Appendix C provides planting palettes for BMP facilities. These areas should not receive any fertilizers, pesticides, or herbicides. Vegetation on the pond embankments should be mowed as appropriate to prevent the establishment of woody vegetation.
 - vii. Outlet – Design the outlet properly with the fine trash rack in front of the outlet orifices and is submerged the full depth of the micropool. This allows flow under the clogged portions of the trash rack.
 - viii. Drawdown – The surcharge of the wet basin should drain within 12-hours. (*See Section 4.8*).
- e. Note – Texas Commission on Environmental Quality (TCEQ) Dam Safety requirements shall be accounted for as required with higher depth structures. For ponds with significant earthen embankments, prevent planting of woody vegetation in berms to comply with state dam safety rules.

3.4.4 MAINTENANCE CONSIDERATIONS DURING DESIGN AND CONSTRUCTION

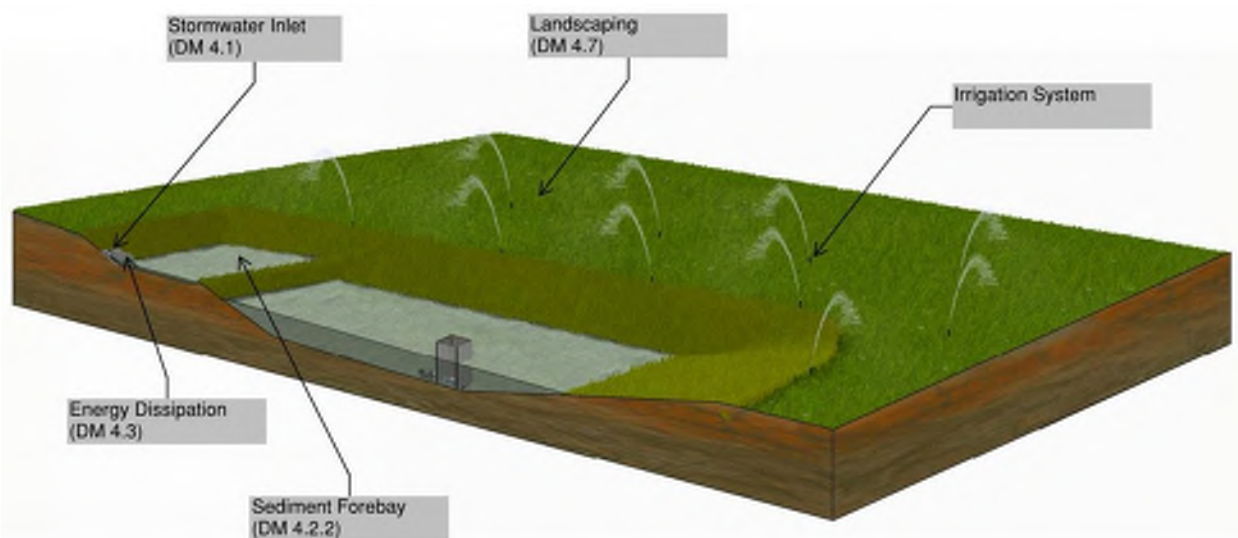
Inspection and maintenance are critical to the performance of wet basins. The activities, schedule, and additional maintenance considerations and requirements are attached in Appendix D “BMP Inspection and Maintenance” of this manual. The following should be considered during design and construction of the BMP:

- Maintenance should be considered during the design and layout. For example, there must be easy accessibility to the outlet structure and other features that will need to be maintained¹. Access should be provided to the wet basin, particularly to the sediment forebay. A maintenance ramp should be a minimum of 10-feet in width and have a maximum slope of 25%. For mowing, it is recommended to keep side slopes at a maximum of 3:1 (horizontal:vertical). Sediment accumulation in the forebay should be monitored using vertical depth markers to indicate when sediment accumulation equals 20% of the forebay volume.
- The BMP should be kept offline until the construction activities are completed. However, the BMP excavation can be used as a sediment trap during construction before filtration or other media are placed in the basin. In that case, the bottom of the basin should not be excavated below 2-feet of the final grade.
- Temporary BMPs should be in place as detailed in the project Sediment and Erosion Control Plan to protect receiving waters during construction activities (the Sediment and Erosion Control Plan requirements are not discussed in this manual). Sediment discharged during construction can clog the system and would require additional maintenance.
- Monitor and minimize use of fertilizers that can increase nutrient concentrations in discharge and cause algal blooms

¹ Urban Drainage and Flood Control District (UDFCD). (2010). Urban Storm Drainage Criteria Manual (USDCM): Volume 3 Stormwater Quality.

3.5 RETENTION / IRRIGATION BASIN¹

The following description and design criteria is consistent with that provided in the Complying with the Edwards Aquifer Rules: Technical Guidance on Best Management Practices prepared by Michael E. Barrett, Ph.D., P.E. for the TCEQ (June 20, 2005). Figure 3.5 provides a conceptual rendering of a retention / irrigation basin with major components identified. Area protection should also be considered in the design.

Figure 3.5 Conceptual Rendering of a Retention / Irrigation Basin

* Note – wet well should be separated from wet basin where possible

3.5.1 DESCRIPTION OF BMP

Retention / irrigation refers to the capture of stormwater runoff in a holding pond, then use of the captured WQv for irrigation of appropriate landscape areas. Collection of roof runoff for subsequent use (rainwater harvesting) also qualifies as a retention / irrigation practice but should be operated and sized to provide adequate capture volume. Rainwater harvesting design will not be described in Section 3.5.

Retention / irrigation systems represent a highly effective approach to stormwater quality control. The goal of this technology is to use infiltration and evapotranspiration to treat runoff. Pollutant removal effectiveness is accomplished through physical filtration of solids in the soil profile and uptake of nutrients by vegetation. The primary drawback of this approach is the potentially high maintenance requirements for the irrigation system, which must remain operational for this BMP to function effectively.

Retention / irrigation can replace or reduce the use of potable water for irrigation. When properly designed, constructed, operated, and maintained, retention / irrigation systems are considered to be highly effective at removing pollutants for the water quality capture volume.

3.5.2 APPLICABILITY

Retention / irrigation systems depend heavily on available land for irrigation. Land uses should be limited to residential, commercial, or light industrial developments. Given the high infiltration rate of the designed system, this system should not be used for areas with the potential to contaminate groundwater such as areas with high levels of toxic compounds. Irrigation is assumed in this section; however, other uses of the retained water may be considered and submitted for consideration.

The system includes mechanical components; therefore, observation and maintenance will be required to ensure the system is performing as designed. Active sites that are routinely inspected and maintained are preferred. The long-term availability of irrigated lands should be considered during BMP selection.

3.5.3 DESIGN CRITERIA

This section provides the design criteria for retention / irrigation basins. Capture of stormwater in retention / irrigation systems can be accomplished in virtually any kind of runoff storage facility ranging from fully dry, concrete-lined to vegetated with a permanent pool. The design of the storage system can be quite flexible. The pump and wet well system should be automated with a rainfall or soil moisture sensor to allow for irrigation only during periods when required infiltration rates (based on soils, evapotranspiration rates, etc.) can be realized.

The structural criteria provide information about the components and include references to the component design section of this manual (Section 4). The details and specifications for the components are provided in that section. The design/review spreadsheet in Appendix E outlines the design steps and calculations for the BMPs.

1) General Criteria

- a. Runoff from all impervious surfaces should be directed to a BMP.
- b. Maintenance plans – Maintenance plan for retention / irrigation basins must contain a guarantee of maintenance in accordance with the Stormwater Facility Maintenance Agreement for Water Quality Devices and be in conformance with Appendix D. The plan must be submitted for review by TRWD.

2) Site Conditions

- a. Drainage area – Retention / irrigation basins should be implemented at locations where there is a larger drainage area. It is recommended that sites be less than 128-acres².
- b. Depth to water table – 2-feet are required between the bottom of the retention basin and the elevation of the seasonally high-water table.
- c. Floodplain – Where feasible, the BMP should be located outside of the 100-year floodplain. Where not feasible, the top of walls / embankments for the BMP should be above the 100-year floodplain and the BMP should be designed to protect against surcharge from downstream waters.
- d. Space – The space required for the BMP is a function of available head at the site, required treatment WQv, and availability of make-up water.
- e. Irrigated area – The irrigated area must be pervious and have an overall slope no greater than 10%. The area must be distinct from areas that are used for wastewater effluent irrigation, and it should be at least 100-feet from wells, septic systems, natural wetlands, and streams. The minimum area requires intermittent irrigation over a period of 60-hours at low rates to use the entire WQv without allowing runoff. This intensive irrigation may be harmful to vegetation that is not adapted to long periods of wet conditions (*see Section 4.7*). In practice, a much larger

irrigation area will provide better use of the retained water and promote a healthy landscape.

- f. Soils – The permeability of the soils in the area proposed for irrigation should be assessed. This can be determined using a double ring infiltrometer (ASTM D 3385-94) or from county soil surveys prepared by the Natural Resource Conservation Service. A geomembrane liner must be used for retention basin installations adjacent to streets to prevent water from getting under the pavement into the base material. There should be a minimum of 12-inches of soil cover for irrigated areas. If maintaining a permanent pool, minimize water loss by using an impermeable barrier to prevent infiltration.

3) Structural Criteria

- a. Energy dissipation – The retention / irrigation basin must be designed with energy dissipation structures at the inlet if the entrance velocities exceed the erosive velocity requirement of the BMP surface material (*see Section 4.3*).
- b. Diversion structure – The diversion structure elevation should be equal to or greater than the surface elevation of WQv in the BMP. The diversion structure should be sized to bypass flows from the 10-year annual probability storm and the channel should be able to convey flows from the 100-year annual probability storm with less than 1-foot over the diversion weir.
- c. Runoff storage facility configuration and sizing – The design of the runoff storage facility is flexible as long as an appropriate pump and wet well system can be accommodated.
- d. Sediment forebay – The retention / irrigation basin should have a sediment forebay to prevent sediment accumulation in the basin and to protect the pumps and irrigation system.
 - i. Size – The forebay volume should be sized to contain 0.1-inches of runoff from the impervious portion of the contributing drainage area. For example, for a two-acre drainage basin with 60% impervious cover, the forebay should be designed to hold 0.1 inches of runoff from 1.2 acres.
 - ii. The length to width ratio should be no less than 2:1 (length:width), and the side slopes should be no steeper than 3:1 (horizontal: vertical).
 - iii. Drawdown – The forebay outlet should be sized such that the forebay drains within 24-hours.
- e. Retention basin
 - i. Size – Three typical options for retention basins consist of dry, concrete-lined basin, vegetated basin, and vegetated basin with permanent pool. The permanent pool is sized to contain 100% of the WQv. The retention basin must be sized to contain the WQv, plus the permanent pool volume if included. The retention basin should allow enough freeboard such that the retention basin can pass the 100-year storm over the diversion structure without overtopping the side walls.

- ii. Vegetation – If applicable, consult Section 4.7 for a list of appropriate vegetation for the retention basin.
 - iii. Outlet – Design the outlet properly with the fine trash rack in front of the outlet orifices.
 - iv. Drawdown – The surcharge of the retention basin must drain to the wet well within 72-hours. *(See Section 4.8).*
 - v. Fencing – To prevent risk to the public, it is recommended that retention basins be fenced in accordance with the City of Fort Worth requirements. The contours of the retention basin should be managed to eliminate drop-offs and other hazards. Landscaping can also be used to impede access to the retention basin.
- f. Note – Texas Commission on Environmental Quality (TCEQ) Dam Safety requirements shall be accounted for as required with higher depth structures.
- g. Pump and wet well system - A reliable pump, wet well, and rainfall or soil moisture sensor system should be used to distribute the WQv.
- i. Pumps – The pumps should be able to provide 100% of the design capacity and operate within 20% of their best operating efficiency.
 - ii. The valves should be located outside of the wet well on the discharge side of each pump to allow the pumps to be isolated for maintenance and throttling if necessary.
 - iii. A high/low-pressure pump shut off system should be installed in the pump discharge piping.
 - iv. Wet well – The wet well should be constructed of precast or cast in place concrete and located separate from the retention basin. The wet well and pump must be designed to be low enough to completely evacuate the retention basin.
- h. Irrigation area and system - The details and specifications for irrigation systems are not part of this manual, and the specifications must be approved by a PE licensed in the state of Texas and submitted for review by the TRWD.
- i. Pipes and valves should be marked to indicate that they contain non-potable water.
 - ii. The irrigation schedule should not begin within 12-hours of the end of the rainfall event so that direct storm runoff has ceased, and soils are not saturated.
 - iii. The length of active irrigation period is 60-hours with a cycling factor of $\frac{1}{4}$. The irrigation system should cease in the event that another rainfall event begins during the active irrigation period and should not begin within 12-hours of the end of the rainfall event. Continuous application on any section should be designed to prevent surface runoff from the irrigated area.

- iv. Valves – All valves should be designed specifically for sediment bearing water and be of appropriate design for the intended purpose. All remote control, gate, and quick coupling valves should be located in 10-inch or larger plastic valve boxes.
- v. Sprinklers – Sprinklers should operate at the required rate and distribute water in a uniform manner and not beyond the limits of the designated irrigation area. Sprinkler heads should be capable of passing solids that may pass through the intake. Sprinkler heads should be protected from mowing and service equipment.
- vi. Vegetation – The irrigation area should have native and high water tolerant vegetation or be restored or re-established with native and high water tolerant vegetation (*see Section 4.7*). Appendix C provides planting palettes for BMP facilities. These areas should not receive any fertilizers, pesticides, or herbicides. Vegetation on the pond embankments should be mowed as appropriate to prevent the establishment of woody vegetation.

3.5.4 MAINTENANCE CONSIDERATIONS DURING DESIGN AND CONSTRUCTION

Inspection and maintenance are critical to the performance of retention / irrigation basin. The activities, schedule, and additional maintenance considerations and requirements are attached in Appendix D “BMP Inspection and Maintenance” of this manual. The following should be considered during design and construction of the BMP:

- Maintenance should be considering during the design and layout. Depth markers should be installed in the forebay to monitor sediment accumulation and removal. The basin should be maintained when sediment accumulation is no more than 20% of the forebay volume. Earthen side slopes should not exceed 3:1 (horizontal:vertical) and should terminate on a flat safety bench area.
- Water from the retention basin should pass through a screen or filter to remove solid material and prevent clogging of pipes and sprinklers. The pump and other internal components of the wet well should be accessible through a locked cover to prevent unauthorized access. An isolation valve to prevent flow from the retention basin to the wet well during maintenance activities is recommended.
- Alarms - An alarm system should be provided that is protected against vandals and exposure to weather. The alarm system should be highly visible and should alert when the pumps are not functioning correctly. This could include the water level not being drawn down, the pump not shutting off with low levels of water, or issues with pump pressure.
- The BMP should be kept offline until the construction activities are completed. However, the BMP excavation can be used as a sediment trap during construction before filtration or other media are placed in the basin. In that case, the bottom of the basin should not be excavated below 2-feet of the final grade.

- Temporary BMPs should be in place as detailed in the project Sediment and Erosion Control Plan to protect receiving waters during construction activities (the Sediment and Erosion Control Plan requirements are not discussed in this manual). Sediment discharged during construction can clog the system and would require additional maintenance.
- Monitor and minimize use of fertilizers that can increase nutrient concentrations if there is runoff.
- To the greatest extent practicable, irrigation areas should remain in their natural state. However, vegetation must be maintained in the irrigation area such that it does not impede the spray of water from the irrigation heads. Tree and shrub trimmings and other large debris should be removed from the irrigation area.

¹ Barrett, Michael E. Ph.D., P.E. Complying with the Edwards Aquifer Rules Technical Guidance on Best Management Practices. TCEQ RG-348. Revised July 2005 with Addendum Sheet (updated January 2017).

² "Retention/Irrigation" Highland Lakes Watershed Ordinance Water Quality Management Technical Manual. LCRA. (2007). 7th ed. 4-31 to 4-36.

3.6 EXTENDED DRY DETENTION BASIN

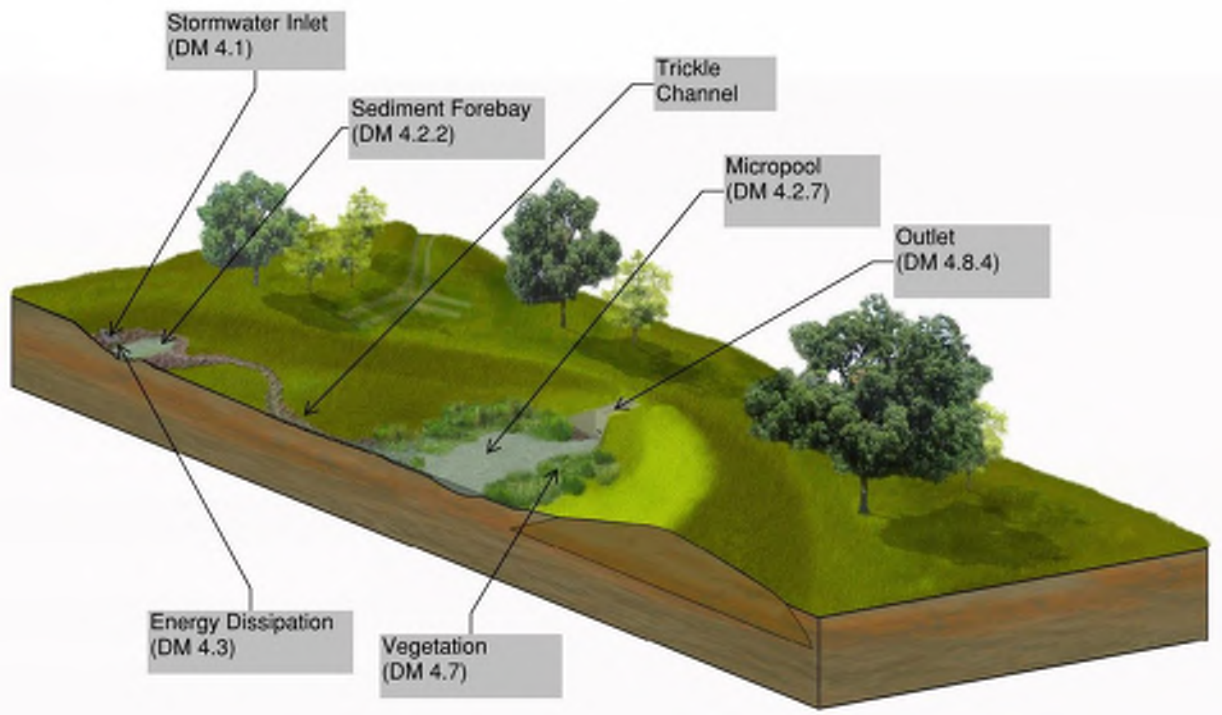
3.6.1 BMP DESCRIPTION

Extended dry detention basins are depressed basins that temporarily store stormwater runoff following a storm event. The water quality benefit of extended detention is achieved through the extended time for particulate pollutants to settle out and incorporating features to promote the capture of sediment, trash, and debris. Detention systems have traditionally been used for flood control to mitigate or regulate flow; however, by extending the detention time from flood control facilities and adding key features that improve water quality, these systems are effective at reducing pollutants. The City of Fort Worth also requires dry detention basins for streambank protection and flood control mitigation. The design and components of extended dry detention basins defined in this manual expand on these requirements and provide additional water quality features (COFW Stormwater Criteria Manual).

When used as a pre- or post-treatment or in conjunction with other water quality treatment systems (i.e. grass swales, vegetated filter systems, sand filters, bioretention basins, constructed wetlands) the performance of the overall BMP approach is increased. Extended dry detention basins must be designed following the criteria specified below and used in conjunction with pre- or post-treatment or other water quality treatment facilities. Figure 3.6 provides a conceptual rendering of an extended detention basin with major components identified. Area protection should also be considered.

3.6.2 DESIGN CRITERIA

This section provides the design criteria for extended detention basins. The structural criteria provide information about the components and include references to the component design section of this manual (Section 4); the details and specifications for the components are provided in that section. The design/review spreadsheet in Appendix E outlines the design steps and calculations for the BMPs.

Figure 3.6 Conceptual Rendering of an Extended Dry Detention Basin

A general overview of design criteria for consideration at the BMP selection stage of the site design process is provided below.

1) General Criteria

- a. Runoff from all impervious surfaces should be directed to a BMP.
- b. Maintenance plans – Maintenance plan for extended dry detention basins must contain a guarantee of maintenance in accordance with the Stormwater Facility Maintenance Agreement for Water Quality Devices and be in conformance with Appendix D. The plan must be submitted for review by TRWD.

2) Site Conditions

- a. Drainage area – Extended dry detention basins should be implemented at locations serving a drainage area greater than 5-acres but less than 100-acres. For larger basins, additional information must be provided to ensure that the basin will perform effectively, and additional maintenance and inspections may be required to verify.
- b. Depth to water table – 2-feet are required between the bottom of the extended dry detention basin and the elevation of the seasonally high-water table.
- c. Soils – Determine if native soils on site are sufficient for infiltration. A geomembrane liner must be used for installations adjacent to streets to prevent water from getting under the pavement into the base material.

- d. Floodplain – Where feasible, the BMP should be located outside of the 100-year floodplain. Where not feasible, the top of walls / embankments for the BMP should be above the 100-year floodplain and the BMP should be designed to protect against surcharge from downstream waters.
- e. Space – The space required for the BMP is a function of available head at the site, required treatment WQv, and availability of make-up water.

3) Structural Criteria

- a. Energy dissipation – The extended dry detention basin must be designed with energy dissipation structures at the inlet if the entrance velocities exceed the erosive velocity requirement of the BMP surface material (*see Section 4.3*).
- b. Diversion structure – The diversion structure should be sized to bypass flows from the 10-year annual probability storm and the channel should be able to convey flows from the 100-year annual probability storm without overtopping.
- c. Forebay – The extended dry detention basin must have a sediment forebay to prevent sediment accumulation in the basin.
 - i. Size – The forebay volume should be sized to contain 10% of the WQv. The length to width ratio should be no less than 2:1 (length:width), and the side slopes no steeper than 3:1 (horizontal:vertical).
 - ii. Drawdown – The forebay outlet should be sized such that the forebay drains within 24-hours.
- d. Basin
 - i. Size – The extended dry detention basin should be designed to contain 100% of the WQv. Side slopes of the basin should be no steeper than 3:1 (horizontal: vertical). (*See Sections 4.4 for additional information on area protection*).
 - ii. Trickle channels should have a design slope of at least 3%. Extended dry detention basins should have a micropool that is at least 2.5-feet in depth at the end of the basin. The micropool does not have to drain within 48-hours.
 - iii. Landscaping – The extended dry detention basin should be appropriately seeded for temporary inundation (*see Section 4.7*).
 - iv. Outlet – Design the outlet properly with the fine trash rack in front of the outlet orifices and submerged the full depth of the micropool. This allows flow under the clogged portions of the trash rack.
 - v. Drawdown – The extended dry detention basin should drain the WQv within 40 to 48-hours. (*See Section 4.8*).
- e. Note – Texas Commission on Environmental Quality (TCEQ) Dam Safety requirements shall be accounted for as required with higher depth structures. For ponds with significant earthen embankments, prevent planting of woody vegetation in berms to comply with state dam safety rules.

3.6.3 MAINTENANCE CONSIDERATIONS DURING DESIGN AND CONSTRUCTION

Inspection and maintenance are critical to the performance of extended detention basins. The activities, schedule, and additional maintenance considerations and requirements are included in Appendix D “BMP Inspection and Maintenance” of this manual. The following should be considered during design and construction of the BMP:

- Maintenance should be considering during the design and layout. For example, pruning and mowing of vegetation and accessibility to other features that will need to be maintained¹. Adequate access must be provided for inspection and maintenance, including the appropriate equipment and vehicles. An access ramp with a minimum width of 10-feet and a maximum slope of 25% shall be provided.
- The BMP should be kept offline until the construction activities are completed. However, the BMP excavation can be used as a sediment trap during construction before filtration or other media are placed in the basin. In that case, the bottom of the basin should not be excavated below 2-feet of the final grade.
- Temporary BMPs should be in place as detailed in the project Sediment and Erosion Control Plan to protect receiving waters during construction activities (the Sediment and Erosion Control Plan requirements are not discussed in this manual). Sediment discharged during construction can clog the system and would require additional maintenance.

¹ Urban Drainage and Flood Control District (UDFCD). (2010). Urban Storm Drainage Criteria Manual (USDCM): Volume 3 Stormwater Quality.

3.7 VEGETATED FILTER STRIP

3.7.1 DESCRIPTION OF BMP¹

Vegetated filter strips are gently sloped flat vegetated areas designed to receive and maintain sheet flows over the entire width of the strip². They are typically linear facilities that run parallel to the impervious surface. These systems are not intended to be used as a stand-alone or primary BMP system for a development. However, if a vegetated filter strip BMP system is used within close proximity to small, low-density impervious areas, the WQ_v for this area can be treated. For these areas, the area that drains to the BMP can be reduced from the total site area. Therefore, the WQ_v from that area is reduced from the total WQ_v for the site.

Vegetated filter strips treat stormwater runoff and can reduce velocity². Vegetated filter strips remove pollutants by sedimentation, filtration, and infiltration. To function correctly, vegetated filter strips require shallow slopes and well drained soils that increase contact time and remove pollutants. Pollutant removal efficiencies are highly variable and primarily depend on the longitudinal slope, the length of the filter strip, and the amount of vegetation. These variables correspond to the contact time for filtration. The extent of infiltration also depends on the type of soil, the drainage capacity of the soil, as it relates to infiltration, the density of the grass, and the slope of the strip³.

3.7.2 APPLICABILITY

These BMPs can be used most effectively in areas with low density impervious cover or linear impervious cover or as pre- or post-treatment for other water quality BMPs. Vegetated filter strips are intended to treat sheet flow only. They are commonly used to receive runoff from roads and highways, roof downspouts, very small parking areas, walkways and driveways, as well as pervious surfaces^{1,3}. Filter strips can be easily integrated into the site design.

3.7.3 DESIGN CRITERIA

This section provides the design criteria for vegetative filter strips. The structural criteria provide information about the components and include references to the component design section of this manual (Section 4). The details and specifications for the components are provided in that section. The design/review spreadsheet in Appendix E outlines the design steps and calculations for the BMPs.

1) General criteria

- a. Maximum depth of sheet flow over the filter strip should not exceed 2-inches for the water quality event; 1-inch is preferred.
- b. Maintenance plans – The maintenance plan must contain a guarantee of maintenance and conform with requirements in Appendix D and the *Stormwater Facility Maintenance Agreement – Water Quality Devices*.

2) Site conditions

- a. Drainage Area – The length of the contributing drainage area in the direction of flow should not exceed 75-feet. A flow spreader device can be placed at the top of the filter strip for large flow lengths to promote sheet flow.
- b. Soils – Soils should have a minimum depth of 12-inches and must allow for dense vegetative coverage.
- c. Space Required – To achieve the desired level of treatment, the length of the filter strip in the direction of flow should be no less than 15-feet, and 25-feet is preferred. However, vegetated areas will provide some level of treatment at less than 15 feet. Therefore, if the available space does not allow for the length of the filter strip to be at least 15-feet, then including vegetated areas is still encouraged to help reduce sediment loads.
- d. Pedestrian traffic across filter strips shall be limited through channeling onto sidewalks.

3) Structural criteria

- a. Slope – The longitudinal (direction of flow) slope of a filter strip should be no less than 2% and no greater than 6%.
- b. Landscaping – An appropriate planting pallet should be selected to ensure vegetation is sustained over the course of wet and dry periods, capable of withstanding large rain events, and able to withstand relatively high velocity flows at the entrances in order to prevent erosion rills (*see Section 4.7*).

- c. Permeable berms – Installed for enhanced filter strips should have a maximum height of 12-inches with a 3:1 side slope. They should be level and constructed with a non-settling core to prevent erosion or channelized flow downstream of the berm resulting from high flow storm events.

3.7.4 MAINTENANCE CONSIDERATIONS DURING DESIGN AND CONSTRUCTION

Inspection and maintenance are critical to the performance of vegetated filter strips. The activities, schedule, and additional maintenance considerations and requirements are attached in Appendix D “BMP Inspection and Maintenance” of this manual. The following should be considered during design and construction of the BMP:

- Access - Limit pedestrian access across filter strips by directing pedestrians to sidewalks or other marked walkways.
- Maintenance should be considering during the design and layout. For example, pruning and mowing of vegetation and accessibility to features that will need to be maintained⁴.
- Consider installing vegetated filter strips 1 to 3-inches below adjacent impervious surfaces⁴.
- Include soil amendments to improve plant establishment and reduce need for irrigation⁴.

¹ Barrett, Michael E. Ph.D., P.E. Complying with the Edwards Aquifer Rules Technical Guidance on Best Management Practices. TCEQ RG-348. Revised July 2005 with Addendum Sheet (updated January 2017).

² King County. April 2016. Surface Water Design Manual

³ North Central Texas Council of Governments. September 2014. iSWM™ Technical Manual.

⁴ Urban Drainage and Flood Control District (UDFCD). (2010). Urban Storm Drainage Criteria Manual (USDCM): Volume 3 Stormwater Quality.

3.8 GRASS SWALE

3.8.1 DESCRIPTION OF BMP¹

Grass (vegetated) swales are gently sloped channels that are designed to receive and treat stormwater as it is conveyed to a standalone or primary BMP or after discharge from a BMP². These systems are not intended to be used as a stand-alone or primary BMP system for a development. However, if a grass swale BMP system is used within close proximity to small, low-density impervious areas, the WQ_v for this area can be treated. For these areas, the area that drains to the BMP can be reduced from the total site area. Therefore, the WQ_v from that area is reduced from the total WQ_v for the site.

These remove pollutants primarily by maintaining shallow flow through vegetation that encourages sedimentation or particle settling and infiltration². These processes can be enhanced by resistance of vegetation to flow². To a much lesser degree, pollutants may adhere or sorb to grass and thatch². Swales generally do not remove dissolved pollutants effectively, although some infiltration to underlying soils may occur depending on the nature of those soils¹.

The pollutant removal efficiency of swales is highly variable and primarily depends on the density of the vegetation, the width of the swale and depth of flow, the length of the vegetated swale, which corresponds to the contact time for filtration, as well as the drainage capacity of the soil as it relates to infiltration³. There are two types of grass swales: simple and enhanced. An enhanced version includes the use of berms, check dams, or dense or specialized vegetation to slow the flow and increase the residence time. This section discusses each in further detail.

3.8.2 APPLICABILITY

They can be used most effectively in areas with low density impervious cover or linear impervious cover, such as roadways or sidewalks, or as pre- or post-treatment for other water quality BMPs. Grass swales are intended to treat shallow concentrated flow. They are commonly used to receive and convey runoff from road and highways, roof downspouts, parking areas, walkways and driveways, as well as pervious surfaces^{1,3}.

To function correctly, grass swales require shallow slopes and well drained soils that increase contact time and remove pollutants. They can be easily integrated into the site design.

3.8.3 DESIGN CRITERIA

This section provides the design criteria for grass swales. The structural criteria provide information about the components and include references to the component design section of this manual (Section 4). The details and specifications for the components are provided in that section. The design/review spreadsheet in Appendix E outlines the design steps and calculations for the BMPs.

1) General criteria

- a. Maximum depth of sheet flow over the filter strip should not exceed 4-inches during the water quality event.
- b. Maintenance plans – Maintenance plan must include a guarantee of maintenance and conforms with the requirements in Appendix D and the *Stormwater Facility Maintenance Agreement – Water Quality Devices*.

2) Site conditions

- a. Drainage Area – Less than 5-acres. If the practices are used on larger drainage areas, the flows and volumes through the channel become too large to allow for filtering and infiltration of runoff.
- b. Soils – Generally unrestricted. Swales should not be used on soils with infiltration rates less than 0.27-inches per hour if infiltration of small runoff flows is intended.
- c. Space Required – Dependent on the contributing drainage area and anticipated flow.

3) Structural criteria

- a. Cross section design - The swale should have a trapezoidal or parabolic cross section with relatively flat side slopes (generally 3:1 or flatter).

- b. Channel bottom – The bottom of the channel should be between 2 and 6-feet wide. The minimum width ensures an adequate filtering surface for water quality treatment, and the maximum width prevents braiding, which is the formation of small channels within the swale bottom. The bottom width is a dependent variable in the calculation of velocity based on Manning’s Equation. If a larger channel is needed, the use of a compound cross section is recommended.
- c. Slope – Relatively flat slopes of less than 4%; channel slopes between 1% and 2% are recommended.
- d. Maximum Velocity - Target maximum velocity less than 1.0-foot per second.²
- e. Vegetation – An appropriate planting pallet should be selected to ensure vegetation is sustained over the course of wet and dry periods, as well as capable of withstanding large rain events, in order to prevent erosion rills (*see Section 4.7*). These areas should not receive any fertilizers, pesticides, or herbicides. Vegetation on the pond embankments should be mowed as appropriate to prevent the establishment of woody vegetation.
- f. Permeable berms – Should have maximum height of 12-inches with a 3:1 side slope. They should be level and constructed with a non-settling core to prevent erosion or channelized flow downstream of the berm as a result of high flow storm events.
- g. Riprap - Riprap-protected side slopes shall be no steeper than 2:1.²
- h. Check Dams – If check dams are installed, then the ponding depth behind check dams shall be designed to infiltrate or drain stormwater runoff within less than 48 hours.

3.8.4 MAINTENANCE CONSIDERATIONS DURING DESIGN AND CONSTRUCTION

Inspection and maintenance are critical to the performance of grass swales. The activities, schedule, and additional maintenance considerations and requirements are attached in Appendix D “BMP Inspection and Maintenance” of this manual. The following should be considered during design and construction of the BMP:

- Access - Limit pedestrian access across filter strips by directing pedestrians to sidewalks or other marked walkways.
- Maintenance should be considering during the design and layout. For example, mowing of vegetation and accessibility to features that will need to be maintained³.
- Include soil amendments to improve plant establishment and reduce need for irrigation³.

¹ King County. April 2016. Surface Water Design Manual

² North Central Texas Council of Governments. September 2014. iSWM™ Technical Manual.

³ Urban Drainage and Flood Control District (UDFCD). (2010). Urban Storm Drainage Criteria Manual (USDCM): Volume 3 Stormwater Quality.

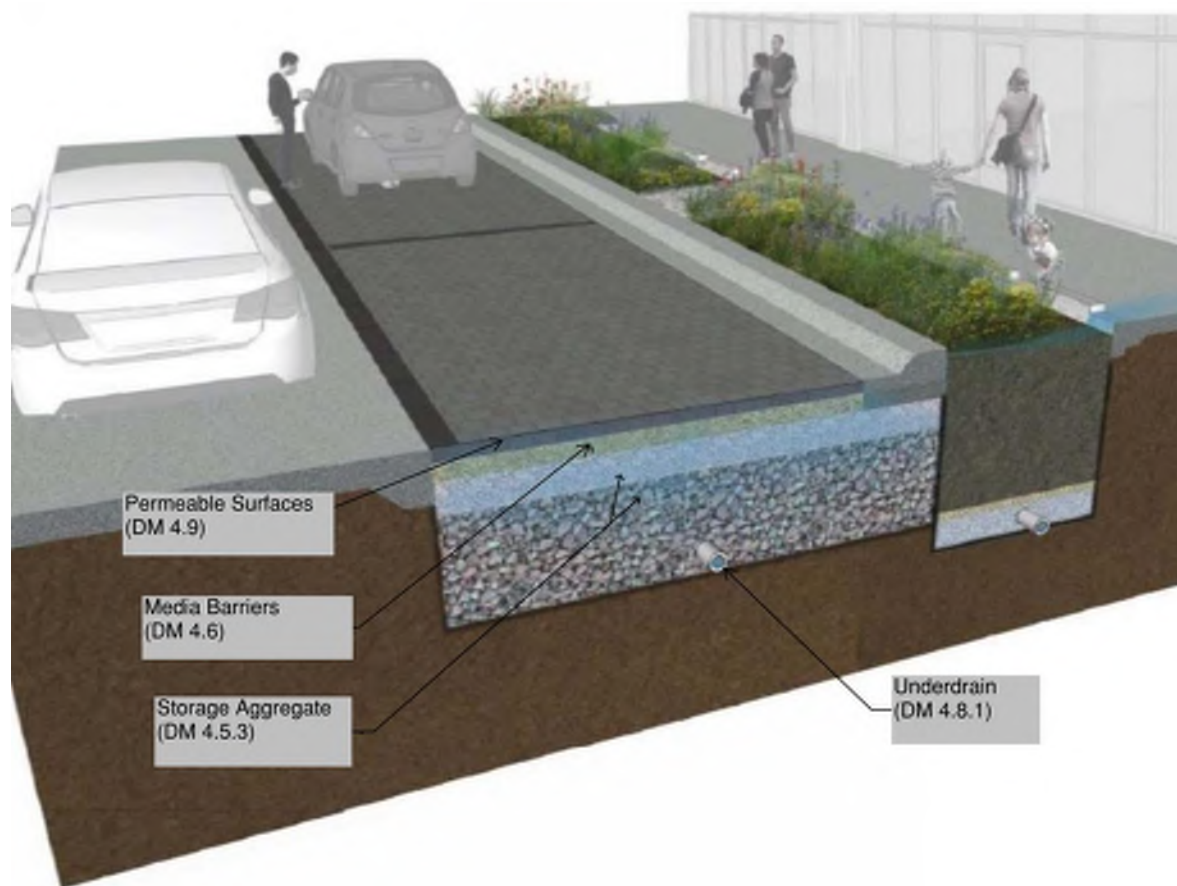
3.9 PERMEABLE SURFACES

3.9.1 DESCRIPTION OF BMP¹

Permeable surfaces include permeable pavers, porous concrete, porous asphalt, and grassed modular grid systems. Permeable surfaces require careful design, construction, and maintenance in order to provide good service life and proper drainage. Permeable surfaces have been used to replace or use in place of impervious surfaces and be used to temporarily store water in the storage aggregate layer. This manual focuses on the use of permeable pavers. Other surfaces can be submitted for review. Porous asphalt is not allowed for compliance with water quality requirements. There are many types of proprietary permeable pavement systems on the market today. When applicable, and unless modified by a civil engineer's signed/sealed design, the manufacturer's recommendations should be strictly followed.

Permeable pavers are not recommended in areas with high sediment loads due to the potential for clogging and may require frequent maintenance to remain effective². To prevent clogging, permeable pavers are recommended at a ratio of treatment drainage area to permeable paver surface area of 1.5 to 1. It is also recommended that impervious surfaces that drain to Permeable Surfaces are regularly swept by street sweepers. Figure 3.7 provides a conceptual rendering of a permeable paver system with an adjacent small bioretention basin.

Figure 3.7 Conceptual Rendering of Permeable Pavers



3.9.2 DESIGN CRITERIA

This section provides the design criteria for permeable pavers. The structural criteria provide information about the components and include references to the component design section of this manual (Section 4). The details and specifications for the components are provided in that section. The design/review spreadsheet in Appendix E outlines the design steps and calculations for the BMPs.

1) General conditions

- a. Specifications for permeable must contain technical information as detailed in Section 4.9.
- b. Maintenance plan for sand filters must include, at a minimum, trash removal, accumulated sediment removal, inspection for standing water, and inspection for 24-hour drawdown as specified in Appendix D

2) Site Conditions

- a. A minimum of 4-feet of clearance is recommended between the bottom of the gravel base course and underlying impermeable layers or the seasonally high groundwater table.
- b. Permeable pavers are recommended at a ratio of treatment drainage area to permeable paver surface area of 1.5 to 1.

3) Structural criteria

- a. Pretreatment – Vegetated filter strips are recommended to be installed for permeable surfaces that receive runoff from vegetated surfaces such as open fields or playgrounds.
- b. Slopes – Permeable paver systems should not be used on slopes greater than 5% with slopes of no greater than 2% recommended. For slopes greater than 1% barriers perpendicular to the direction of drainage should be installed in sub-grade material to keep runoff in the media from flowing downstream and surfacing at the toe, thus not providing the needed WQv under the pavement.
- c. Signage – A warning sign should be placed at the facility that states, “Permeable pavers used on this site to reduce pollution. Do not resurface with non-porous material or sand during icy weather.”

3.9.3 MAINTENANCE CONSIDERATIONS DURING DESIGN AND CONSTRUCTION

Inspection and maintenance are critical to the performance of permeable pavers. The activities, schedule, and additional maintenance considerations and requirements are attached in Appendix D “BMP Inspection and Maintenance” of this manual. The following should be considered during design and construction of the BMP:

- Maintenance should be considering during the design and layout.
- Consider installation of an observation well to monitor drain time of the pavement over time.

- The BMP must be protected until the construction activities are completed. Temporary BMPs should be in place as detailed in the Sediment and Erosion Plan to protect permeable pavers and receiving waters during construction activities (this will not be covered in this manual). Sediment discharged during construction can clog the system and would require additional maintenance. A pre-construction meeting should be held to ensure the contractor is aware that the permeable pavers should be protected from sediment load. A construction fence can also be used during construction to prevent compaction

¹ King County. April 2016. Surface Water Design Manual

² Urban Drainage and Flood Control District (UDFCD). (2010). Urban Storm Drainage Criteria Manual (USDCM): Volume 3 Stormwater Quality.

ADDITIONAL RESOURCES

- ¹ City of Fort Worth. December 20, 2012. Standard Construction Specification Documents.
- ² NCTCOG. September 2014. "iSWM™ Technical Manual: Water Quality: 1.0 Water Quality Protection Volume and Peak Flow", North Central Texas Council of Governments, Arlington, Texas, April 2010, Revised September 2014,
http://iswm.nctcog.org/Documents/technical_manual/Water%20Quality_9-2014.pdf
- ³ Placer County, et. al. West Placer Storm Water Quality Design Manual. April 2016.
- ⁴ Texas Commission on Environmental Quality. November 2015. Rules and Regulations for Public Water Systems.
- ⁵ UWRI. October 5, 2015. Comparison of Water Quality Capture Volume Needs for Ft. Worth, TX Region to Capture of 85th Percentile Runoff Volume and Runoff Events, Urban Watershed Research Institute.

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TRWD WATER QUALITY MANUAL

PLANNING AND IMPLEMENTING STORMWATER QUALITY PRACTICES

SECTION 4

Permanent BMP Design Components

Design components are defined to be the fundamental elements required for a Best Management Practice (BMP) to function. The design components are essentially the building blocks of the BMP that not only facilitate stormwater entering, moving, and discharging from the practice but also consider integration of the BMP within its surroundings to optimize its performance and long-term function. This section provides both designers and TRWD reviewers a standard set of requirements for each BMP component necessary for the design and construction of the BMP practice as a whole. **Figure 4.1** displays an example of how design components are integrated to create a bioretention BMP.

Figure 4.1 Example of Design Components in Bioretention BMP



BMP design components include stormwater inlets, pre-treatment and post-treatment, energy dissipation, area protection, BMP media, media barriers, landscaping, outlets/piping, and/or permeable surfaces. For certain design components, a developer manual-detail component (DM-DC) is shown to give a typical design detail. Because every BMP design and installation is site-specific, not all components will be applicable for every site. Each BMP practice requires a different menu of design components dependent on its

intended function. The BMP types and their minimum applicable design components are outlined in **Table 4.1**. Minimum applicable design components, marked with “X” in **Table 4.1** are the components a designer is required to evaluate for each BMP site to promote proper long-term function. The designer should evaluate the components, determine if they are applicable and necessary for their BMP site, and provide the required design submittal material for each. If a minimum applicable component is determined unnecessary, the designer must submit justification as to why the component is omitted from the design using the Design Review Checklist provided in **Appendix A** (to be submitted to TRWD). Additional components not identified as the minimum

applicable design component for a BMP may be used for improved site-specific aesthetics or function.

Table 4.1 Minimum Applicable Design Components by BMP Practice

BMP	DESIGN COMPONENT								
	<i>Stormwater Inlet</i>	<i>Pre-treatment/ Post-treatment¹</i>	<i>Energy Dissipation</i>	<i>Area Protection</i>	<i>BMP Media</i>	<i>Media Barriers</i>	<i>Land-scaping</i>	<i>Outlets /Piping</i>	<i>Permeable Surfaces</i>
Permeable Surfaces	-	✓	-	✓	✓	✓	-	✓	✓
Bioretention Basins	✓	✓	✓	✓	✓	✓	✓	✓	-
Constructed Wetlands	✓	✓	✓	✓	-	-	✓	✓	-
Sand Filters	✓	✓	✓	✓	✓	✓	✓	✓	-
Wet Basins	✓	✓	✓	✓	-	-	✓	✓	-
Extended Detention Basin	✓	✓	✓	✓	-	-	✓	✓	-
Retention/ Irrigation Basin	✓	✓	✓	✓	-	-	-	✓	-
Vegetative Filter Strip / Grass Swale	✓	✓	✓	✓	✓	✓	✓	✓	-

¹Pre-treatment is required for drainage areas greater than 2-acres and recommend for drainage areas less than 2-acres.

Each design component is described in more detail in the following subsections. Each subsection includes discussion on the following:

- **DESCRIPTION** – Summary of the primary function of the design component within the BMP practice
- **WHERE TO USE** – Description of where the design component should be used within the BMP practice and when it is or is not appropriate
- **DESIGN CONSIDERATIONS** – Minimum specifications required for application of the design component to function as intended
- **DESIGN SUBMITTAL REQUIREMENTS CHECKLIST** – Description of plan submittal requirements for each design component TRWD review and approval of the BMP practice
- **DETAILS** – Defined design components and typical DM-DC for consideration when developing design drawings

- **ADDITIONAL RESOURCES** – Where additional information can be found, including background on requirements and standards used for development of the design component detail and write-up

Design components of BMPs to be described in this manual include the following:

- **SECTION 4.1 – INLETS:** Inlets include design components that collect and allow stormwater to enter a BMP.
- **SECTION 4.2 – PRE -TREATMENT AND POST-TREATMENT:** Pre-treatment design components reduce or prevent sediment, trash, and/or oil from either entering a BMP and post-treatment design components reduce or prevent sediment and trash in stormwater from exiting the BMP.
- **SECTION 4.3– ENERGY DISSIPATION:** Energy dissipation includes design components that dissipate the energy of stormwater entering a BMP to prevent and reduce potential erosion from incoming stormwater.
- **SECTION 4.4 – AREA PROTECTION:** Area protection includes design components that provide some level of protection between a BMP and the pedestrian environment.
- **SECTION 4.5 – BMP MEDIA:** BMP media includes the media layers within a BMP that filter, store, and infiltrate stormwater underground to help achieve the required water quality volume. Media layers may not be applicable to all BMPs.
- **SECTION 4.6 – MEDIA BARRIERS:** Media barriers include permeable or impermeable barriers within the BMP that allow for the control or prevention of soil, aggregate, and/or stormwater migration through the BMP.
- **SECTION 4.7 – LANDSCAPING:** Landscaping includes planting and landscape materials for the application of BMPs.
- **SECTION 4.8 – OUTLETS/PIPING:** Outlets/piping include design components that convey stormwater, protect piping, allow access to piping, allow monitoring of a BMP, and/or provide a safe release of stormwater from a BMP.
- **SECTION 4.9 – PERMEABLE SURFACES:** Permeable surfaces include design components that allow stormwater to infiltrate through the surface of a permeable pavement system into the BMP media layer.

4.1 STORMWATER INLETS

DESCRIPTION

Inlets facilitate directing of stormwater runoff into the BMP. Inlets that collect stormwater runoff at a single concentrated point include curb cuts, depressed curbs, trench drains, gutter apron, manufactured at-grade inlets, flow splitters, and distribution piping. Guidance on inlet types not discussed in this section can be found in City of Fort Worth Stormwater Criteria Manual¹.

WHERE TO USE

An inlet should be used in applications where it is necessary to collect and/or convey stormwater into a BMP system. Curb cuts, depressed curbs, trench drains, manufactured at-grade inlets, and gutter aprons should be used in locations where it is necessary to collect stormwater from the street or sidewalk and convey it to the surface of a BMP facility. Manufactured at-grade inlets may also be used in locations where there are higher sediment loads, such as streets or parking lots, to remove sediments prior to the stormwater runoff entering the BMP. Trench drains may also serve as an inlet to collect or intercept stormwater across a path of travel such as a sidewalk or parking lot. Flow splitters should be used in locations upstream of the BMP. Distribution piping should be used when stormwater runoff cannot be discharged to the surface of the BMP due to site grading or stormwater collection system constraints.

DESIGN CONSIDERATIONS

- Inlets shall be sized to collect the water quality volume or design control volume. BMP flow splitters should be analyzed in conjunction with the existing storm system to verify adequate bypass for larger storm events is provided.
- Inlets collecting concentrated flow may require energy dissipation (Section 4.3) to mitigate erosion of the BMP at the stormwater entrance.
- Pretreatment components (Section 4.2) should also be considered to remove coarse materials that could result in erosion or clogging of the BMP system.
- A metal wheel guard across the top of the inlet should be considered for curb cuts and depressed curbs within the street cross section to protect the curb and prevent unintentional movement of the vehicle into the BMP.
- It is recommended that bypass around the BMP is provided for stormwater exceeding either the water quality volume or the 10-year storm events to mitigate scouring of the BMP. This will depend on the size and type of the BMP.

DETAILS

4.1.1 CURB CUT/DEPRESSED CURB

A curb cut or depressed curb allows stormwater runoff from the pavement or sidewalk to enter a BMP system located directly behind the back edge of the curb cut. A curb cut is a notch cut in standard roadway curb. A depressed curb is a new curb that is poured with one or more sides tapered down to an at-grade opening. See detail DM-DC 4.1.1 for additional information.



Photo Credit: San Francisco Public Utilities Commission²

4.1.2 TRENCH DRAIN

A trench drain is a shallow concrete trench with a grate or solid cover over the top of the trench that allows collection and conveyance of stormwater runoff across a paved surface including sidewalks or vehicular pavement. A trench drain can convey water at or just below the surface. See detail DM-DC 4.1.2 for additional information.



Photo Credit: CDM Smith, designed by others

4.1.3 GUTTER APRON



Photo Credit: National Association of City Transportation Officials³

A gutter apron is a depressed section of gutter with increased cross and longitudinal slope placed in front of a BMP inlet to increase stormwater capture. See detail DM-DC 4.1.3 for additional information.

4.1.4 MANUFACTURED AT-GRADE INLET

A manufactured at-grade inlet is a proprietary type of stormwater inlet that collects from the curb line of pavement and may include a built-in pre-treatment function allowing for the removal of debris, such as sediment, leaves, and sand, prior to stormwater entering the BMP. Pre-treatment prevents debris from clogging the BMP and improves long-term performance. Rain Guardian™ is an example of a manufactured at-grade inlet which provides debris and sediment management for stormwater entering a BMP.



4.1.5 FLOW SPLITTER

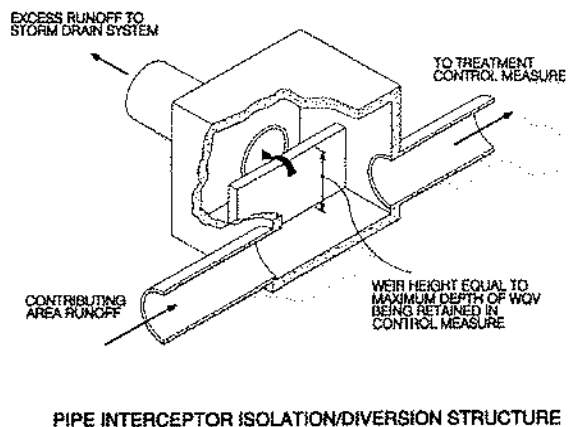


Photo Credit: iSWM Guidance Manual⁵

A flow splitter, also known as flow regulator, is a component that is designed to convey only the water quality volume into the BMP and to allow flow in excess of that volume to be bypassed or diverted. It may also be used to regulate peak flow rates into the BMP to minimize potential erosion. A flow splitter or flow regulator is used in off-line facilities where the entire storm event is not routed through the BMP. This differentiates the BMP from the on-line version which receives but does not necessarily treat the entire storm event. A low flow orifice, weir, baffle structure, or other device can be used to regulate the flow to the BMP.

4.1.6 DISTRIBUTION PIPE

A distribution pipe conveys stormwater to the storage aggregate layer of the BMP and distributes flow through perforations in the pipe. Distribution piping must meet the following parameters, see detail DM-DC 4.1.4 for additional design information:

- Distribution pipes shall be a minimum of 6-inches in diameter.
- Acceptable pipe materials and fittings including PVC pipe shall be in accordance with City of Fort Worth STD Specification 33 46 00.
- Bedding and granular backfill shall consist of crushed rock per Section 4.5.3.
- Distribution pipes shall consist of solid piping when passing through areas where stormwater needs to be conveyed without exfiltration from the pipe such as from the extents of the BMP system to the existing drainage system or outfall point.



Photo Credit: CDM Smith

DESIGN SUBMITTAL REQUIREMENTS CHECKLIST

Design submittal requirements checklist may be applicable to all or some of the inlet components:

- Plan and detail view of inlet including northing/easting locations, invert and RIM elevations, opening size, and base materials with specified depths, as applicable. Specify longitudinal slopes, cross slopes, and transition to adjacent grade.
- Calculation summary sheet for allowable concentrated flows and capacities for an inlet.
- Specify manufacturer information including product number, materials, painting specifications, and fastener and frame details, as applicable.

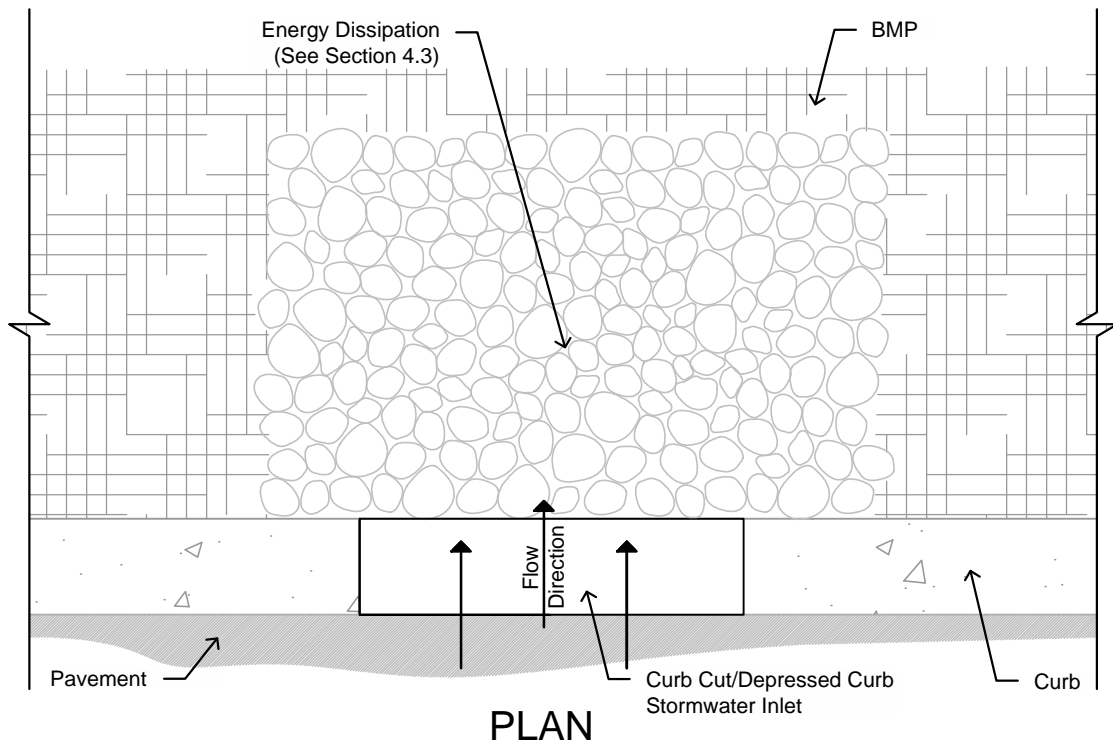
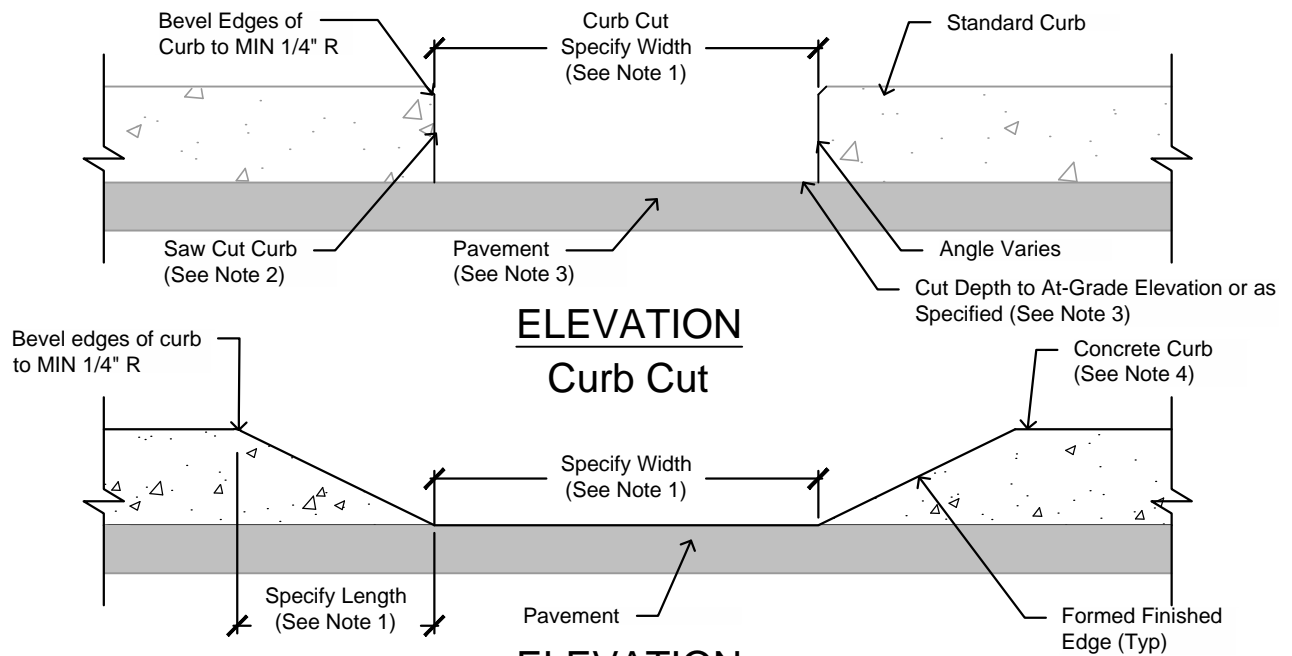
Inlet designs and specifications outside the parameters of this guideline shall be submitted to a licensed PE for review and approval.

ADDITIONAL RESOURCES

- ¹ City of Fort Worth. September 29, 2015. City of Fort Worth Stormwater Criteria Manual.
- ² Curb cut. San Francisco Public Utilities Commission. Accessed January 2018.
- ³ Gutter aprons. National Association of City Transportation Officials. Accessed January 2018.
<https://nacto.org/publication/urban-street-design-guide/>
- ⁴ American Society of State Highway and Transportation Officials. AASHTO HS-20 Loading.
- ⁵ City of Fort Worth. August 31, 2012. Standard Construction Drawings. *Detail D534 – Standard Curb & Gutter*.
- ⁶ City of Fort Worth. May 22, 2015. Standard Construction Drawings. *Detail D405 – Standard Storm Drain Inlet*.
- ⁷ Rain Guardian. Accessed: April 26, 2017. Web address: <http://www.rainguardian.biz/>.
- ⁸ iSWM Technical Manual. April 2010, revised September 2014. Site Development Controls.

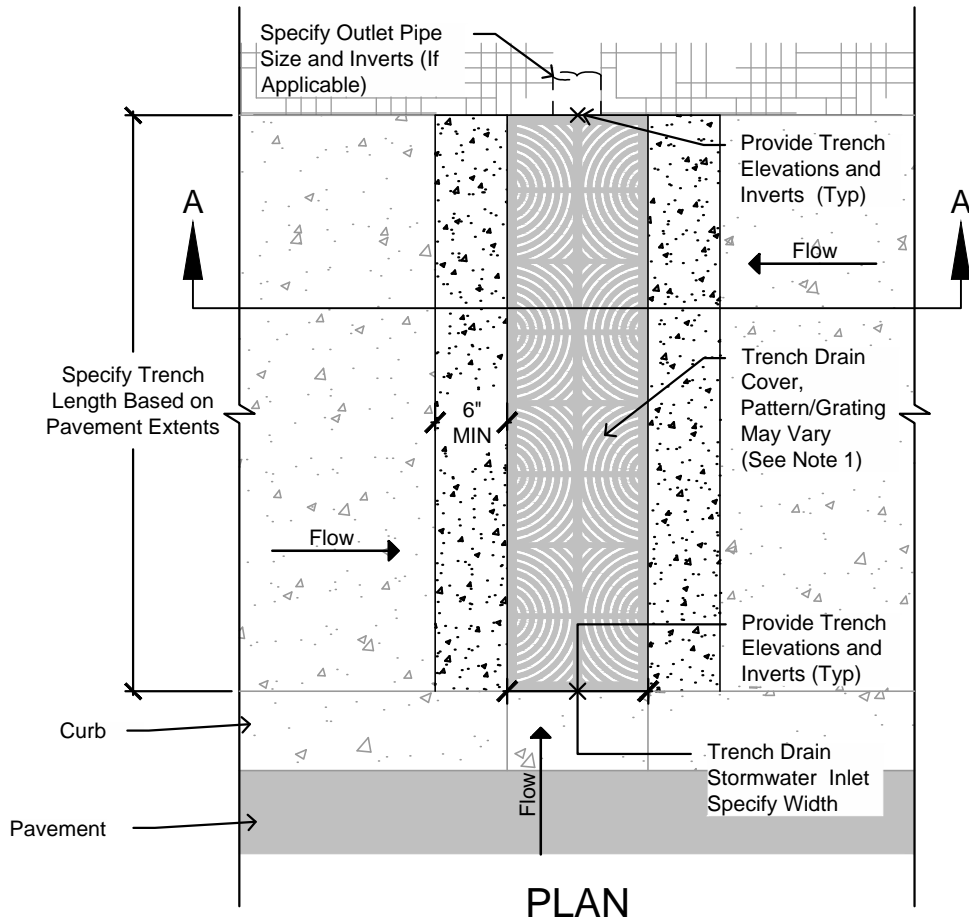
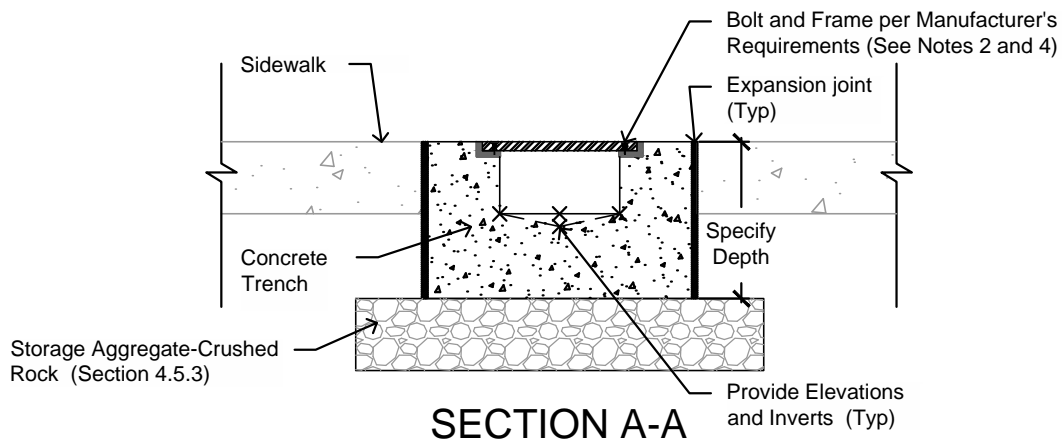
DM-DC DRAWING RESOURCES

- City of Fort Worth. December 20, 2012. Standard Construction Specification Documents. Section 02 41 15 Utility Removal/Abandonment.
- City of Fort Worth. December 20, 2012. Standard Construction Specification Documents. Section 32 13 13 Concrete Paving.
- City of Fort Worth. December 12, 2016. Standard Construction Specification Documents. Section 33 05 10 Utility Trench Excavation, Embedment and Backfill.
- City of Fort Worth. July 1, 2011. Standard Construction Specification Documents. Section 33 46 02 Trench Drains.
- Texas Department of Licensing and Regulation. March 15, 2012. 2012 Texas Accessibility Standards.



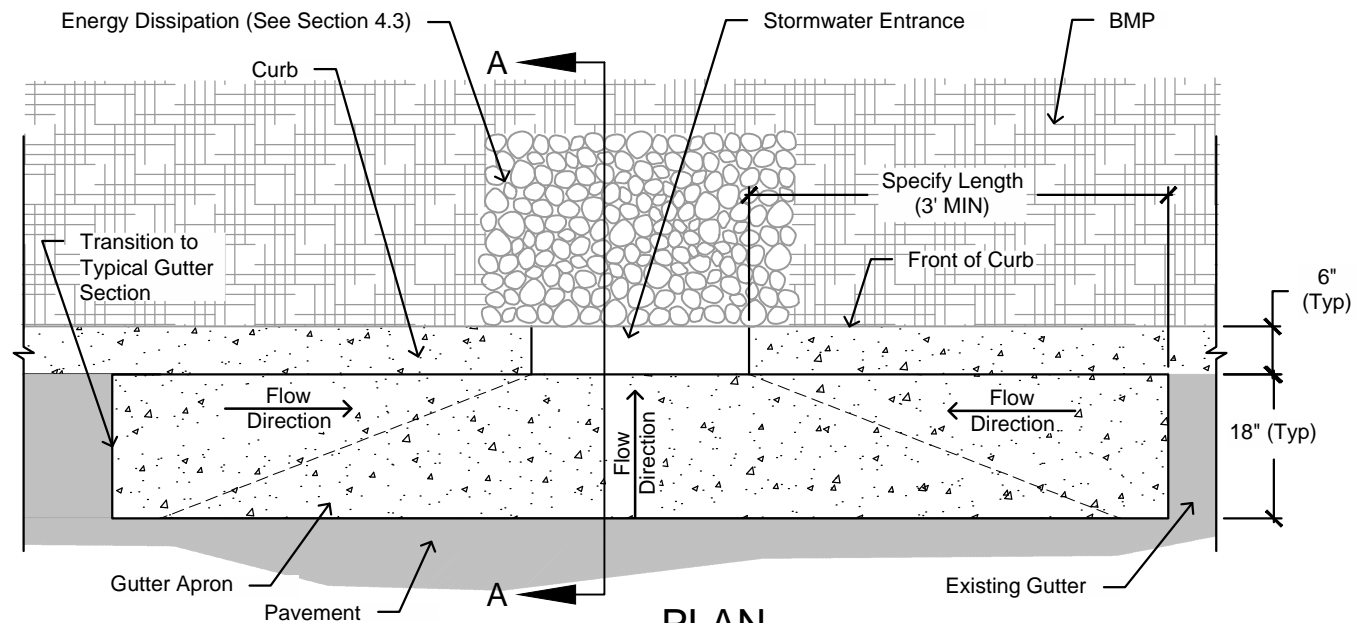
Notes

1. A curb cut is a cut in an existing curb, and a depressed curb is a curb poured in-place with a tapered opening. Width and angle of curb cut or taper varies based on site and stormwater capture requirements. If existing curb is damaged beyond extents specified for cut, curb shall be replaced to the nearest joint.
2. Curb cuts must be saw-cut such that all edges are square and edges beveled to a min $\frac{1}{4}$ " radius. Saw-cut per City of Fort Worth STD Specification 02 41 15.
3. Horizontal surface must have positive slope toward BMP installation.
4. Concrete curb materials shall conform to City of Fort Worth STD Specification 32 13 13. All exposed surfaces shall have a broom finish.
5. Depressed curb shall transition to typical curb section per City of Fort Worth STD DWG D534.

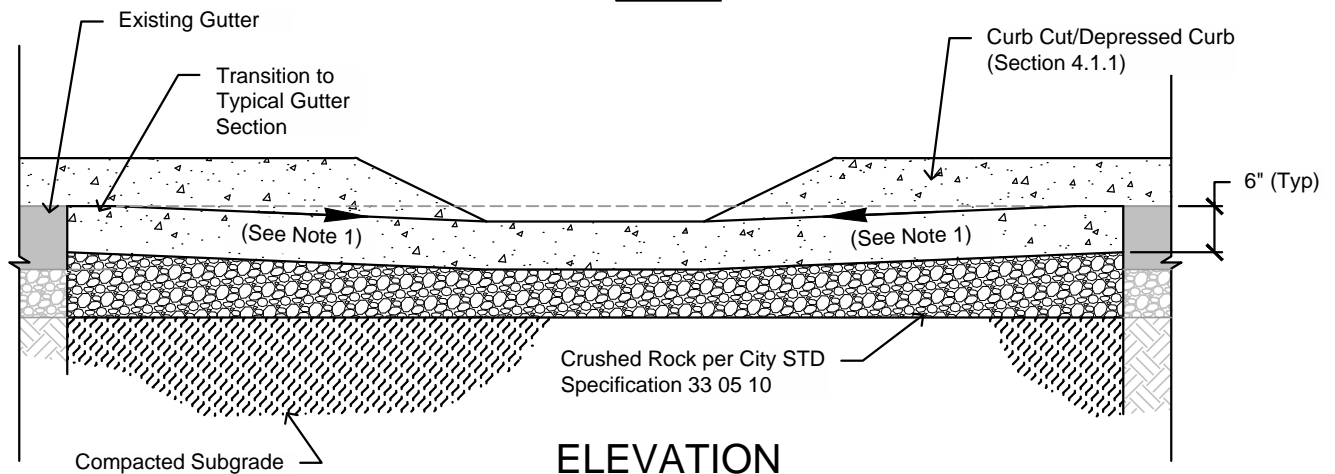


Notes

1. Grated located in walking surface shall have openings no greater than 1/2" in one direction, and elongated openings shall be placed so that the long dimension is perpendicular to the dominant direction of travel per Texas Accessibility Standards.
2. If trench drain assembly includes metal frame and channel, install per manufacturer instructions.
3. Cross slope and longitudinal slope of trench channel bottom may vary by design.
4. Bolt down grate and frame is required. All bolts shall be flush with existing grade of the paved surface.
5. Trench drain materials, installation, and other considerations shall comply with City of Fort Worth STD Specification 33 46 02 including compliance with AASHTO HS-20 loading.



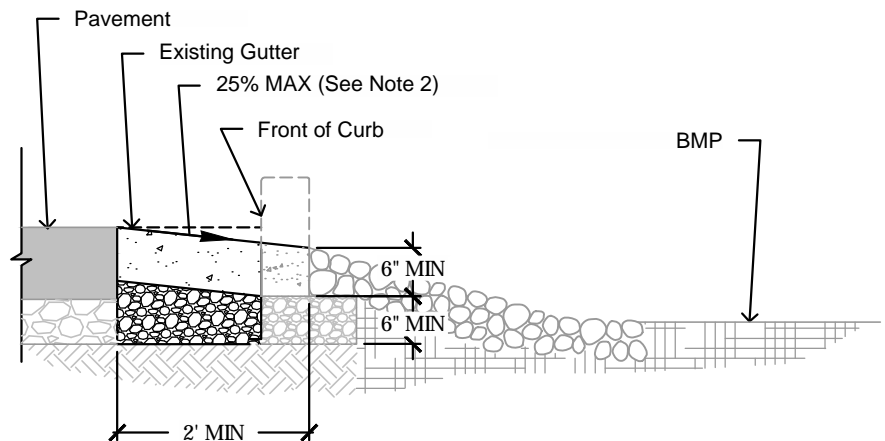
PLAN



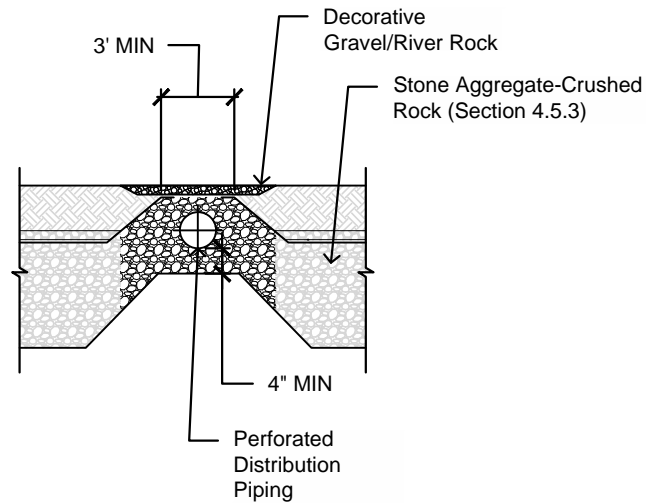
ELEVATION

Notes

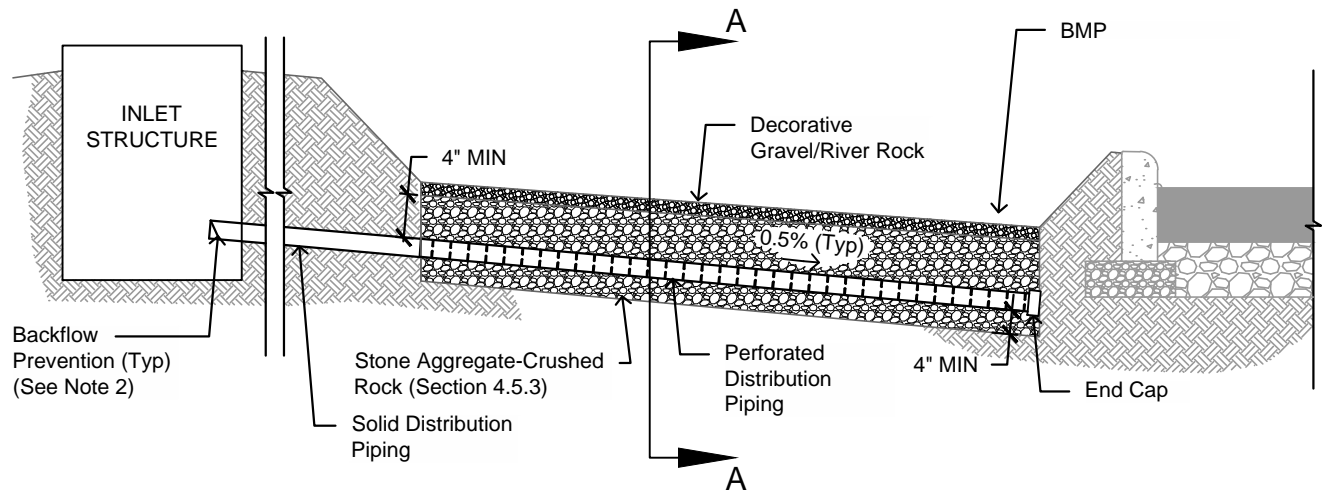
1. Max Slope of apron parallel to the curb is 16.67% per City of Fort Worth STD DWG D405.
2. Max Slope of gutter apron cross slope is 25% per City of Fort Worth STD DWG D405. Slopes will be governed by stormwater capture requirements and entrance velocities.
3. Concrete shall conform to City of Fort Worth STD Specification 32 13 13.



SECTION A-A



SECTION A-A



PROFILE

Notes

1. Acceptable pipe materials shall be in accordance with City of Fort Worth STD Specification 33 46 00.
2. Distribution piping shall include a backflow prevention device such as a check valve, a flap gate, or other appropriate measure to prevent the flow of ponded water back into the inlet structure.

4.2 PRE-TREATMENT/POST-TREATMENT

DESCRIPTION

Pre-treatment/post-treatment is a component of the BMP practice which provides additional treatment of stormwater. Pre-treatment of stormwater is intended to enhance the long-term performance of BMPs and reduce routine maintenance events for BMPs by removing floatable matter (i.e., trash, leaves, debris, etc.), settling particles, capturing hydrocarbons, and providing for bacteria load reduction. Post-treatment of stormwater may reduce discharge velocities of stormwater and encourage additional settling and infiltration. Pre-treatment components include vegetated filter strip, floatable separators, grass swale, hydrodynamic separator, and gravity (oil-grit) separator. Post-treatment components include a grass swale or micropool. A grass swale may be used for either pre-treatment or post-treatment depending on stormwater being conveyed to or away from a BMP. This manual does not discuss nonstructural pre-treatment practices, such as litter and animal waste control that would reduce and/or prevent the stormwater runoff from collecting these pollutants.

WHERE TO USE

Both pre-treatment and post-treatment components are located in urbanized areas to assist with stormwater quality control. Pre-treatment components are typically placed at or upstream of a BMP inlet and can be located beneath the ground surface to maximize land use. Pre-treatment components are important to BMPs that function as infiltration and filtration BMPs because pre-treatment removes floatable material, sediment, and oil products that may otherwise clog a BMP. As discussed Section 2, runoff from rooftops and parking lots will require pre-treatment prior to conveyance to approved BMPs. Post-treatment components are typically placed at the outlet of a BMP for stormwater treatment prior to the stormwater being conveyed to a receiving water body. Post-treatment components may be applied to any type of BMP.

DESIGN CONSIDERATIONS

- Floatable separators, hydrodynamic separators, and gravity (oil grit) separators may be placed below ground to maximize land use.
- Underdrains (Section 4.9.1) shall be installed for vegetated filter strips, sediment forebays, and grass swales as necessary to prevent ponding water for prolonged periods of time. Underdrains shall be shown on the project's design drawings.
- Consider placement of pre-treatment and post-treatment components in locations where maintenance can be easily conducted.

DETAILS

4.2.1 VEGETATED FILTER STRIP

A vegetated filter strip is a narrow section of grass that is typically placed along impervious areas such as parking lots and streets to capture stormwater for velocity dissipation and initial filtration of sediment prior to stormwater entering a BMP. Vegetated filter strips may be placed along streets between the back of the curb and the BMP or may be placed along a street with no curb to capture stormwater from streets or parking lots. A vegetated filter strip treats stormwater effectively for small impervious areas that maintain sheet flows in order to remove sediment across the reach of the vegetated filter strip. By removing sediment prior to a BMP, the BMP may perform more efficiently and effectively between maintenance periods. See detail DM-DC 4.2.1 for additional design information for vegetated filter strips. For design and maintenance criteria, see Section 3.7.



4.2.2 SEDIMENT FOREBAY

A sediment forebay is typically used for pre-treatment and consists of an isolated basin that allows stormwater runoff to settle sediments. By removing sediment prior to stormwater entering a BMP, the BMP may perform more efficiently and effectively between maintenance periods. To ensure maintenance will be easily performed, place sediment forebay in easily accessible locations.

- Sizing requirements for specific BMP sediment forebays are discussed accordingly in Section 3.
- Hardscape materials, such as riprap, concrete, articulating concrete block mat products such as Flexamat® or approved comparable product are acceptable. The product chosen should be reviewed by a licensed PE.



The product shall line the bottom of the basin to allow for easier removal of sediment and to protect against scour and erosion.

4.2.3 FLOATABLE SEPARATORS

A floatable separator is typically a proprietary technology that consists of screens to separate out coarse trash and debris from incoming stormwater prior to stormwater entering the BMP. Floatable separators remove the majority of trash and debris within the inlet chamber, which limits the amount of floatable material entering a downstream BMP. This may improve the function of the BMP by preventing buildup of trash and clogging from debris in downstream BMPs.

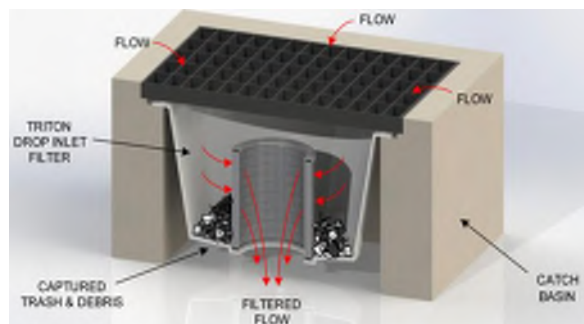


Photo credit: REM Triton Filters Website²

4.2.4 HYDRODYNAMIC SEPARATOR

A hydrodynamic separator is usually a proprietary technology that is installed underground as a flow through structure which uses the energy of the flowing water to physically remove suspended sediments, floatables, and oils from stormwater prior to stormwater entering a BMP. Hydrodynamic separators are typically placed underground in order to maximize useable land space above ground and may be designed to handle multiple stormwater inlets. A typical hydrodynamic separator uses cyclonic separation and/or indirect filtration in order to settle sediments and separate floatables and oils from stormwater runoff.



Photo credit: Humes Website³

4.2.5 GRAVITY (OIL GRIT) SEPARATOR

A gravity (oil grit) separator is typically a proprietary technology that removes sediments, floatables, and oils from stormwater through gravitational settling and trapping prior to stormwater entering a BMP. A gravity separator typically consists of multiple separation/storage chambers to allow for suspended solids to settle, floatables to be trapped, and oil and grease to be stored in a secondary chamber until removal during maintenance. Since re-suspension of settled sediments is possible during peak flows, gravity separators are typically installed off-line to limit excess flows from entering the device.

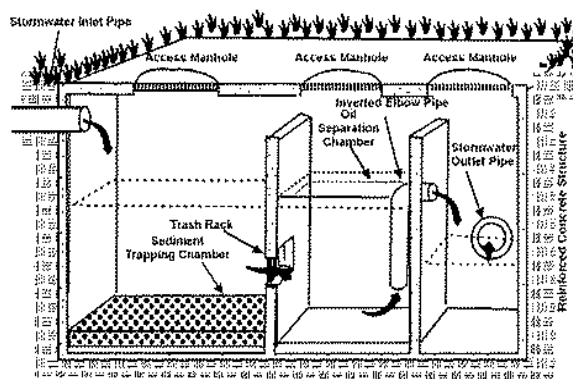


Photo credit: Georgia Stormwater Management Manual⁴

4.2.6 GRASS SWALE

Grass swales are shallow, vegetated open channels that are graded to reduce the velocity of stormwater conveyance to allow treatment through filtration and potentially infiltration while stormwater is conveyed to or away from a BMP. Check dams maybe utilized to slow the flow of stormwater and encourage temporary ponding which will promote capture of sediments. A grass swale may be used as a pre-treatment or post-treatment component to a BMP. Stormwater conveyed from a grass swale to a BMP is considered as pre-treatment, and stormwater discharging from a BMP into a grass swale is considered post-treatment. For design and maintenance criteria, see Section 3.7.



Photo credit: Chesapeake Stormwater Network⁵

4.2.7 MICROPPOOL

Micropools are smaller permanent pools typically placed at the outlet of a BMP to control re-suspension of solids and floatable materials. A micropool is typically used as a post-treatment component to an extended detention basin in order to provide additional treatment prior to the stormwater being discharged.



Photo credit: Urban Drainage and Flood Control⁶

DESIGN SUBMITTAL REQUIREMENTS CHECKLIST

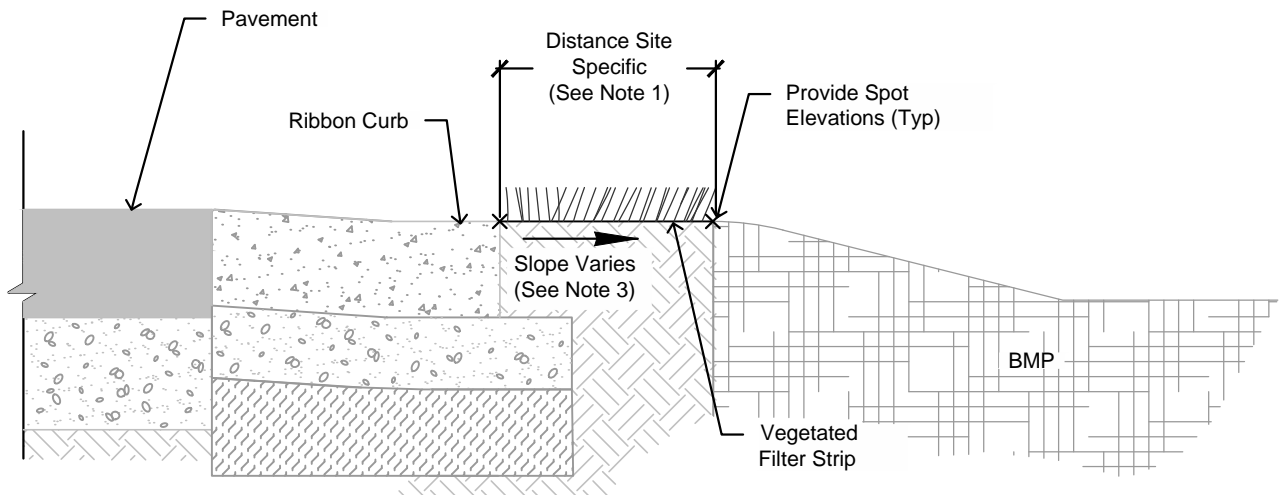
Design submittal requirements checklist may be applicable to all or some of the pre-treatment/post-treatment components:

- Plan and detail views of pre-treatment/post-treatment components including inlet and outlet invert elevations, pipe diameters, manhole or inlet RIM elevation, and dimensions of components, as applicable.
- Calculation summary sheet for average and/or peak flows through and/or exiting the pre-treatment/post-treatment components.
- Pre-treatment/post-treatment capacity calculation summary sheet including storage volume of floatables, sediment, and oil, as applicable.
- Specify pollutant removal efficiencies.

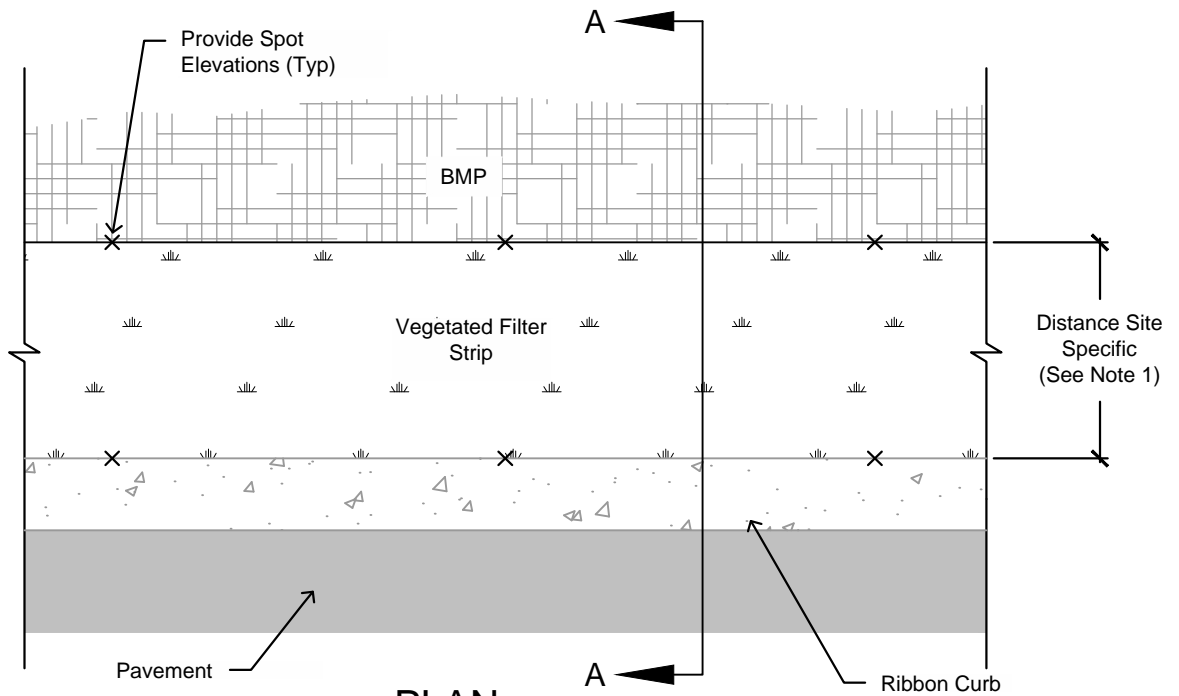
- Specify relevant manufacturer information including product number, materials, painting specifications, and fastener and frame details, and installation requirements as applicable.
- Pre-treatment/post-treatment component designs and specifications outside the parameters of this guideline shall be reviewed and approved by a licensed PE and submitted to TRWD.

ADDITIONAL RESOURCES

- ¹ Cleanwater Nashville: Overflow Abatement Program. Green Infrastructure. Accessed: March 23, 2018. Web address: http://www.cleanwaternashville.org/_about-green-infrastructure
- ² REM Filters. Accessed: August 14, 2017. Web address: <http://remfilters.com/drop-inlet-filters/>
- ³ Humes. Stormwater Solutions. Accessed: August 11, 2017. Web address: <http://www.humes.com.au/precast-concrete-solutions/stormwater-solutions/stormwater-treatment/secondary.html>
- ⁴ Werntz, G. Georgia Stormwater management Manual Post Construction Water Quality BMP Overview. Accessed: August 14, 2017. Web address: <https://www.slideshare.net/gwerntz24/post-construction-water-quality-bmps>
- ⁵ Chesapeake Stormwater Network. Accessed: August 15, 2017. Web address: <http://chesapeakestormwater.net/events/webcast-advanced-stormwater-design-grass-swales-and-channels/>
- ⁶ Extended Detention Basin at Grant Ranch. Urban Drainage and Flood Control District. Accessed January 29, 2018. Web address: <http://udfcd.org/extended-detention-basin/>
- ⁷ iSWM Technical Manual. April 2010, revised September 2014. Site Development Controls.



SECTION A-A



PLAN

Notes

1. For optimal filtration performance, a vegetated filter strip shall have a minimum length of 15-feet in the direction of the flow unless site constraints prevent meeting this requirement.
2. The longitudinal (direction of flow) slope of a filter strip should be no less than 2% and no greater than 6%. The transverse slope should be no more than 2% and preferably 1%.
3. Filter strip shall be parallel to the adjacent pavement grade.

4.3 ENERGY DISSIPATION

DESCRIPTION

Energy dissipation is a component to reduce the velocity of stormwater entering a BMP to minimize erosion and potential damage caused by the incoming stormwater. Energy dissipation typically consists of either a splash pad or a sump condition at the entrance of a BMP to slow the flow of the stormwater entering the facility. Splash pads are comprised of aggregate material that may be loose or embedded in concrete for greater stability and ease of maintenance.



Photo credit: NRCS – Illinois¹

WHERE TO USE

Energy dissipation shall be included when concentrated stormwater flows are entering a BMP and may cause erosion of BMP media. Energy dissipation may also be used around the perimeter of BMPs accepting sheet flow, acting as a level spreader to trap sediment and better distribute stormwater inflow. This is applicable in BMPs with surface layers containing sand, soil, mulch, vegetation, or other materials with the potential for erosion.

DESIGN CONSIDERATIONS

- **Table 4.2** shows the allowable channel velocities for surface materials per iSWM Technical Manual². If the entrance velocity of the stormwater exceeds the permissible velocity, energy dissipation is required to prevent erosion.

Table 4.2 Maximum Permissible Entrance Velocities for Typical BMP Surface Materials

<i>Typical BMP Surface Material</i>	<i>Maximum Permissible Channel Velocity (ft/s)</i>
<i>Bermuda Grass – Clay</i>	6
<i>Bermuda Grass – Sandy and Silty Soils</i>	5
<i>Sandy Soils</i>	2.5
<i>Silts</i>	1.5
<i>Sandy Silts</i>	3.0
<i>Clays</i>	5.0
<i>Coarse Gravels</i>	6.0
<i>Shale</i>	10.0
<i>Rock</i>	15.0

- Include concrete energy dissipation devices in situations where the entrance velocity exceeds 6.0 ft/s.

- Widths and lengths of energy dissipation will vary based on type and size of inlet used and velocity of stormwater entering the BMP. Designer shall provide entrance velocity calculations based on the inlet condition.
- Decorative gravel, river rock, or cobble should be considered when using hardscape materials to provide a more aesthetically pleasing energy dissipation component.
- Accessibility and ease of maintenance energy dissipaters must be considered during design to prevent coarse sediment and other debris from clogging inlets to the BMP.
- The size and weight of individual components shall be sufficient to resist movement due to water entrance velocities.

DETAILS

4.3.1 SPLASH PAD

A splash pad consists of hardscape material, such as aggregate or brick, which may be embedded in concrete for increased stability and ease of maintenance. See detail DM-DC 4.3.1 for additional design information for concrete embedded splash pads.



4.3.2 SUMP

Sumps are shallow depressions placed directly behind the inlet opening that dissipate energy by allowing stormwater to pond and slowly drain into the BMP through openings in the sump structure. See detail DM-DC 4.3.2 for additional design information for sumps.



DESIGN SUBMITTAL REQUIREMENTS CHECKLIST

- Design calculations for entrance flow and velocity of stormwater entering the BMP
- Plan view and typical detail of splash pad, including placement northing/easting locations, length, width, materials, and cross section

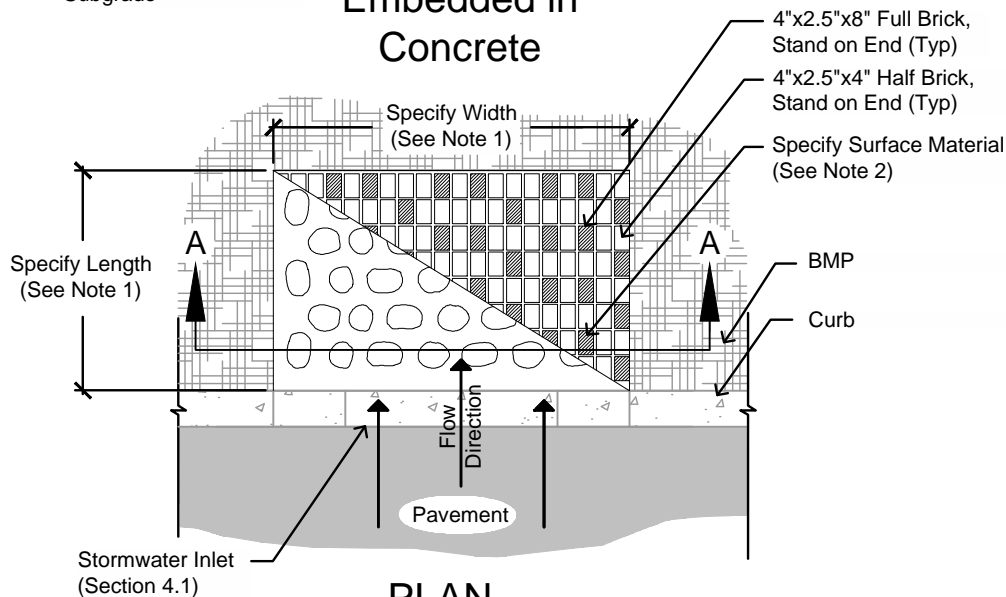
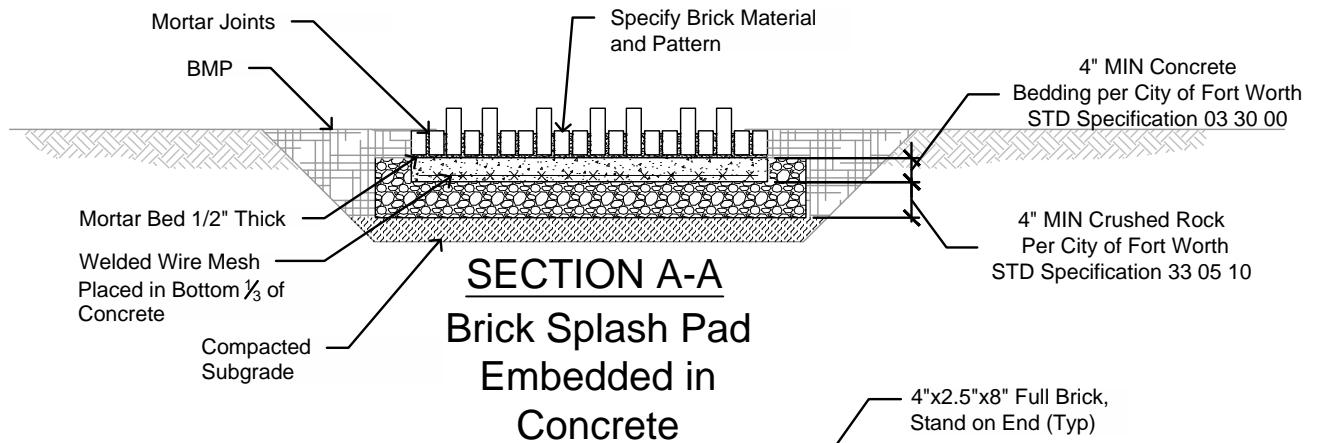
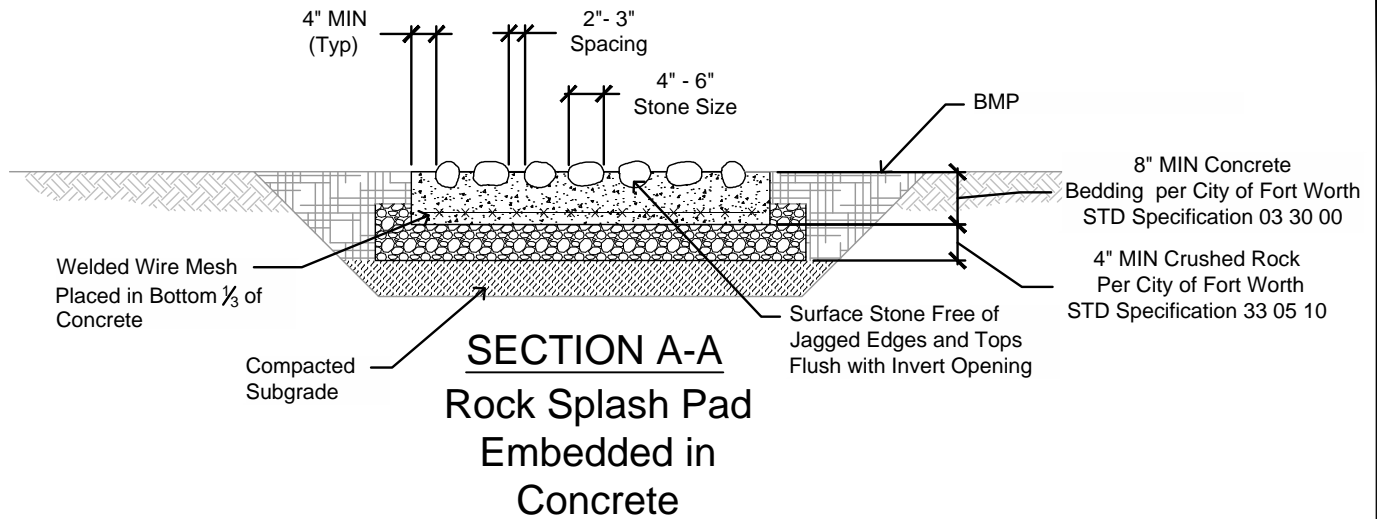
Splash pad designs and specifications outside the parameters of this guideline shall be reviewed and approved by a Professional Engineer and submitted for review and approval to the TRWD.

ADDITIONAL RESOURCES

- ¹ Natural Resources Conservation Service - Illinois. Accessed: August 29, 2017. Web address: <http://infohouse.p2ric.org/ref/02/01524/urbst910.htm>
- ² iSWM Technical Manual. April 2010, revised September 2014. Hydraulics.
- ³ SvR Design. Washington. Accessed January 2018. Web address: <http://www.svrdesign.com/streets-mobility/>
- ⁴ Curb cut and sump. Designed by David Dods-AECOM. Photo credit to CDM Smith.

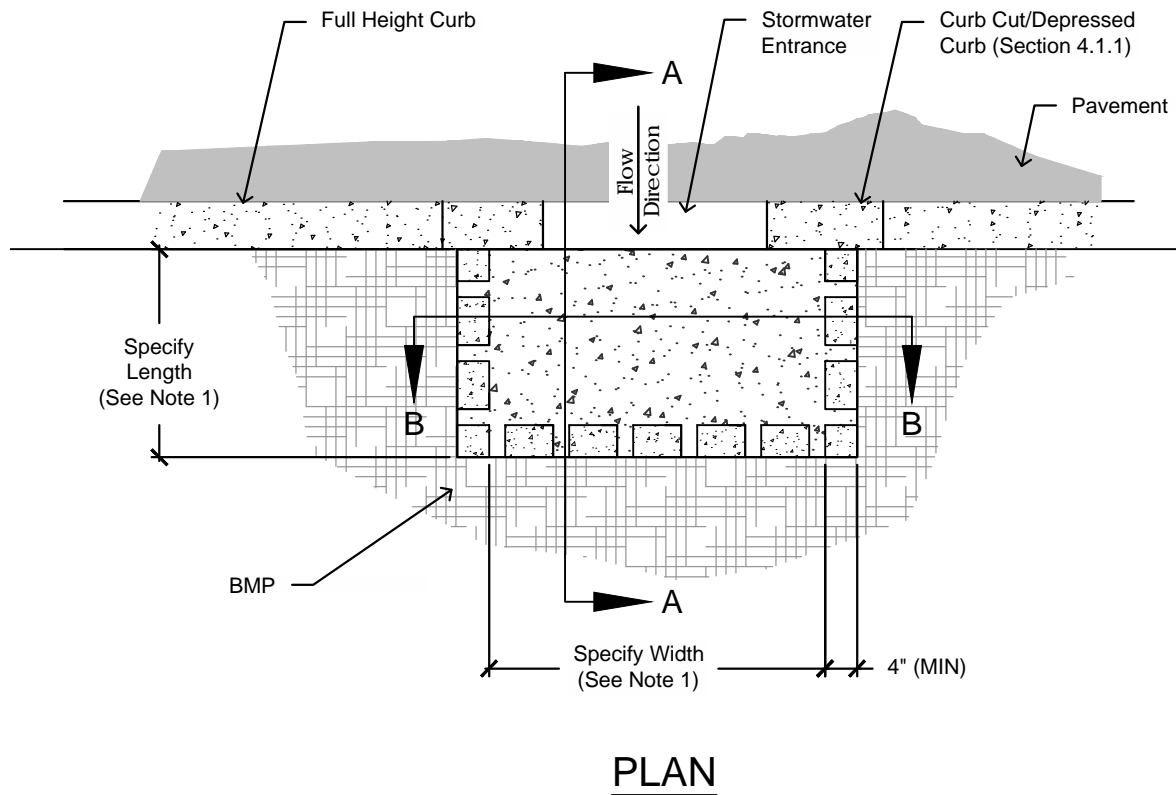
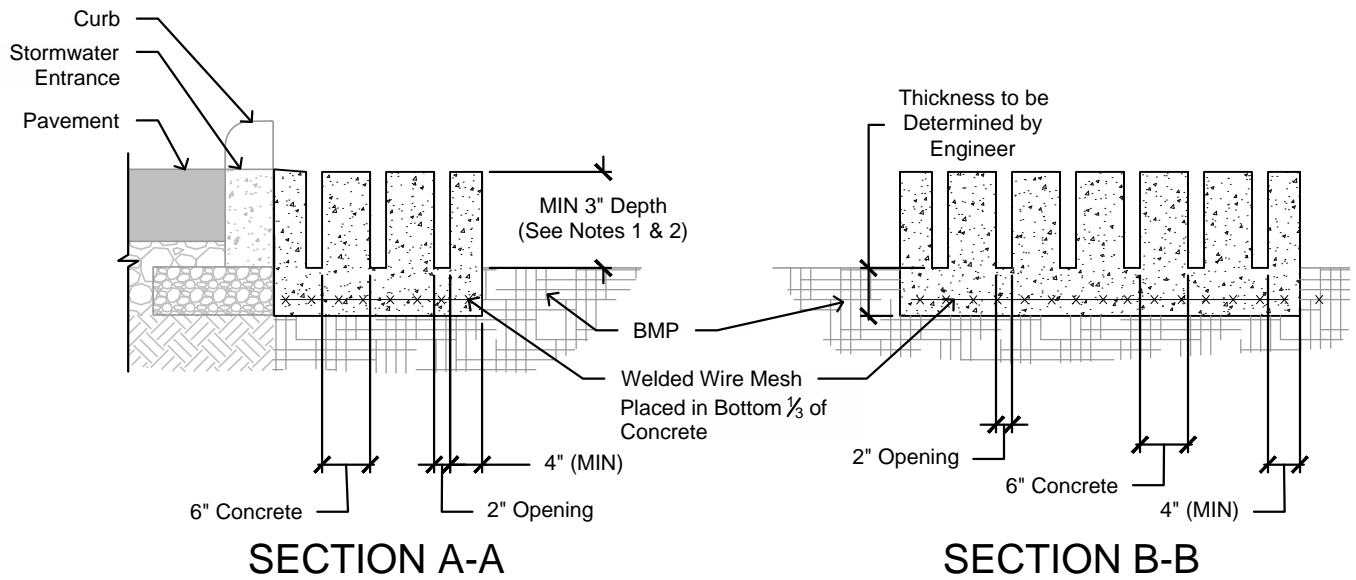
DM-DC DRAWING RESOURCES

- City of Fort Worth. December 20, 2012. Standard Construction Specification Documents. Section 03 30 00 Cast-in-Place Concrete.
- City of Fort Worth. December 12, 2016. Standard Construction Specification Documents. Section 33 05 10 Utility Trench Excavation, Embedment and Backfill.



Notes

1. Dimensions of splash pad are dependent on inlet size and type, and the velocity of stormwater entering the BMP. Width of splash pad shall be greater than total stormwater entrance width and consider potential for erosion adjacent to splash pad.
2. Surface material shall be clean washed aggregate or clay bricks. Splash pad not embedded in concrete must use aggregate with a minimum 2" diameter surrounded with permanent edging, such as anchored angle iron or concrete, to prevent material from migrating into the BMP. Loose surface material shall require a permeable geotextile (Section 4.6.3) to separate the energy dissipation aggregate and underlying BMP media.
3. A minimum 3" of freeboard is required between the top of energy dissipation material and the inlet grade elevation to account for sediment accumulation.



Notes

1. Dimensions of sump are dependent on inlet size and type, and the velocity of stormwater entering the BMP.
2. A minimum of 3" of freeboard is required between the top of energy dissipation sump and inlet to account for sediment accumulation.
3. Steel reinforcement shall be determined by the engineer.

4.4 AREA PROTECTION

DESCRIPTION

Area protection is a component used to provide a physical barrier between the BMP and adjacent pedestrian, bicycle, and/or vehicle travel areas. Barriers protect both the BMP and pedestrians by providing a visible delineation to prevent pedestrian and/or vehicular traffic from entering the BMP. The area protection may expand the entire perimeter of the BMP to separate the facility from the surrounding features or may be a vertical demarcation to provide visual awareness of the practice. Acceptable types of area protection include curbing and bollards.

WHERE TO USE

The design engineer should consider area protection for safety of pedestrians and motorists. Area protection is suggested when the BMP is directly adjacent to pedestrian and/or vehicular traffic areas where no other horizontal buffer or physical demarcation exists. If the BMP side slopes are steeper than 4:1, or if a 6 inch or greater drop from the adjacent grade to the top of the BMP exists, then area protection is suggested.

DESIGN CONSIDERATIONS

- Area protection should be designed in compliance with City of Fort Worth and other local requirements.
- When BMP is applied adjacent to on-street parking zones, a minimum of 2-feet of clearance between the edge of pavement and the area protection or edge of the BMP should be incorporated for vehicular door opening. If the area protection exceeds 12-inches in height, a 3-foot minimum buffer should be incorporated.
- When area protection is applied within pedestrian areas, a sidewalk clear zone minimum width of 3-feet must be maintained per Section 403 of Texas Accessibility Standards¹.
- Area protection greater than 24-inch in height applied at intersections must not obstruct the minimum sight triangles per Public Work's Traffic Engineering Design Standards and Policy Guidelines².

DETAILS

4.4.1 CURB

Curbing used for BMP area protection is a concrete barrier along the outside edge or edges of the BMP similar to that used for standard roadway construction. Ribbon curb may also be used to protect the asphalt edge, separate paving materials, or delineate the edge of the BMP for maintenance purposes when combined with a bollard (Section 4.4.2) to provide a vertical barrier. Below are photographs of examples of curbing that have been used for BMPs in other parts of the country. See detail DM-DC 4.4.1 for additional design information.



4.4.2 BOLLARDS

Bollards used for area protection are a fixed vertical post placed at specified intervals around the BMP to provide visual barriers and vertical demarcation for traffic and pedestrians. Bollards are encouraged for BMP bumpout applications to provide a vertical warning easily visible to drivers. Below are photographs of examples of bollards that have been used for BMPs in other parts of the country. See detail DM-DC 4.4.2 for additional design information.



DESIGN SUBMITTAL REQUIREMENTS CHECKLIST

- Plan view of area protection alignment, including northing/easting and elevation points, total length and/or spacing, radii (if applicable), and offset dimensions from existing pavement and proposed BMP
- Cross-sectional view of the area protection, including bedding or anchoring/embedment material and dimensions as well as offset dimension from BMP such as side slope and/or depth from adjacent grade
- Manufacturer details, including materials or painting specifications (optional)

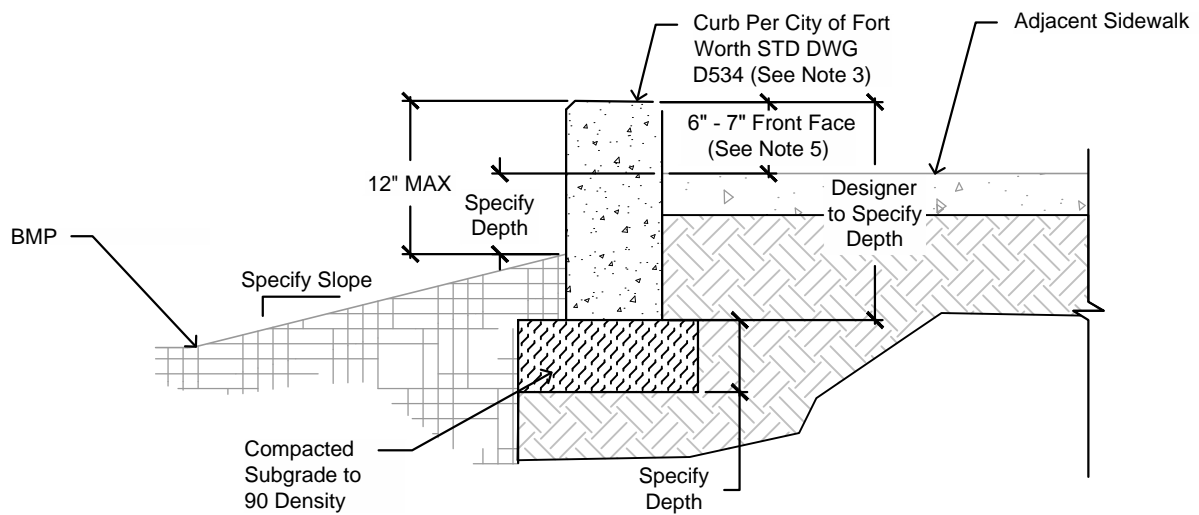
Area protection designs and specifications outside the parameters of this guideline shall be reviewed and approved by a licensed PE and submitted to TRWD.

ADDITIONAL RESOURCES

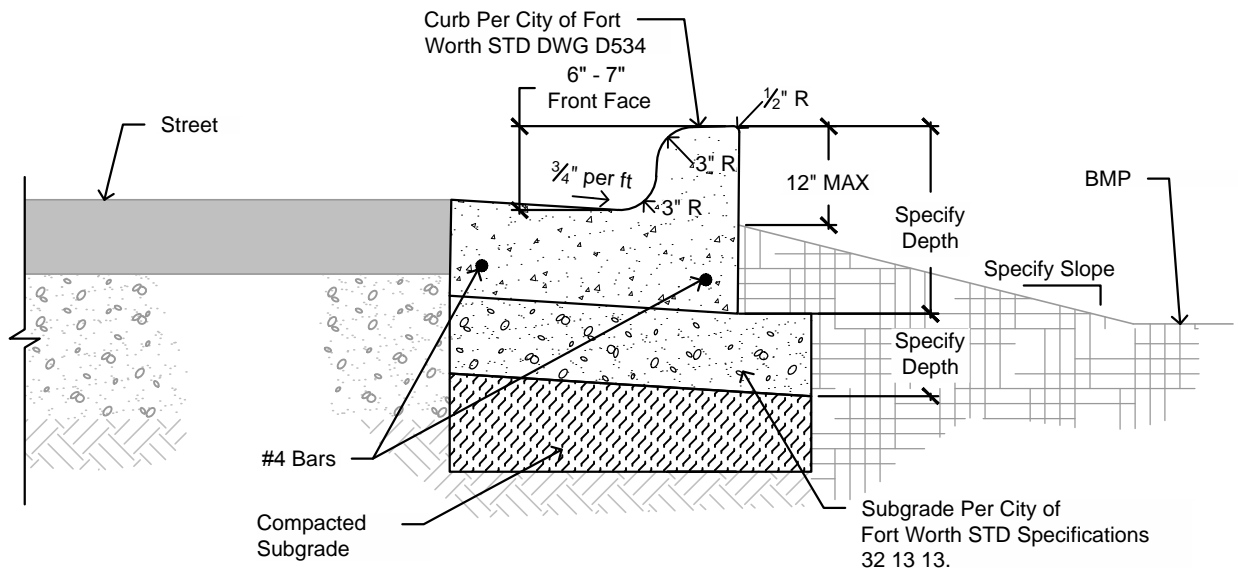
- ¹ Texas Department of Licensing and Regulation. March 15, 2012. 2012 Texas Accessibility Standards.
- ² Department of Transportation and Public Works City of Fort Worth, Texas. July 1987. Traffic Engineering Design Standards and Policy Guidelines.
- ³ Curb-Area Protection. Designed by David Dods-AECOM. Photo credit to CDM Smith.
- ⁴ BEGA®. Accessed: August 29, 2017. Web address: <https://www.bega.de/en/products/led-garden-and-pathway-luminaires-for-the-private-sector-77237/>.
- ⁵ Bollard-Area Protection. Designed by David Dods-AECOM. Photo credit to CDM Smith.

DM-DC DRAWING RESOURCES

- Texas Department of Transportation. October 2014. Roadway Design Manual.
- City of Fort Worth. August 31, 2012. Standard Construction Drawings. *Detail D534 – Standard Curb & Gutter*.
- City of Fort Worth. August 31, 2012. Standard Construction Drawings. *Detail D546 – Sidewalk Details*.
- City of Fort Worth. December 20, 2012. Standard Construction Specification Documents. *Section 32 13 13 Concrete Paving*.



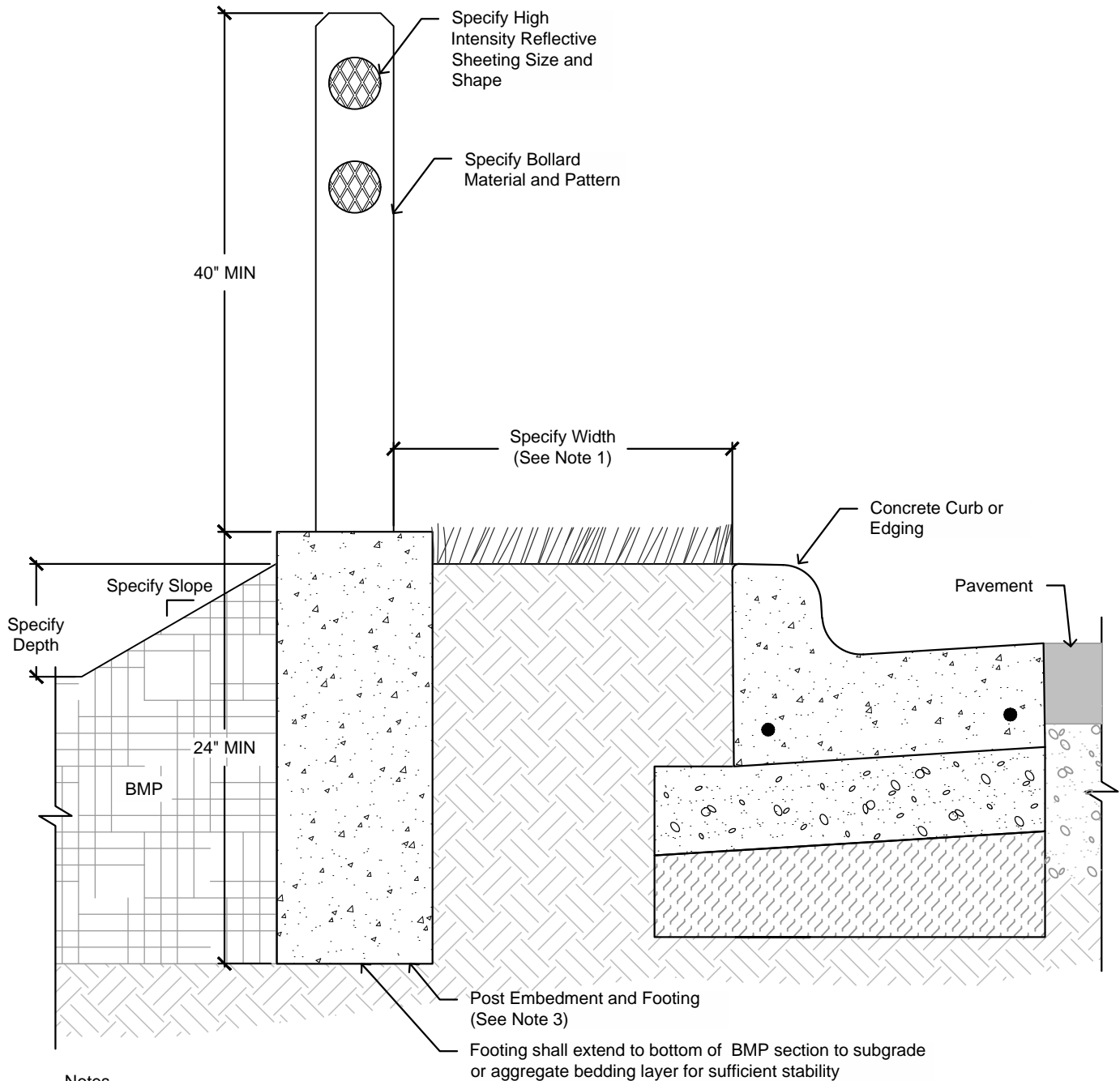
SECTION Straight Curb



SECTION Curb & Gutter

Notes

1. Curbing shall conform to City of Fort Worth STD DWG D534 - Standard Curb and Gutter.
2. Combination curb and gutter is preferred for curbing on existing curb and gutter street sections. Straight back curb per may be used where curb is proposed for existing non-curb and gutter street sections, permeable pavement applications, and for sidewalk butting the BMP.
3. Curb heights exceeding 7" on the front face shall be considered a curb with retaining wall and shall conform to City of Fort Worth STD DWG D534.
4. Concrete curb materials shall conform to City of Fort Worth STD Specification 32 13 13. All exposed surfaces shall have a brushed finish.
5. Ribbon curb may be used to facilitate overland sheet flow to BMP where applicable. Ribbon curb shall have the same design as the standard curb, with the exception that the top of curb elevation shall be flush with the surrounding grade.



Notes

1. When BMP is applied adjacent to on street parking zones, a minimum 2' clearance for vehicular door openings will be required between the back of curb or edge of pavement and the edge of the BMP. Bollards applied at intersections must not obstruct the minimum sight triangles per City of Fort Worth Public Work's Traffic Engineering Design Standards and Policy Guidelines.
2. Bollard design shall conform to manufacturer specifications and requirements. Product manufacturer or equal shall be specified on the detail.
3. Bollard post embedment shall be site specific. Footing may be embedded directly in BMP planting media or within adjacent sidewalk area. Bollards that require embedment for additional or traffic rated stability shall be designed by an engineer licensed in the State of Texas.
4. Bollards located within sidewalk area shall maintain a minimum 3' clear zone in the pedestrian pathway per ADA requirements. See City of Fort Worth STD DWG D546 for minimum sidewalk widths.
5. For Bollards located in BMPs without curb, local DOT standards shall be used to determine placement of bollard.

4.5 BMP MEDIA

DESCRIPTION

BMP media provides two primary functions within a BMP practice: filtration and storage. Stormwater is captured by the BMP, temporarily stored in the BMP media layers, and either filtered and discharged through an underdrain or infiltrated into the surrounding native soil. BMP media typically consists of bioretention or engineered soil mixture, or sand that removes pollutants primarily through filtration. While the BMP media provides some storage capacity, aggregate with greater void space offers more available volume for stormwater storage.



WHERE TO USE

BMP media includes bioretention or engineered soil media, sand, and coarse aggregate used as the primary media within a BMP practice. Bioretention or engineered soil is used in bioretention or media filter basins. Sand is used in sand filters or sand filter basins. Aggregate can be used in a BMP practice where additional below grade storage is needed such as permeable pavements or below the bioretention soil media. Aggregate is also used for underdrain bedding, where applicable.

DESIGN CONSIDERATIONS

- Bioretention or engineered soil media layer that will be planted with vegetation must maintain a minimum depth of 30-inches to allow for adequate root establishment.
- Storage volumes and depths will vary by BMP and site application. Designers shall provide storage capacity calculations based on the BMP media components used and the water quality volume calculations outlined in **Section 2** and BMP requirements discussed in **Section 3**.
- All BMP aggregate and sand media shall be clean, washed, and free of fines.

DETAILS

4.5.1 BIORETENTION OR ENGINEERED SOIL

Bioretention or engineered soil media is soil mix consisting of native soil or shale, sand, and compost that is typically classified as a sandy loam, loamy sand, or loam. Bioretention media must meet the following parameters:

- Media porosity assumption of 0.30.
- Bioretention soil media layer thickness shall be a minimum depth of 30-inches and is recommended not to exceed 48-inches.
- Pre- and post-construction permeability tests per ASTM D5093 or D6391 are required to verify installed soil meets a minimum permeability of 1.0 feet per day (0.5 inch per hour). It is recommended that additional post-construction permeability tests be performed 6 months following construction to determine if compaction or clogging has occurred during the initial months of operation.
- Bioretention soil media shall not include stones, stumps, roots, or other woody material over 1-inch in diameter.
- Bioretention component mix proportions are as follows:
 - Compost – 50 percent: Compost component of the bioretention mix shall be derived from plant material and the result of aerobic (biological) decomposition of organic matter. Compost shall not include food waste, stable waste, treated lumber, pallets, pine bark, raw manure, or mushroom compost waste. Compost used must meet the parameters shown in **Table 4.3**.



Photo credit: CDM Smith

Table 4.3 Compost for Bioretention Soil Mix Testing Parameter Requirements

<i>Parameter</i>	<i>Value</i>	<i>Test Method</i>
pH range	7.9–8.9	ASTM D4972
Maturity (Germination and Vigor)	≥ 90%	TMECC 5.05-A
Solvita® Compost Maturity Index	≥ 7	Solvita® Compost Maturity Test or Approved Equal
Composting Time	6–12 Months	n/a
Percent Passing ¾-inch sieve	≥ 99%	ASTM C33
Percent Passing ½-inch sieve	97%	ASTM C33

- Expanded Shale, Washed Sand, or Native Soil (if acceptable) – 25 percent
 - *Expanded Shale component of the bioretention soil mix shall be 3/8-inch Expanded Shale (Horticulture Grade, G Pile) as manufactured by Trinity Lightweight or comparable material and must meet the gradation shown in **Table 4.4**.*

Table 4.4 Expanded Shale Gradation Requirements

Sieve Size	Percent Passing
½-inch (12.5 mm)	100
3/8-inch (9.5 mm)	90–100
No. 4 (4.75 mm)	40–90
No. 8 (2.36 mm)	0–20
No. 16 (1.18 mm)	0–10

- *Native soil may be used in lieu of expanded shale component of the bioretention soil mix, if material is acceptable. Native soil must be free of weeds, deleterious materials, rocks, and debris with 100 percent passing through a ¾-inch sieve and less than 25 percent passing through a #200 sieve. This should be specified in the BMP plans and verified by construction inspectors.*
- *Washed sand also may be used in lieu of the expanded shale component, making up a full 50 percent of the bioretention soil mix with approval from a licensed PE. Sand must meet comply with Section 4.5.2.*
- Washed Sand – 25 percent (see Section 4.5.2 for sand requirements)
- Bioretention soil media mix shall be tested and meet the parameters in **Table 4.5**.

Table 4.5 Bioretention Soil Mix Testing Parameter Requirements

Parameter	Value	Test Method
pH range	5.2 to 7.0	ASTM D4972
Organic matter	1.5 to 4.0%	AASHTO T194
Magnesium	35 lbs/acre, minimum (0.0072 lbs/sq yd)	TMECC 4.05-Mg
Phosphorus (P2O5)	75 lbs/acre, minimum (0.0154 lbs/sq yd)	TMECC 4.03-A
Potassium (K2O)	85 lbs/acre, minimum (0.0175 lbs/sq yd)	TMECC 4.04-A
Soluble salts	500 ppm	TMECC 4.10-A
Infiltration Rate	0.25 inch/hour (minimum)	ASTM D3385

4.5.2 SAND

Sand is used as the primary BMP media and typically used in sand filters.

Note that sand used as a media barrier (Section 4.6.1) is a thin layer of sand primarily used to filter sediment to prevent clogging in transitional layers and may be applicable in various types of BMP practices.

Sand media for sand filters must meet the following parameters:

- Media porosity minimum of 0.32.²
- Sand media thickness shall be between 12-inch and 24-inch.²
- Sand media must meet gradation requirements per TxDOT Fine Aggregate Grade No. 1.²
- Alternative sand media gradation per ASTM C-33, Standard Specification for Concrete Aggregates, is also acceptable.³



Photo credit: Storm-Tex Services¹

4.5.3 STORAGE AGGREGATE

Aggregate storage materials include No. 3, 56, 57, and 67 stone. Use a No. 56, 57, or 67 size aggregate within the underdrain collection system layer or as the primary aggregate storage layer. A No. 3 size aggregate storage layer can be placed below the No. 56, 57, or 67 layer if additional storage capacity is required. Storage aggregate media must meet the following parameters:

- Void space in open graded No. 56, 57, or 67 and No. 3 aggregate ranges from 30 to 40 percent. This void space is available for water storage.



Photo credit: CDM Smith

Crushed Rock Storage Layer

- Media porosity assumption of 0.40.
- Crushed rock shall be per City of Fort Worth Standard Specification 33 05 10 and all aggregate must be clean, washed, and free of fines.⁴ If using recycled concrete as aggregate, the crushed recycled concrete will need to be approved for use as a storage layer within the BMP by a licensed PE due to potential oil or organics that may be in the existing concrete.
- Coarse-aggregate grading sizes No. 56, 57, or 67 or crushed rock per City of Fort Worth STD Specification 33 05 10 and ASTM D448, as shown in **Table 4.6**.

Table 4.6 Crushed Rock Aggregate Gradation

Sieve Size	Percent Passing		
	No. 56	No. 57	No. 67
1 ½-inch (37.55 mm)	100	100	-
1-inch (25.0 mm)	90–100	95–100	100
¾-inch (19.0 mm)	40–85	-	90–100
½-inch (12.5 mm)	10–40	26–60	-
3/8-inch (9.5 mm)	0–15	-	20–55
No. 4 (4.75 mm)	0–5	0–10	0–10
No. 8 (2.36 mm)	-	0–5	0–5

No. 3 Storage Layer

- Media porosity assumption of 0.40⁴
- Coarse-aggregate grading size No. 3 per ASTM D488 as shown in **Table 4.7**.



Photo credit: CDM Smith

Table 4.7 No. 3 Aggregate Storage Gradation Requirements

Sieve Size	Percent Passing
2 ½-inch (63 mm)	100
2-inch (50 mm)	90–100
1 ½-inch (37.55 mm)	35–70
1-inch (25.0 mm)	0–15
½-inch (12.5 mm)	0–5

DESIGN SUBMITTAL REQUIREMENTS CHECKLIST

- Plan view of BMP practice specifying extents of media with northing/easting points
- Section view of BMP practice specifying depth of all media layers used and material specifications of the BMP media
- BMP media storage capacity calculations and corresponding design water quality volume
- All BMP media specifications for BMP practice design
- Results of BMP media and soil testing

BMP media designs and specifications outside the parameters of this guideline shall be reviewed and approved by a licensed PE and submitted to TRWD.

ADDITIONAL RESOURCES

- ¹ Storm-Tex Services. Sand Filter basins and Ponds. Accessed: August 29, 2017. Web address: <http://www.storm-tex.com/sand-filter-basins-ponds/>.
- ² North Central Texas Council of Governments. September 2014. iSWM™ Technical Manual. *Site Development Controls*.
- ³ American Society for Testing and Materials International. February 2016. ASTM C33/C33M Standard Specification for Concrete Aggregates.
- ⁴ City of Fort Worth. December 12, 2016. Standard Construction Specification Documents. *Section 33 05 10 Utility Trench Excavation, Embedment and Backfill*.

TESTING STANDARDS RESOURCES

- Texas Department of Transportation. November 1, 2014. Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges. *Item 421 Hydraulic Cement Concrete*.
- StormTech. November 2012. Tech Sheet #1. *Porosity of Structural Backfill*.
- American Society for Testing and Materials International. 2012. ASTM D448 Standard Classification for Sizes of Aggregate for Road and Bridge Construction.
- American Society for Testing and Materials International. November 2013. ASTM D4972 Standard Test Method for pH of Soils.
- American Society for Testing and Materials International. 2015. ASTM D5093 Standard Test Method for Field Measurement of Infiltration Rate Using Double-Ring Infiltrometer with Sealed-Inner Ring.
- American Society for Testing and Materials International. 2011. ASTM D6193 Standard Test Method for Field Measurement of Hydraulic Conductivity Using Borehole Infiltration.

- American Society for Testing and Materials International. 2010. F1632 Standard Test Method for Particle Size Analysis and Sand Shape Grading of Golf Course Putting Green and Sports Field Rootzone Mixes.
- American Society of State Highway and Transportation Officials. 2013. AASHTO T 194 Determination of Organic Matter in Soils by Wet Combustion.
- USDA and US Composting Council. 2002. Test Methods for Examination of Composting and Compost. *TMECC 4.03-A Total Phosphorus*.
- USDA and US Composting Council. 2002. Test Methods for Examination of Composting and Compost. *TMECC 4.04-A Total Potassium*.
- USDA and US Composting Council. 2002. Test Methods for Examination of Composting and Compost. *TMECC 4.05-Mg Magnesium*.
- USDA and US Composting Council. 2002. Test Methods for Examination of Composting and Compost. *TMECC 4.10-A 1:5 Slurry pH*.
- USDA and US Composting Council. 2002. Test Methods for Examination of Composting and Compost. *TMECC 5.05-A Seedling Emergence and Relative Growth*.

4.6 MEDIA BARRIERS

DESCRIPTION

A media barrier is a permeable or impermeable layer used to control or prevent the migration of soil, aggregate, and/or stormwater runoff within the subsurface or out of a BMP practice. Permeable media barriers include sand, pea gravel, and permeable geotextile, which control the movement of soil materials within the BMP while allowing stormwater to permeate. Impermeable media barriers include geomembrane sheets and clay liners, which prevent stormwater from migrating out of the BMP practice.



Photo credit: CDM Smith

WHERE TO USE

Media barriers may be used in any BMP practice as transitional layers between differing BMP media and the surrounding soil in both horizontal and vertical applications. A permeable media barrier is typically placed between overlying soil or sand layers and aggregate storage layers to provide a transition between the media functions and surrounding underdrains to prevent clogging. Vertical separation may also be desired between BMP media and surrounding soil or subgrade to prevent mixing of the surrounding native soil with the BMP media.

An impermeable media barrier shall be installed wherever the infiltration into surrounding native soil is not desired or a potential exists for stormwater runoff to migrate away from the BMP practice toward a below grade feature that must be protected from contact with water such as an underground utility, building foundation, or street/parking lot subgrade (see Section 2 and respective utility's guidance regarding proximity of other utilities for reference). Impermeable barriers may also be appropriate when potential exists for water to migrate into contaminated soil or to prevent leakage when a permanent pool is installed.

DESIGN CONSIDERATIONS

- All media barrier aggregate and sand shall be clean, washed, and free of fines.
- Impermeable barriers shall be geomembrane sheets, compacted clays, or other impermeable material as approved by a licensed PE. Impermeable barriers shall have a permeability of no more than 1×10^{-7} cm/s.
- An anti-seep collar (Section 4.9.6) should be considered where impermeable barriers are used for installation at the edge of the BMP facility for outlet piping that passes through non-BMP areas before connection to an outlet structure.

- It is preferred that all utilities be located outside of the BMP facility rather than using an anti-seep or impermeable barrier.

DETAILS

4.6.1 SAND

Sand media barriers allow for filtering of smaller particles and pollutants to avoid clogging potential within the transitional layers within the subsurface of the BMP practice. Within the entire BMP practice, the sand is a thin layer and has applicability within various types of BMP practices. It should be noted that the sand material used for media barriers is the same material as the sand BMP media (Section 4.5.2) layer used in sand filters or sand filter basins. When used as a media barrier, sand functions as a thin filter layer rather than the primary BMP media.

- Sand media thickness shall be between 4 and 6 inches.¹
- Sand media must meet gradation requirements per TxDOT² Fine Aggregate Grade No. 1.
- Alternative sand media gradation per ASTM C-33, Standard Specification for Concrete Aggregates, is also acceptable.³

4.6.2 PEA GRAVEL (NO. 7 OR 8)

Pea gravel is a coarse-aggregate comprised of No. 7 or 8 stone. Pea gravel allows for the settling of soil material and pollutants within the void spaces and acts as a level spreader for stormwater runoff flows in the subsurface of the BMP practice. Pea gravel may be used between transitional layers in the subsurface of the BMP or on the BMP surface to dissipate flow and separate surface storage areas of the BMP. Pea gravel must meet the following parameters:

- Pea gravel media thickness shall be between 2 and 6 inches.¹
- Coarse-aggregate grading sizes No. 7 or 8 must meet the gradation requirements per ASTM D448 as shown in **Table 4.8**.



Photo credit: CDM Smith

Table 4.8 No. 7 and No. 8 (Pea Gravel) Gradation Requirements

Sieve Size	Percent Passing	
	No. 7	No. 8
¾-inch (19.0 mm)	100	-
½-inch (12.5 mm)	90–100	100
3/8-inch (9.5 mm)	40–70	85–100
No. 4 (4.75 mm)	0–15	10–30
No. 8 (2.36 mm)	0–5	0–10
No. 16 (1.18 mm)	-	0–5

4.6.3 PERMEABLE GEOTEXTILE

Permeable geotextile is a fabric-based filter material, often referred to as geotextile filter fabric. Permeable geotextile must meet the following parameters:

- Permeable geotextile is preferred only to be used in vertical or near-vertical applications. A horizontal application on the bottom of the BMP facility may be considered. Designer should consider the higher clogging potential when using the geotextile in a horizontal application.
- Permeable geotextile may be used to prevent native soil from migrating by lining the side slopes and bottom of the BMP. Geomembrane liner (Section 4.6.4) may be used if the intent is to prevent the migration of water from exiting the BMP (i.e., near buildings with basements or road sections)
- If permeable geotextile is applied horizontally between BMP media layers or on the bottom of the BMP facility, a permeable pea gravel or sand filter aggregate layer should be included over the geotextile.
- Permeable geotextile shall comply with City of Fort Worth STD Specification 33 05 10 – Utility Trench Excavation, Embedment and Backfill.⁴ Material and ASTM requirements are dependent on soil classifications, as follows:
 - Soils classified as ML or OH per ASTM D2487, Mirafi FW402 or comparable shall be used.
 - Soils classified as other than ML or OH per ASTM D2487, Mirafi 140N or comparable shall be used.
- At a minimum, permeable geotextiles shall comply with iSWM Technical Manual¹, as shown in **Table 4.9**.



Photo credit: CDM Smith

Table 4.9 Permeable Geotextile Requirements

<i>Geotextile Property</i>	<i>Value</i>	<i>Test Method</i>
<i>Trapezoidal Tear</i>	40 lbs	ASTM D4533
<i>Permeability</i>	0.2 cm/sec	ASTM D4491
<i>AOS</i>	#60–#70 sieve size	ASTM D4751
<i>Ultraviolet Resistance</i>	70% or greater	ASTM D4355

4.6.4 GEOMEMBRANE LINER

Geomembrane, or impermeable liner, is a synthetic material with a very low permeability that acts as a barrier to prevent the migration of water into or out of the BMP. Geomembrane liners must meet the following parameters:

- The geomembrane material shall be free of holes, blisters, undispersed raw materials, or any sign of contamination by foreign matter.
- Geomembrane sheets shall at a minimum meet TxDOT Special Specification² values as shown in **Table 4.10**.



Photo credit: CDM Smith

Table 4.10 Geomembrane Requirements

<i>Property</i>	<i>Value</i>	<i>Test Method</i>
<i>Nominal Thickness</i>	30 mil (mm)	N/A
<i>Density</i>	0.033 oz/cm ³	ASTM D1505
<i>Tensile Strength at Break</i>	240 lbs/in-width	N/A
<i>Tensile Strength at Yield</i>	140 lbs/in-width	N/A
<i>Elongation at Break</i>	700%	N/A
<i>Elongation at Yield</i>	13%	N/A
<i>Tear Resistance Initiation</i>	45.0 lbs	ASTM D1004
<i>Puncture Resistance</i>	80 lbs	FTMS 101c Method 2065
<i>Carbon Black Content</i>	2–3%	N/A

- Geomembrane adjacent strips shall overlap by a maximum of 4 inches for an extrusion weld prior to the welding or a maximum overlap of 5 inches for a hot wedge weld prior to welding per TxDOT Special Specification².
- If adjacent strips of the geomembrane are not to be welded, then the adjacent strips need to be bound as specified by the manufacturer and approved by a licensed PE.

4.6.5 CLAY LINER

A clay liner is comprised of compacted clays with a very low permeability that act as a barrier to prevent the migration of stormwater through the liner.

- Recommended soil physical characteristics for compacted clay impermeable barriers include >50 percent fines, liquid limit between 35 and 60, and a plasticity index versus liquid limit above the A-line. USCS Soil Classification of CH, CL, MH are recommended.
- Field compaction should achieve 95 percent standard max density as determined by ASTM D698. Proctor testing to determine the optimum moisture content for compaction should be performed and results should be retained.

DESIGN SUBMITTAL REQUIREMENTS CHECKLIST

- Plan view of BMP practice specifying extents of media with northing/easting points.
- Section view of BMP facility noting the location, limits, thickness, and material specifications of the media barrier.
- Sieve analysis shall be submitted when applicable.
- Specify product manufacturer, if applicable, and submit product details, including material, performance standards, and installation requirements.

Media barrier component designs and specifications outside the parameters of this guideline shall be reviewed and approved by a licensed PE and submitted to TRWD.

ADDITIONAL RESOURCES

- ¹ iSWM Technical Manual. April 2010, revised September 2014. Site Development Controls.
- ² Texas Department of Transportation. 2014. Special Specification 5056: Impermeable Liner.
- ³ American Society for Testing and Materials International. February 2016. ASTM C33/C33M Standard Specification for Concrete Aggregates.
- ⁴ City of Fort Worth. December 12, 2016. Standard Construction Specification Documents. *Section 33 05 10 Utility Trench Excavation, Embedment and Backfill*.

TESTING STANDARD RESOURCES

- American Society for Testing and Materials International. 2012. ASTM D448 Standard Classification for Sizes of Aggregate for Road and Bridge Construction.
- American Society for Testing and Materials International. May 2012. ASTM D698 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft³ (600 kN-m/m³)).
- American Society for Testing and Materials International. April 2013. ASTM D1004 Standard Test Method for Tear Resistance (Graves Tear) of Plastic Film and Sheeting.
- American Society for Testing and Materials International. July 2010. ASTM D1505 Standard Test Method for Density of Plastics by the Density-Gradient Technique.

- American Society for Testing and Materials International. May 2011. ASTM D2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System).
- American Society for Testing and Materials International. 2014. ASTM D4355 Standard Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture and Heat in a Xenon Arc Type Apparatus.
- American Society for Testing and Materials International. 2017. ASTM D4491 Standard Test Methods for Water Permeability of Geotextiles by Permittivity.
- American Society for Testing and Materials International. 2016. ASTM D4751 Standard Test Methods for Determining Apparent Opening Size of a Geotextile.
- Federal Test Method Standards. March 1980. FTMS 101C – Method 2065. Test Method for Puncture Resistance and Elongation Test (1/8 in. radius probe).

4.7 LANDSCAPING

DESCRIPTION

Plant selection for green stormwater infrastructure is crucial for the successful performance and aesthetic of that feature or facility. The plant types, species, sizes, and varieties are determined by the applications and requirements to stabilize soils, grow in varying soil moisture conditions, and detain, retain, and treat stormwater. The recommended plant lists for seeding and plants have been selected for use in each of the different BMP practices.

WHERE TO USE

These plant types are recommended for use in bioretention basins, constructed wetlands, sand/media filter slopes, wet ponds, extended dry detention basins, retention/irrigation basins, and vegetative filter strips/swales. Plants in these environments should be tolerant of the soils types and media for the varying conditions; be of appropriate size for each type of application regrading maintenance and mature height; be drought tolerant for this region to adapt to varying rainfall events and seasons; be tolerant of dry, hot conditions; not require supplemental irrigation once well established for the larger practice features; be provided with permanent irrigation to provide supplemental water to establish larger shrubs, and trees; be provided with permanent irrigation for supplemental watering within bioretention basins and extensive centralized bioretention areas in the right-of-way due to extended drought conditions; be native or adaptive to the North Texas region or non-invasive if not native; be capable of living in the soil media and amended soils for each type of BMP practice; and be commonly available in the regional seed or nursery trade.

DESIGN CONSIDERATIONS

- Other plants not specifically listed in the seeding or plant list palettes may be suitable and available. The seed and plant lists does exclude non-cultivars and other varieties of plants and grasses. Plants and herbaceous perennials not specifically listed on the seed mix and plant lists must be submitted to TRWD for review.
- Plant and Seed (and/or sod) selection and location must be coordinated with the specific requirements, application, and local attributes of each feature and practice. Selection and application of the plants are based on: size and location of basin, grading plan, slope stabilization, amount of water received, water retention depth, drawdown time, subsurface or water table elevations, depth of surface soils/subbase/restrictive soils, remediation of soil compaction for root penetration, coefficient of runoff, infiltration rate of the planting and drainage media, soil media composition and depth, root zone volume, drought resistance/hardiness and adaptability, sun exposure, diversity to adapt to changing rainfall events and environment, and type of roadway or runoff area.
- Plant density will vary depending on feature's basin size, plant species size, available root zone volume, and appropriate application for different sized and types of features. To prevent root competition, plant densities should be considered and sufficient spacing should be provided for plants.

- Seeds should be supplied by local seed suppliers for seed gathered or produced and shall be in compliance with TDA (Texas Department of Agriculture) seed laws. All seeds shall be tested by independent laboratories utilizing standards approved by AOSA (Association of Official Seed Analysts). Noxious weed seeds and non-native species shall not be included in seed mixes, unless specifically called out for application. Plants shall be nursery or contract nursery grown for regional adaptability, and will meet the requirements of local codes and ordinances. Plants should be of sufficient size to establish successfully.
- For BMP features at intersections, mature plant height shall not exceed 2.5 feet to avoid sight-line or visibility triangle obstructions within the clear vision triangle, per City of Fort Worth codes and DPS Site Distances at Intersections Policy.
- Planting plans for BMP features shall have a limited variety of species to provide for ease of maintenance. Depending on size of the BMP feature, 3 to 7 species are recommended with no more than 50 percent of plantings of one species. Grouping of plant species allows for ease of maintenance and visual impact, but is not required. The planting design style should be based on the context of the application.
- All planting areas, not seeded or sodded, should be covered with a 3-inch layer of double shredded and/or hammer mill processed native hardwood mulch. Mulch should be natural, undyed, heat processed to eliminate latent weed seeds or harmful diseases; recommended size range: 8 inches maximum, 2 inch minimum for high volume features, or size range: 4 inches maximum, 1 inch minimum for smaller low volume features; pH 6.5 – 8.5. Water all mulch with fine spray immediately following installation to minimize mulch flotation.
- Separate mulched areas from sodded areas with perforated metal, concrete mow strips, or stone block edging.
- Decorative gravel aggregate, river rock, or rip-rap, may be used at inflow into the BMP feature to minimize wash-out of native hardwood mulch, but not throughout an entire planting bed since it is not a BMP media barrier (such as aggregate used to direct the flow path in a basin). Decorative gravel aggregate shall be locally available, washed, crushed graded stone, or rounded river gravel or river rock.
- Provide temporary fencing, if required, to protect the BMP from traffic through and around the feature until it is established. Provide temporary runoff protection to prevent soil erosion and to allow establishment of seeded and planted surfaces.
- Irrigation systems, both temporary and/or permanent, will be installed to establish and maintain planted features depending on location, type, and visibility. Temporary irrigation shall be provided to establish seeded areas with supplemental permanent irrigation to provide for long term establishment of larger plant materials such as shrubs and trees. Permanent irrigation should be included in smaller high visibility features, and to provide supplemental water in extended drought periods.
- Existing trees shall be protected and incorporated into BMP designs where opportunity allows.
- Consider both short and long-term maintenance requirements and specify, as applicable.
- Comply with local codes and ordinances where implemented.

DETAILS

4.7.1 CHART FOR APPLICATION OF LANDSCAPING

BMP	Seed or Plant Mix
Bioretention Basin	Plant List 1 – size & species of plants selected according to size of basin, location, visibility, and specific application
Constructed Wetland	Plant Lists 2, 3, 4, 5, 6, 7 and 8
Sand/Media Filter	Seed Mix determined by slope of bank, location, and visual application
Wet Pond	Nurse Crop if needed, Seed Mixes 1, 2, 3, 4 and 5 for access roads/ramps
Extended Dry Detention	Nurse Crop if needed, Seed Mixes 2, 3, and 5 for access roads/ramps
Retention / Irrigation Basin	Seed Mix or Plant List determined by slope of bank, location, and adjacent conditions for irrigation application
Vegetative Filter Strip / Swale	Nurse Crop if needed, Seed Mixes 1 and 2
^Access Roads / Pedestrian Access Ramps	Nurse Crop if needed, Seed Mix 5

^ Supplemental to each BMP depending on project conditions and access requirements for maintenance.

4.7.2 SEED MIXES

4.7.2.1 NURSE CROP SEED MIX

Seed mix to establish and provide soil stabilization in all applications for cool-season nurse crop. Installation window is October to March 1st as a nurse crop (over seed) to other seed mixes for immediate germination and stabilization until other seeds can establish.

Table 4.7.2.1 Nurse Crop

Herbaceous Species - Grasses	Percentage (%) by Weight	Germination Percentage (%)
Cereal Rye	100.00	100
Application Rate = 100 lbs./acre (1 lb./436 sf.)		

4.7.2.2 SEED MIX 1: DRY/WET CONDITIONS – BOTTOM AND SIDES

Seed mix to establish and provide soil stabilization to the bottoms and sides of BMP features with conditions that vary from dry to wet. The grass mix below is a warm-season crop. Installation window is Spring (March 1st -May 15th) or Fall (September 1st – November 15th) if installed with Seed Mix 3.

Table 4.7.2.2 Seed Mix 1

Herbaceous Species - Grasses	Percentage (%) by Weight <>	Germination Percentage (%)
Blue Grama	31.05	75
Buffalograss	11.00	94
Little Bluestem	11.00	42
Sideoats Grama	10.18	86
Big Bluestem	4.95	*
Green Sprangletop	4.90	*
Eastern Gamagrass	4.90	*
Sand Dropseed	4.90	*

<i>Herbaceous Species - Grasses</i>	<i>Percentage (%) by Weight <></i>	<i>Germination Percentage (%)</i>
<i>Prairie Wildrye</i>	4.75	*
<i>Switchgrass</i>	3.50	*
<i>Sand Lovegrass</i>	3.02	*
<i>Indiangrass</i>	2.90	*
<i>Western Wheatgrass</i>	1.00	*
<i>Cane Bluestem</i>	0.07	*
<i>Texas Cupgrass</i>	0.55	*
<i>Curly Mesquite</i>	0.25	*
<i>White Tridens</i>	0.20	*
<i>Bushy Bluestem or Halls Panicum</i>	0.20	*
Application Rate = 22 lbs./acre (1 lb./2,000 sf.)		

<> Percentage (%) by Weight may vary depending on seed availability

* Germination Percentage (%) not required by TDA (Texas Department of Agriculture)

4.7.2.3 SEED MIX 2: DRY/WET CONDITIONS – BOTTOM

Seed mix to establish and provide soil stabilization to the bottoms of BMP features with conditions that vary from dry to wet. The mix below is a cool-season crop and provides seasonal flowers. Installation window is Fall (September 1st – November 15th) or Spring (March 1st -May 15th) if installed with Seed Mix 1.

Table 4.7.2.3 Seed Mix 2

<i>Herbaceous Species - Perennials</i>	<i>Percentage (%) by Weight <></i>	<i>Germination Percentage (%)</i>
<i>American Basketflower</i>	49.66	8
<i>Illinois Bundleflower</i>	23.91	12
<i>Clasping Coneflower</i>	8.07	99
<i>Plains Coreopsis</i>	3.23	*
<i>Black-eyed Susan</i>	3.23	*
<i>Scarlet Sage</i>	3.07	*
<i>Cutleaf Daisy</i>	2.67	*
<i>Pink Evening Primrose</i>	1.94	*
<i>Maximillian Sunflower</i>	0.96	*
<i>Giant Goldenrod</i>	0.17	*
Application Rate = 22 lbs./acre (1 lb./2,000 sf.)		

<> Percentage (%) by Weight may vary depending on seed availability

* Germination Percentage (%) not required by TDA (Texas Department of Agriculture)

4.7.2.4 SEED MIX 3: DRY CONDITIONS – UPPER AND BACK SLOPES

Seed mix to establish and provide soil stabilization to the upper and back slopes of BMP features with conditions that are dry. The mix below is a cool-season crop. Installation window is Fall (September 1st – November 15th) or Spring (March 1st -May 15th) if installed with Seed Mix 1.

Table 4.7.2.4 Seed Mix 3

<i>Herbaceous Species - Perennials</i>	<i>Percentage (%) by Weight <></i>	<i>Germination Percentage (%)</i>
American Basketflower	19.93	8
Texas Bluebonnet	18.23	21
Plains Coreopsis	15.52	15
Indian Blanket	15.32	88
Lemon Mint	11.82	77
Purple Prairie Clover	10.31	26
White Prairie Clover	6.66	91
Partridge Pea	1.90	*
Gayfeather	0.20	*
Tall Goldenrod	0.10	*
Texas Yellow Star	0.01	*
Application Rate = 22 lbs./acre (1 lb./2,000 sf.)		

<> Percentage (%) by Weight may vary depending on seed availability

* Germination Percentage (%) not required by TDA (Texas Department of Agriculture)

4.7.2.5 SEED MIX 4 – OVERSEED: WET AND MOIST CONDITIONS – REGULAR DRAINAGE OR SEEPAGE ALONG BOTTOM

Seed mix to establish and provide soil stabilization for wet or moist conditions where there is regular drainage or seepage along the bottom of a BMP feature. The mix below is a nurse crop (Cereal Rye Grain) mixed with a warm-season crop to initially hold and stabilize the soils and for the grasses to germinate in the warmer season. Installation window is Winter (November 1st – February) installed over Seed Mix 2.

Table 4.7.2.5 Seed Mix 4

<i>Grasses</i>	<i>Percentage (%) by Weight <></i>	<i>Germination Percentage (%)</i>
Cereal Rye Grain	75.4	98
Big Bluestem	8.20	98
Eastern Gamagrass	4.99	*
Switchgrass	4.00	*
Prairie Wildrye	3.00	*
Green Sprangletop	2.80	*
White Tridens	0.75	*
Broomsedge Bluestem	0.04	*
Application Rate = 218 lbs./acre (1 lb./200 sf.)		

<> Percentage (%) by Weight may vary depending on seed availability

* Germination Percentage (%) not required by TDA (Texas Department of Agriculture)

4.7.2.6 SEED MIX 5: ACCESS ROADS OR PEDESTRIAN ACCESS RAMPS

Seed mix to establish and provide soil stabilization for access roads and pedestrian access ramps. The mix below is a warm-season crop mixed with a nurse crop to hold and stabilize surface soils. Installation window is Spring (March 1st -May 15th) or Fall (September 1st – November 15th) if regular rain has occurred and up to 8 weeks before average frost date.

Table 4.7.2.6 Seed Mix 5

Grasses	Percentage (%) by Weight	Germination Percentage (%)
Buffalograss	82.00	98
Blue Grama	17.00	98
Curly Mesquite	1.00	*
Application Rate = 44 lbs./acre (3 lbs./1,000 sf. or 1 lb./333 sf.)		

<> Percentage (%) by Weight may vary depending on seed availability

* Germination Percentage (%) not required by TDA (Texas Department of Agriculture)

4.7.2.7 PLANT LIST 1: BIORETENTION

Plants recommended for Bioretention application due to size, visibility clearances, maintenance, and appearance. Plants within visibility/sight distance triangles at intersections shall be less than 30" height and shall comply with all codes per application location to prevent obstruction.

Table 4.7.2.7 Plant List 1

Herbaceous Species – Perennials				
Common Name (Scientific name)	Size (Height x Spread)	Evergreen or Deciduous	Sun or Shade	Location (Wet or Dry Range)
Zexmenia (<i>Wedelia acapulcensis</i> var. <i>hispida</i>)	1'-2' x 2'-3'	Evergreen/Semi-Evergreen	Sun/Part Shade	Semi-Wet/Dry
Aromatic Aster (<i>Symphyotrichum oblongifolium</i>)	1'-3' x 1'-2'	Winter Dieback	Sun/Part Shade	Semi-Wet/Dry
Gregg's Mistflower (<i>Conoclinium gregii</i>)	18"-2' x 2'-3'	Winter Dieback	Sun/Part Shade	Semi-Wet/Semi-Dry/Dry
Mealy Blue Sage (<i>Salvia farinacea</i>)	2'-3' x 2'-3'	Winter Dieback	Sun	Semi-Wet/Semi-Dry/Dry
Black-Eyed Susan (<i>Rudbeckia hirta</i>)	2' x 2'	Winter Dieback	Sun	Wet/Dry
Turk's Cap (<i>Malvaviscus drummondii</i>)	2'-3' x 3'-4'	Winter Dieback	Part Shade/Shade	Wet/Dry
Tall Aster (<i>Symphyotrichum praealtum</i> vaf. <i>Praealtum</i>)	1'-3' x 1'-2'	Winter Dieback	Sun/Part Shade/Shade	Wet/Semi-Wet
Joe Pye Weed (<i>Eupatorium fistulosum</i>)	4' x 2'	Winter Dieback	Part Shade/Shade	Wet/Semi-Wet
Cardinal Flower (<i>Lobelia cardinalis</i>)	2' x 2'-4'	Winter Dieback	Part Shade/Shade	Wet/Semi-Wet

Louisiana Iris (<i>Iris ser. Hexagonae</i>)	3' x 6"	Evergreen/Semi-Evergreen	Part Shade/Shade	Wet/Semi-Wet
Herbaceous Species – Ornamental Grasses				
Common Name (Scientific name)	Size (Height x Spread)	Evergreen or Deciduous	Sun or Shade	Location (Wet or Dry)
'Regal Mist' Gulf Muhly (<i>Muhlenbergia capillaris</i> 'Regal Mist')	2' x 3'	Yes	Sun	Wet/Dry
Lindheimer Muhly (<i>Muhlenbergia lindheimeri</i>)	4'-5' x 3'-4'	Evergreen/Semi-Evergreen	Sun/Part Shade	Wet/Dry
Cherokee Sedge (<i>Carex cherokeensis</i>)	1'-2' x 1'-2'	Evergreen	Part Shade/Shade	Wet/Dry
Emory's Sedge (<i>Carex emoryi</i>)	2' x 2'	Semi-Evergreen	Sun/Part Shade	Wet/Semi-Dry
Inland Sea Oats (<i>Chasmanthium latifolium</i>)	3'-4' x 2'	Yes	Part Shade/Shade	Wet/Semi-Dry
Shrubs				
Common Name (Scientific name)	Size (Height x Spread)	Evergreen or Deciduous	Sun or Shade	Location (Wet or Dry)
Dwarf Yaupon Holly (<i>Ilex vomitoria</i> 'Nana')	3' x 3'	Evergreen	Sun/Shade	Semi-Wet/Dry
Pale Leaf Yucca (<i>Yucca pallida</i>)	1'-2' x 1'-3'	Evergreen	Sun	Wet/Dry
Cast Iron Plant (<i>Aspidistra elatior</i>)	2' x 2'	Evergreen/Semi-Evergreen	Part Shade/Shade	Wet/Dry
American Beautyberry (<i>Callicarpa americana</i>)	4'-6' x 5'-8'	Deciduous	Part Shade/Shade	Wet/Dry
Dwarf Palmetto (<i>Sabal minor</i>)	4' x 5'	Evergreen	Shade	Wet/Dry
Dwarf Wax Myrtle (<i>Morella cerifera</i> var. <i>pumilla</i> or <i>Myrica pusilla</i>)	3' x 3'-5'	Evergreen	Sun/Part Shade	Wet/Dry
Ornamental Trees				
Common Name (Scientific name)	Size (Height x Spread)	Evergreen or Deciduous	Sun or Shade	Location (Wet or Dry)
Redbud var. – 'Oklahoma', Texas, or Mexican (<i>Cercis canadensis</i> var.)	20' x 20'	Deciduous	Sun/Part Shade/Shade	Dry
Reverchon Hawthorn (<i>Crataegus reverchonii</i>)	20' x 15'-20'	Deciduous	Part Sun/Part Shade	Semi-Wet/Dry
Eve's Necklace (<i>Sophora affinis</i>)	30' x 20'	Deciduous	Sun/Shade	Semi-Wet/Dry
Shantung Maple (<i>Acer truncatum</i>)	25' x 20'	Deciduous	Sun/Part Shade	Semi-Wet/Dry

Possumhaw (Deciduous Holly - away from road edges) (<i>Ilex decidua</i>)	15'-30' x 15'-20'	Deciduous	Sun/Part Shade	Wet/Dry
Yaupon Holly (Male by roadways) (<i>Ilex vomitoria</i>)	20' x 20'	Evergreen	Sun/Part Shade/ Shade	Wet/Dry
Yaupon Holly (Female – away from roads) (<i>Ilex vomitoria</i>)	20' x 20'	Evergreen (with berries)	Sun/Part Shade/ Shade	Wet/Dry
Southern Waxmyrtle (<i>Myrica cerifera</i>)	6'-12' x 12'-15'	Evergreen	Sun/Part Shade	Wet/Semi-Wet
Trees				
Common Name (Scientific name)	Size (Height x Spread)	Evergreen or Deciduous	Sun or Shade	Location (Wet or Dry)
Texas Ash (<i>Fraxinus albicans</i>)	30'-40' x 25'-35'	Deciduous	Sun/Part Shade	Semi-Wet/Dry
Slippery Elm (<i>Ulmus rubra</i>)	40'-60' x 30'-50'	Deciduous	Sun	Semi-Wet/Dry
Bald Cypress (<i>Taxodium distichum</i>)	50'-70' x 20'-40'	Deciduous	Sun	Wet/Semi-Dry
Montezuma Cypress (<i>Taxodium mucronatum</i>)	45'-80' x 40'-50'	Evergreen	Sun	Wet/Semi-Wet
Pond Cypress (<i>Taxodium ascendens</i>)	30'-70' x 15'-20'	Deciduous	Sun	Wet/Semi-Wet
Cedar Elm (<i>Ulmus crassifolia</i>)	60' x 30'	Deciduous	Sun	Wet/Dry

4.7.2.8 PLANT LIST 2: DEEP WATER ZONE (18" DEEP TO 6' DEEP)

Plants recommended for Constructed Wetland for water depths ranging from 18" to 6'.

Table 4.7.2.8 Plant List 2

Aquatic Plants	
Common Name	Scientific Name
Yellow Water Lily	<i>Nymphaea mexicana</i>
Fragrant Water Lily	<i>Nymphaea odorata</i>
Spatterdock	<i>Nuphar luteum</i>

4.7.2.9 PLANT LIST 3: AQUATIC BENCH (18" DEEP TO NORMAL WATER LEVEL)

Plants recommended for Aquatic Bench applications for Wet Pond and Constructed Wetland for water depths ranging from 18" to normal water level.

Table 4.7.2.9 Plant List 3

Herbaceous Species - Perennials and Grasses	
Common Name	Scientific Name
Sweetflag	<i>Acrois calamus</i>
Caric Sedge	<i>Carex spp.</i>
Square Stem Spikerush	<i>Elocharis quadrangulata</i>
Swamp Sunflower	<i>Helianthus angustifolius</i>
Halberdleaf Hibiscus	<i>Hibiscus laevis</i>
Soft Rush	<i>Juncus effusus</i>
Rice Cut Grass	<i>Leersia oryzoides</i>
Switchgrass	<i>Panicum virgatum</i>
Green Arum	<i>Peltandra virginica</i>
Smartweed	<i>Polygonum hydropiperoides</i>
Pickerelweed	<i>Pontederia cordata</i>
Pickerelweed	<i>Pontederia lanceolata</i>
Lance-leaf Arrowhead	<i>Sagittaria landifolia</i>
Duck Potato	<i>Sagittaria latifolia</i>
Lizard's Tail	<i>Saururus cernuus</i>
Three-square	<i>Scirpus americanus</i>
Giant Bulrush	<i>Scirpus californicus</i>
Softstem Bulrush	<i>Scirpus validus</i>
Virginia Chain Fern	<i>Woodwardia virginica</i>

4.7.2.10 PLANT LIST 4: WETLAND PLANTS (NORMAL WATER LEVEL TO +6")

Plants recommended for Wet Ponds and Constructed Wetlands for water depths ranging from normal water level to +6" above.

Table 4.7.2.10 Plant List 4

Herbaceous Species - Perennials and Grasses	
Common Name	Scientific Name
Bushy Broom Grass	<i>Andropogon glomeratus</i>
Upland Sea Oats	<i>Chasmanthium latifolium</i>
Dwarf Tickseed	<i>Coreopsis tinctoria</i>
Late Boneset	<i>Eupatorium serotinum</i>
Maximilian Sunflower	<i>Helianthus maximiliani</i>
Halberdleaf Hibiscus	<i>Hibiscus laevis</i>
Spiked Gayfeather	<i>Liatris spicata</i>
Cardinal Flower	<i>Lobelia cardinalis</i>
Cinnamon Fern	<i>Osmunda cinnamomea</i>
Royal Fern	<i>Osmunda regalis</i>
Witchgrass	<i>Panicum capillare</i>
Pickerelweed	<i>Pontederia cordata</i>
Softstem Bulrush	<i>Scirpus validus</i>
Eastern Gamagrass	<i>Tripsacum dactyloides</i>

4.7.2.11 PLANT LIST 5: SEMI-WET ZONE (NORMAL WATER LEVEL TO +4')

Plants recommended for Wet Ponds and Constructed Wetlands for water depths ranging from normal water level to +4' above.

Table 4.7.2.11 Plant List 5

Herbaceous Species - Perennials and Grasses	
Common Name	Scientific Name
Bushy Broom Grass	<i>Andropogon glomeratus</i>
Broom Grass	<i>Andropogon virginicus</i>
Upland Sea Oats	<i>Chasmanthium latifolium</i>
Dwarf Tickseed	<i>Coreopsis tinctoria</i>
Canada Wildrye	<i>Elymus Candensis</i>
Virginia Wildrye	<i>Elymus virginicus</i>
Joe Pye Weed	<i>Eupatorium fistulosum</i>
Late Boneset	<i>Eupatorium serotinum</i>
Texas Bluebells	<i>Eustoma grandiflora</i>
Maximilian Sunflower	<i>Helianthus maximiliani</i>
Halberdleaf Hibiscus	<i>Hibiscus laevis</i>
Spiked Gayfeather	<i>Liatris spicata</i>
Cardinal Flower	<i>Lobelia cardinalis</i>
Turk's Cap	<i>Malvaviscus drummondii</i>
Cinnamon Fern	<i>Osmunda cinnamomea</i>
Royal Fern	<i>Osmunda regalis</i>
Witchgrass	<i>Panicum capillare</i>

Table 4.7.2.11 Plant List 5

Herbaceous Species - Perennials and Grasses	
Common Name	Scientific Name
Pickernelweed	<i>Pontederia cordata</i>
Black-eyed Susan	<i>Rudbeckia hirta</i>
Softstem Bulrush	<i>Scirpus validus</i>
Yellow Indian Grass	<i>Sorgham nutans</i>
Eastern Gamagrass	<i>Tripsacum dactyloides</i>

4.7.2.12 PLANT LIST 6: WOODED VEGETATION (+6" ABOVE NORMAL WATER LEVEL AND UP)

Plants recommended for Wet Ponds, Constructed Wetlands and other BMP features for elevations ranging from +6" above normal water level to 4' that are regularly inundated.

Table 4.7.2.12 Plant List 6

Herbaceous Species - Perennials and Grasses	
Common Name	Scientific Name
Broom Grass	<i>Andropogon virginicus</i>
Canada Wildrye	<i>Elymus Candensis</i>
Virginia Wildrye	<i>Elymus virginicus</i>
Late Boneset	<i>Eupatorium serotinum</i>
Texas Bluebells	<i>Eustoma grandiflora</i>
Maximilian Sunflower	<i>Helianthus maximiliani</i>
Turk's Cap	<i>Malvaviscus drummondii</i>
Witchgrass	<i>Panicum capillare</i>
Black-eyed Susan	<i>Rudbeckia hirta</i>
Yellow Indian Grass	<i>Sorgham nutans</i>
Eastern Gamagrass	<i>Tripsacum dactyloides</i>
Shrubs and Ornamental Trees	
Common Name	Scientific Name
Common Buttonbush	<i>Cephalanthus occidentalis</i>
Possumhaw (Deciduous Holly)	<i>Ilex decidua</i>
Southern Waxmyrtle	<i>Myrica cerifera</i>
Wafer Ash	<i>Ptelea trifoliata</i>
Trees	
Common Name	Scientific Name
Green Ash	<i>Fraxinus pennsylvanica</i>
Bald Cypress	<i>Taxodium distichum</i>
Pond Cypress	<i>Taxodium distichum var. nutans</i>

4.7.2.13 PLANT LIST 7: PERIODICALLY INUNDATED (+4' AND UP)

Plants recommended for Wet Ponds, Constructed Wetlands and other BMP features for elevations ranging from 4' above normal water level and up that are periodically inundated.

Table 4.7.2.13 Plant List 7

Herbaceous Species – Perennials and Grasses	
Common Name	Scientific Name
Common Milkweed	<i>Asclepias syriaca</i>
Buffalograss	<i>Bouteloua dactyloides</i>
Partridge Pea	<i>Chamaecrista fasciculata</i>
Canada Wildrye	<i>Elymus Candensis</i>
Virginia Wildrye	<i>Elymus virginicus</i>
Texas Cupgrass	<i>Eriochloa sericea</i>
Turk's Cap	<i>Malvaviscus drummondii</i>
Halls Panicum	<i>Panicum hallii</i>
Obedient Plant	<i>Physostegia virginiana</i>
Black-eyed Susan	<i>Rudbeckia hirta</i>
Shrubs and Ornamental Trees	
Common Name	Scientific Name
Possumhaw (Deciduous Holly)	<i>Ilex decidua</i>
Yaupon Holly	<i>Ilex vomitoria</i>
Southern Waxmyrtle	<i>Myrica cerifera</i>
Trees	
Common Name	Scientific Name
Pecan	<i>Carya illinoensis</i>
Common Persimmon	<i>Diospyros virginiana</i>
Texas Ash	<i>Fraxinus texensis</i>
Bur Oak	<i>Quercus macrocarpa</i>
Chinkapin Oak	<i>Quercus muhlenbergii</i>
Shumard Oak	<i>Quercus shumardii</i>
Live Oak	<i>Quercus virginiana</i>
Bald Cypress	<i>Taxodium distichum</i>
Pond Cypress	<i>Taxodium distichum</i> var. <i>nutans</i>
Cedar Elm	<i>Ulmus crassifolia</i>
Slippery Elm	<i>Ulmus rubra</i>

4.7.2.14 PLANT LIST 8: INFREQUENTLY INUNDATED

Plants recommended for Constructed Wetlands and other BMP features for elevations that are infrequently inundated.

Table 4.7.2.14 Plant List 8

Herbaceous Species – Perennials and Grasses	
Common Name	Scientific Name
Big Bluestem	<i>Andropogon gerardii</i>
Butterfly-weed	<i>Asclepias tuberosa</i>
Sideoats Grama	<i>Bouteloua certipendula</i>
Buffalograss	<i>Bouteloua (Buchloe) dactyloides</i>
Bermuda Grass	<i>Cynodon dactylon</i>
Texas Cupgrass	<i>Eriochloa sericea</i>
Purple Coneflower	<i>Echinacea purpurea</i>
Green Sprangletop	<i>Leptochola dubia</i>
Texas Gayfeather	<i>Liatris punctata</i> var. <i>mucronatum</i>
Turk's Cap	<i>Malvaviscus drummondii</i>
Witchgrass	<i>Panicum capillare</i>
Texas Bluegrass	<i>Poa arachnifera</i>
Mealy Blue Salvia	<i>Salvia farinacea</i>
Autumn Sage	<i>Salvia greggii</i>
Little Bluestem	<i>Schizachyrium scoparium</i>
White Tridens	<i>Tribens albescens</i>
Shrubs and Ornamental Trees	
Common Name	Scientific Name
Texas Redbud	<i>Cercis canadensis</i> var. <i>texensis</i>
Reverchon Hawthorn	<i>Crataegus reverchonii</i>
Possumhaw (Deciduous Holly)	<i>Ilex decidua</i>
Yaupon Holly	<i>Ilex vomitoria</i>
Southern Waxmyrtle	<i>Myrica cerifera</i>
Trees	
Common Name	Scientific Name
Pecan	<i>Carya illinoensis</i>
Texas Ash	<i>Fraxinus texensis</i>
Bur Oak	<i>Quercus macrocarpa</i>
Chinkapin Oak	<i>Quercus muhlenbergii</i>
Shumard Oak	<i>Quercus shumardii</i>
Live Oak	<i>Quercus virginiana</i>
Bald Cypress	<i>Taxodium distichum</i>
Cedar Elm	<i>Ulmus crassifolia</i>
Slippery Elm	<i>Ulmus rubra</i>
Green Ash	<i>Fraxinus pennsylvanica</i>

4.7.3 MAINTENANCE

Specific knowledge and experience in the establishment and maintenance of the BMP practices and applications within the Dallas-Fort Worth Region requires understanding of our climate, seasons, soils, plants, weeds, and irrigation, along with related products and equipment. Each different practice requires specific maintenance and frequency of maintenance in order to function as designed.

Grasses, perennials, shrubs, trees and aquatic plants shall be protected, maintained and established. Weeding is crucial to remove competitive and invasive plants from seeding, establishing, and choking out the designed plant applications.

Applications of chemical herbicides, fungicides, and pesticides are discouraged due to their detrimental effect on beneficial mycorrhizal fungi and other soil microorganisms that contribute to soil porosity, root health, and adaptation of the plants. Organic materials and methods are preferred.

Additional activities include, but are not limited to, temporary protections, site erosion stabilization, sedimentation removal, maintain the mulch and aggregates, trash collection, testing, inspections, and reporting.

Maintenance		
Activity	Time of Year	Frequency per Year
Tree straightening	Depending on install date	Varies
Tree pruning to provide canopy clearance over walks & visibility sight lines	January, February, March, & December	Varies
Trees – remove dead wood and suckers	As needed	Varies
Trees – remove excess soil from base of tree to expose root flare	As needed	Varies
Trees – treat damage to trunks by vandalism or natural event	As needed	Varies
Trim/ cut back warm season ornamental grasses to 1/3rd plant height & remove cuttings	February	0.5 – every 2 years
Lindheimer's Muhly – comb & pull dried seed stalks by hand with rubber gloves yearly; only cut back to 1/3rd overall plant height every 3 years	February February	1 0.3 – every 3 years
Trim / cut back sedge to 1/3rd plant height & remove cuttings	September	0.5 – every 2 years
Trim spent yucca blooms & remove dead lower foliage if it easily releases or pulls out	Varies per species	1
Dead head perennials – pick prune by hand or with pruning tools and remove cuttings - Bioretention basins (publicly visible)	As needed	Varies
Trim back dead stalks of perennials after plant becomes dormant to 6 inch height – Bioretention basins (publicly visible)	October, November, December	Varies
Pick prune all shrubs to maintain natural character – no shearing or topping	As needed	Varies
Repair & restore erosion protection to allow plant establishment	As needed	Varies
Replace dead plants & reseed to retain soils	As needed	Varies
Mowing of grasses and perennials to no less than 6 to 8 inch height	January and July	2

Maintenance		
Activity	Time of Year	Frequency per Year
<i>Remove all debris, trimmings, fallen branches, leaves & thatch to prevent clogging of system</i>	As needed	Varies
<i>Applications & treatments with organic: insecticides, herbicides & fungicides</i>	April and July	2
<i>Ant control – organic herbicide</i>	As needed	8
<i>Apply organic biological fertilizer – Bioretention basins only</i>	March and October	2
<i>Remove decomposed mulch around outlet drains & catch basins</i>	March and October	2
<i>Apply mulch to maintain a full 3 inch depth to help control weeds – Bioretention basins & mulch dependent features</i>	March and October	2
<i>Refresh, topdress, & remove sediment & debris from surface</i>	March and October	2
<i>Clean & remove sediments from energy dissipation & media barriers</i>	June	1
<i>Irrigation inspection & repair</i>	As needed	Varies
<i>Remove litter</i>	Weekly	52
<i>Snow, Ice & Sand removal from curb openings & forebays after ice storm event</i>	As needed	1
<i>Hydraulic Conductivity Test – at base of exposed media around and adjacent to outlet drains & catch basins</i>	March	1
<i>Inspection with Owner /3rd Party/Landscape Architect for inspection of systems pertaining to applications/maintenance</i>	March	1
<i>Reporting</i>	March	1

DESIGN SUBMITTAL REQUIREMENTS CHECKLIST

- Planting plans, schedules, details, and specifications to be designed specific to each BMP feature or basin by a professional landscape architect licensed in the State of Texas
- Planting plan to reflect application extents of different seed mixes per elevations related to normal water level, or for BMP features that do not retain water
- Plant schedule for BMP feature specifying types, species, sizes, spacing and locations of different plants, seed mixes, topdressing mulch, and aggregate/gravel/river rock surfacing.
- Details for planting and stabilizing plants below water level and on slopes
- Specifications for planting bed soil preparation for each different seed mix or plant type bed depth. Refer to Section 4.5.1 for information about compost and expanded shale. Additional materials and treatments to be included in the specifications are noted below, but are not exhaustive:
 - Soil compaction remediation
 - Topsoil
 - Topdressing – Mulch
 - Topdressing at BMP entry - Aggregates/Gravel/River rock

- Applications of organic herbicides, fungicides and fertilizer due to runoff issues with chemical fertilizers and detrimental effect to soils
- Bioretention Soil Mix refer to Section 4.5.1 Bioretention or Engineered Soil.
- Irrigation plan for both temporary establishment and permanent systems for each BMP feature or basin designed by an irrigation consultant licensed in the State of Texas
- Plant palette designs and specifications outside the parameters of this guideline shall be reviewed and approved by a licensed Professional Engineer and submitted to TRWD for review.

ADDITIONAL RESOURCES

- ¹ American Standard for Nursery Stock, Edition approved May 12, 2004 by American Nursery and Landscape Association (ANSI Z60.1-2004) – plant materials.
- ² Hortus Third, 1976 – Cornell University – plant nomenclature.
- ³ iSWM Technical Manual. April 2010, revised September 2014. Landscape and Aesthetics Guidance.
- ⁴ Seed Certification. Texas Department of Agriculture - Licenses and Registrations, 2017.
- ⁵ Seed Testing. Association of Official Seed Analysts – AOSA Rules for Testing Seeds, updated 2014.

4.8 OUTLETS/PIPING

DESCRIPTION

Piping primarily consists of PVC or HDPE components and appurtenances with the purpose of controlling stormwater conveyance into and out of the BMP and/or providing access to or observation of other BMP components. BMP piping and outlet components include underdrains, distribution pipes, cleanouts, observation wells, anti-seep collars, and utility sleeves.

WHERE TO USE

Piping and outlet component use depends on the primary intended function such as to convey, access, monitor, or protect the BMP or adjacent utilities. Underdrains and distribution pipes are in the subsurface layers of the BMP to regulate the conveyance of stormwater in or out of the BMP facility. Cleanouts and observation wells provide access from the surface of the BMP facility to the below grade piping and/or media in order to maintain or monitor. Anti-seep collars and utility sleeves are used to prevent exfiltration of stormwater at the edge of the BMP facility or protect existing utilities adjacent to or through the BMP. Outlets are used to provide controlled release of the design volume or allow overflow/bypass of larger stormwater flows out of the BMP.

DESIGN CONSIDERATIONS

- Underdrains to facilitate stormwater outflow from the BMP facility are recommended for all sites with underlying soil infiltration rates less than 0.5 inches per hour. If a BMP is a function of infiltration, the designer must conduct subsurface soil investigation to determine the soil characteristics for BMP design and drainage system needs. A minimum of two geotechnical borings should be performed per BMP site to determine the NRCS soil textural classification and infiltration rate⁴.
- Underdrain or distribution piping shall be sized to convey at a minimum the water quality volume into or out of the BMP. A minimum slope of 0.5 percent should be used to maintain positive drainage and mitigate sediment buildup in the pipe.
- Outflow rate should be calculated based on BMP capacity, required drawdown rate, and target water quality volume.
- Outflow control devices, such as valves, orifice plates, upturned elbows or weirs, are highly recommended within underdrain piping and outlets to maximize the treatment capacity of the BMP.
- An overflow or bypass path must be identified to address stormwater flows in excess of the design. Outlets may be used as part of this overflow control.

DETAILS

4.8.1 UNDERDRAIN

Underdrains are perforated pipes used to intercept, collect, and convey stormwater from the storage or subsurface layers of a BMP. Underdrains must meet the following parameters, see detail DM-DC 4.8.1 for additional design information:

- BMPs that use infiltration as a function the BMP facility shall include underdrains unless results of infiltration testing show that in situ soils are adequate for infiltration within the required drawdown time of the BMP. Drawdown times for infiltration BMPs shall be no longer than 48 hours.
- All underdrains shall be capable of withstanding the expected loading applied above it, including vehicular or pedestrian loading for underground BMPs.
- Underdrains shall be capable of exceeding the drainage capacity of the soil media layers of the BMP system.
- Sites expected to produce greater fines in runoff or in planting soil should use an aggregate permeable media barrier (Section 4.6) between the BMP media and the underdrain aggregate. Bedding and filter aggregate shall be double washed prior to installation to reduce suspended solids and the potential for clogging.
- Perforations for underdrains shall be based on the allowable storage aggregate size (Section 4.5.3). Perforated pipes shall at a minimum meet the following sizes as shown in **Table 4.11**.

Table 4.11 Sizing Perforated Pipes

Allowable Storage Aggregate Size	Maximum Hole Diameter (in)	Open Area (per ft)
No. 56	3/8	1.98 in ²
No. 57	3/8	
No. 67	1/4	
No. 3	7/8	

4.8.2 CLEANOUT

Cleanouts are vertical pipes extending from subsurface piping to the surface of the BMP that provide access to piping for inspection, maintenance, and cleaning. If cleanouts are placed within a ponding area, at least one cleanout shall extend out of the filter bed to be accessible even if the pond is full. See detail DM-DC 4.8.2 for additional design information.



Photo Credit: CDM Smith

4.8.3 OVERFLOW RISER

Overflow risers are components used to provide a safe release of excess flows greater than the water quality volume or to facilitate a faster drawdown time for larger stormwater events from a BMP facility. Overflow risers typically consist of a vertical riser pipe or structure with a grated lid located within a BMP facility to allow overflow of stormwater runoff above the design ponding elevation to the existing BMP. Grated inlet risers should be sized assuming 50% clogging at the entry. See detail DM-DC 4.8.3 for additional design information.



Photo Credit: CDM Smith

4.8.4 MULTI-STAGE OUTLET STRUCTURE

Multi-stage outlet structure is a component similar to the overflow riser but should be applied to larger centralized BMPs that can be utilized to control stormwater volumes and rates in excess of water quality requirements. The outlet structure should provide a safe and controlled release of excess flows greater than the water quality volume or to facilitate a faster drawdown time for larger stormwater events from a BMP facility. Multi-stage outlet structure typically consists of a trash rack, orifice, and BMP maintenance drain. Depending on the type of BMP, an underdrain (Section 4.8.1) may be a necessary component. See detail DM-DC 4.8.4 for additional design information.



Photo Credit: CDM Smith

4.8.5 OBSERVATION WELL

Observation wells consist of vertical slotted piping that extends through the BMP media layers and allows for measurement of the sub-surface water level to evaluate infiltration performance of the BMP. Observation wells are recommended for all BMP facilities that are designed for infiltration and/or storage. See detail DM-DC 4.8.5 for additional design information.

4.8.6 ANTI-SEEP COLLAR

An anti-seep collar is used to prohibit exfiltration of stormwater laterally along piping from the BMP toward adjacent utilities or surrounding subgrade. Anti-seep collars are installed on both upstream and downstream ends of utility sleeves (Section 4.8.7) or on BMP piping transitioning from perforated to solid pipe that passes through the edge of the BMP facility. Typical anti-seep collars consist of a collar, clamp, and/or bands connected to and surrounding the pipe. See detail DM-DC 4.8.6 for additional design information.

4.8.7 UTILITY SLEEVE

Utility sleeves are components used to protect existing utilities from exfiltration of stormwater from the BMP toward the adjacent utility or to protect the BMP from the utility service. Utility sleeves typically consist of solid PVC or HDPE piping installed over utility piping or other service piping that passes through or is directly adjacent to the BMP facility. It is recommended to avoid locating utilities within the extents of the BMP. When possible, a utility should be removed and relocated outside of the BMP footprint. See detail DM-DC 4.8.7 for additional design information.

DESIGN SUBMITTAL REQUIREMENTS CHECKLIST

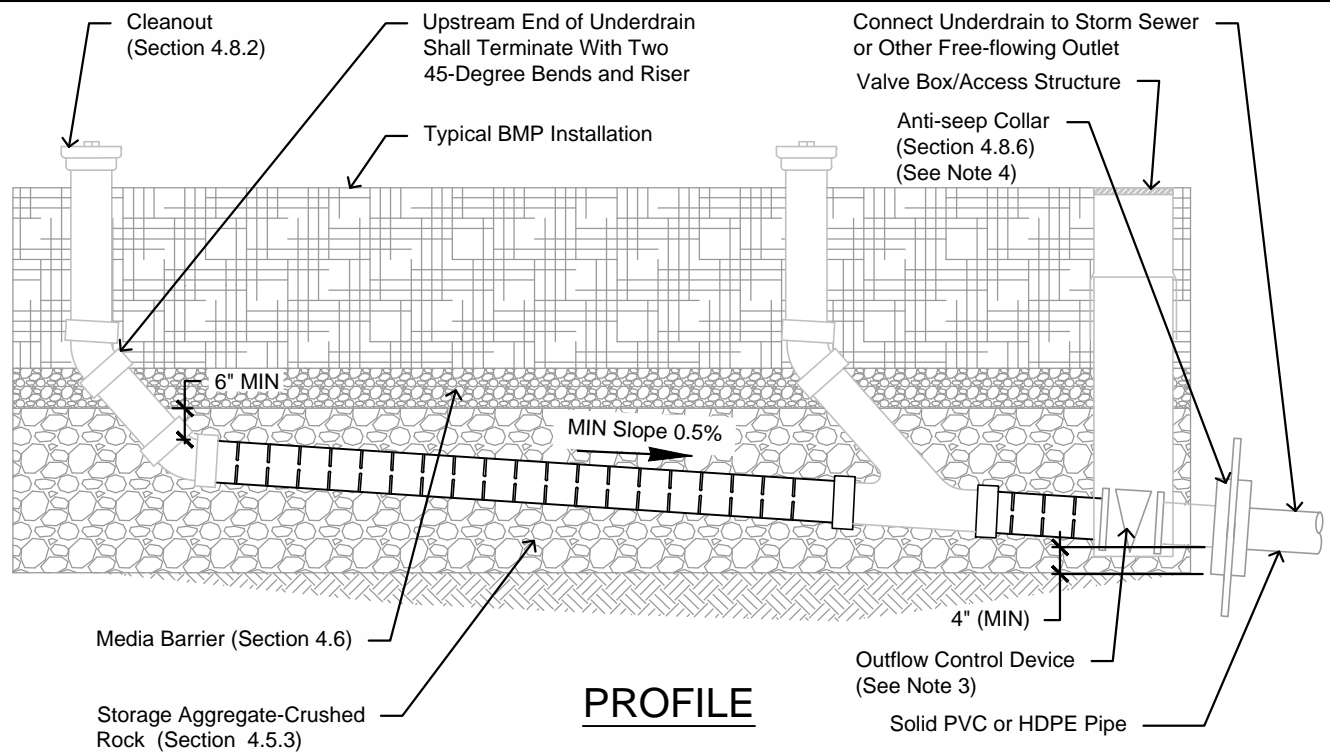
- Pipe sizing, design flow rates, maximum flow rates, and minimum and maximum velocity calculations.
- Plan view of piping component placement within the BMP, including northing/easting, RIM and invert elevations, and stationing, as applicable. Outlets should include grading and spot elevations to determine drainage and overflow pathways and verify that overflow discharge will not damage adjacent property or structures.
- Cross-sectional view of piping component, including details of all materials, fittings, required depths, and offset dimensions.
- Manufacturer details, including product number, materials, painting specifications, and fastener and frame, as applicable.
- Detail of existing drainage system connection or outlet and discharge control mechanisms used.
- Design calculations for flows and velocities entering and discharging from piping and outlet components.
- A plan view of the BMP facility showing all overflow pathways and elevations, confirming that overflows are maintained on public property and do not flow onto private property or into any structure.

Piping and Outlet component designs and specifications outside the parameters of this guideline shall be submitted for review and approval by a licensed PE.

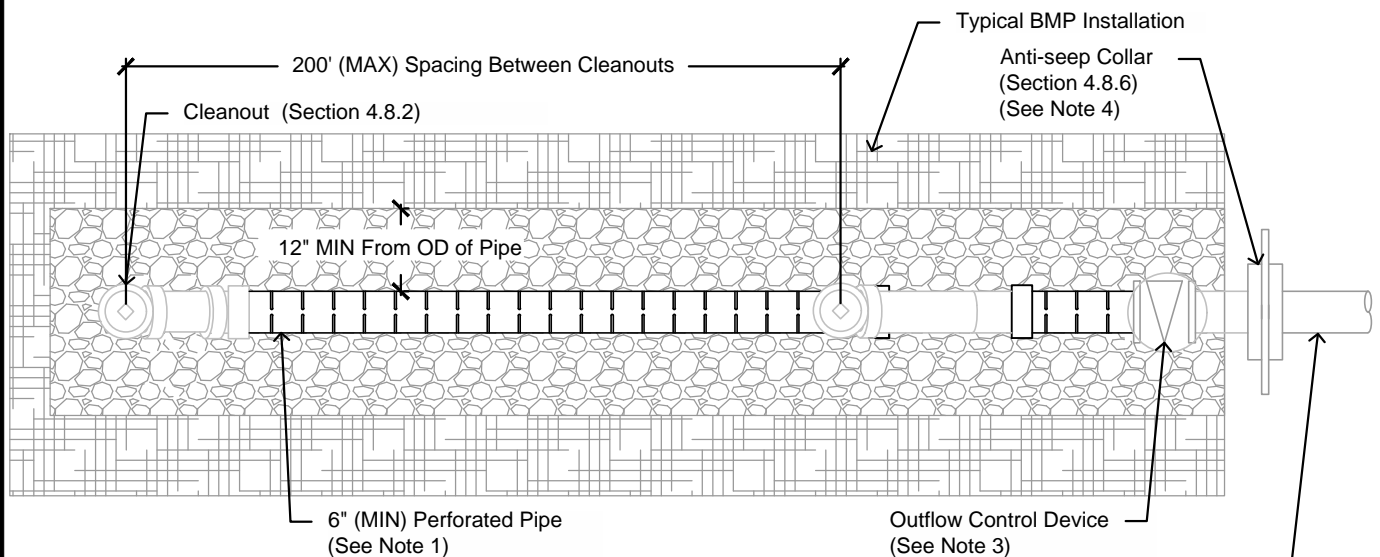
ADDITIONAL RESOURCES

DM-DC DRAWING RESOURCES

- City of Fort Worth. December 20, 2016. Standard Construction Specification Documents. Section 33 46 00 Subdrainage.
- City of Fort Worth. December 12, 2016. Standard Construction Specification Documents. Section 33 05 10 Utility Trench Excavation, Embedment and Backfill.
- City of Fort Worth. June 19, 2013. Standard Construction Specification Documents. Section 33 31 20 Polyvinyl Chloride (PVC) Gravity Sanitary Sewer Pipe.
- City of Fort Worth. August 31, 2012. Standard Construction Drawings. Detail D416 – Concrete Pipe Collar.
- North Central Texas Council of Governments. September 2014. iSWM Technical Manual. Site Development Controls.



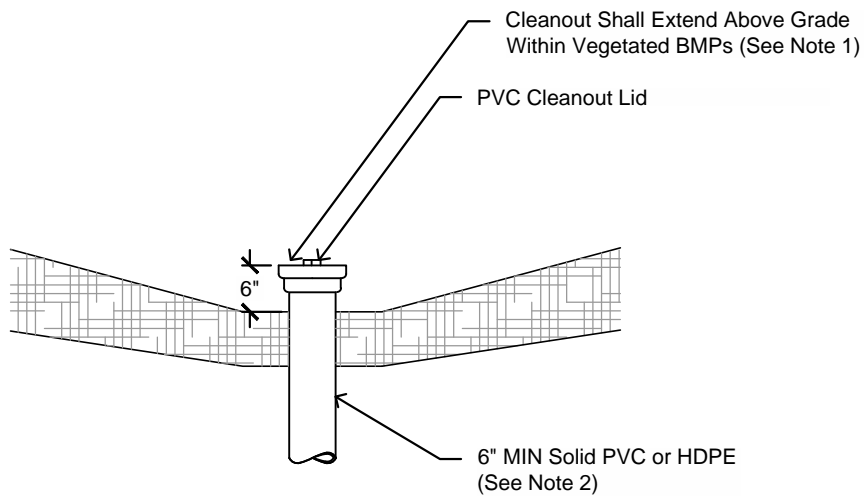
PROFILE



PLAN

Notes

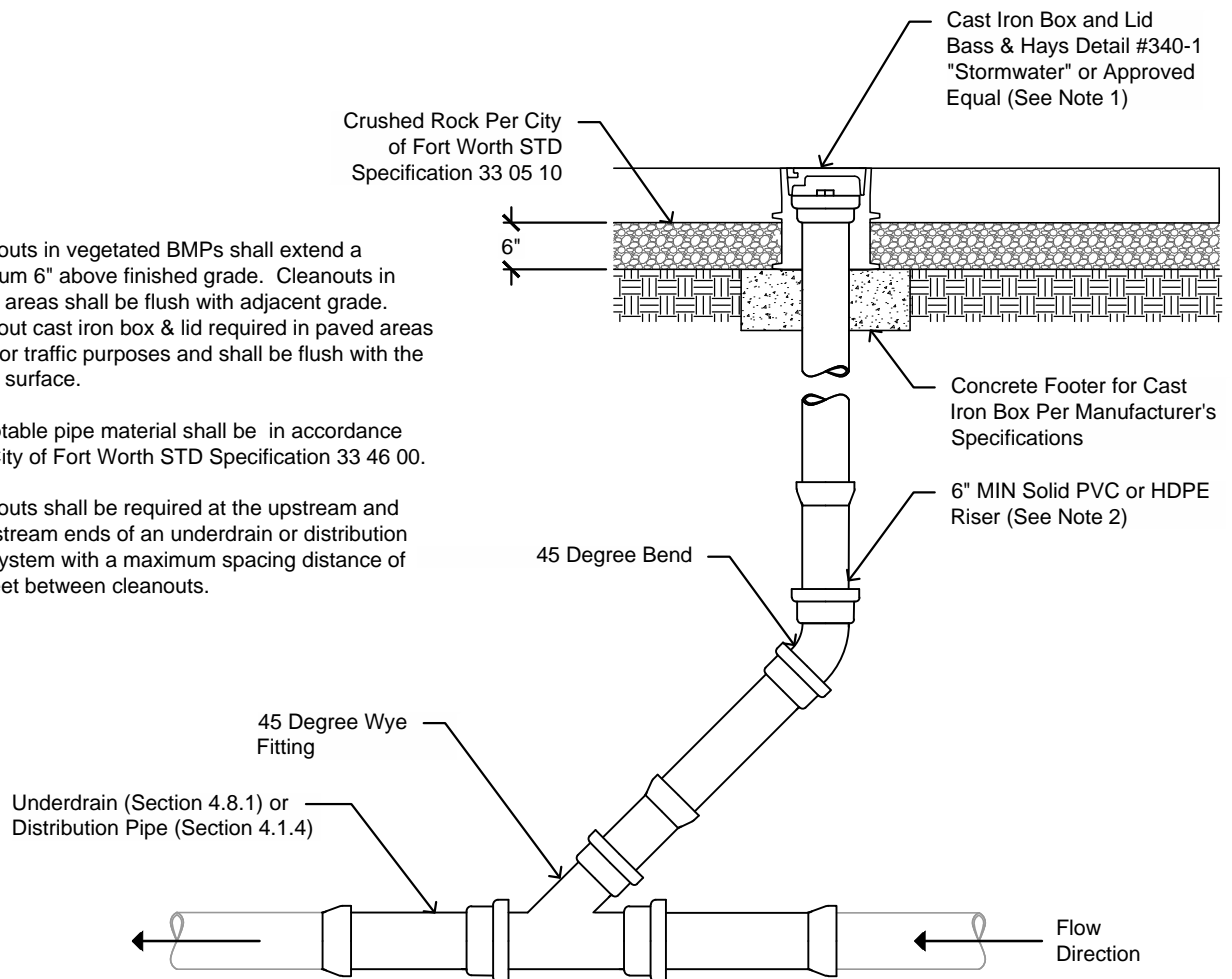
1. Acceptable pipe materials shall be in accordance with City of Fort Worth STD Specification 33 46 00.
2. Lateral or parallel underdrains may be installed if necessary depending on size and slope of BMP. Intersecting underdrains shall be installed such that flow enters the pipe in the downstream direction.
3. A flow control mechanism such as a valve, orifice, or upturned elbow is highly recommended to be installed on the downstream end of underdrains to control discharge from the BMP.
4. Anti-seep collar should be completely free of bedding.



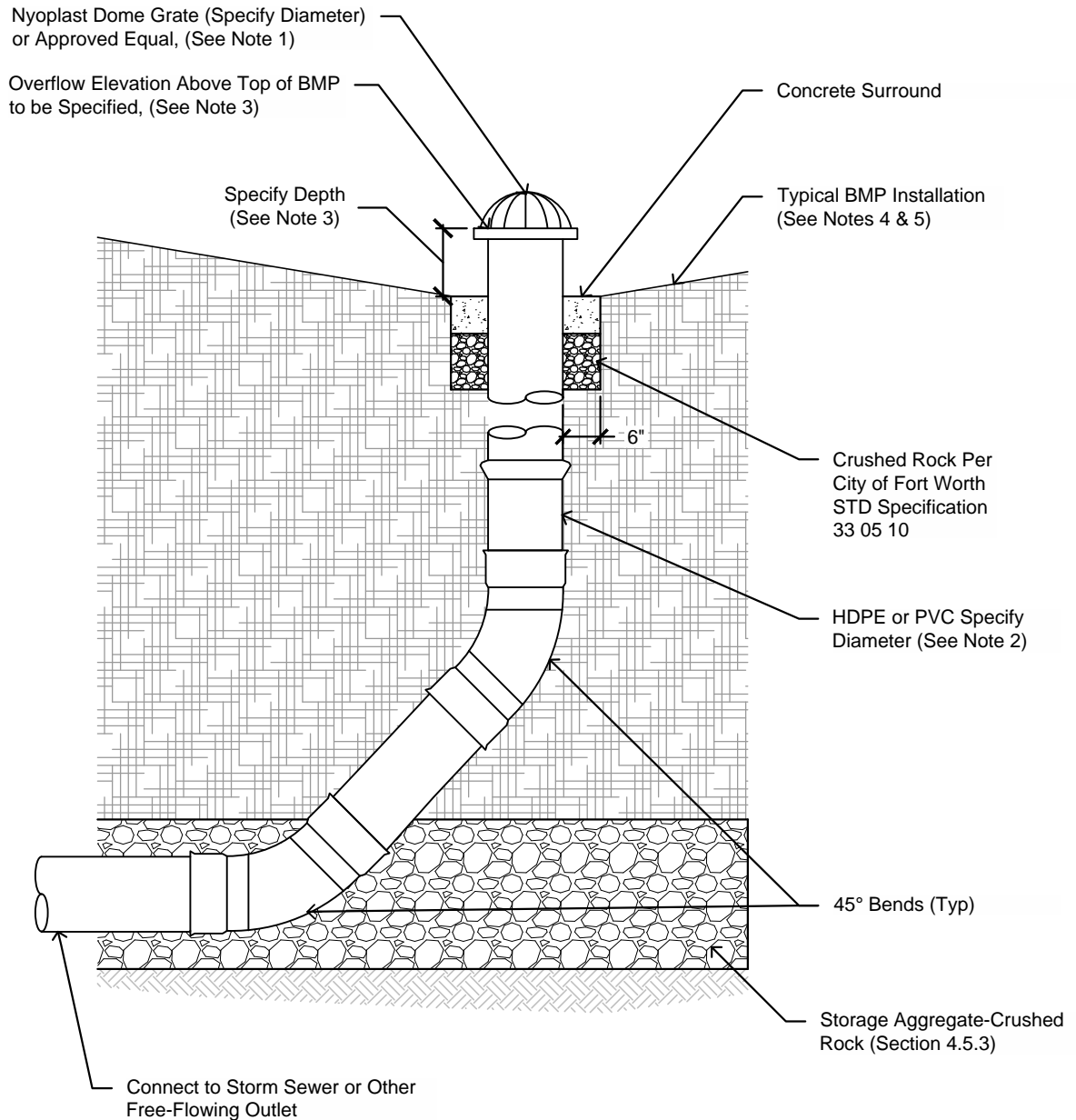
CLEANOUT IN SOIL

Notes

1. Cleanouts in vegetated BMPs shall extend a minimum 6" above finished grade. Cleanouts in paved areas shall be flush with adjacent grade. Cleanout cast iron box & lid required in paved areas used for traffic purposes and shall be flush with the paved surface.
2. Acceptable pipe material shall be in accordance with City of Fort Worth STD Specification 33 46 00.
3. Cleanouts shall be required at the upstream and downstream ends of an underdrain or distribution pipe system with a maximum spacing distance of 200 feet between cleanouts.



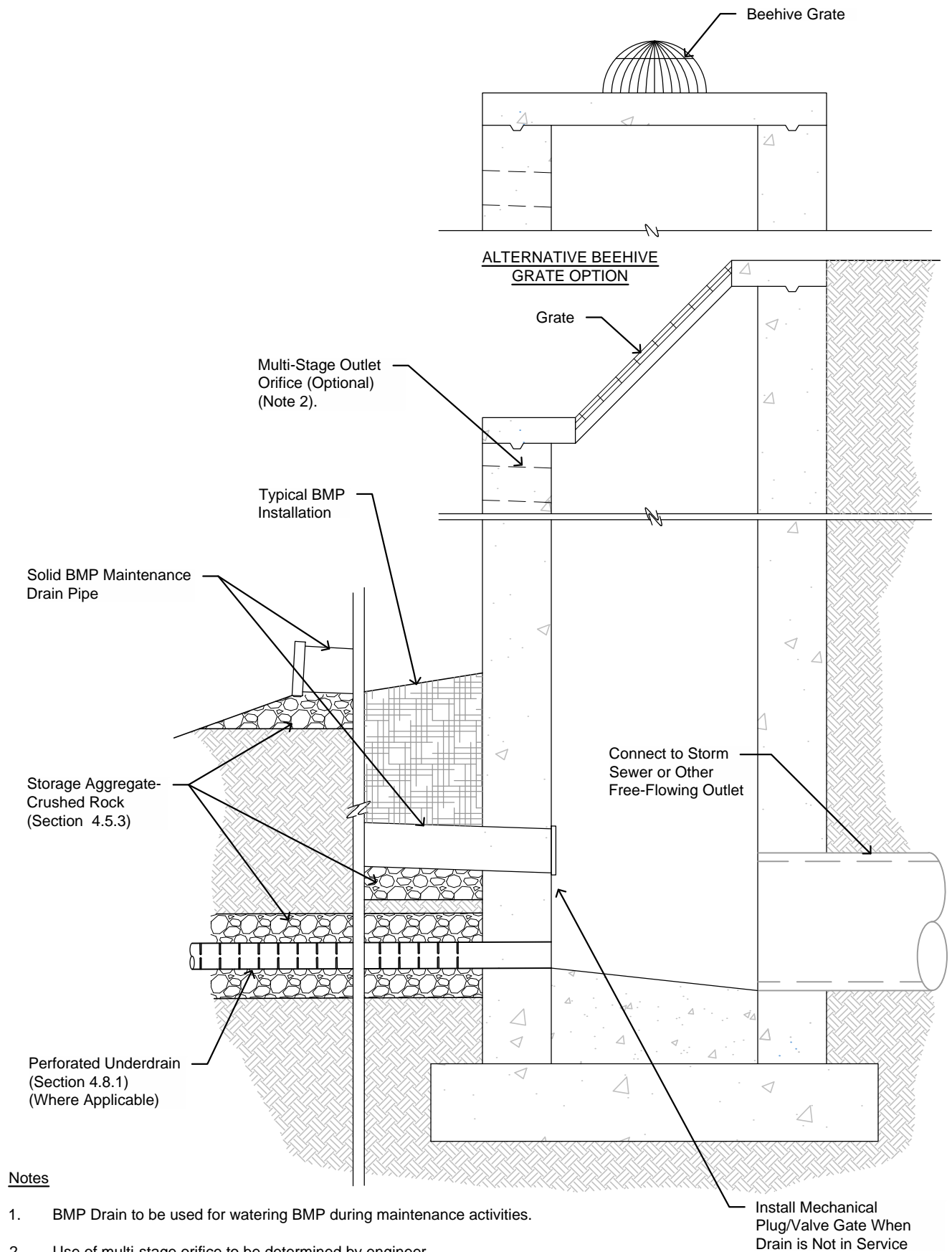
CLEANOUT IN PAVED SURFACE



SECTION

Notes

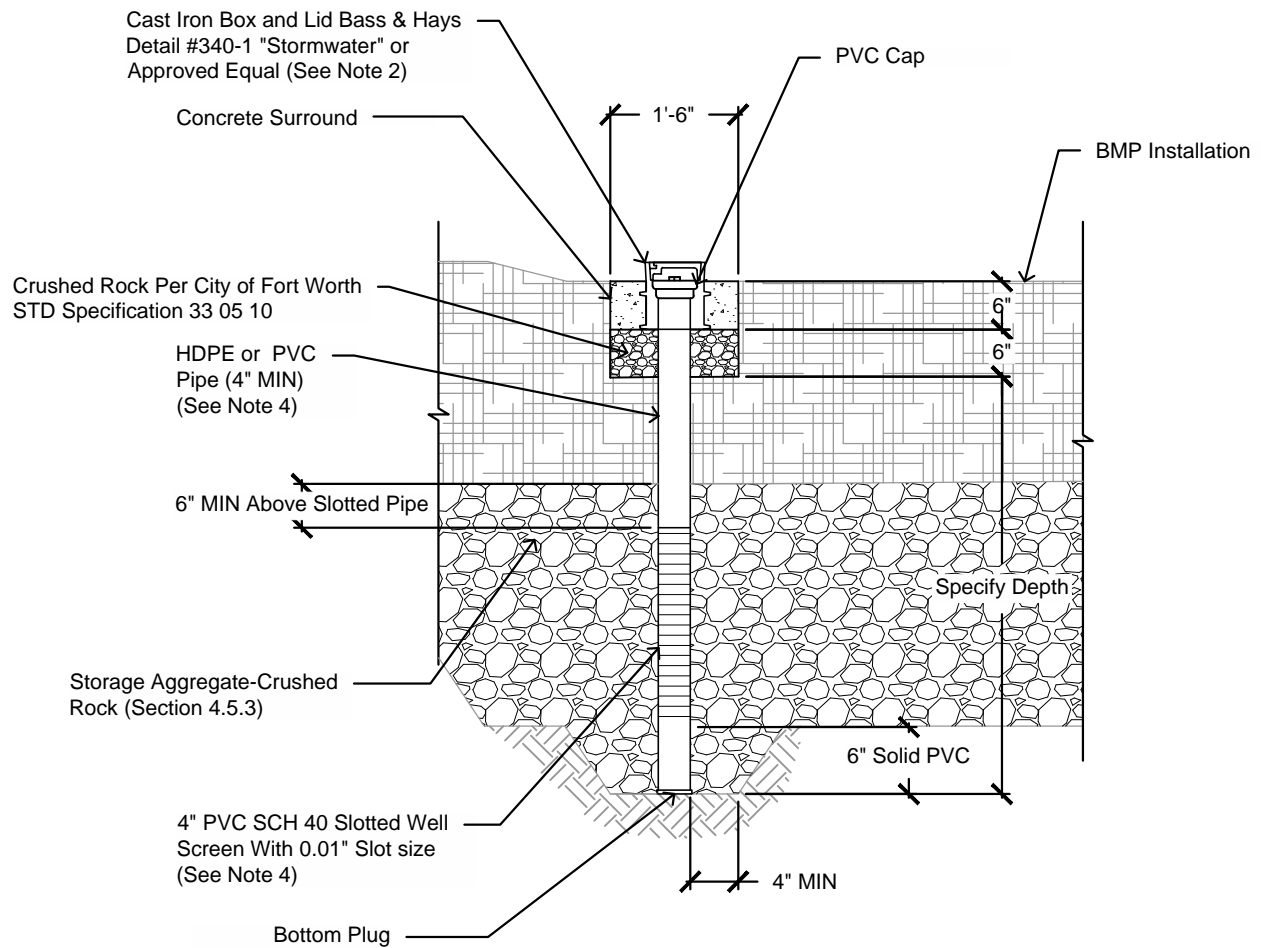
1. Nyoplast Drain Basin or equal is an acceptable alternative to standpipe overflow. Bedding and anchoring details shall be per manufacturer requirements.
2. Riser piping shall be made of soil tight seals and fittings and conform to City of Fort Worth STD Specification 33 31 20.
3. Overflow elevations shall be set at or above design ponding height such that overflow occurs only as necessary to prevent flooding of BMP facility and surrounding area.
4. Vegetation placed in the vicinity of the outlet shall maintain a minimum distance of 12-inches to prevent plant debris from clogging the structure.
5. Surface of the BMP shall be graded for positive drainage towards the outlet.



Notes

1. BMP Drain to be used for watering BMP during maintenance activities.
2. Use of multi-stage orifice to be determined by engineer.

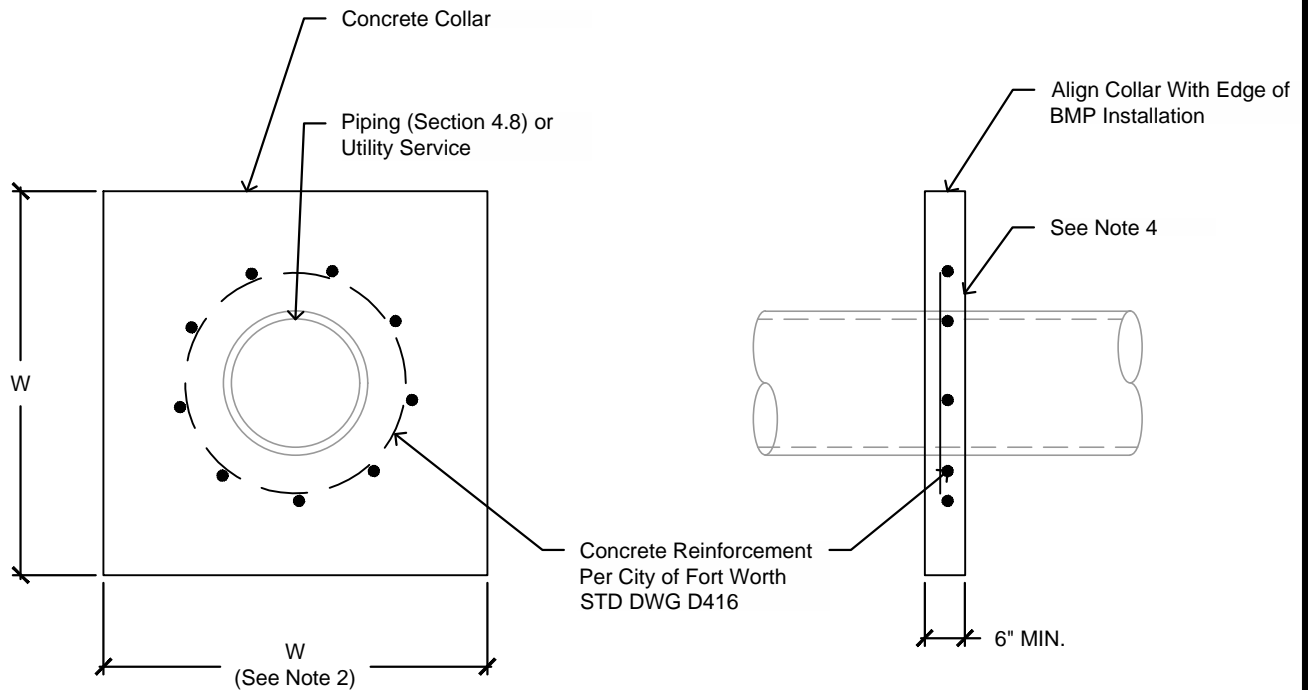
SECTION



SECTION

Notes

1. If the observation well is located within a parking area, then it shall be flush with the paved surface. Not recommended to place observation wells in areas with high vehicular traffic due to safety concerns.
2. Well covers shall be secured in concrete surround if not secured in pavement surface restoration. Well covers in pavement shall be flush with finished grade.
3. Area surrounding well shall be restored in kind with the adjoining area. Any geotextile filter fabric penetrated during installation shall be cut and wrapped to a height of 6" upward along the solid well section.
4. Larger piping material may be required to accommodate need for monitoring or data recording equipment.

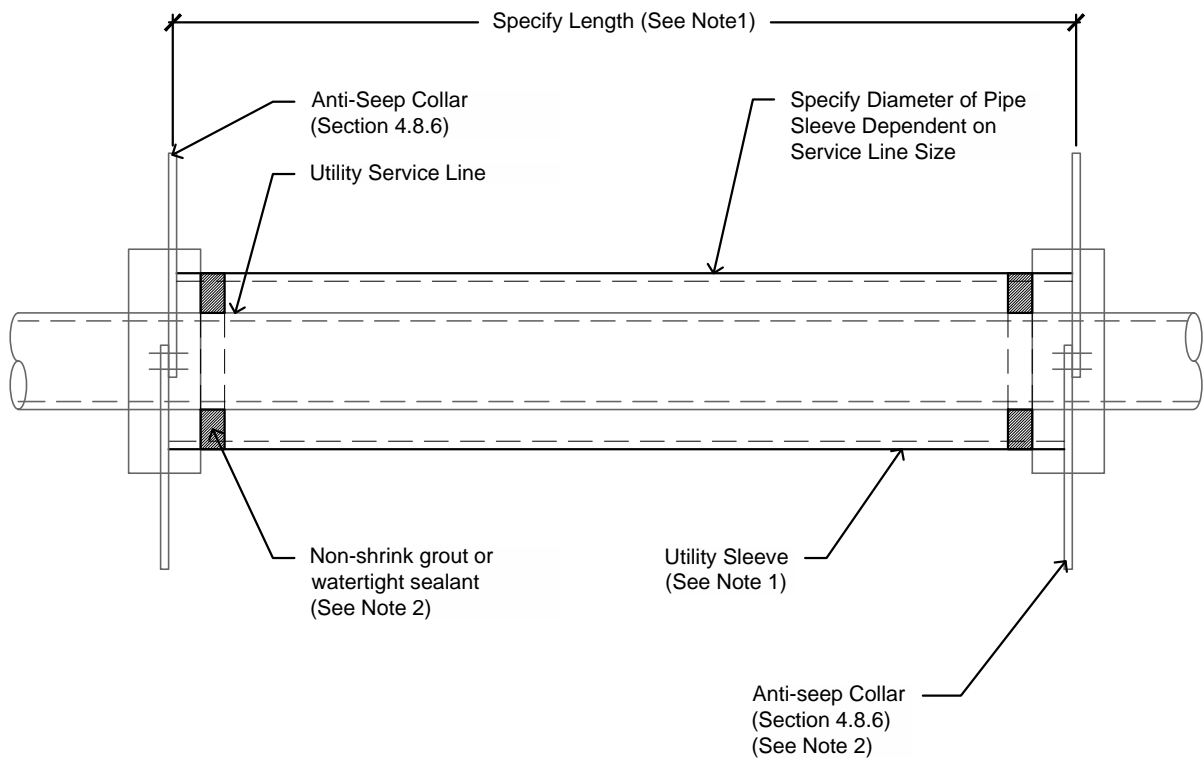


ELEVATION

SECTION

Notes

1. Anti-seep collars used in conjunction with Utility Sleeves (Section 4.8.7) shall be installed on the upstream and downstream end of the piping at each edge of the BMP facility. Anti-seep collars and Utility sleeves shall also be installed on all utility piping joints, bends, and splices that are within the BMP.
2. 'W' shall be 3' for pipes 12" and smaller.
3. Collar shall be constructed of 4000 psi compressive strength concrete or other material providing watertight connection compatible to pipe, as approved by a PE and reviewed by the TRWD.
4. Geomembrane Liner (Section 4.6.4) shall be used where anti-seep collars are required on vertical sides of the BMP. Liners shall be minimally cut to allow for the collar and sealed with the external sheets of the anti-seep collar.
5. All fittings and seals to be installed and tested to a water-tight seal per manufacturer specifications.
6. Hydrophilic water stops may be an allowable substitute for anti-seep collars for situations where the utility or other piping passes through a concrete structure.



PROFILE

Notes

1. Length of required utility sleeve dependent on type of utility service and location within or adjacent to the BMP.
2. Seal surface of utility, utility sleeve and anti-seep collar (if necessary) with non-shrink grout or other sealant.
3. Anti-seep collars (Section 4.8.6) used in conjunction with utility sleeves shall be installed on the upstream and downstream end of the piping at each edge of the BMP facility. Anti-seep collars and Utility sleeves shall also be installed on all utility piping joints, bends, and splices that are within the BMP.

4.9 PERMEABLE SURFACES

DESCRIPTION

Permeable surfaces essentially function as inlets, collecting stormwater runoff that sheet flows from the surrounding area and allows it to infiltrate through the surface of the permeable pavement system and into the BMP media layer. Allowable permeable pavement systems include permeable pavers and porous pavers. Permeable asphalt is not an allowable permeable pavement system because this system is a developing practice that presents significant challenges during manufacturing and construction that can result in inconsistent performance.

WHERE TO USE

Permeable surfaces could be considered in all areas where traditional concrete would be used, including, but not limited to sidewalks, street parking, and parking lots. In this type of application, the permeable surface infiltrates stormwater where it can be collected and conveyed subgrade to the BMP facility.

DESIGN CONSIDERATIONS

- Permeable surfaces should not be implemented in areas where significant sedimentation or organic matter, such as nuts and leaves, is expected to accumulate.
- Permeable surfaces should be located downgradient and maintain a minimum distance of 10-feet from buildings and 50-feet from drinking water wells¹.
- Permeable surfaces should be designed to collect sheet flow. Concentrated or point loading of stormwater runoff is not recommended.
- Underdrains (Section 4.8.1) shall be installed with all permeable surfaces used as an inlet. Underdrains shall be shown on the project's design drawings.

DETAILS

4.9.1 PERMEABLE PAVERS

Permeable pavers are solid, interlocking paving comprised of standard concrete or clay pavers that allow water to flow through joints between the individual paving units. The joints can be filled with open-graded, small aggregate or left open to allow for higher infiltration rates and ease of maintenance. Pavers can come in various shapes, sizes, finishes, and colors. See detail DM-DC 4.9.1 for additional information.



4.9.2 POROUS PAVERS

Porous pavers are typically comprised of cellular grid systems filled with porous material such as grass, sand, sand, or gravel. Stormwater is able to both infiltrate through and be stored in the porous material. The type of cellular grid system is dependent on vehicular or pedestrian usage. The grid systems are proprietary technology and require specific aggregate gradations to fill the grid system. TrueGrid® or approved comparable device are acceptable porous pavers. All products to be used for porous pavers will require approval by a licensed PE.

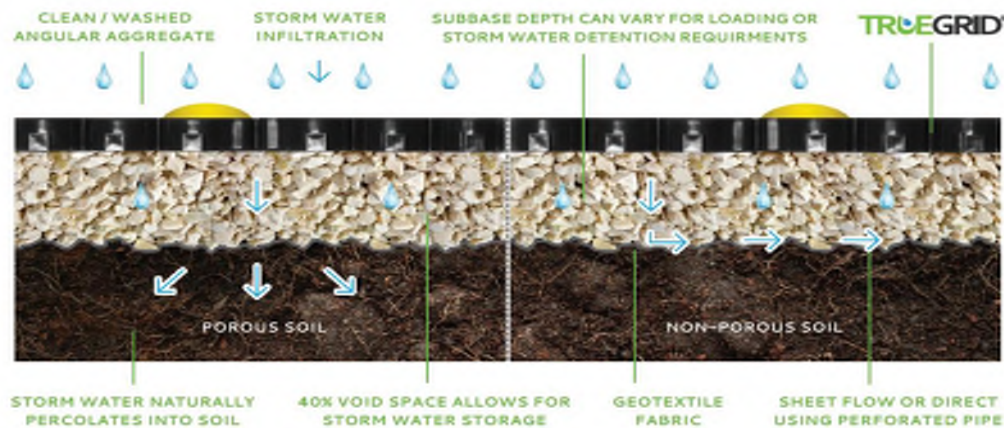


Photo Credit: TrueGrid®

DESIGN SUBMITTAL REQUIREMENTS CHECKLIST

Design submittal requirements checklist may be applicable to all or some of the inlet components:

- Plan and detail view of permeable surfaces, including northing/easting of pavement extents, total surface area of permeable surface, and grading showing longitudinal slopes, cross slopes, and transition to adjacent grade.
- Typical detail of permeable surface layout pattern, if applicable.
- Calculation summary sheet for allowable sheet flows onto permeable surface area.
- Manufacturer information, including product number, materials, painting specifications, and fastener and frame details, as applicable.
- Approval of the fire department/emergency services if proposed in a fire lane area.

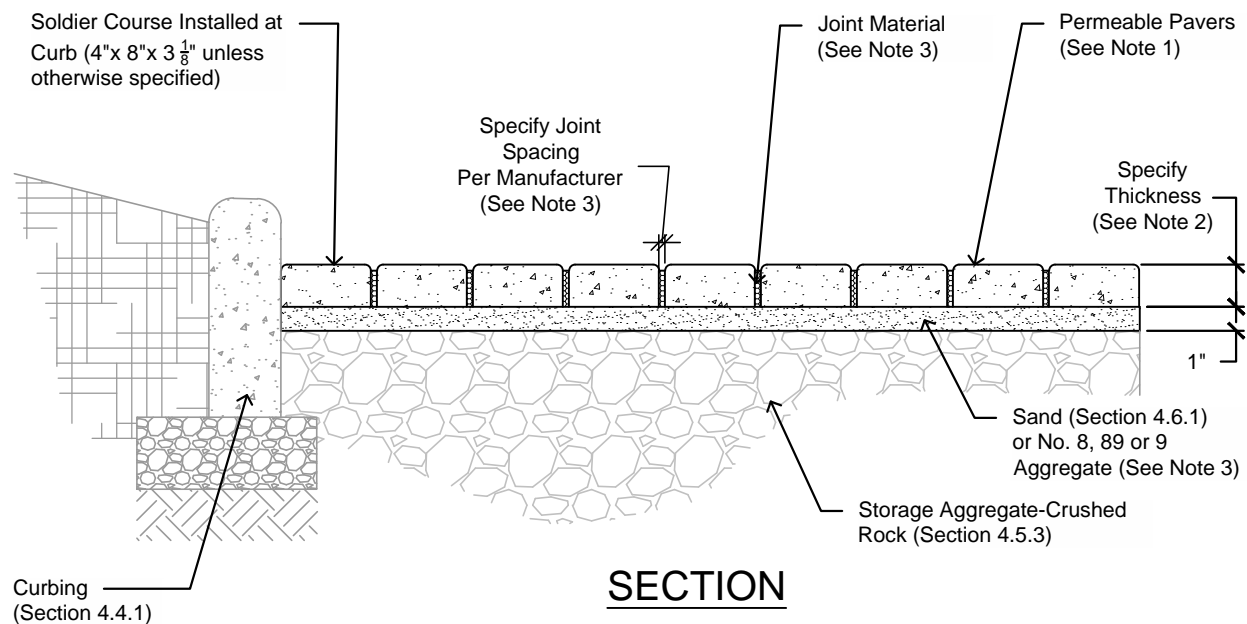
Component designs and specifications outside the parameters of this guideline shall be reviewed and approved by a licensed PE and submitted to TRWD for review.

ADDITIONAL RESOURCES

- ¹ North Central Texas Council of Governments. September 2014. iSWM™ Technical Manual. *Site Development Controls*.
- ² Porous pavers. TrueGrid®. Accessed August 2017. www.truegridpaver.com.

DM-DC DRAWING RESOURCES

- American Society of State Highway and Transportation Officials. AASHTO HS-20 Loading.
- American Society for Testing and Materials International. 2016. C936 Standard Specification for Solid Concrete Interlocking Paving Units.
- American Society for Testing and Materials International. 2016. C1272 Standard for Heavy Vehicular Paving Brick.
- Texas Department of Licensing and Regulation. March 15, 2012. 2012 Texas Accessibility Standards.
- City of Fort Worth. December 12, 2016. Standard Construction Specification Documents. Section 33 05 10 Utility Trench Excavation, Embedment and Backfill.
- City of Fort Worth. December 20, 2012. Standard Construction Specification Documents. Section 32 14 16 Brick Unit Paving.
- Kevern, J. Pervious Concrete Mix Designs. Accessed: May 2, 2017. Web address: http://www.concretepromotion.com/pervious_mix_design.html.
- Texas Commission on Environmental Quality. November 2015. Rules and Regulations for Public Water Systems.



Notes

1. Permeable Paver material shall be either brick paver per City of Fort Worth STD Specification 32 14 16 or permeable interlocking concrete paver per ASTM C936. All pavers shall be laid in an interlocking pattern for increased stability. Attention shall be paid to joint material to ensure uniform spacing is achieved for application that do not use interlocking pavers.
2. Thickness of brick paver shall be a minimum of 2.25" unless specified per City of Fort Worth STD Specification 32 14 16. Thickness of a permeable interlocking concrete paver shall be dependent on usage (minimum of 2.75" for vehicular use and 2.25" for pedestrian use).
3. Joint material shall either be sand per Section 4.6.1 or No. 8, 89, or 9 per ASTM C33. For interlocking concrete paver systems, open joints with no jointing material may be acceptable per manufacturer requirements. Open joints shall not exceed 1/2" openings per Texas Accessibility Standards.
4. Pavers shall have chamfered edges.
5. See Section 3 for full pavement section requirements for permeable pavers.



TRWD WATER QUALITY MANUAL

PLANNING AND IMPLEMENTING STORMWATER QUALITY PRACTICES

SECTION 5

Water Quality Requirements Specific to Zone 1 (Panther Island)

5.1 INTRODUCTION AND BACKGROUND

To cost-effectively meet water quality goals from stormwater runoff originating from Panther Island, TRWD is requiring revised procedures for selecting and implementing water quality practices in Zone 1 (maps of which are included in Appendix F). The Panther Island form-based code implemented by the City of Fort Worth is designed to provide for high-density, mixed use developments. While the practices and procedures for Zones outside of Panther Island could be applied in Zone 1, it would be much costlier to property owners and also place more restrictions on how an owner/operator/developer of a property could use their available footprint to achieve the needed water quality goals while meeting other requirements expressed by the form-based code as each developer would be trying to individually place and maintain stormwater quality practices on their property.

The water quality requirements for Zone 1 are designed to achieve the same results in pollutant removal as they would from Zone 2. However, by constraining the number of available water quality practices that can be used in Zone 1 and placing them predominantly in the public right-of-way instead. This results in several benefits to TRWD, TRVA, and owner/operator/developers of properties:

- 1) It improves consistency with the Panther Island Form-Based Code (which is designed in-part to maintain look and feel compatibility among the many properties that will be built on the Island).
- 2) It removes most of the responsibility for operating and maintaining any stormwater quality treatment system from the owner/operator of the property and shifts it to Public Improvement District (PID) planned for Panther Island.
- 3) Because the number of available practices is constrained for Zone 1, this greatly increases the efficiency of stormwater quality management, substantially lowers the aggregate footprint (square footage) needed for stormwater treatment, and substantially reduces the cost of stormwater treatment for developers.

5.2 REQUIREMENTS SPECIFIC TO ZONE 1

TRWD's requirements for Zone 1 (Panther Island) in many ways simplify the implementation of this manual. The following are the specific requirements and restrictions for Zone 1:

- 1) The vast majority of stormwater treatment will be operated and maintained by the aforementioned PID (those treatment practices within a public right-of-way);
- 2) Placement and type of practice required will be reviewed and approved by TRWD for Zone 1 in accordance with this manual. Placement and type of practice may be adjusted accordingly based on additional evaluation by TRWD and reflected in subsequent versions of this manual. Therefore, those working to comply with this manual are encouraged to make sure they are working with the most recent version of the manual.
- 3) Currently, only bioretention basins (sections 3.2.3.3.1 and 3.2.3.3.2) and permeable surfaces in the form of pervious pavers (Section 3.9) may be used in public right-of-way locations approved by TRWD. Predominantly these will be distributive bioretention basins (Section 3.2.3.3.2).
- 4) Because of groundwater conditions on the island, all practices must have underdrains to collect and convey treated stormwater to stormwater drainage infrastructure.
- 5) Because of groundwater conditions on the island, it is critical that all practices, especially bioretention, have positive-side waterproofing consistent ASTM Standards (see references). Because groundwater is shallow, the significant incursion of groundwater into bioretention facilities may cause plants to die from excess water around root systems.
- 6) Additional treatment of stormwater may be required by TRWD for installation, operation, and maintenance by property owner/operators where the risk of pollutant discharge is increased such as in any directly-connected impervious surface (an example would be parking-garage rooftops with drainage directly to the Panther Island waterway or canals and no treatment between the two).
- 7) Larger detention practices (serving a larger number of properties) may be prescribed by TRWD and implementation of any larger practices for stormwater treatment is at TRWD's sole discretion in coordination with TRVA and its implementation of the Panther Island form-based code.

Figure 5.1 shows the current distribution of stormwater practices in the public right-of-way by practice-type and is subject to revision by TRWD.

5.3 REFERENCES

The following references are useful in specifying either elastomeric sheet waterproofing or hot fluid-applied, rubberized asphalt waterproofing (two of the more common techniques used to prevent groundwater intrusion). Other references will be needed for design purposes.

ASTM International. ASTM C 1305: Test Method for Crack Bridging Ability of Liquid-Applied Waterproofing Membrane. West Conshohocken, PA: ASTM, 2008.

ASTM D 5329: Test Methods for Sealants and Fillers, Hot-Applied, for Joints and Cracks in Asphaltic and Portland Cement Concrete Pavements. 2009.

ASTM D 6622: Guide for Application of Fully Adhered Hot-Applied Reinforced Waterproofing Systems. 2001 (Reapproved 2009).







ASTM E 96/E 96M: Test Methods for Water Vapor Transmission of Materials. 2010.

Sealant, Waterproofing, and Restoration Institute. Below Grade Waterproofing Manual. Kansas City, MO: SWRI, 2000, (Available at www.swrionline.org)

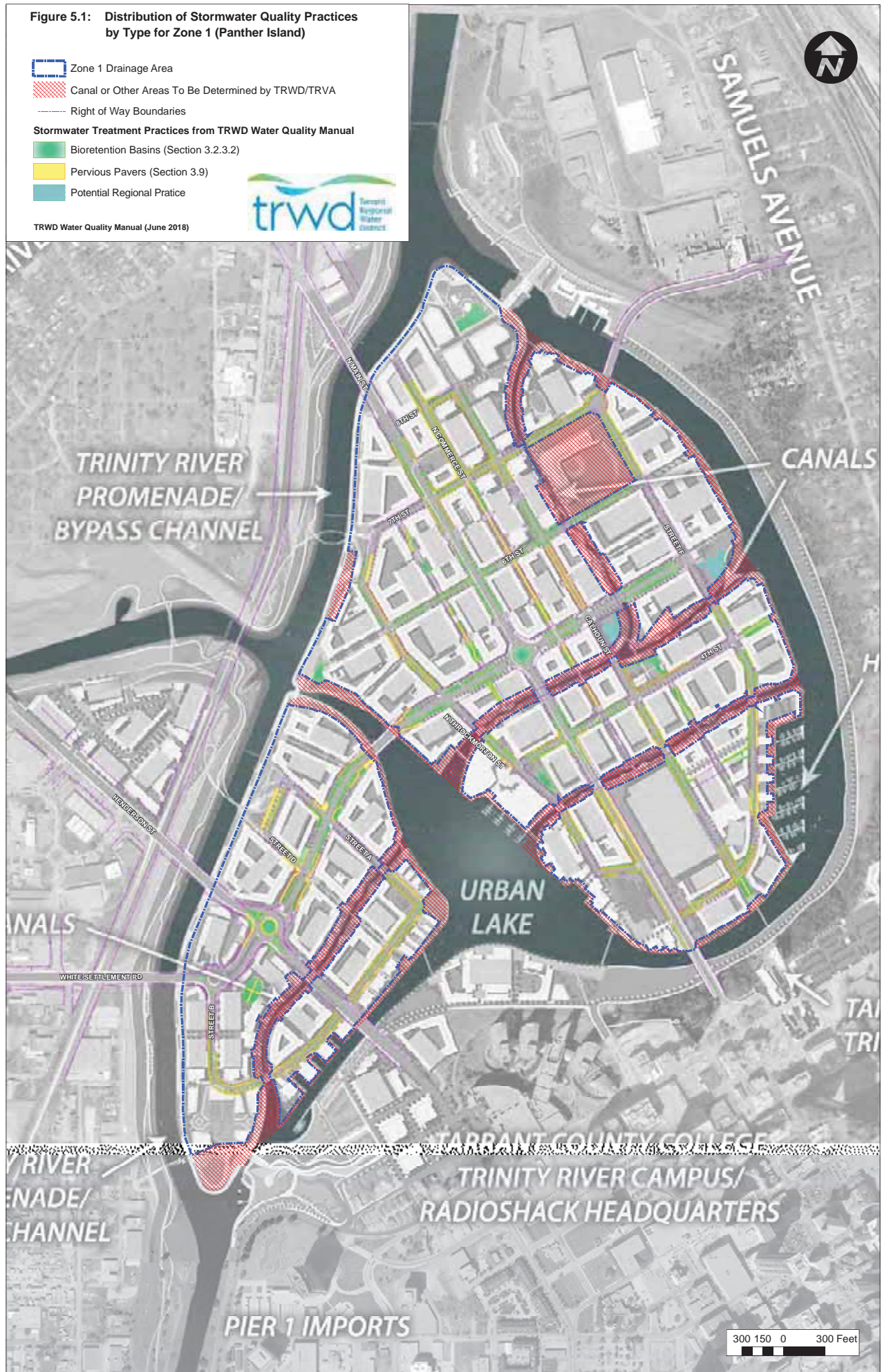
ASTM International. ASTM D 5295: Guide for Preparation of Concrete Surfaces for Adhered (Bonded) Membrane Waterproofing Systems. West Conshohocken, PA: ASTM, 2000 (Reapproved 2006).

ASTM D 5898/D 5898M: Guide for Standard Details for Adhered Sheet Waterproofing. 1996 (Reapproved 2013).

Figure 5.1: Distribution of Stormwater Quality Practices by Type for Zone 1 (Panther Island)

-  Zone 1 Drainage Area
 -  Canal or Other Areas To Be Determined by TRWD/TRVA
 -  Right of Way Boundaries
- Stormwater Treatment Practices from TRWD Water Quality Manual**
-  Bioretention Basins (Section 3.2.3.2)
 -  Pervious Pavers (Section 3.9)
 -  Potential Regional Practice

TRWD Water Quality Manual (June 2018)



300 150 0 300 Feet



TRWD WATER QUALITY MANUAL

PLANNING AND IMPLEMENTING STORMWATER QUALITY PRACTICES

Appendix A

Design Review Resources

TRWD WATER QUALITY MANUAL

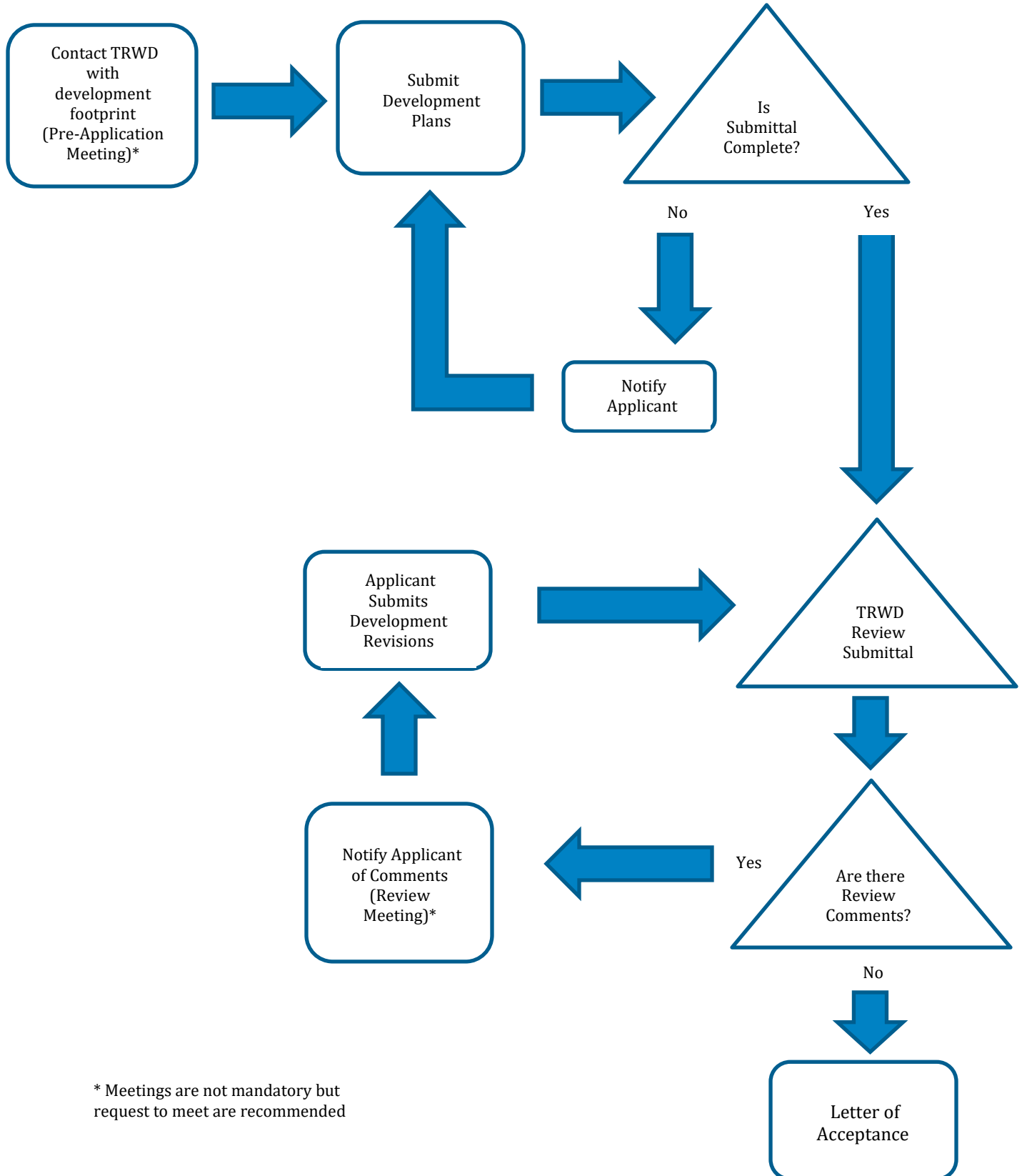
PLANNING AND IMPLEMENTING STORMWATER QUALITY PRACTICES

APPENDIX A – DESIGN REVIEW RESOURCES

		Y or N	Notes
Project Coordination			
Meeting Requests	Has Developer requested to meet with TRWD?		
Site Plan			
Project Area	Does the plan set show the total project area and has the project area been defined correctly?		
	Does the plan set include the drainage area for the BMP and has this been delineated correctly?		
	Have all drainage plans and stormwater piping plans been included?		
Water Quality Volume	Is the water quality volume calculated correctly?		
	Has the BMP footprint and volume been calculated correctly to treat the entire water quality volume?		
	Is flow diversion addressed?		
Site Activity Plan for BMP Projects			
Runoff Management During Construction	Will the BMP facility be kept offline until construction is complete? Alternatively, the excavation can be used as a sediment trap during construction before filtration or other BMP media are placed in the basin. In that case, the bottom of the basin should not be excavated below 2-feet of the final grade. Engineer should authorize discharge of runoff into completed BMP facility.		
	Will the upstream drainage areas be stabilized before installation of BMP components?		
	Sediment accumulation in BMP must be promptly removed. Is this noted?		
BMP Design and Implementation			
BMP Design Spreadsheets (Appendix E)	Have the necessary design sheets and specifications outlined in Sections 3 and 4 and Appendix E been completed and provided?		
General BMP	Submittals include material certificates, aggregate gradation, contractor's qualifications, construction procedures, and quality control plan?		
Maintenance	Facility Maintenance Agreement submitted?		
	Facilities provided for maintenance access?		

		Y or N	Notes
Maintenance	Plan meets maintenance requirements?		
	Is maintenance access provided for BMP facilities, including pre- and / or post-treatment?		

Process Flow Chart





TRWD WATER QUALITY MANUAL

PLANNING AND IMPLEMENTING STORMWATER QUALITY PRACTICES

Appendix B

BMP Fact Sheets

Bioretention Basin

Overview:

Bioretention basins are commonly used Best Management Practices (BMP) due to the effectiveness for pollutant load reduction and visual appeal. There are two main types of bioretention basins outlined in this manual: centralized and distributive. Centralized bioretention basins are intended for larger drainage areas and include a sedimentation forebay. Distributive bioretention basin can be implemented for drainage areas less than 1-acre. These are often placed adjacent to impervious surfaces to capture runoff directly. Bioretention basins utilize infiltration and filtration through soils and vegetation in depressed basins or landscape areas to provide both water quantity and water quality benefits. The vegetation, microbes, and soils in bioretention basins provide additional treatment and removal of pollutants from stormwater runoff.



Rendering of Bioretention with Components (TRWD Developer Manual, 2018)

Benefits:

- Effective removal of suspended solids, heavy metals, adsorbed pollutants, nitrogen, phosphorous, and pathogens
- Based on soil conditions, groundwater levels, and geology, bioretention basins can be designed to provide groundwater recharge
- Flexible for use in urban retrofits or new development and can be used in both small and medium drainage basins
- Can be well integrated into landscaping and provide natural look and aesthetics

Potential Constraints and Considerations:

- The design and construction of bioretention systems is critical to their performance
- Maintenance requirements may be time intensive and expensive
- Surface soil may require restoration or replacement if it becomes clogged (often after multiple years of operation)
- Plant materials and mulching require maintenance
- Effectiveness of BMP may be dependent upon site geology and soils, but an underdrain can be added if site soil infiltration capacity is insufficient
- May be subject to drainage area size limitations

Design Guidance:

All runoff from impervious surfaces should be directed towards BMPs. Important site parameters to be considered during design include the drainage area and the portion that is impervious, depth to the water table, permeability of soils, downstream water surface, and overall space required for the BMP. Bioretention basins can be designed using both centralized and distributed configurations, the main difference being the allowable drainage area and the inclusion of a sediment forebay. The water quality capture volume (WQV) should drain in less than 24-hours with a goal of 12-hours. The minimum components for a bioretention basin are as follows: stormwater inlet, pre- and post-treatment, energy dissipation, area protection (where necessary), BMP media, media barriers, landscaping, and outlets/piping. Refer to Section 4 of the TRWD Developer Manual for specific information on these components.



Bioretention Basin with Components Labeled (CDM Smith, 2017)

Sizing Criteria:

The calculations below are from Section 3.2 of the TRWD Developer Manual. This table contains the main calculations for sizing the BMP. Reference Section 3.2 and Appendix E for the specific design calculations and criteria.

STEP 1	WATER QUALITY VOLUME	$(WQ_v = DA * [d_i / (12 \text{ in} / \text{ft})] * 43,560 \text{ ft}^3 / \text{ac})$	ft ³
	Contributing Drainage Area (DA)		ac
	Capture Depth for 12 Hour or 24 Hour Drawdown Time (d_i)		in
STEP 2	SEDIMENT FOREBAY VOLUME	$(V_{bc} = 10\% WQ_v)$ (if required)	ft ³
STEP 3	TOTAL AVAILABLE BIORETENTION STORAGE VOLUME		ft ³
	Top of ponding surface area (SA_T)		ft
	Bottom of ponding surface area (SA_B)		ft
	Ponding depth (d_p)		in
	Void ratio		-
	Storage aggregate depth (df)		in
STEP 4	ORIFICE DIAMETER	$(d_o = 2 * (A_o / \pi)^{0.5})$	in
	Max. discharge of WQv (Q_o)		ft ³ /s
	Drain time (t_d)		hr
	Orifice opening area (A_o)		in ²
	Orifice coefficient (c)		-
	Average head (H_{avg})		ft

Inspection and Maintenance Requirements:

Inspections help to ensure that the bioretention basin continues to operate effectively and as designed throughout its lifespan. Regular inspection also indicates when certain maintenance practices are necessary. Like inspection, regular maintenance keeps the BMP operating smoothly and prolongs, or eliminates, the need for intensive rehabilitation such as side slope restabilization or replacing of corroded pipes. The table below outlines the regular and as-needed maintenance practices for bioretention basins. Specific information on inspection and maintenance requirements can be found in Appendix D of the TRWD Developer Manual.

Regular Maintenance

MAINTENANCE ACTION	FREQUENCY
Mow grassy areas	Annually or more frequently during growing season
Prune excessive vegetation/branches	Annually or more frequently during growing season
Replant annuals	Before corresponding growing season
Clearing trash, debris, and foliage	Monthly

As-Needed Maintenance

INSPECTION ISSUE	FREQUENCY
Standing water after design storm event and drawdown time	Check the inlet/outlet for clogging. Clear if present. Check for excessive fines/hard-packing on the surface
Foul odors or insects such as mosquitos	Promote insect predators and/or prevent stagnant water
Inlet/outlets clogged with debris	Clear out accumulated debris. Install debris screens.
Accumulated sediment/debris	Dredge or remove accumulated sediment or debris to design elevations. Vacuum clogged permeable surfaces.
Poor vegetative health / invasive species	Replant vegetation and remove invasive species, taking care not to spread seeds/spores.
Excessive or overgrown vegetation	Prune the excessive/overgrown vegetation.
Banks/slopes eroded	Repair banks/slopes such that they match design slopes. Install energy dissipaters or flow diversions.
Signs of channeling or worn paths	Mow or possibly regrade.
Pipe corrosion	Replace piping. Consider different material or covering the pipe with a corrosion resistant coating.

Pollutant Removal Effectiveness:

POLLUTANT	REMOVAL EFFECTIVENESS*
Sediment	High
Nutrients	Moderate
Trash	High
Metals	High-Moderate
Bacteria	High
Oil and Grease	High
Organics	Moderate

(SARA, 2013; iSWM, 2014; and TCEQ, 2005)

*Removal effectiveness varies dependent on infiltration capacity and design

References or Future Reading:

"Complying with the Edwards Aquifer Rules: Technical Guidance on Best Management Practices". July 2005. TCEQ. RG-348. Accessed September 2017. < http://www.storm-tex.com/wp-content/uploads/2016/04/TCEQ_RG-348.pdf >.

"iSWM Technical Manual: Site Development Controls". (2014). North Central Texas Council of Governments. Accessed September 2017. < http://iswm.nctcog.org/Documents/technical_manual/Site_Development_Controls_9-2014.pdf >.

Roach, V. (CDM Smith). March 6, 2017. "Green Infrastructure Design in Your CSO Long Term Control Plan". NJ Water Environment Association: Winter Technology Transfer Seminar. New Jersey. Presentation. Accessed September 2017.

"San Antonio River Basin Low Impact Development Technical Design Guidance Manual". (2013). San Antonio River Authority. Accessed September 2017. < <https://www.sara-tx.org/wp-content/uploads/2015/05/Full-LID-Manual.pdf> >.

"Tarrant Regional Water District Developer Manual". (2018). Tarrant Regional Water District (TRWD).

Constructed Wetlands

Overview:

Constructed Wetlands, also referred to as stormwater wetlands, are designed to permanently hold water and increase detention time between storm events for improved treatment. This Best Management Practice (BMP) requires more land than other BMPs and a constant source of influent water. However, constructed wetlands can be an excellent option for improving water quality. Constructed wetlands employ complementary mechanisms (i.e. physical and biological) to effectively treat stormwater inflow. The slow, sinuous flow and extended detention time promotes particle settling and plant uptake. Because this BMP is not intended for infiltration, its stormwater runoff volume reduction is minimal, except through evaporation and evapotranspiration. As such, constructed wetlands are ideal at the end of a storm-to-stream sequence for final treatment before discharge into a stream. Constructed wetlands can provide site aesthetics and provide habitat for local wildlife.

Benefits:

- Well suited for removal of particulate matter and some dissolved contaminants (TCEQ, 2005)
- Provides an aesthetically pleasing space for the surrounding community
- Provides wildlife habitat (see note below on bacterial indicator loads)
- Effective for large tributary areas

Potential Constraints and Considerations:

- Requires continuous source of base flow (i.e. stormwater and dry weather inflow or make-up water inflow)
- Potential significant maintenance costs and large amounts of sediment removal to prevent pond stagnation, floating debris, scum, algal blooms, and unpleasant odor (TCEQ, 2005).
- Potential accumulation of salts and scum that can be discharged during large storm events
- Proper design must be used to prevent habitat for undesirable insects such as mosquitos
- May not be appropriate for locations with high groundwater levels due to potential for contamination
- Overgrowth and sediment accumulation may reduce hydraulic capacity
- Wildlife are a potential source of bacteria indicator loads



(iSWM, 2014; EPA, 2009)

Design Guidance:

All runoff from impervious surfaces should be directed towards the BMP. Important site considerations during design include the drainage area and the proportion of which is impervious, depth to the water table, permeability of soils, downstream water surface, and overall space required for the BMP. A long, sinuous flow path promotes pollutant removal. A micropool has been added at the outlet to improve maintenance and provide additional treatment before discharge. The water quality volume (WQV) should drain within 24 hours. The minimum components for a constructed wetland include, a stormwater inlet, pre- and post-treatment, energy dissipation, area protection, landscaping, and outlets/piping. Refer to Section 4 of the TRWD Design Manual for specific information on these components.



*Constructed Wetland
Rendering (TRWD
Design Manual, 2018)*

Sizing Criteria:

The calculations below are from Section 3.3 of the TRWD Design Manual. This table contains the main calculations for sizing the BMP. Reference Section 3.3 and Appendix E for the specific design calculations and criteria.

STEP 1	WATER QUALITY VOLUME	$(WQ_v = DA * [d_i / (12 \text{ in} / \text{ft})] * 43,560 \text{ ft}^2 / \text{ac})$	ft ³
	Contributing Drainage Area (DA)		ac
	Capture Depth for 24 Hour Drawdown Time (d _i)		in
STEP 2	Sediment Forebay Volume	$(V_{fb} = 0.1 \text{ in per impervious acre of drainage area})$	ft ³
	Impervious Drainage Area (A _{imp})		ft ²
STEP 3	Basin Volume	$(V_b = V_p + V_s)$	ft ³
	Permanent Pool Volume (V _p) = 100% WQ _v		ft ³
	Surcharge Pool Volume (V _s) = 120% WQ _v		ft ³
STEP 4	Orifice Diameter	$(d_o = 2 * (A_o / \pi)^{0.5})$	in
	Max. discharge of WQ _v (Q _o)		ft ³ /s
	Drain time (t _d)		hr
	Orifice coefficient (c)		-
	Average head (H _{avg})		ft
	Orifice opening area (A _o)		in ²

Inspection and Maintenance Requirements:

Inspections help to ensure that the constructed wetland continues to operate effectively and as designed throughout its lifespan. Regular inspection also indicates when certain maintenance practices are necessary. Like inspection, regular maintenance keeps the BMP running smoothly and prolongs, or eliminates, the need for intensive rehabilitation such as side slope restabilization or replacing of corroded pipes. The table below outlines the regular and as-needed maintenance practices for constructed wetlands. Specific information on inspection and maintenance requirements can be found in Appendix D of the TRWD Design Manual.

Regular Maintenance

MAINTENANCE ACTION	FREQUENCY
Clear trash, debris, weeks, and foliage	Monthly or as needed
Mow grassy areas	Annually, but monthly during growing season Before corresponding growing season
Prune excessive vegetation / branches	Annually, but monthly during growing season
Replant Annuals	Before corresponding growing season

References or Future Reading:

"Complying with the Edwards Aquifer Rules: Technical Guidance on Best Management Practices". July 2005. TCEQ. RG-348. Accessed September 2017. < http://www.storm-tex.com/wp-content/uploads/2016/04/TCEQ_RG-348.pdf >.

"ISWM Technical Manual: Site Development Controls". (2014). North Central Texas Council of Governments. Accessed September 2017. < http://iswm.nctcog.org/Documents/technical_manual/Site_Development_Controls_9-2014.pdf >.

Clary, J. et al. "International Stormwater BMP Database 2016 Summary Statistics: Final Report". (2017). The Water Environment & Reuse Foundation. Accessed September 2017. < <http://www.bmpdatabase.org/Docs/03-SW-1COH%20BMP%20Database%202016%20Summary%20Stats.pdf> >.

"San Antonio River Basin Low Impact Development Technical Design Guidance Manual". (2013). San Antonio River Authority. Accessed September 2017. < <https://www.sara-tx.org/wp-content/uploads/2015/05/Full-LID-Manual.pdf> >.

"Stormwater Wet Pond and Wetland Management Guidebook". February 2009. EPA. EPA 833-B-09-001.

"Tarrant Regional Water District Developer Manual". (2018). Tarrant Regional Water District (TRWD).



Constructed Wetland (CDM Smith, 2017)

As-Needed Maintenance

INSPECTION ISSUE	FREQUENCY
Standing water after drawdown period	Check the inlet/outlet for clogging.
Foul odors or insects such as mosquitos	Retrofit BMP to prevent stagnant water
Inlet/outlets clogged with debris	Clear out accumulated debris. Install debris screens.
Accumulated sediment/debris higher than limit	Dredge or remove accumulated sediment or debris to design elevations. Vacuum clogged permeable surfaces.
Poor vegetative health / invasive species	Replant vegetation and remove invasive species, taking care not to spread seeds/spores.
Excessive or overgrown vegetation	Prune the excessive/overgrown vegetation.
Banks/slopes eroded	Repair banks/slopes such that they match design slopes. Install energy dissipaters or flow diversions.
Signs of channeling or worn paths	Assess drainage conditions. Consider regrade.
Broken or missing area protection	Repair or replace area protection.
Pipe corrosion	Replace piping. If reoccurring issue, consider different material or covering the pipe with a corrosion resistant coating.

Pollutant Removal Effectiveness:

POLLUTANT	REMOVAL EFFECTIVENESS*
Sediment	High
Nutrients	Medium to High
Trash	High
Metals	Medium
Bacteria	High**
Oil and Grease	High
Organics	High**

*(SARA Manual, 2013; Clary, J. 2017)

** Wetlands or other BMPs with wildlife habitat can have high internal loads of bacterial indicators, nutrients, and organics

Extended Dry Detention Basins

Overview:

Extended dry detention basins are a type of Best Management Practice (BMP) used for temporary storage of stormwater during small to moderate storm events. This BMP is designed to provide flood control by mitigating or regulating runoff while the extended storage promotes particle settling. Extended dry detention basins can be combined easily with other water quality treatment BMPs for holistic stormwater management and are meant for larger drainage areas. Unlike wet ponds and constructed wetlands, extended dry detention basins should drain completely after a storm and remain dry between storm events.



Extended Dry Detention Basin, City of Lenexa, KS

Benefits:

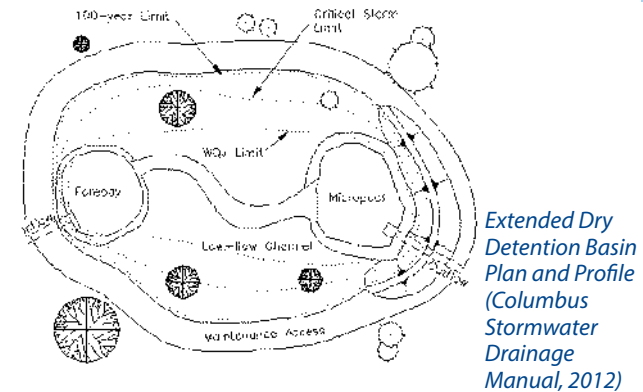
- Easily incorporated into a sequence of BMPs for holistic treatment of stormwater
- Provides temporary stormwater storage to mitigate downstream flooding
- Effective for larger drainage areas
- Can be used for recreation between storm events
- Relatively low cost compared to other BMPs such as wet ponds due to less excavation
- Requires less stringent maintenance than other BMPs which maintain permanent pools throughout the year
- If properly prevented, less chance of harboring pests such as mosquitoes than other BMPs with permanent pools of water

Potential Constraints and Considerations:

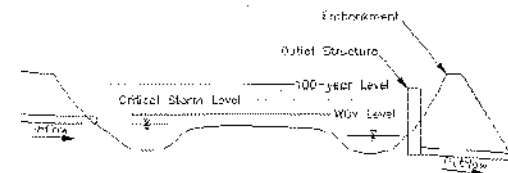
- Limited effectiveness for some pollutants. Coordinate with other BMPs where possible or include pre- / post-treatment
- Water quality treatment is limited to small to moderate storm events

Design Guidance:

The first step in design is to accurately delineate the drainage area of the BMP. Next, all runoff from impervious surfaces should be directed towards the BMP. Important site considerations during design include the drainage area and the portion of which is impervious, depth to the water table, permeability of soils, downstream



Extended Dry Detention Basin Plan and Profile (Columbus Stormwater Drainage Manual, 2012)



Rendering of an Extended Dry Detention Basin and Components After a Storm (TRWD Developer Manual, 2018)

water surface, and overall space required for the BMP. Micropools should be included at the outlet for maintenance and water quality benefits. The water quality volume (WQv) should drain within 40 to 48 hours. The minimum components for an extended dry detention basin include, a stormwater inlet, pre- and post-treatment, energy dissipation, area protection, landscaping, and outlets/piping. Refer to Section 4 of the TRWD Developer Manual for specific information on these components.

Sizing Criteria:

The calculations below are from Section 3.6 of the TRWD Developer Manual. This table contains the main calculations for sizing the BMP. Reference Section 3.6 and Appendix E for the specific design calculations and criteria.

STEP 1	Water Quality Capture Volume ($WQ_v = A_o * [d_i / (12 \text{ in/hr})] * 43,560 \text{ ft}^2/\text{ac}$)	ft ³
	Contributing Drainage Area (A_o)	ac
	Capture Depth for 48 Hour Drawdown Time (d_i)	in
STEP 2	Sediment Forebay Volume ($V_{fb} = 10\% WQ_v$)	ft ³
STEP 3	Basin Volume ($V_b = 100\% WQ_v$)	ft ³
STEP 4	Orifice Diameter ($d_o = 2 * (A_o / \pi)^{0.5}$)	in
	Max. discharge of WQv (Q_o)	ft ³ /s
	Drain time (t_d)	hr
	Orifice opening area (A_o)	in ²
	Orifice coefficient (c)	-
	Average head (H_{avg})	ft

Inspection and Maintenance Requirements:

Inspections help to ensure that the extended dry detention basin continues to operate effectively throughout its lifespan. Regular inspection also indicates when certain maintenance practices are necessary. Like inspection, regular maintenance keeps the BMP running smoothly and prolongs, or eliminates, the need for intensive rehabilitation such as side slope restabilization or replacing of corroded pipes. The table below outlines the regular and as-needed maintenance practices for extended dry detention basins. Specific information on inspection and maintenance requirements can be found in Appendix D of the TRWD Developer Manual.

Regular Maintenance

MAINTENANCE ITEMS	FREQUENCY
Clear trash, debris, weeds, and foliage	Monthly or as needed
Mow lawn	Annually, but monthly during growing season
Replant Annuals	Before corresponding growing season

As-Needed Maintenance

INSPECTION ISSUE	FREQUENCY
Standing water after drawdown period	Check the inlet/outlet for clogging. Check for excessive fines/hard-packing on the surface
Foul odors or insects such as mosquitos	Retrofit BMP to prevent stagnant water
Inlet/outlets clogged with debris	Clear out accumulated debris
Accumulated sediment/debris higher than limit	Dredge or remove accumulated sediment. Vacuum clogged permeable surfaces.
Poor vegetative health / invasive species	Replant vegetation and remove invasive species.
Excessive or overgrown vegetation	Prune the excessive/overgrown vegetation.
Banks/slopes eroded	Repair banks/slopes such that they match design slopes. Install energy dissipaters or flow diversions if reoccurring issue.
Signs of channeling or worn paths	Mow or possibly regrade.
Broken or missing area protection	Repair or replace area protection.
Pipe corrosion	Replace piping. Consider different material or cover the pipe with a corrosion resistant coating.

Pollutant Removal Effectiveness:

POLLUTANT	REMOVAL EFFECTIVENESS*
Sediment	Medium
Nutrients	Low to Medium
Trash	High
Metals	Medium
Bacteria	Medium to High
Oils and Grease	No Data
Organics	Low

(iSWM, 2014; TCEQ, 2005; International Stormwater BMP Database, 2017)

*nutrient, metals, and organics removal when bound to sediments that are removed

References or Future Reading:

"Complying with the Edwards Aquifer Rules: Technical Guidance on Best Management Practices". July 2005. TCEQ. RG-348. Accessed September 2017. <http://www.storm-tex.com/wp-content/uploads/2016/04/TCEQ_RG-348.pdf>.

Extended Dry Detention Basin. "Green Infrastructure". (no year pub.). City of Lenexa, Kansas. Image. Accessed September 2017. <http://www.lenexa.com/government/departments_divisions/rain_to_recreation/learn_more/green_infrastructure/>.

"Facilities". Stormwater Partners. Image. Accessed January 2018. <<http://www.stormwaterpartners.com/facilities/index.html>>.

"iSWM Technical Manual: Site Development Controls". (2014). North Central Texas Council of Governments. Accessed September 2017. <http://iswm.nctcog.org/Documents/technical_manual/Site_Development_Controls_9-2014.pdf>.

"San Antonio River Basin Low Impact Development Technical Guidance Manual". (2013). San Antonio River Authority. 1st edition. Accessed September 2017. <<https://www.sara-tx.org/wp-content/uploads/2015/05/Full-LID-Manual.pdf>>.

"Columbus Stormwater Drainage Manual". (2012). The City of Columbus: Division of Sewerage and Drainage. Accessed September 2017. <https://www.columbus.gov/uploadedFiles/Public_Uilities/Document_Library/Publications/Sewer/StormwaterDrainageManual.pdf>.

"Tarrant Regional Water District Developers Manual". (2018) Tarrant Regional Water District (TRWD).

"BMP Database Tool: Texas BMPs." (2016). International Stormwater BMP Database. Accessed August 2017. <<http://bmpdatabase.org/retrieveBMPs.asp>>

Permeable Surfaces

Overview:

Permeable surfaces are a type of Best Management Practice (BMP) that treats stormwater sheet flow over what would alternatively be conventional impervious surfaces. This type of stormwater BMP consists of permeable pavers, porous concrete, porous asphalt, and grassed-modular grid systems. The TRWD Developer Manual (DM) only covers the use of permeable pavers. Permeable pavers can be used to replace or in place of impervious surfaces and to temporarily store water in the storage aggregate layer. The overall performance of permeable surfaces is variable based on design, duration of use, and frequency of maintenance.



Permeable pavers and porous concrete sidewalk (CDM Smith, 2017)



Permeable pavers – aggregate joints (S. Landgren, 2011)

Benefits:

- Permeable pavers are easily adapted to site layout plan
- Can be effective at reducing runoff rate and volume instead of traditional impervious areas
- Can reduce stormwater infrastructure footprint requirements of downstream BMPs
- Promotes dual-purpose usage of pavement as a transportation surface and water treatment media
- Can be used to reduce stormwater pollutants loading to downstream surface waters

Potential Constraints and Considerations:

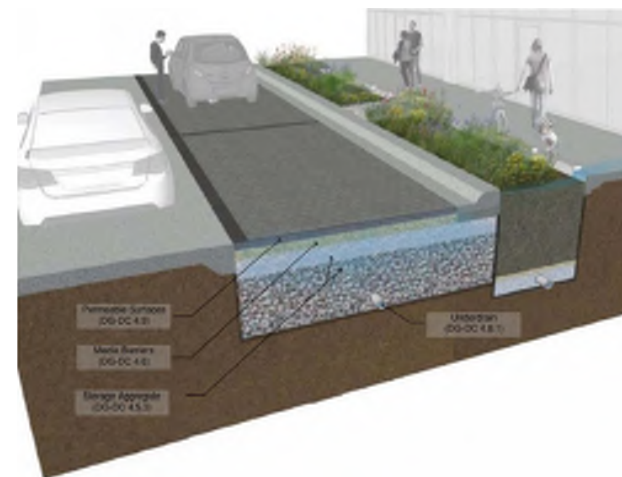
- Regular maintenance required to prevent clogging of porous media by sediment, which may result in reduced pollutant removal effectiveness (SARA Manual, 2013)
- Permeable surfaces have potential to compress and lose permeability when installed in areas subject to heavy vehicle loads.
- Restricted to surfaces with minimal slopes
- Restricted to grades of 5% or less. 2% or less is recommended.



Permeable pavers and rain gardens (Harroch, W., et al., 2017)

Design Guidance:

The first step is accurate delineation of the drainage area of the BMP. Important site considerations during design include the drainage area and the portion of which is impervious, depth to the water table, permeability of soils, downstream water surface, and overall space required for the BMP. When delineating the drainage area and considering use of permeable pavers, the recommended ratio of treated drainage area to permeable pavers surface area is 1.5 to 1. The water quality capture volume (WQv) should drain completely between 12 hours to 48 hours after the storm event. The minimum components for permeable pavers are as follows: area protection, BMP media, media barriers, outlets/piping, and permeable surfaces. Refer to Section 4 of the TRWD DM for specific information on these components.



Rendering of permeable pavers with components after a storm (TRWD DM, 2018)



Pervious Pavement, National Association of City Transportation Officials

Sizing Criteria:

The calculations below are from Section 3.8 of the TRWD Developer Manual. This table contains the main calculations for sizing the BMP. Reference Section 3.8 and Appendix E for the specific design calculations and criteria.

STEP 1	Water Quality Capture Volume	$(WQ_v = DA * [d_i / 12 * 43,560 \text{ ft}^3 / \text{ac}])$	ft ³
	Contributing Drainage Area (DA)		ac
	Capture Depth for 24 Hour Drawdown Time (d_i)		in
STEP 2	Required Permeable Surface Area	$(SA_p = DA / 1.5)$	ft ²
STEP 3	Orifice Diameter	$(d_o = 2 * (A_o / \pi)^{0.5})$	in
	Max. discharge of WQ_v (Q_o)		ft ³ /s
	Drain time (t_d)		hr
	Orifice opening area (A_o)		in ²
	Orifice coefficient (c)		-
	Average head (H_{avg})		ft

Inspection and Maintenance Requirements:

Inspections help to ensure that the permeable pavers continue to operate effectively and as designed throughout their lifespan. Regular inspection also indicates when certain maintenance practices are necessary. Like inspection, regular maintenance keeps the BMP running smoothly and prolongs, or eliminates, the need for intensive rehabilitation such as side replacing pavers. The table below outlines the regular and as-needed maintenance practices for permeable pavers. Specific information on inspection and maintenance requirements can be found in Appendix D of the TRWD DM.

Regular Maintenance

MAINTENANCE ITEMS	FREQUENCY
Clear trash, debris, and foliage	Monthly or as needed
Vacuum sweeping	Annually

As-Needed Maintenance

INSPECTION ISSUE	ACTION
Pooling of water over surface course 48 hours after storm event	Additional vacuum sweeping when dry
Significant deterioration of surface course or pavers and structural integrity of pavement, inlets/outlets, and observation wells	Possible replacement of surface course, pavers, inlets/outlets, and observation well components depending on severity
Inlet/outlets clogged with debris	Clear out accumulated debris. If needed and not installed previously, install debris screens.
Pipe corrosion	Replace piping. If reoccurring issue, consider different material or covering the pipe with a corrosion resistant coating.

Pollutant Removal Effectiveness:

POLLUTANT	REMOVAL EFFECTIVENESS*
Sediment	High
Nutrients	Low**
Trash	High
Metals	Medium
Bacteria	High
Oil and Grease	Medium
Organics	Low

*(SARA, 2013; International Stormwater BMP Database, 2017)

** Removal occurs when associated with retainment of nutrient- and metal-bound sediments or filtering oil/grease on underlying soil media.

References or Future Reading:

Harrouch, W., Roach, V., and M. Dodson (CDM Smith). October 23, 2017. "Turning Ultra Urban Into Ultra Green for CSO Control in the Bronx". Main Stormwater Conference. Portland, Maine. Presentation. Accessed September 2017.
 "ISWM Technical Manual: Site Development Controls". (2014). North Central Texas Council of Governments. Accessed September 2017. < http://iswm.nctcog.org/Documents/technical_manual/Site_Development_Controls_9-2014.pdf >.
 Landgren, S. "Hartford, CT Green Capitals Project". (2011). CDM Smith. Photograph.
 "Pervious Pavement". (no year). National Association of City Transportation Officials. Accessed September 2017. < <https://nacto.org/publication/urban-street-design-guide/street-design-elements/stormwater-management/pervious-pavement/> >.
 Roach, V. (CDM Smith). March 6, 2017. "Green Infrastructure Design in Your CSO Long Term Control Plan". NJ Water Environment Association: Winter Technology Transfer Seminar. New Jersey. Presentation. Accessed September 2017.
 "San Antonio River Basin Low Impact Development Technical Design Guidance Manual". (2013). San Antonio River Authority. Accessed September 2017. < <https://www.sara-tx.org/wp-content/uploads/2015/05/Full-LID-Manual.pdf> >.
 "Tarrant Regional Water District Developer Manual". (2018). Tarrant Regional Water District (TRWD).
 "Tennessee Permanent Stormwater Management and Design Guidance Manual". December 2014. Tennessee Department of Environment and Conservation. 1st ed. Accessed September 2017. < <https://app.box.com/s/pd1afehg00s1wwqa94d8qmizyptxw3i/file/25367692645> >.

Retention & Irrigation Basin

Overview:

Retention/irrigation basins are a Best Management Practice (BMP) used to collect stormwater runoff with the intention of using it for irrigation of appropriate landscape areas. Unlike other BMPs such as extended dry detention basins or wet basins, retention/irrigation basins use mechanical components such as pumps, wet wells, and an irrigation system. Retention/irrigation basins typically are used in large contributing drainage areas, but site selection must be balanced with available landscape area to irrigate. This BMP relies on the infiltration capacity of the irrigated areas to discharge the full captured water quality volume (WQv). While the sediment forebay removes the majority of the suspended solids, collected water is treated further through infiltration and plant uptake in the irrigated area.



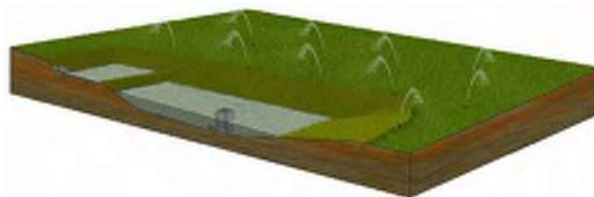
Retention irrigation pond (City of Austin Watershed Protection Department, TX)

Benefits:

- Excellent pollutant removal through filtration of sediments, pollutant-bound sediments, oils, greases, and other organics as well as uptake of nutrients and some metals by vegetation when properly designed, constructed, and maintained
- Beneficial for areas that do not have much rainfall because it can reduce irrigation demand on groundwater
- Can provide indirect groundwater recharge through infiltration

Potential Constraints and Considerations:

- Maintenance requirements and costs to keep the irrigation system operational are potentially high (TCEQ, 2005)
- Must match the amount of irrigated land to the captured stormwater volume
- Potential for groundwater contamination if inadequate soil coverage over irrigated areas (TCEQ, 2005; iSWM, 2014)
- This system requires mechanical components such as pumps, irrigation system, and electrical power which adds additional cost to the BMP



Retention/irrigation basin and components rendering after storm event (TRWD Developer Manual, 2018)

Design Guidance:

First, accurately delineate the drainage area of the BMP. Next, all runoff from impervious surfaces should be directed towards the BMP. Important site considerations during design include the drainage area and the portion of which is impervious, depth to the water table, permeability of soils, downstream water surface, and overall space required for the BMP. Retention/irrigation basins range from dry-concrete basins to vegetated basins with a permanent pool. Stored water drains to a wet well outside of the basin and is then pumped to irrigate a landscaped area. The minimum components for an extended dry detention basin include, a stormwater inlet, pre- and post-treatment, energy dissipation, area protection, landscaping, and outlets/piping. Refer to Section 4 of the TRWD Developer Manual for specific information on these components. Retention/irrigation basins also require wet wells, pumps, and an irrigation system.



Retention basin, outlet, and inlet structure (Kannan, 2014)



Sizing Criteria:

The calculations below are from Section 3.5 of the TRWD Developer Manual. This table contains the main calculations for sizing the BMP. Reference Section 3.5 and Appendix E for the specific design calculations and criteria.

STEP 1	Water Quality Capture Volume ($WQ_v = DA * [d_i / (12 \text{ in/hr})] * 43,560 \text{ ft}^3/\text{ac}$)	ft^3
	Contributing Drainage Area (DA)	ac
	Capture Depth (d_i)	in
STEP 2	Sediment Forebay Volume ($V_{fb} = 0.1 \text{ in per impervious acre of drainage area}$)	ft^3
	Impervious Drainage Area (A_{imp})	ft^2
STEP 3	Retention Basin Volume ($V_{RB} = 100\% WQ_v$ or $2.2 WQ_v$ if includes a permanent pool)	ft^3
STEP 4	Orifice Diameter ($d_o = 2 * (A_o / \pi)^{0.5}$)	in
	Max. discharge of WQv (Q_o)	ft^3/s
	Drain time (t_d)	hr
	Orifice opening area (A_o)	in^2
	Orifice coefficient (c)	-
	Average head (H_{avg})	ft
STEP 5	Irrigation Area ($A_i = [(12 \text{ in/ft}) WQ_v] / (60r)$)	in
	Soil permeability (r)	in/hr

Inspection and Maintenance Requirements:

Inspections help to ensure that the retention/irrigation basin continues to operate effectively and as designed throughout its lifespan. Regular inspection also indicates when certain maintenance practices are necessary. Like inspection, regular maintenance keeps the BMP running smoothly and prolongs, or eliminates, the need for intensive rehabilitation such as side slope restabilization or replacing of corroded pipes. The table below outlines the regular and as-needed maintenance practices for retention/irrigation basins. Specific information on inspection and maintenance requirements can be found in Appendix D of the TRWD Developer Manual.

Regular Maintenance

MAINTENANCE ITEMS	FREQUENCY
Clear trash, debris, weeds, and foliage	Monthly or as needed
Mow lawn	Annually, but monthly during growing season
Prune excessive vegetation / branches	Annually, but monthly during growing season

As-Needed Maintenance

INSPECTION ISSUE	ACTION
Standing water after design storm event and drawdown time	Check the inlet/outlet for clogging. Clear if necessary. Check for excessive fines/hard-packing on the surface.
Foul odors or insects such as mosquitos	Retrofit BMP to prevent stagnant water
Inlet/outlets clogged with debris	Clear out accumulated debris.
Accumulated sediment/debris higher than limit	Dredge or remove accumulated sediment or debris to design elevations.
Poor vegetative health / invasive species	Replant vegetation and remove invasive species.
Excessive or overgrown vegetation	Prune the excessive/overgrown vegetation.
Banks/slopes eroded	Repair banks/slopes. Install energy dissipaters or flow diversions.
Signs of channeling or worn paths	Mow or possibly regrade.
Broken or missing area protection	Repair or replace area protection.
Pipe corrosion	Replace piping. Consider different material or covering the pipe with a corrosion resistant coating.
Pump/Irrigation Equipment Failure	Replace or repair equipment.

Pollutant Removal Effectiveness:

POLLUTANT	REMOVAL EFFECTIVENESS*
Sediment	High
Nutrients	Medium to High**
Trash	High
Metals	High
Bacteria	High
Oil and Grease	No Data
Organics	No Data

* (ISWM, 2014)

** Depends on vegetation in the retention ponds for nutrient uptake

References or Future Reading:

"Complying with the Edwards Aquifer Rules: Technical Guidance on Best Management Practices". July 2005. TCEQ. RG-348. Accessed September 2017. < http://www.storm-tex.com/wp-content/uploads/2016/04/TCEQ_RG-348.pdf >.

"ISWM Technical Manual: Site Development Controls" (2014). North Central Texas Council of Governments. Accessed September 2017. < http://iswm.nctcog.org/Documents/technical_manual/Site_Development_Controls_9-2014.pdf >.

Kannan, N., Jeong, J., Arnold, J., Gosselink, L. "Hydrologic Modeling of a Retention Irrigation System". (2014). American Society of Civil Engineers: Journal of Hydrologic Engineering: 19(5). Accessed September 2017. < [http://ascelibrary.org/doi/full/10.1061/\(ASCE\)HE.1943-5584.0000867](http://ascelibrary.org/doi/full/10.1061/(ASCE)HE.1943-5584.0000867) >.

"Retention Irrigation Ponds". The City of Austin: Watershed Protection Department. Image. Accessed January 2018. < <https://austintexas.gov/content/1361/FAQ/2483> >.

"Tarrant Regional Water District Developer Manual". (2018). Tarrant Regional Water District (TRWD).

Sand and Media Filters

Overview:

Sand and media filters are a versatile, well-established structural Best Management Practice (BMP) that provides treatment of stormwater runoff by filtration through sand or other filtration media. To improve treatment effectiveness, sand and media filters are paired with a pre-treatment BMP to remove large debris and sediment from the runoff inflow. This BMP is easily incorporated into new developments or adapted for retrofits in re-development sites. The sand and media filters are suitable for relatively large, highly impervious drainage areas.



Surface Sand Filter Seneca Best Management Practice. DEP Montgomery County, MD.

Benefits:

- Offer design flexibility and can be implemented in urban retrofits or new development projects
- Effective in the removal of suspended solids, oil and grease, heavy metals, and particle-bound nutrients and pathogens
- Can be used to reduce peak runoff rates for relatively frequent storms
- Can incorporate deeper ponding depths of up to 5-feet to limit the required footprint

Potential Constraints and Considerations:

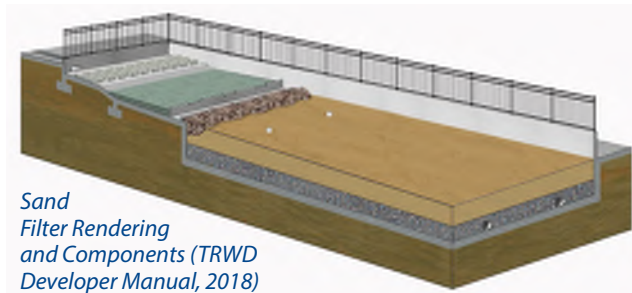
- Sand filters in basins with heavy sediment loads are subject to clogging and require more frequent maintenance to maintain optimal filtration rate
- Frequent trash removal may be required for sites with high traffic volume
- Can lack aesthetic appeal
- Stagnant water due to clogging and /or inadequate maintenance may create breeding habitat for nuisance conditions



Example of Surface Sand Filter (Bender Wells Clark Design, SARA, 2013)

Design Guidance:

First, delineate the drainage area of the BMP. Next, all runoff from impervious surfaces should be directed towards the BMP. Important site considerations during design include the drainage area and the portion of which is impervious, depth to the water table, permeability of soils, downstream water surface, and overall space required for the BMP. Sand and media filters include multiple chambers: a sediment forebay or sedimentation chamber, and a filtration chamber. If the drainage area is less than 2 acres, then a vegetated filter strip or grass swale can be used in lieu of a sediment forebay. The depth of the filtration basin must be balanced with the frequency of required maintenance. The deeper the filtration basin, the more frequent the maintenance. The water quality volume (WQv) in the sand and media filter should drain in 24 hours. The minimum components for the sand and media filter is as follows: stormwater inlet, pre- and post-treatment, energy dissipation, area protection, BMP media, media barriers, landscaping, and outlets/piping. Refer to Section 4 of the TRWD Developer Manual for specific information on these components.



Sand Filter Rendering and Components (TRWD Developer Manual, 2018)

Sizing Criteria:

The calculations below are from Section 3.1 of the TRWD Developer Manual. This table contains the main calculations for sizing the BMP. Reference Section 3.1 and Appendix E for the specific design calculations and criteria.

STEP 1	Water Quality Capture Volume $(WQ_v = DA * [d_i / 12 * 43,560 \text{ ft}^3/\text{ac}])$	ft^3
	Contributing Drainage Area (DA)	ac
	Capture Depth for 24 Hour Drawdown Time (d_i)	in
STEP 2	Sediment Forebay Volume $(V_{fb} = 25\% WQ_v)$	ft^3
STEP 3	Surface Area of Filtration Chamber $(A_f = WQ_v / [kT_i] \text{ where } k=3.5 \text{ ft/day})$	ft^2
	Filtration chamber drain time (T_i)	days
STEP 4	Total Available Sand Filter Water Quality Storage Volume	ft^3
	Surface area top of basin ponding storage (SA_T)	ft^2
	Surface area bottom of basin ponding storage (SA_B)	ft^2
	Depth of ponding (H_i)	ft
	Depth of storage aggregate (H_{agg})	ft
	Void ratio	-
STEP 5	Sand Filter Chamber Total Depth $(H_t = [H_i / (12 \text{ in/ft})] + H_m)$	ft
	Filter media depth (H_f)	in
	Filtration chamber depth (H_m)	ft
STEP 6	Orifice Diameter $(d_o = 2 * (A_o / m)^{0.5})$	in
	Max. discharge of WQv (Q_o)	ft^3/s
	Drain time (t_d)	hr
	Orifice opening area (A_o)	in^2
	Orifice coefficient (c)	-
	Average head (H_{avg})	ft

Inspection and Maintenance Requirements:

Inspections help to ensure that the sand and media filters continue to operate effectively and as designed throughout their lifespan. Regular inspection also indicates when certain maintenance practices are necessary. Like inspection, regular maintenance keeps the BMP running smoothly and prolongs, or

eliminates, the need for intensive rehabilitation such as media replacement. The table below outlines the regular and as-needed maintenance practices for sand and media filters. Specific information on inspection and maintenance requirements can be found in Appendix D of the TRWD Developer Manual.

Regular Maintenance

MAINTENANCE ITEMS	FREQUENCY
Clearing trash, debris, and foliage	Monthly or as needed

As-Needed Maintenance

INSPECTION ISSUE	ACTION
Standing water after drawdown time	Check the inlet/outlet for clogging. Clear if necessary.
Foul odors or insects such as mosquitos	Retrofit BMP to prevent stagnant water
Inlet/outlets clogged with debris	Clear out accumulated debris.
Accumulated sediment/debris	Dredge or remove accumulated sediment or debris.
Surface media spent	Replace the top of the surface media
Broken or missing area protection	Repair or replace area protection.
Pipe corrosion	Replace piping. If reoccurring issue, consider different material or covering the pipe with a corrosion resistant coating.

Pollutant Removal Effectiveness:

POLLUTANT	REMOVAL EFFECTIVENESS*
Sediment	High
Nutrients	Low to Moderate
Trash	High
Metals	Medium to High
Bacteria	Medium to High
Oil and Grease	High
Organics	Medium to High

(SARA, 2013; iSWM, 2014; and TCEQ, 2005)

* removal effectiveness varies dependent on infiltration capacity and design

** Sources have ranged from low removal to high removal

References or Future Reading:

"Complying with the Edwards Aquifer Rules: Technical Guidance on Best Management Practices". July 2005. TCEQ. RG-348. Accessed September 2017. < http://www.storm-tex.com/wp-content/uploads/2016/04/TCEQ_RG-348.pdf >.

"iSWM Technical Manual: Site Development Controls". (2014). North Central Texas Council of Governments. Accessed September 2017. < http://iswm.nctcog.org/Documents/technical_manual/Site_Development_Controls_9-2014.pdf >.

"San Antonio River Basin Low Impact Development Technical Design Guidance Manual". (2013). San Antonio River Authority. Accessed September 2017. < <https://www.sara-tx.org/wp-content/uploads/2015/05/Full-LID-Manual.pdf> >.

"Tarrant Regional Water District Developer Manual". (2018). Tarrant Regional Water District (TRWD).

Young, G.K., et al. 1996. "Evaluation and Management of Highway Runoff Water Quality". U.S. Department of Transportation. Federal Highway Administration: Office of Environment and Planning. Publication No. FHWA-PD-96-032.

Vegetated Filter Strips and Grass Swales

Overview:

Vegetated Filter Strips (VFS) and Grass Swales can be used to treat stormwater runoff from low density impervious areas or along linear impervious surfaces, such as roadways or sidewalks. VFS are linear strips of natural, grass vegetation extended over a gentle slope which use the biological and physical properties of the vegetation and infiltration to remove sediment and other pollutants in sheet flow runoff. Grass swales are grass-lined ditches that can be used to convey and treat shallow concentrated flow. These Best Management Practices (BMPs) should not be used as a stand-alone BMP for developments and can be used as pre- or post-treatment along with other water quality BMPs.



Grass Swale (Dominican College-DEC, NY, 2007)

Benefits:

- VFS and grass swales are relatively simple and low cost to design and construct
- Both can be used for pretreatment and reduction of sediment from stormwater
- Both have simple, aesthetically pleasing qualities and provide landscaping opportunities
- Low maintenance requirements
- VFS and grass swales are effective along linear, narrow, impervious surfaces and are easily distributed around a site

Potential Constraints and Considerations:

- May not be suitable for industrial sites or large drainage areas, unless used to convey sub-areas as replacement for storm sewers
- VFS requires sheet flow across vegetated areas
- Require mild slopes to allow vegetation to provide filtration and to maintain low velocities
- Application in arid areas is limited because of the need for dense vegetation
- Does not provide sufficient attenuation of peak flows, unless check dams or other storage mechanisms are installed to the grass swale



Vegetated Grass Swale (Dott Architecture, 2010)

Design Guidance:

First, delineate the drainage area of the BMP. Next, all runoff from impervious surfaces should be directed towards the BMP(s). Important site



Grass Swale (Niskayuna Business Park-DEC, NY, 2005)

considerations during design include assessment of the impervious portion of the drainage area, depth to the water table, permeability of soils, downstream water surface, and overall space required for the BMP. VFS typically have one gentle side slope where the sheet flow runoff is treated. Grass swales are more channelized, having shallow side slopes on both sides of the channel perpendicular to the longitudinal flow path. VFS and grass swales can be enhanced by constructing check dams along the flow path to store and treat the stormwater for an extended period. Water should not pool in these BMPs. If check dams are installed, then the ponding behind the dams must drain within 48 hours. The minimum components for VFS and grass swales are as follows: stormwater inlet, pre- and post-treatment, energy dissipation, area protection, BMP media, media barriers, landscaping, and outlets/piping. Refer to Section 4 of the TRWD Developer Manual for specific information on these components.

Sizing Criteria:

The criteria below are from Section 3.7 of the TRWD Developer Manual. This table contains the main calculations for sizing the BMP. Reference Section 3.7 and Appendix E for the specific design calculations and criteria.

STEP 1	WATER QUALITY CAPTURE VOLUME
	Grass Swale: Contributing Drainage Area (DA) less than 5ac?
	VFS: Length of contributing drainage area in direction of flow less than 75-feet?
STEP 2	UPSTREAM OR DOWNSTREAM BMP? IF NOT, JUSTIFICATION?
STEP 3	INFLOW PARAMETERS
	Grass Swale: Less than 4 inches of sheet flow?
	Grass Swale: Energy dissipation at the inlet to reduce channelized water velocities to < 1-ft/s?
	VFS: Less than 2 inches of sheet flow?
STEP 4	VFS OR GRASS SWALE PARAMETERS
	Grass swales: Longitudinal slope less than 4% with max. water velocity less than 1-ft/s?
	Grass swale: Side slopes no steeper than 3:1 (horizontal:vertical) and channel bottom between 2-feet and 6-feet?
	VFS: Flow path at least 15-feet with 2% to 6% longitudinal slope and transverse slope less than 2%?
	VFS: Minimum of 12-inches of soil cover and dense vegetative cover?
STEP 5	CHECK DAM PARAMETERS
	Does it drain within 48-hours?
	Dam has max. height of 12-inches with 3:1 side slopes?

Inspection and Maintenance Requirements:

Inspections help to ensure that the VFS and the grass swales continue to operate at their designed effectiveness throughout their lifespan. Regular inspection also indicates when certain maintenance practices are necessary. VFS and grass swales require less maintenance than other BMPs, but consistent inspection and maintenance keeps the BMP running smoothly and prolongs, or eliminates, the need for intensive rehabilitation such as side

slope restabilization. The table below outlines the regular and as-needed maintenance practices for VFS and grass swales. Specific information on inspection and maintenance requirements can be found in Appendix D of the TRWD Developer Manual.

Regular Maintenance

MAINTENANCE ITEMS	FREQUENCY
Clear trash, debris, weeds, and foliage	Monthly or as needed
Mow lawn	Annually, but monthly during growing season

As-Needed Maintenance

INSPECTION ISSUE	ACTION
Standing water after drawdown time	Check for excessive fines/hard-packing on the surface
Foul odors or insects such as mosquitos	Retrofit BMP to prevent stagnant water
Inlet/outlets clogged with debris	Clear out accumulated debris.
Accumulated sediment/debris higher than limit	Dredge or remove accumulated sediment or debris.
Poor vegetative health / invasive species	Replant vegetation and remove invasive species.
Excessive or overgrown vegetation	Prune the excessive/overgrown vegetation.
Banks/slopes eroded	Repair banks/slopes such that they match design slopes. Install energy dissipaters or flow diversions.
Signs of channeling or worn paths	Mow or possibly regrade.
Pipe corrosion	Replace piping. If reoccurring issue, consider different material or covering the pipe with a corrosion resistant coating.

Pollutant Removal Effectiveness:

POLLUTANT	REMOVAL EFFECTIVENESS
Sediment	Medium to High
Nutrients	Low to Medium
Trash	Low to Medium
Metal	Low to Medium
Bacteria	Low*
Oil and Grease	Medium to High
Organics	Medium to High

(SARA, 2013; iSWM, 2014)

* Removal effectiveness will vary based on removal mechanism (i.e. adsorption to sediment or vegetation or infiltration)

References or Future Reading:

"Dominican College Dry Swale." (2007). New York State Department of Environmental Conservation. Accessed September 2017. < <http://www.dec.ny.gov/lands/59332.html> >.

"iSWM Technical Manual: Site Development Controls". (2014). North Central Texas Council of Governments. Accessed September 2017. < http://iswm.nctcog.org/Documents/technical_manual/Site_Development_Controls_9-2014.pdf >.

"Niskayuna Busiess Park Dry Swale." (2005). New York State Department of Environmental Conservation. Accessed September 2017. < <http://www.dec.ny.gov/lands/59335.html> >.

"San Antonio River Basin Low Impact Development Technical Design Guidance Manual". (2013). San Antonio River Authority. Accessed September 2017. < <https://www.sara-tx.org/wp-content/uploads/2015/05/Full-LID-Manual.pdf> >.

"Sustainable practices for landscape design: vegetated swales". (2010). Dott Architecture. Accessed September 2017. < <https://dottarchitecture.com/2010/06/03/sustainable-practices-for-landscape-design-vegetated-swales/> >.

"Tarrant Regional Water District Developer Manual". (2018). Tarrant Regional Water District (TRWD).

Wet Basins

Overview:

Wet basins are a Best Management Practice (BMP) designed to retain stormwater between runoff events to allow the retained volume to be treated for an extended period. These BMPs are also known as wet ponds, stormwater ponds, or retention ponds. They are similar to extended dry detention basins, but this BMP maintains a permanent pool throughout the year. Wet basins remove pollutants from the surcharge primarily through particle settling and plant uptake of nutrients. This BMP is not intended for infiltration. Therefore, the stormwater runoff volume reduction is minimal, except through evaporation and evapotranspiration. Wet basins require large amounts of space and contributing drainage area. A source of inflow is needed to maintain a permanent pool throughout the year.



Wet basin (Tennessee Permanent SW Mgmt and DGM, 2014)

Benefits:

- Well suited for removal of particulate matter and some dissolved contaminants (TCEQ, 2005)
- Provides an aesthetically pleasing space for the surrounding community
- Provides wildlife habitat. See note below on bacterial indicator loads
- Effective for large tributary areas

Potential Constraints and Considerations:

- Requires continuous source of base flow (i.e. stormwater inflow or make-up water inflow)
- Potential significant maintenance costs and large amounts of sediment removal to prevent pond stagnation, floating debris, scum, algal blooms, and unpleasant odor (TCEQ, 2005).
- Potential accumulation of salts and scum that can be discharged during large storm events
- Proper design must be used to prevent habitat for undesirable insects such as mosquitos
- May not be appropriate for locations with high groundwater levels due to potential for contamination
- Overgrowth and sediment accumulation may reduce hydraulic capacity



Wet basin (CDM Smith, 2017)

Design Guidance:

First, delineate the drainage area of the BMP. Next, all runoff from impervious surfaces should be directed towards the BMP. Important site considerations during design include assessment of the portion of which is impervious, depth to



Wet basin multi-stage outlet (SARA Manual, 2013)

the water table, permeability of soils, downstream water surface, and overall space required for the BMP. The wet basin does not vary in depth as much as the constructed wetland, though, 15% of the total surface area of the basin must be made up of a littoral zone, or safety bench. Like the constructed wetland, it has a micropool at the outlet for additional treatment before discharge. The water quality volume (WQv) should drain within 12 hours. The minimum components for a wet basin include, a stormwater inlet, pre- and post-treatment, energy dissipation, area protection, landscaping, and outlets/piping. Refer to Section 4 of the TRWD DM for specific information on these components.



Rendering of a wet basin after a storm (TRWD DM, 2018)

Sizing Criteria:

The calculations below are from Section 3.4 of the TRWD DM. This table contains the main calculations for sizing the BMP. Reference Section 3.4 and Appendix E for the specific design calculations and criteria.

STEP 1	Water Quality Capture Volume ($WQ_v = DA \cdot [d_i / (12 \text{ in/hr})] \cdot 43,560 \text{ ft}^3/\text{ac}$)	ft³
	Contributing Drainage Area (DA)	ac
	Capture Depth for 12 Hour Drawdown Time (d_i)	in
STEP 2	Sediment Forebay Volume ($V_{fb} = 0.1 \text{ in per impervious acre of drainage area}$)	ft³
	Impervious Drainage Area (A_{imp})	ft ²
STEP 3	Basin Volume ($V_b = V_p + V_s$)	ft³
	Permanent Pool Volume (V_p) = 100% WQ_v	ft ³
	Surcharge Pool Volume (V_s) = 120% WQ_v	ft ³
STEP 4	Orifice Diameter ($d_o = 2 \cdot (A_o / \pi)^{0.5}$)	in
	Max. discharge of WQ_v (Q_o)	ft ³ /s
	Drain time (t_d)	hr
	Orifice opening area (A_o)	in ²
	Orifice coefficient (c)	-
	Average head (H_{avg})	ft

Inspection and Maintenance Requirements:

Inspections help to ensure that the wet basin continues to operate as designed and effectively throughout its lifespan. Regular inspection also indicates when certain maintenance practices are necessary. Like inspection, regular maintenance keeps the BMP running smoothly and prolongs, or eliminates, the need for intensive rehabilitation such as side slope restabilization or replacing of corroded pipes. The table below outlines the regular and as-needed maintenance practices for wet basins. Specific information on inspection and maintenance requirements can be found in Appendix D of the TRWD DM.

Regular Maintenance

MAINTENANCE ITEMS	FREQUENCY
Clear trash, debris, weeks, and foliage	Monthly or as needed
Mow lawn	Annually, but monthly during growing season
Prune excessive vegetation / branches	Annually, but monthly during growing season
Replant Annuals	Before corresponding growing season

As-Needed Maintenance

INSPECTION ISSUE	ACTION
Standing water after design storm event and drawdown time	Check the inlet/outlet for clogging. Clean if necessary.
Foul odors or insects such as mosquitos	Retrofit BMP to prevent stagnant water
Inlet/outlets clogged with debris	Clear out accumulated debris.
Accumulated sediment/debris higher than limit	Dredge or remove accumulated sediment or debris to design elevations. Vacuum clogged permeable surfaces.
Poor vegetative health / invasive species	Replant vegetation and remove invasive species, taking care not to spread seeds/spores.
Excessive or overgrown vegetation	Prune the excessive/overgrown vegetation.
Banks/slopes eroded	Repair banks/slopes such that they match design slopes. Install energy dissipaters or flow diversions if reoccurring issue.
Signs of channeling or worn paths	Mow or possibly regrade.
Broken or missing area protection	Repair or replace area protection.
Pipe corrosion	Replace piping. If reoccurring issue, consider different material or covering the pipe with a corrosion resistant coating.

Pollutant Removal Effectiveness:

POLLUTANT	REMOVAL EFFECTIVENESS*
Sediment	High
Nutrients	Medium to High
Trash	High
Metals	Medium
Bacteria	High**
Oil and Grease	High
Organics	High

*(SARA Manual, 2013); Clary, J. 2017)

** Wetlands or other BMPs with wildlife habitat can have high internal loads of bacterial indicators

References or Future Reading:

"Complying with the Edwards Aquifer Rules: Technical Guidance on Best Management Practices". July 2005. TCEQ. RG-348. Accessed September 2017. < http://www.storm-tex.com/wp-content/uploads/2016/04/TCEQ_RG-348.pdf >.

"ISWM Technical Manual: Site Development Controls". (2014). North Central Texas Council of Governments. Accessed September 2017. < http://iswm.nctcog.org/Documents/technical_manual/Site_Development_Controls_9-2014.pdf >.

Clary, J. et al. "International Stormwater BMP Database 2016 Summary Statistics: Final Report". (2017). The Water Environment & Reuse Foundation. Accessed September 2017. < <http://www.bmpdatabase.org/Docs/03-SW-1COh%20BMP%20Database%202016%20Summary%20Stats.pdf> >.

"San Antonio River Basin Low Impact Development Technical Design Guidance Manual". (2013). San Antonio River Authority. Accessed September 2017. < <https://www.sara-tx.org/wp-content/uploads/2015/05/Full-LID-Manual.pdf> >.

"Tarrant Regional Water District Developer Manual". (2018). Tarrant Regional Water District (TRWD).

"Tennessee Permanent Stormwater Management and Design Guidance Manual". December 2014. Tennessee Department of Environment and Conservation. 1st ed. Accessed September 2017. < <https://app.box.com/s/pdl1afehg00s1wwqa94d8qmizyptxw3i/file/25367692645> >.



TRWD WATER QUALITY MANUAL

PLANNING AND IMPLEMENTING STORMWATER QUALITY PRACTICES

Appendix C

Planting Palettes

Herbaceous Species - Grasses



Cereal Rye
Secale cereale L.



Bermudagrass
Cynodon dactylon



Buffalo Grass
Buchloe dactyloides



Blue Grama
Bouteloua gracilis



Little Bluestem Grass
Schizachyrium scoparium



Side Oats Grama /
Bouteloua curtipendula



Big Bluestem
Andropogon gerardii



Green Sprangletop
Leptochola dubia

Herbaceous Species - Grasses



Eastern Gamagrass
Tripsacum dactyloides



Sand Dropseed
Sporobolus cryptandrus



Prairie Wildrye
Elymus canadensis



Switchgrass
Panicum virgatum



Sand Lovegrass
Eragrostis trichodes



Indiangrass
Sorghastrum nutans



Western Wheatgrass
Pascopyrum smithii



Cane Bluestem
Bothriochloa barbinodis



Texas Cupgrass
Eriochloa sericea

Herbaceous Species - Grasses



Curly Mesquite
Hilaria belangeri



White tridens
Tridens albescens



Bushy Bluestem
Andropogon glomeratus



Halls Panicum
Panicum hallii



Broomsedge Bluestem
Andropogon virginicus



Regal Mist Gulf Muhly
Muhlenbergia capillaris
'Regal Mist'



Lindheimer Muhly
Muhlenbergia lindheimeri



Cherokee Sedge
Carex cherokeensis



Emory's Sedge
Carex emoryi

Herbaceous Species - Grasses



Inland Sea Oats
Chasmanthium latifolium



Witchgrass
Panicum capillare



Virginia Wildrye
Elymus virginicus



Texas Bluegrass
Poa arachnifera

Herbaceous Species – Perennials



American Basketflower
Centaurea americana



Illinois Bundleflower
Desmanthus illinoensis



Clasping Coneflower
Dracopis amplexicaulis



Plains Coreopsis
Coreopsis lanceolate



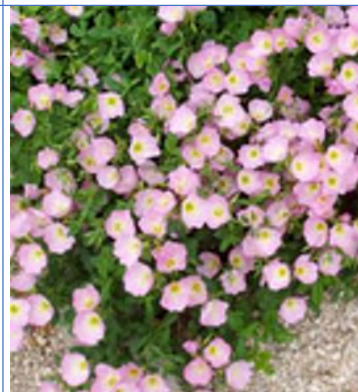
Blackeyed Susan
Rudbeckia hirta



Scarlet Sage
Salvia coccinea



Cutleaf Daisy
Engelmannia peristenia



Pink Evening Primrose
Oenothera speciosa



Maximilian Sunflower
Helianthus maximiliani

Herbaceous Species – Perennials



Giant Goldenrod
Solidago gigantea



Texas Bluebonnet
Lupinus texensis



Indian Blanket
Gaillardia pulchella



Lemon Mint
Monarda citriodora



Purple Prairie Clover
Dalea purpurea



White Prairie Clover
Dalea candida



Partridge Pea
Chamaecrista fasciculata



Gayfeather
Liatris spicata



Tall Goldenrod
Solidago altissima

Herbaceous Species – Perennials



Texas Yellow Star
Lindheimera texana



Zexmenia / Wedelia
Wedelia acapulcensis var. *hispida*



Aromatic Aster / *Symph-*
yotrichum oblongifolium



Gregg's Mistflower
Conoclinium greggii



Mealy Blue Sage
Salvia farinacea



Turk's Cap
Malvaviscus drummondii



Tall Aster / *Symphiotrichum*
praealtum var. *Praealtum*



Joe Pye Weed
Eupatorium fistulosum



Cardinal Flower
Lobelia cardinalis

Herbaceous Species - Perennials



Louisiana Iris
Iris ser. Hexagonae



Halberdleaf Hibiscus
Hibiscus laevis



Dwarf Tickseed
Coperopsis tinctoria



Late Boneset
Eupatorium serotinum



Cinnamon Fern
Osmunda cinnamomea



Royal Fern
Osmunda regalis



Texas Bluebells
Eustoma grandiflora



Common Milkweed
Aesclepias syriaca



Obedient Plant
Physostegia virginiana

Herbaceous Species - Perennials



Butterfly Weed
Asclepias tuberosa



Purple Coneflower
Echinacea purpurea



Texas Gayfeather / *Liatris punctata* var. *mucronatum*



Autumn Sage
Salvia greggii

Shrubs



Dwarf Yaupon Holly
Ilex vomitoria 'Nana'



Pale Leaf Yucca
Yucca pallida



Cast Iron Plant
Aspidistra elatior



American Beautyberry
Callicarpa americana



Dwarf Palmetto
Sabal minor



Dwarf Waxmyrtle
Morella cerifera var. pumilla



Common Buttonbush
Cephalanthus occidentalis

Ornamental Trees



Oklahoma Redbud /
Cercis canadensis
'Oklahoma'



Texas Redbud / *Cercis*
canadensis 'Texensis'



Mexican Redbud / *Cercis*
canadensis 'Mexicana'



Reverchon Hawthorn
Crataegus reverchonii



Eve's Necklace
Sophora affinis



Shantung Maple
Acer truncatum



Possumhaw
Ilex decidua



Yaupon Holly - Male
Ilex vomitoria



Yaupon Holly - Female
Ilex vomitoria

Ornamental Trees



Southern Waxmyrtle
Myrica cerifera



Wafer Ash
Ptelea trifoliata

Trees



Texas Ash
Fraxinus albicans



Slippery Elm
Ulmus rubra



Bald Cypress
Taxodium distichum



Montezuma Cypress
Taxodium mucronatum



Pond Cypress
Taxodium ascendens



Cedar Elm
Ulmus crassifolia



Green Ash
Fraxinus pennsylvanica



Pecan
Carya illinoensis



Common Persimmon
Diospyros virginiana

Trees



Bur Oak
Quercus macrocarpa



Chinkapin Oak
Quercus muhlenbergii



Shumard Oak
Quercus shumardii



Live Oak
Quercus virginiana

Aquatic Plants – Perennials and Grasses



Yellow Waterlily
Nymphaea mexicana



Fragrant Waterlily
Nymphaea odorata



Spatterdock
Nuphar luteum



Sweetflag
Acorus calamus



Caric Sedge
Carex spp.



Square Stem Spikerush
Elocharis quadrangulata



Swamp Sunflower
Helianthus angustifolius



Soft Rush
Juncus effusus



Rice Cut Grass
Leersia oryzoides

Aquatic Plants – Perennials and Grasses



Green Arum
Peltandra virginica



Smart Weed / *Polygonum hydropiperoides*



Pickerelweed
Pontederia cordata



Pickerelweed
Pontederia lanceolata



Lance-leaf Arrowhead
Sagittaria landifolia



Duck Potato
Sagittaria latifolia



Lizard's Tail
Saururus cernuus



Three-square
Scirpus americanus



Giant Bulrush
Scirpus californicus

Aquatic Plants – Perennials and Grasses



Softstem Bulrush
Scirpus validus



Virginia Chain Fern
Woodwardia virginica



TRWD WATER QUALITY MANUAL

PLANNING AND IMPLEMENTING STORMWATER QUALITY PRACTICES

Appendix D

Design Component Inspection and Maintenance



TRWD WATER QUALITY MANUAL

PLANNING AND IMPLEMENTING STORMWATER QUALITY PRACTICES

APPENDIX D - DESIGN COMPONENT INSPECTION AND MAINTENANCE

This appendix discusses the inspection and maintenance items for each BMP to help maintain desired removal rates over the lifetime of the BMP. The following tools are intended to provide quick references and checklists that a Contractor, an Inspector, and an Operator could use to ensure that construction and operational use complies with this Manual. It is recommended to discuss these items during the pre-construction meeting.

INSPECTIONS

Construction Inspections

During construction, the BMPs must be installed according to design and installation procedures provided in this manual and outlined in the SWPPP. The site activity plan should cover the construction schedule, the runoff management plan, the site access plan, and the site utilization plan.

Contractor should be aware of final inspection requirements defined in the SWPPP, as well as local requirements for BMPs. **Table D-1** lists inspection items for construction inspection(s) and final construction inspection. During the pre-construction meeting, the Inspector and the Contractor should discuss these items and the other inspections required throughout the Construction Schedule.

When reporting the inspection activity, include the inspection date, the condition of the BMP components, any maintenance activity performed, and any notes for future maintenance.

Table D-1 Construction Inspection Items

Date Performed

Construction Site Inspection (include any maintenance activity performed and notes for future maintenance)		Condition? (Good, Fair, or Poor)	Notes
BMP condition	Inlets and outlets clear of debris		
	Sediment accumulation level within BMP (BMP should not be used for stormwater collection or conveyance until construction is complete)		
	Trash and debris accumulation within BMP		
	Fallen leaves, weeds, and dead or diseased plants removed and replaced		
	Condition of BMP media		
	Condition of basin structure (erosion, damage, etc.)		
	Mulch condition (if used on-site)		
Vegetation Establishment	Sufficient watering		
	Plant condition / survival		
	Inspections by certified arborists performed		
BMP implementation	BMP has positive grade from inlet to outlet		
	BMP constructed consistent with design		
Construction Activities	Owner / Contractor to coordinate with trades and subcontractors to prevent vehicle travel across bioretention footprint		
	Excess materials to be temporarily stockpiled in approved areas		
	Material storage areas are protected		
	Excavation areas are protected from heavy equipment to prevent compaction of soils within BMP footprint		
	BMP areas to be protected from use, wear and damage during construction period.		
Final Inspection Items	Underdrains operational and clear		
	Observation wells operational and clear		
	Clean-outs operational and clear		
	Stockpiled materials removed		
	Bioretention soils covered with mulch and / or vegetation		
Records	Detailed monthly records kept on site		

Post-Construction Inspection

The post-construction inspection and monitoring period covers the lifespan of the BMP from immediately after construction/establishment period to the decommissioning of the BMP. **Table D-2** lists inspection items for post-construction inspection(s) after the BMPs are in operation. Several of the inspection items include a frequency. The others should be inspected on a regular basis during other inspections and after storm events. The Inspectors should use the following timeline for ensuring that the BMPs are operating at their designed parameters.

When reporting the inspection activity, include the inspection date, the condition of the BMP components, any maintenance activity performed, and any notes for future maintenance.

Table D-2 Post-Construction Inspection Items

Date Performed

Inspection Items (include any maintenance activity performed and notes for future maintenance)		Condition? (Good, Fair, or Poor)	Notes
All BMPs	Foul odors or insects such as mosquitos		
	Inlet/outlets clogged with debris		
	Condition of BMP media		
	Condition of basin structure (erosion, damage, etc.)		
	Mulch condition (if used on-site)		
	Accumulated sediment/debris in forebay or channel higher than limit		
	Trash and debris accumulation within BMP		
	Underdrains operational and clear		
	Observation wells operational and clear		
	Clean-outs operational and clear		
	Broken or missing area protection		
	Signs of channeling or worn paths		
	Standing water after design drawdown subsequent to a storm event (for BMPs without permanent pools) (after storm events)		
	Poor vegetative health / invasive species (quarterly to bi-annually)		
	Fallen leaves, weeds, and dead or diseased plants removed and replaced		
	Banks/slopes eroded (bi-annually to annually and after large storm events)		
	Pipe corrosion (bi-annually to annually)		
	Surface media spent (bi-annually to annually)		
	Excessive or overgrown vegetation (Annually)		
Permeable Surfaces	Significant deterioration of surface course or pavers and structural integrity of pavement, inlets, and observation wells (bi-annually to annually)		
Retention and Irrigation Basin	Pump/Irrigation Equipment Failure (bi-annually to annually)		
Records	All submittals (including as-builts) submitted by owner to TRWD		
	Detailed monthly records kept on site		

MAINTENANCE

Maintaining BMPs should be performed on a regular basis and as needed based on the results of inspections. The following subsections will list the action and the frequency at which these maintenance items should be performed.

Regular Maintenance

Regular maintenance is necessary for continued performance throughout the lifetime of the BMP. Maintenance items in this category include mowing of lawns, pruning of branches, clearing debris and foliage, and vacuum sweeping. **Table D-3** lists these types of maintenance activities and the frequency at which they should be performed.

Table D-3 Regular Maintenance Requirements

Maintenance Items	Frequency	Notes
Clear trash, debris, weeds, and foliage	Monthly or as needed	
Manufactured Treatment Devices	Based on manufacturer specifications	Need to be maintained on a regular basis based on specifications
Mow, trim, and / or maintain vegetation	Annually or monthly based on safety. Monthly or more frequently during growing season	Any BMPs with landscaping. Don't mow vegetation too low and reduce the effectiveness of the vegetation
Prune excessive vegetation / branches	Annually, but monthly during growing season	
Replant Annuals	Before corresponding growing season	Incorporate plants that do not or rarely need to be replanted
Vacuum sweeping	Annually	Critical for permeable pavers

As-Needed Maintenance

As-needed maintenance are actions that should be performed resulting from an inspection. These actions include clearing accumulated sediments in forebays, vacuuming clogged surfaces, replanting vegetation, replacing corroded inlets/outlets, and restoring bank slopes. The following table lists the inspection item and the action required to fix the issue. These activities are performed as-needed, typically following the inspection timeline.

Table D-4 As Needed Maintenance Requirements

Inspected Issue	Required Action	BMPs
Pooling of water over surface course 48 hours after storm event	Additional vacuum sweeping when dry	Permeable Surfaces
Significant deterioration of surface course or pavers and structural integrity of pavement, inlets/outlets, and observation wells	Possible replacement of surface course, pavers, inlets/outlets, and observation well components depending on severity	Permeable Surfaces
Banks/slopes of impervious surface eroding such that it contributes high sediment loads to the permeable pavers	Stabilize or replace banks/slopes to minimize sediment loads to permeable pavers	Permeable Surfaces
Standing water after design storm event and drawdown time	Check the inlet/outlet for clogging. Clear if true. After water drains and basin, filter, or swale is dry, check for excessive fines/hard-packing on the surface	All BMPs
Foul odors or insects such as mosquitos	Retrofit BMP to promote insect predators and/or prevent stagnant water (e.g. fountain/sprinkler for permanent water or clear clogging for temporary water storage BMPs)	All BMPs
Inlet/outlets clogged with debris	Clear out accumulated debris. If needed and not installed previously, install debris screens.	All BMPs
Backflow prevention devices operating effectively	Inspect and maintain backflow prevention devices as necessary	All BMPs with backflow prevention system
Accumulated sediment/debris higher than limit	Dredge or remove accumulated sediment or debris to design elevations. Ensure that the accumulation marker is situation properly. Vacuum clogged permeable surfaces.	All BMPs
Poor vegetative health / invasive species	Replant vegetation and remove invasive species, taking care not to spread seeds/spores.	All Vegetated BMPs
Excessive or overgrown vegetation	Prune the excessive/overgrown vegetation. Reinstall or establish a routine pruning.	All Vegetated BMPs
Surface media spent	Replace the top of the surface media	Sand/Media Filters
Banks/slopes eroded	Repair banks/slopes such that they match design slopes. Install energy dissipaters or flow diversions if bank/slope erosion is a reoccurring issue.	All BMPs
Signs of channeling or worn paths	Mow or possibly regrade.	All BMPs with Grass Banks/Channels
Broken or missing area protection	Repair or replace area protection.	All BMPs
Underdrains and distribution pipes	Use observation wells and clean outs to identify clogged underdrains and to perform maintenance and clear out the underdrain system.	All BMPs with underdrains
Pipe corrosion	Replace piping. If reoccurring issue, consider different material or covering the pipe with a corrosion resistant coating.	All BMPs
Check valves	Inspect and maintain for proper operation	All BMPs
Pump/Irrigation equipment failure	Replace or repair equipment.	Retention and Irrigation Basin
Hydrodynamic separators and manufactured pre- and post-treatment devices	Inspect and maintain based on the manufacturer specifications.	Pre- and Post-Treatment Devices

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TRWD WATER QUALITY MANUAL

PLANNING AND IMPLEMENTING STORMWATER QUALITY PRACTICES

Appendix E

BMP Spreadsheets
(Provided Electronically)

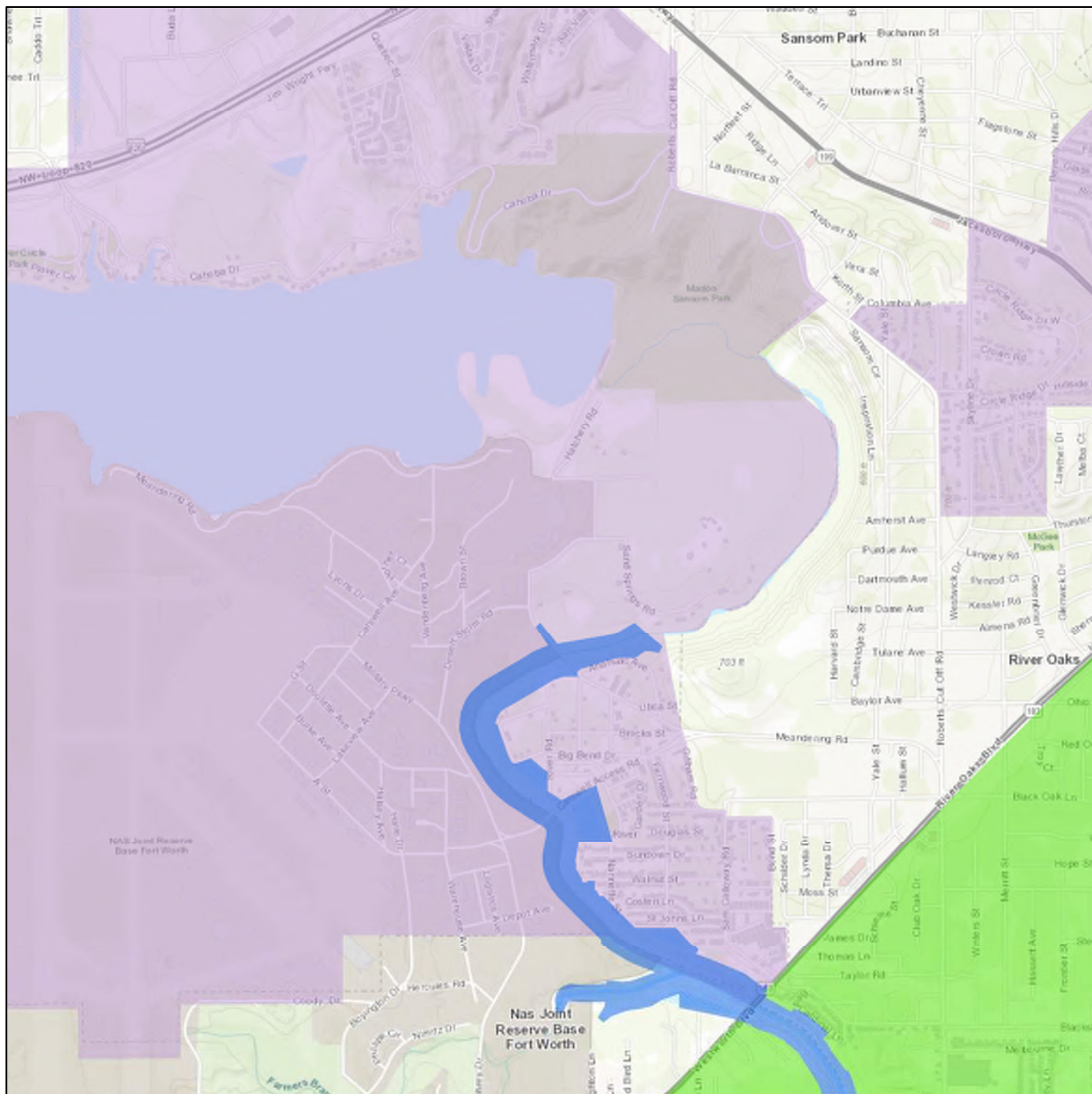


TRWD WATER QUALITY MANUAL

PLANNING AND IMPLEMENTING STORMWATER QUALITY PRACTICES

Appendix F

Zone Maps

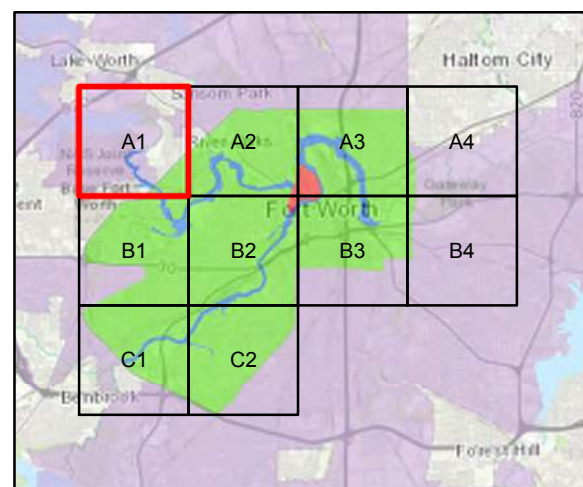
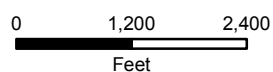


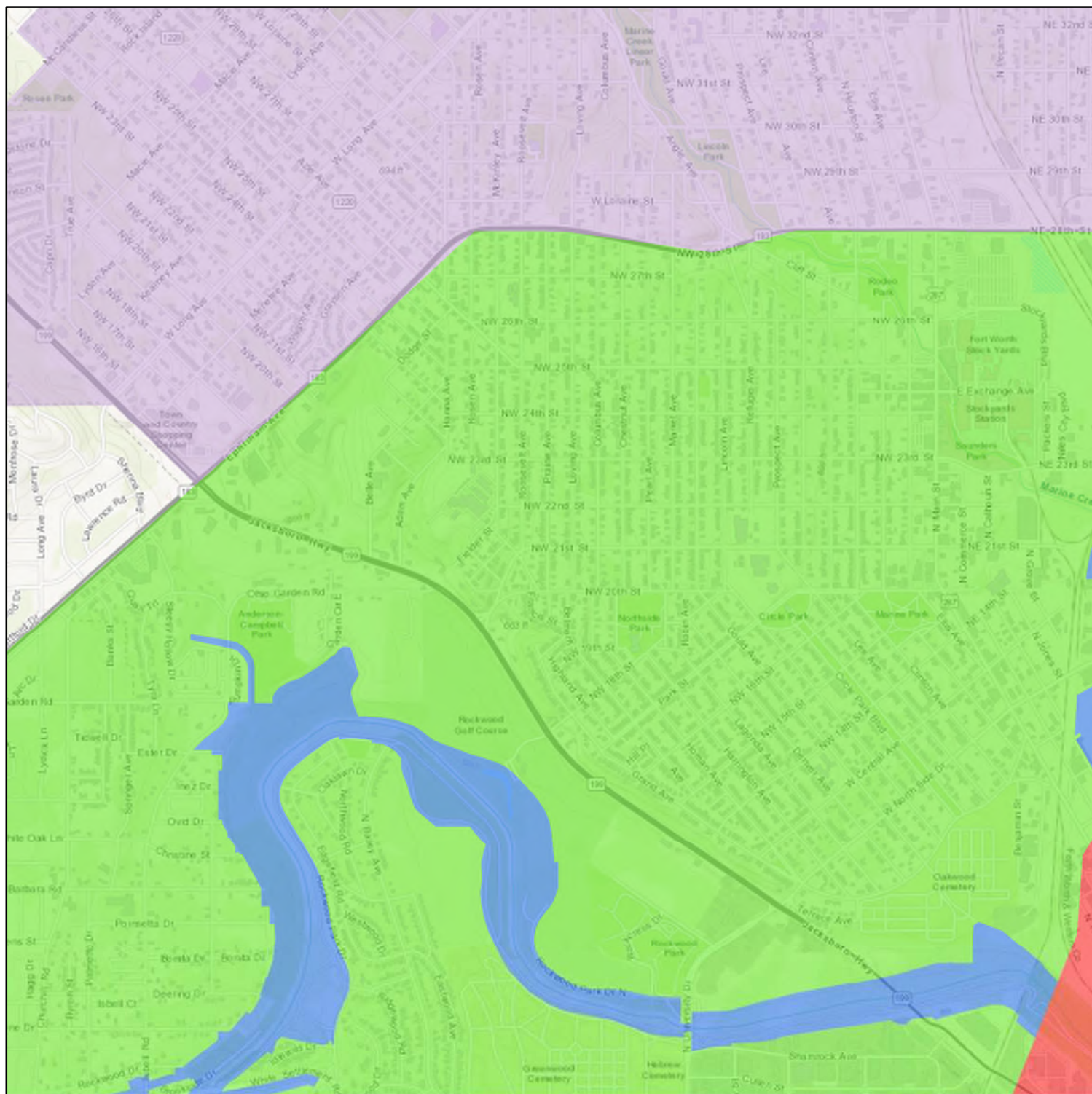
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- Zone 2 - Floodway Corridor
- Zone 3 – Water Quality Zone (Conceptual)
- Zone 4 - City of Fort Worth



A1





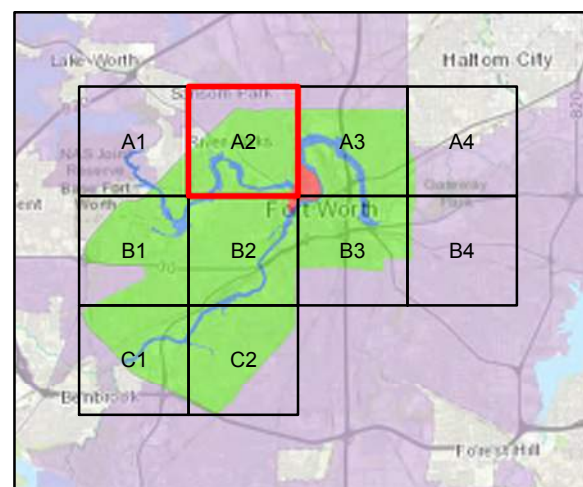
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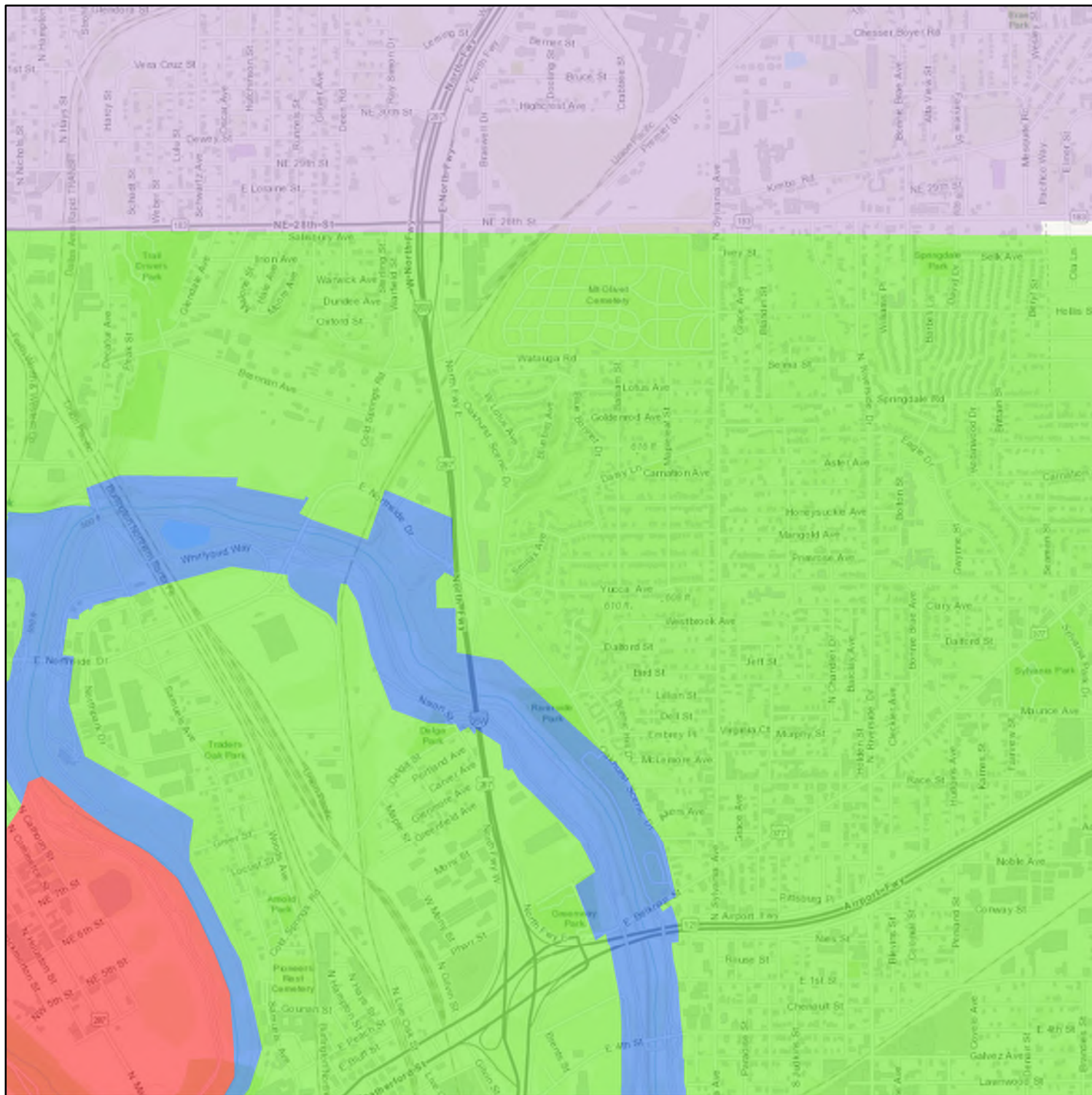
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- Zone 2 - Floodway Corridor
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- Zone 4 - City of Fort Worth



A2

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Feet





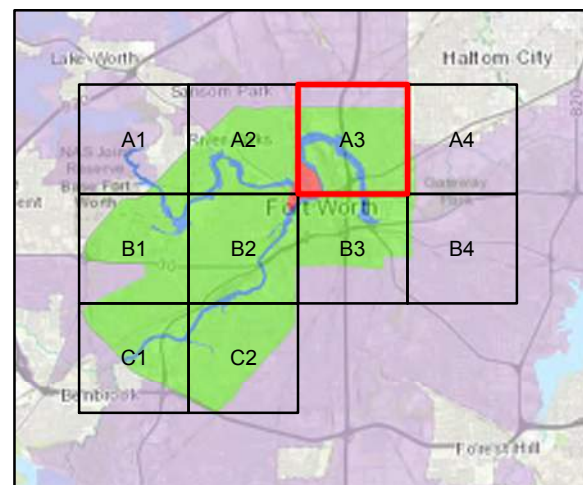
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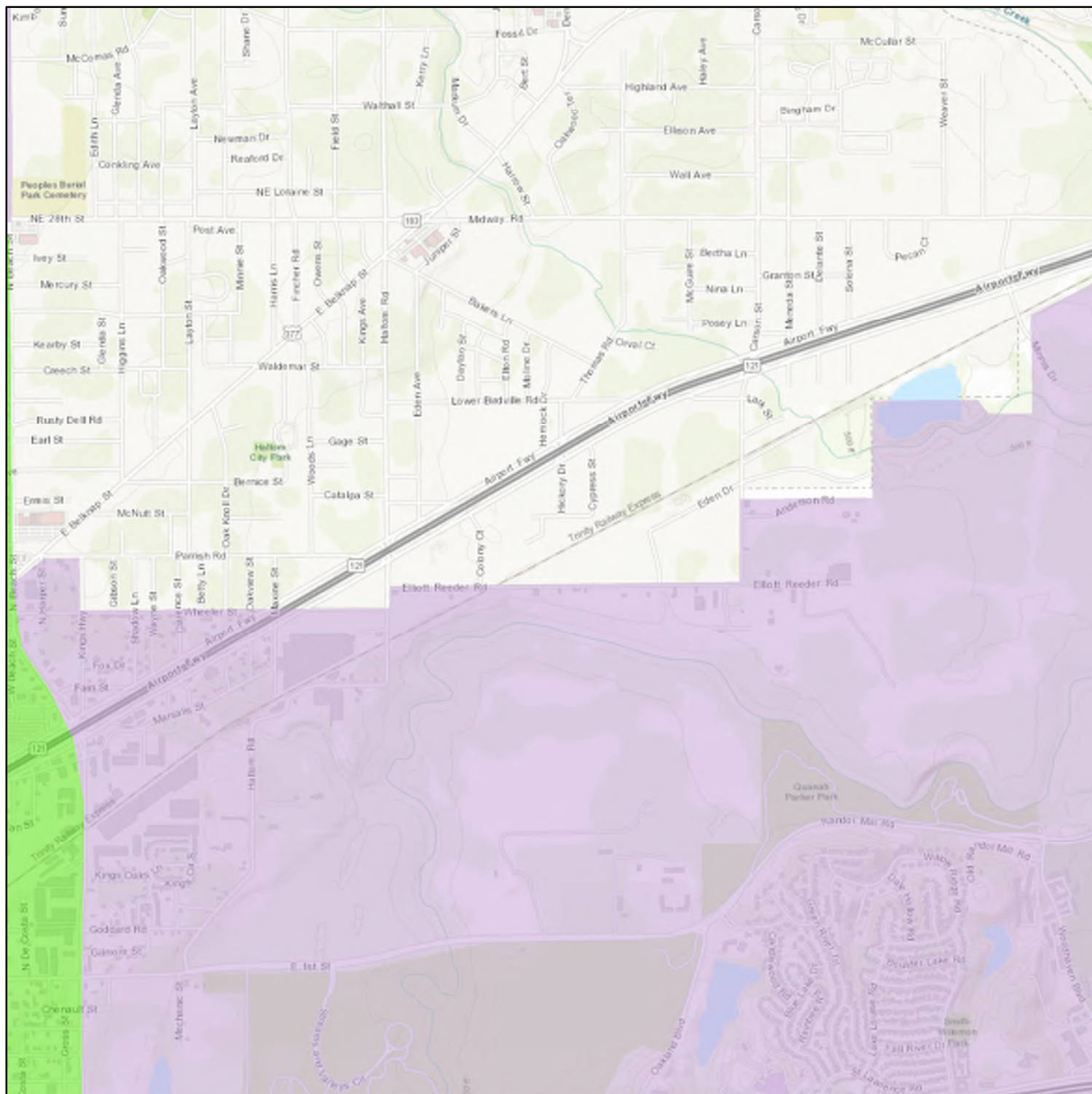
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A3

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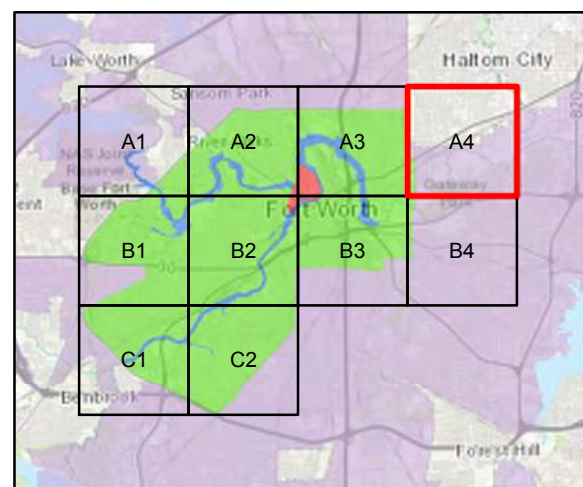
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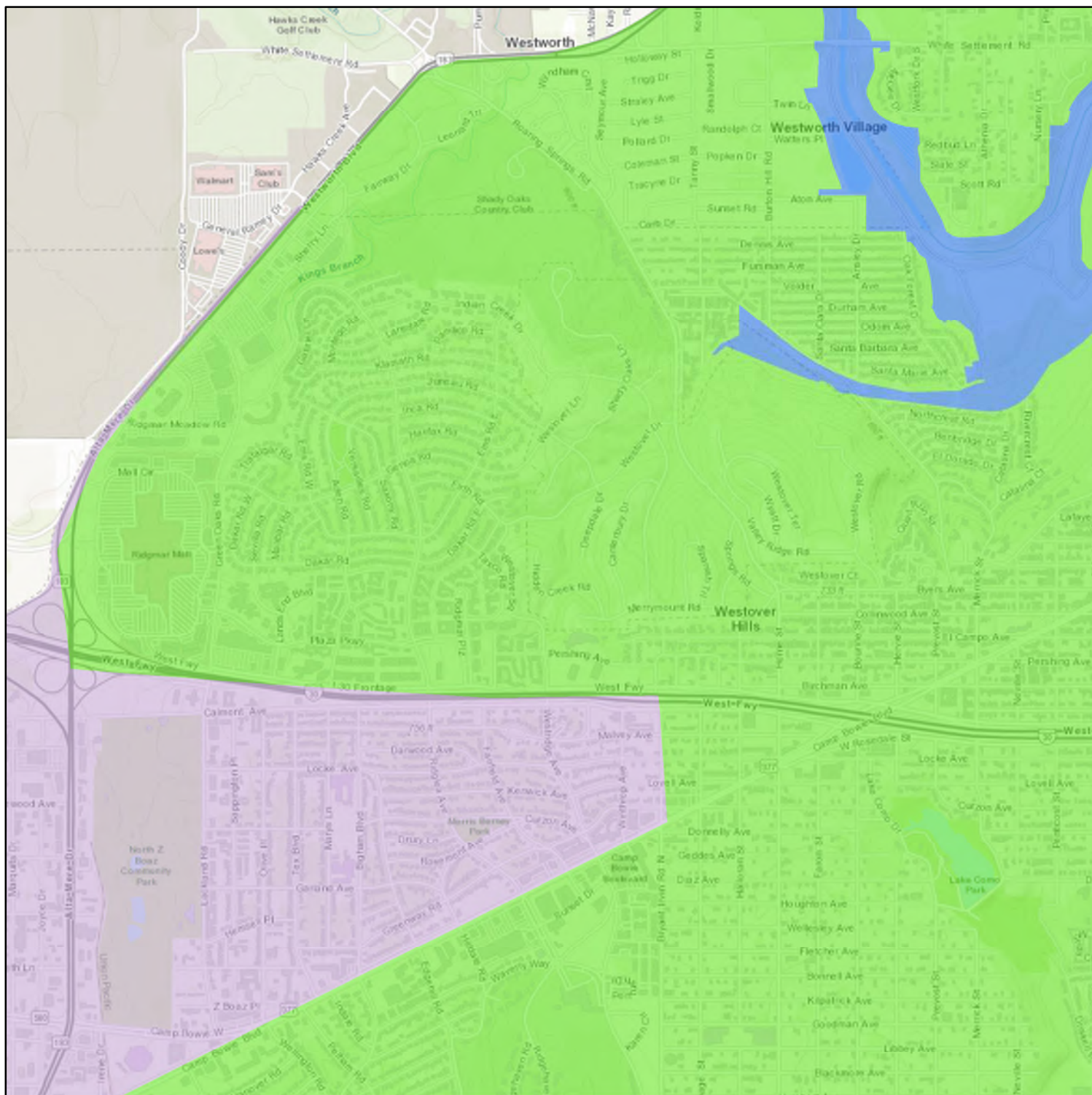
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A4

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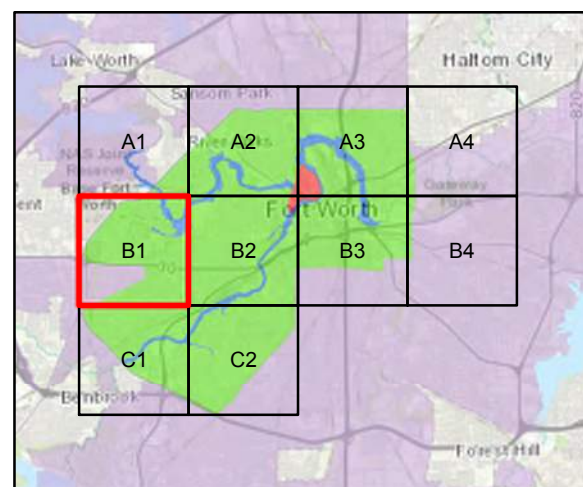
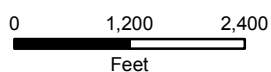


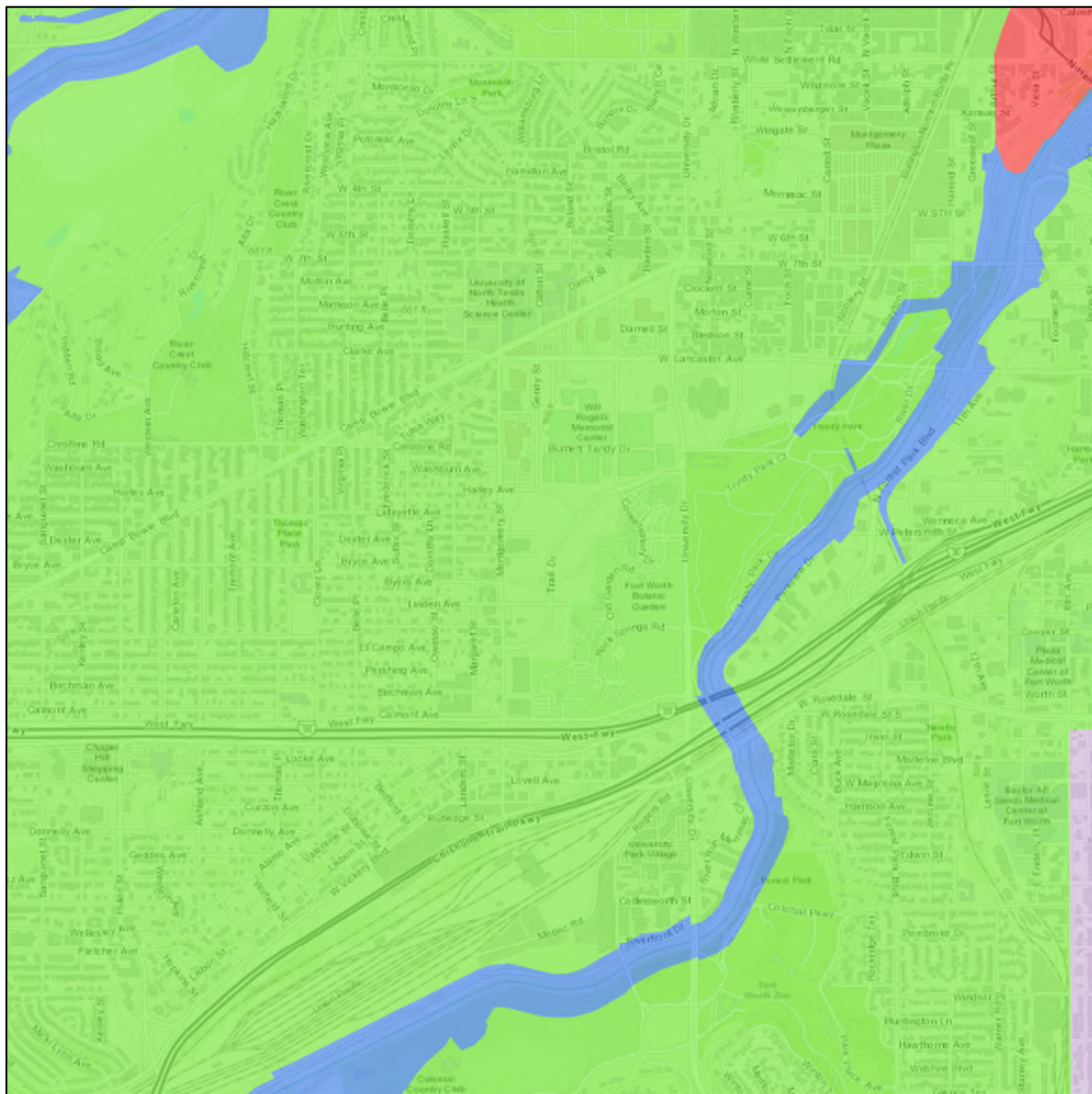
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B1



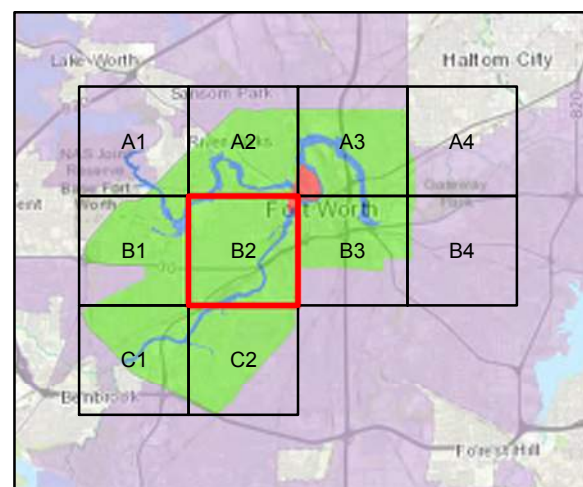
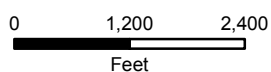


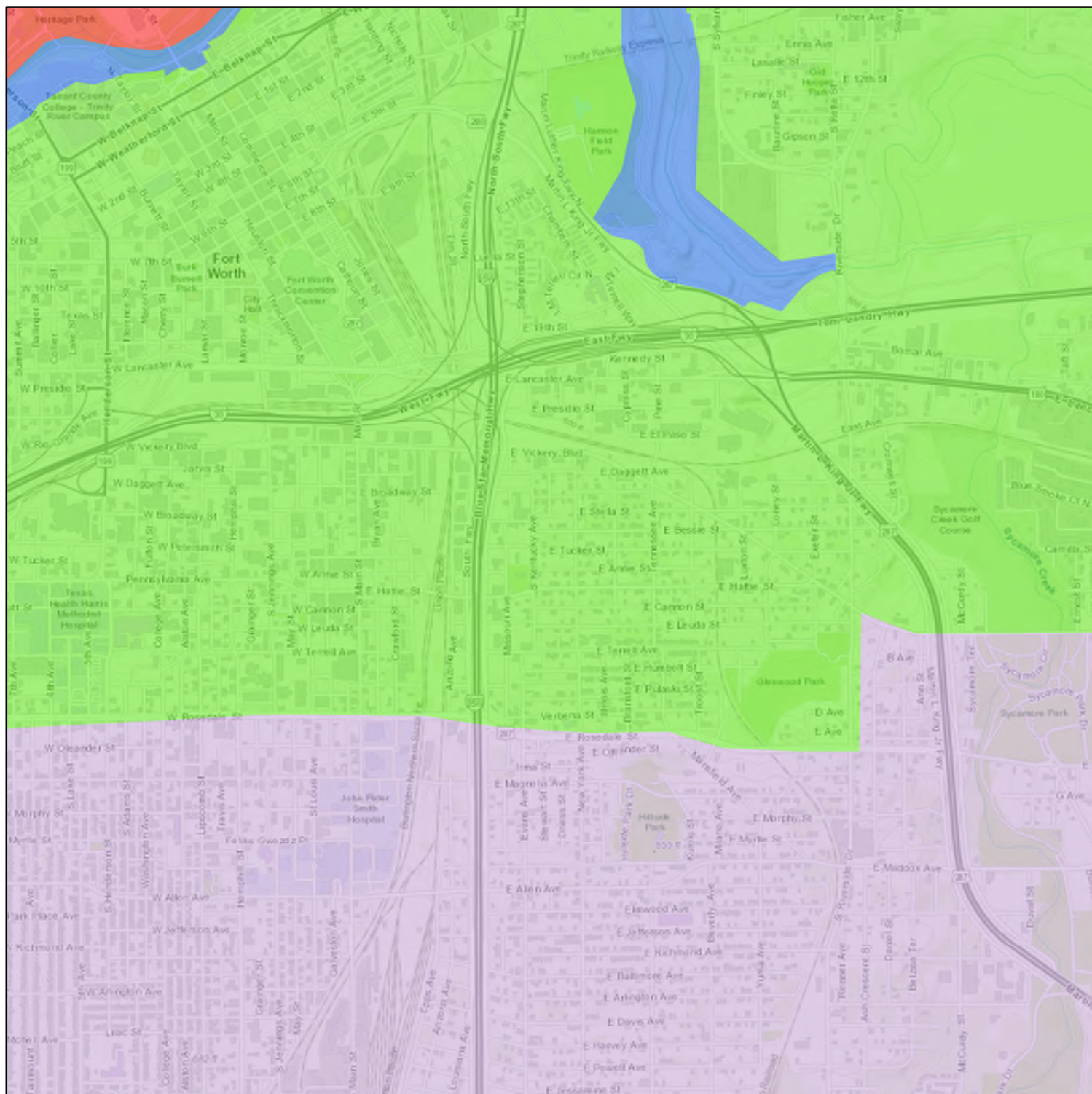
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- Zone 1 - Panther Island
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B2





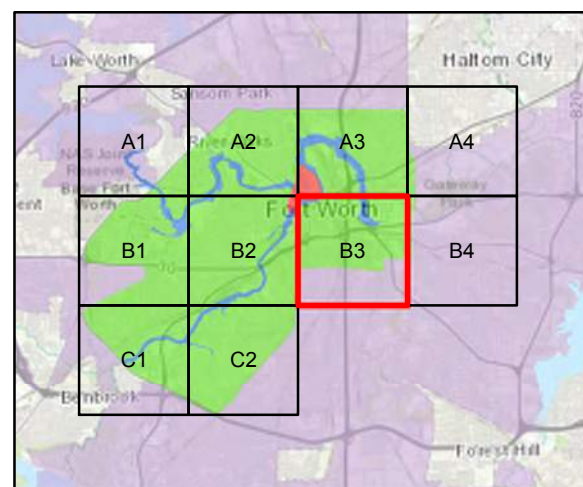
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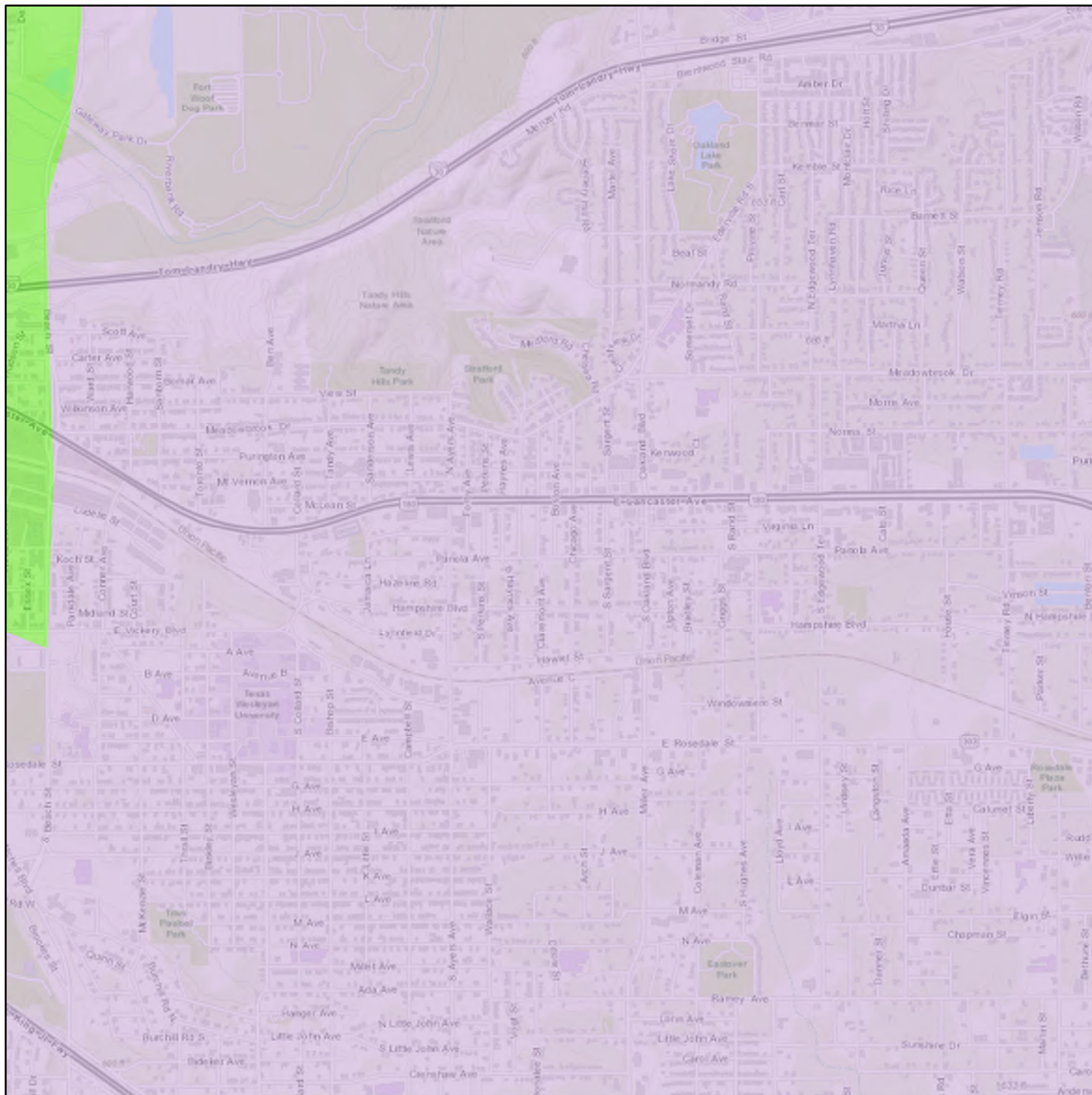
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B3

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Feet



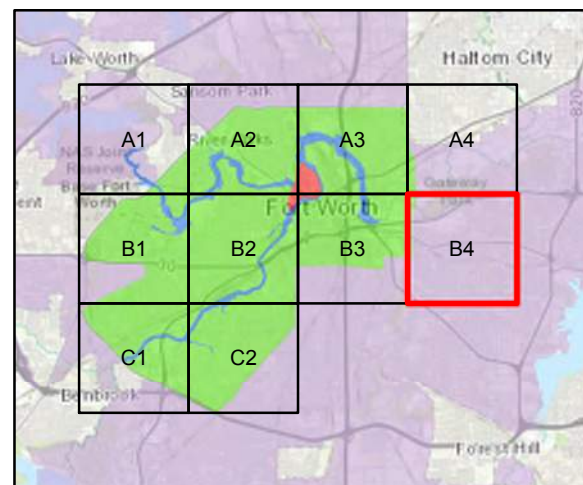
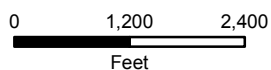


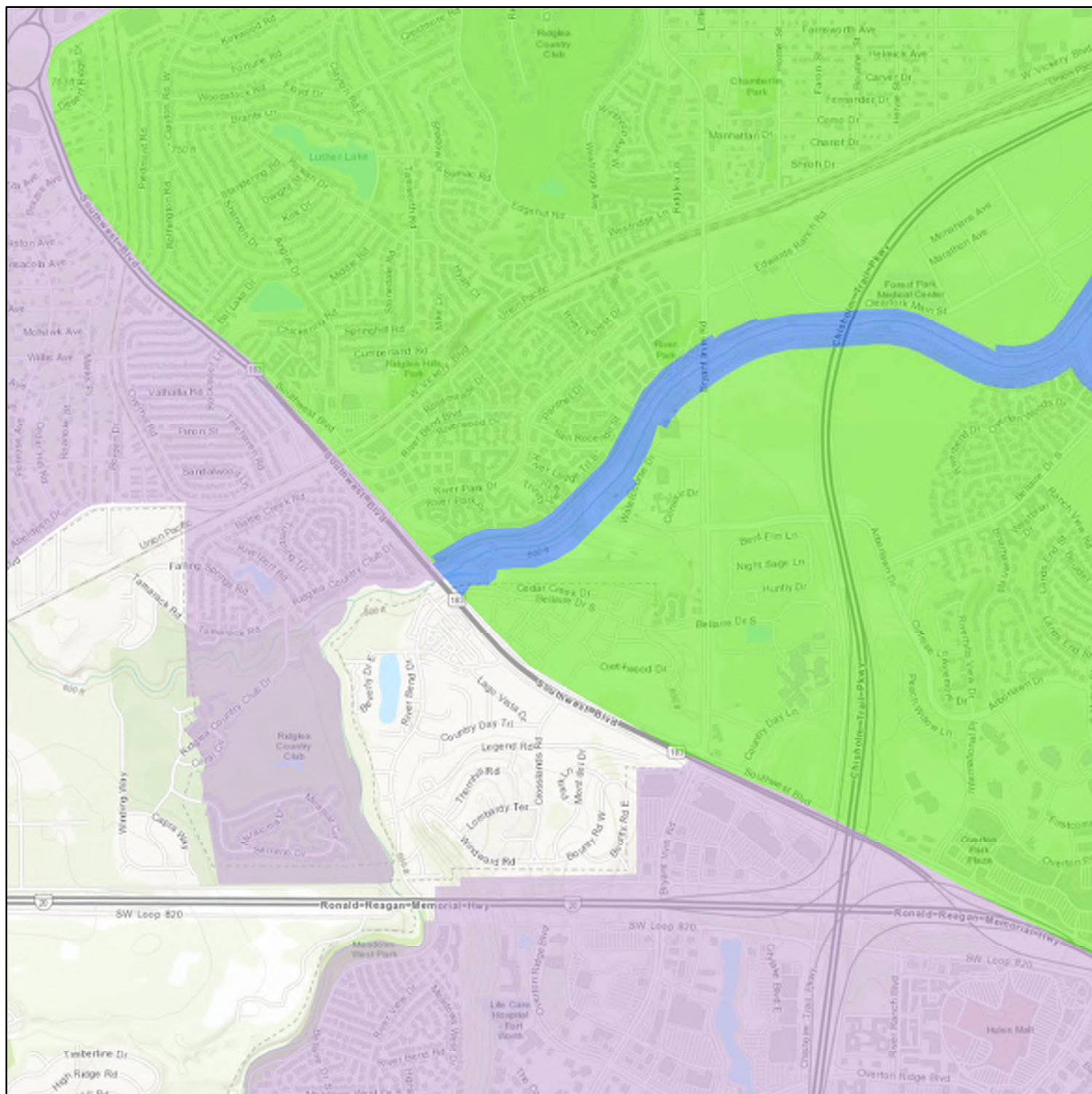
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B4



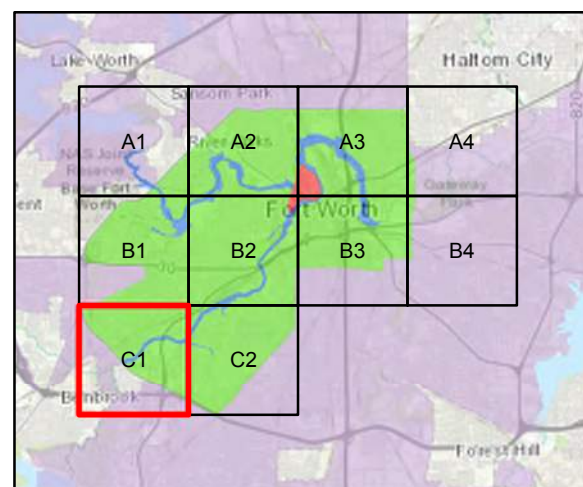
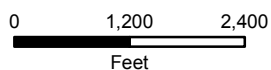


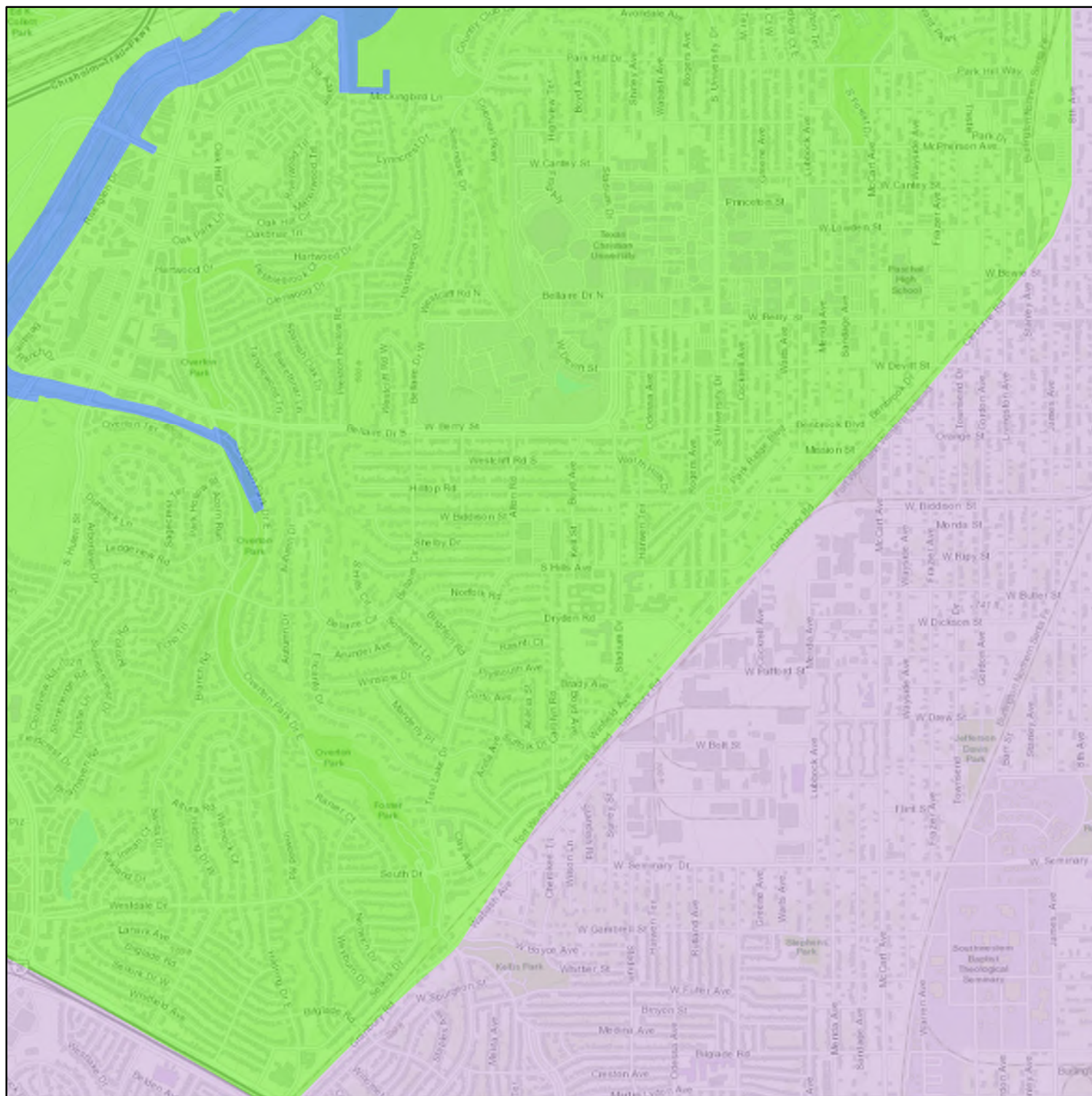
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C1





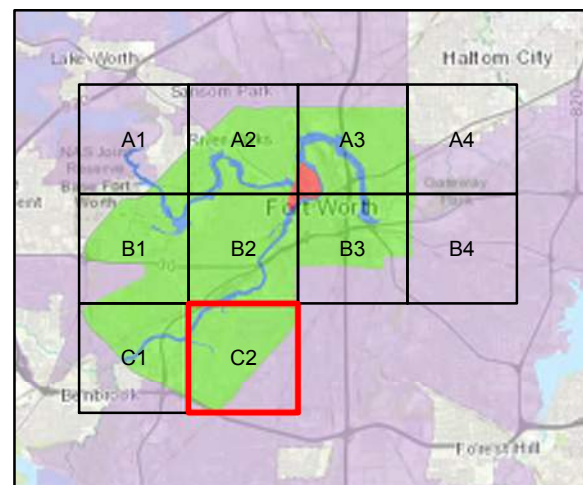
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C2

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Feet





TRWD WATER QUALITY MANUAL

PLANNING AND IMPLEMENTING STORMWATER QUALITY PRACTICES

Appendix G

Example Specifications

SECTION 32 14 13.19

PERMEABLE INTERLOCKING CONCRETE PAVEMENT

[Text in Blue is for information or guidance. Remove all blue text in the final project document.]

Note: This guide specification for U.S. applications describes construction of permeable interlocking concrete pavers on permeable, open-graded crushed stone bedding layers. The pavers and bedding layer are placed over an open-graded crushed stone subbase with exfiltration to the subgrade whenever site conditions permit. In low infiltration soils or installations with impermeable liners, some or all drainage is directed to an outlet via slotted drain pipes. While this guide specification does not cover excavation, notes are provided on these aspects.

The text that follows is a draft of sample specifications that will need to be edited to suit specific project requirements by a Licensed Qualified Professional Designer.

PART 1 – GENERAL

1.1 SUMMARY

A. Section Includes

1. Permeable interlocking concrete pavers
2. Crushed stone bedding material
3. Open-graded subbase aggregate
4. Open-graded base aggregate
5. Bedding and joint/opening filler materials
6. Edge restraints
7. [Coarse sand media]
8. [Geotextile fabric]
9. [Impermeable geomembrane liner]

B. Related Specifications Sections include, but are not necessarily limited to:

1. Division 0 – Bidding Requirements, Contract Forms, and Conditions of the Contract
2. Division 1 – General Requirements
3. Section 33 46 26 – Sand Filter [for Impermeable Geomembrane liner, Coarse Sand Media and Underdrain Pipe]

C. Other Related Specification Standards

Note: It is the responsibility of the Licensed Qualified Professional Designer to determine all applicable standards that relate to this section. For example: Section 33 05 10 – Utility Trench Excavation, Embedment, and Backfill as per the City of Fort Worth.

1.2 PRICE AND PAYMENT PROCEDURES

A. Measurement and Payment

DISCLAIMER: The content of this specification is for informational purposes only and does NOT necessarily constitute a design requirement of the Tarrant Regional Water District or any of its project partners. Information contained herein is for guidance and reference. It is the responsibility of the design engineer to provide specifications appropriate for each individual project.

1.3 REFERENCES

- A. American Society for Testing and Materials International (ASTM); use all active and updated standards
 - 1. ASTM C131 Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.
 - 2. ASTM C136 Method for Sieve Analysis for Fine and Coarse Aggregate.
 - 3. ASTM C140 Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units.
 - 4. ASTM D448 Standard Classification for Sizes of Aggregate for Road and Bridge Construction.
 - 5. ASTM C936 Standard Specification for Solid Interlocking Concrete Pavers.
 - 6. ASTM C979 Specification for Pigments for Integrally Colored Concrete.
 - 7. ASTM C1645 Standard Test Method for Freeze-thaw and De-icing Salt Durability of Solid Concrete Interlocking Paving Units.
 - 8. ASTM C1781 Standard Test Method for Surface Infiltration Rate of Permeable Unit Pavement Systems.
 - 9. ASTM D3385 Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer.
 - 10. ASTM E2835 Standard Test Method for Measuring Deflections using a Portable Impulse Plate Load Test Device.
- B. Interlocking Concrete Pavement Institute (ICPI)
 - 1. Permeable Interlocking Concrete Pavement manual (current edition)
 - 2. Permeable Design Pro software for hydrologic and structural design (*as determined by Design Professional for assistance of design sizing of permeable interlocking concrete pavement*)

1.4 ADMINISTRATIVE REQUIREMENTS

- A. Permitting
 - 1. Obtain Street Use Permit from the Transportation and Public Works Department in conformance with current ordinances.
 - 2. Transportation and Public Works Department will inspect paving after construction.

1.5 SUBMITTALS

- A. In accordance with Conditions of the Contract and Division 1 Submittal Procedures Section.
- B. Paver manufacturer's/installation subcontractor's drawings and details: Indicate perimeter conditions, junction with other materials, expansion and control joints, paver [layout,] [patterns,] [color arrangement,] installation [and setting] details. Indicate layout, pattern and relationship of paving joints to fixtures, and project formed details.
- C. Minimum 3 lb. (2 kg) samples of subbase, base and bedding aggregate materials.
- D. Sieve analysis of aggregates for subbase, base and bedding materials per ASTM C 136.

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- E. Project specific or producer/manufacturer source test results for void ratio and bulk density of the base and subbase aggregates.
- F. Geotextile fabric sample at 12" x 12" and manufacturer's literature (if applicable).
- G. Impermeable geomembrane liner sample at 12" x 12" and manufacturer's literature (if applicable).
- H. Soils report indicating density test reports, classification, and infiltration rate measured on-site under compacted conditions, and suitability for the intended project.
- I. Erosion and sediment control plan.
- J. [Stormwater management (quality and quantity) calculations; structural analysis for vehicular applications] using ICPI Permeable Interlocking Concrete Pavements manual, Permeable Design Pro or [specify] design methods and models.
- K. Permeable concrete pavers
 - 1. Paver manufacturer's catalog sheets with product specifications.
 - 2. [Four] representative full-size samples of each paver type, thickness, color, and finish. Submit samples indicating the range of color expected in the finished installation.
 - 3. Accepted samples become the standard of acceptance for the work of this Section.
 - 4. Laboratory test reports certifying compliance of the concrete pavers with ASTM C 936.
 - 5. Manufacturer's certification of concrete pavers by ICPI as having met applicable ASTM standards.
 - 6. Manufacturers' material safety data sheets for the safe handling of the specified paving materials and other products specified herein.
 - 7. Paver manufacturer's written quality control procedures including representative samples of production record keeping that ensure conformance of paving products to the product specifications.
- L. Paver Installation Subcontractor
 - 1. Demonstrate that job foremen on the project have a current certificate from the Interlocking Concrete Pavement Institute Concrete Paver Installer Certification program and a record of completion from the PICP Installer Course.
 - 2. Job references from projects of a similar size and complexity. Provide Owner/Client/General Contractor names, postal address, phone, fax, and email address.
 - 3. Written Method Statement and Quality Control Plan that describes material staging and flow, paving direction and installation procedures, including representative reporting forms that ensure conformance to the project specifications.

1.6 QUALITY ASSURANCE

- A. Paver Manufacturer Qualifications
 - 1. The manufacturer shall have a minimum of ten (10) years successful experience in the manufacture of pavers.

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2. The manufacturer shall have sufficient production capacity and established quality control procedures to produce, transport, and deliver the required pavers of the quality specified, without causing delay to the work.
3. The manufacturer shall have suitably experienced personnel and a management capability sufficient to produce pavers as depicted on the Drawings and specified herein.

B. Paver Installation Subcontractor Qualifications

1. The installer shall have a minimum of ten (10) years successful experience in the installation of unit pavers, similar to the pavers and setting systems required for this project.
2. Utilize an installer having successfully completed concrete paver installation similar in design, material and extent indicated on this project.
3. Utilize an installer with job foremen holding a record of completion from the Interlocking Concrete Pavement Institute PICP Installer Technician Course.
4. The installer shall have suitably experienced personnel and a management capability sufficient to execute the work shown on the Drawings and specified herein.
5. The installer's foreman/supervisor shall have a minimum of five (5) years experience in the installation of unit paver systems similar in size and nature to this project. The contractor shall ensure that the foreman/supervisor is on site for the entire duration of the work.

C. Regulatory Requirements and Approvals: [Specify applicable licensing, bonding or other requirements of regulatory agencies.].

D. Review the manufacturers' quality control plan, paver installation subcontractor's Method Statement and Quality Control Plan with a pre-construction meeting of representatives from the manufacturer, paver installation subcontractor, general contractor, engineer and/or owner's representative.

E. Mock-Ups: Use materials, methods and workmanship to show the standard of appearance and finish expected of the final paving. One (1) mock-up shall be required for each paving pattern.

1. Install a 10 ft x 10 ft (3 x 3 m) paver area.

Note: Mechanized installations may require a larger mock-up area. Consult with the paver installation contractor on the size of the mock-up.

2. Use this area to determine surcharge of the bedding layer, joint sizes, and lines, laying pattern, color and texture of the job.
3. This area will be used as the standard by which the work will be judged.
4. Subject to acceptance by owner, mock-up may be retained as part of finished work.
5. If mock-up is not retained, remove and properly dispose of mock-up.

1.7 DELIVERY, STORAGE, AND HANDLING

A. General: Comply with Division 1 Product Requirement Section.

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- B. Comply with manufacturer's ordering instructions and lead-time requirements to avoid construction delays.
- C. Delivery: Deliver materials in manufacturer's original, unopened, undamaged container packaging with identification tags intact on each paver bundle.
 - 1. Coordinate delivery and paving schedule to minimize interference with normal use of buildings adjacent to paving.
 - 2. Deliver concrete pavers to the site in steel banded, plastic banded, or plastic wrapped cubes capable of transfer by forklift or clamp lift.
 - 3. Unload pavers at job site in such a manner that no damage occurs to the product or existing construction.
- D. Rate of supply: Deliver and concrete pavers to the construction site in such quantities and at such times as will assure the continuity of the installation.
- E. Storage and Protection: Store materials in protected area such that they are kept free from mud, dirt, and other foreign materials. Store pavers at job site in such a manner that no damage occurs to the product or existing conditions.
- F. Storage: Place pallets on firm, level, and smooth surfaces and at least four (4) inches above the ground. Pallets shall be separated by a space of at least two (2) feet and shall not be stacked more than two (2) high. Place stored pallets so that identification marks are visible. Covers shall allow air to circulate freely around the pallets.
- G. Damaged pavers: No paver, or part thereof, used in the Works shall exhibit obvious signs of damage on the top surface, including but not limited to chipping, cracking and staining. Such damage shall be grounds for rejection.
- H. Bedding and Void (Jointing) aggregate: Deliver jointing sand in bags and store in such a way as to minimize contamination. Sand shall be covered with waterproof covering to prevent exposure to rainfall or removal by wind. The covering shall be secured in place.
- I. The contractor is responsible for providing fencing or other methods to prevent theft of vandalism of stored materials.

1.8 ENVIRONMENTAL REQUIREMENTS

- A. Do not install in rain, sleet, or snow.
- B. Do not install frozen bedding materials.

1.9 MAINTENANCE

- A. Extra materials: Provide [Specify area] [Specify percentage] additional material for use by owner for maintenance and repair.
- B. Pavers shall be from the same production run as installed materials.

PART 2 – PRODUCTS

2.1 OWNER FURNISHED PRODUCTS [IF NEEDED]

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2.2 PAVING UNITS

- A. Manufacturer: [Specify ICPI member manufacturer name.].
 - 1. Contact: [Specify ICPI member manufacturer contact information.].
- B. Permeable Interlocking Concrete Paver Units
 - 1. Paver Type: [Specify name of product group, family, series, etc.].
 - a. Material Standard: Comply with ASTM C936. Use -15 deg. C as the lowest temperature for freeze-thaw durability testing while test specimens are immersed in a 3% saline solution per ASTM C1645.
 - b. Color [and finish]: [Specify color.] [Specify finish].
 - c. Color Pigment Material Standard: Comply with ASTM C979.
 - Note: Concrete pavers may have spacer bars on each unit. Spacer bars are recommended for mechanically installed pavers. Manually installed pavers may be installed with or without spacer bars. Verify with manufacturers that overall dimensions do not include spacer bars.*
 - d. Size: [Specify.] inches [({Specify.} mm)] x [Specify.] inches [({Specify} mm)] x [Specify.] inches [({Specify.} mm)] thick.
- C. Visual Inspection
 - 1. The concrete pavers shall be free of chips that extend more than 3/8 in. in from the edge. The cumulative length of chips on a single edge shall not exceed 5% of the length of that edge.
 - 2. All concrete pavers shall be free from defects that interfere with the proper placing of the concrete pavers or impair the strength or performance thereof or the permanence of the construction.
 - 3. Minor cracks incidental to the usual methods of manufacture, or chipping resulting from customary methods of handling in shipment and delivery, shall not be deemed grounds for rejection.
 - 4. The color range of the concrete pavers shall be as depicted on the drawings and shall be submitted to and approved by the Owner's Representative.
- D. Records
 - 1. The Contractor shall ensure that the manufacturer maintains a production record showing batch numbers and date of manufacture. The product shall be marked with the batch number on the packaging for identification.

2.3 PRODUCT SUBSTITUTIONS

- A. Substitutions: Permitted for gradations for crushed stone jointing material, base and subbase materials. Base and subbase materials shall have a minimum 0.32 porosity. All substitutions shall be approved in writing by the project engineer.

2.4 CRUSHED STONE FILLER, BEDDING, BASE, AND SUBBASE

- A. Crushed stone with 90% fractured faces, LA Abrasion < 40 per ASTM C 131.
- B. Do not use rounded river gravel for vehicular applications.
- C. All stone materials shall be washed with less than 2% passing the No. 200 sieve.

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D. Joint/opening filler, bedding, base and subbase: conforming to ASTM D448 gradation as shown in Tables 1, 2, 3 and 4 below:

Note: No. 89 or No. 9 stone may be used to fill pavers with narrow joints.

Table 1	
ASTM No. 8 Joint/Opening Filler and Bedding	
Grading Requirements	
<u>Sieve Size</u>	<u>Percent Passing</u>
1/2"	100
3/8"	85-100
#4	10-30
#8	0-10
#16	0-5

Table 2	
ASTM No. 57 Base	
Grading Requirements	
<u>Sieve Size</u>	<u>Percent Passing</u>
1 1/2"	100
1"	95-100
1/2"	25-60
#4	0-10
#8	0-5

Table 3	
ASTM No. 3 Subbase	
Grading Requirements	
<u>Sieve Size</u>	<u>Percent Passing</u>
2 1/2"	100
2"	95-100
1 1/2"	35-70
1"	0-15
1/2"	0-5

Note: ASTM No. 2 stone may be used as subbase material if ASTM No. 3 stone is unavailable.

Table 4	
ASTM No. 2 Subbase	
Grading Requirements	
<u>Sieve Size</u>	<u>Percent Passing</u>
3"	100
2 1/2"	90-100
2"	35-70
1 1/2"	0-15
3/4"	0-5

2.5 IMPERMEABLE GEOMEMBRANE LINER – refer to Section 33 46 26 – Sand Filter.

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2.6 COARSE SAND MEDIA – refer to Section 33 46 26 – Sand Filter.

2.7 UNDERDRAIN PIPE – refer to Section 33 46 26 – Sand Filter.

2.8 ACCESSORIES

A. Provide accessory materials as follows

Note: Curbs will typically be cast-in-place concrete or precast set in concrete haunches. Concrete curbs may be specified in another Section. Do not use plastic edging with steel spikes to restrain the paving units for vehicular applications.

1. Edge Restraints
 - a. Manufacturer: [Specify manufacturer.].
 - b. Material: [Pre-cast concrete] [Cut stone] [Concrete].
 - c. Material Standard: [Specify material standard.].

Note: See ICPI publication, Permeable Interlocking Concrete Pavements for guidance on geotextile selection. Geotextile use is a designer option.

2. Geotextile
 - a. Material Type and Description: [Specify material type and description.].
 - b. Material Standard: [Specify material standard.].
 - c. Manufacturer: [Acceptable to interlocking concrete paver manufacturer]]

2.9 SOURCE QUALITY CONTROL [IF NEEDED]

PART 3 – EXECUTION

3.1 ACCEPTABLE INSTALLERS

A. [Specify acceptable paver installation subcontractors.].

3.2 EXAMINATION

Note: The elevations and surface tolerance of the soil subgrade determine the final surface elevations of concrete pavers. The paver installation contractor cannot correct deficiencies excavation and grading of the soil subgrade with additional bedding materials. Therefore, the surface elevations of the soil subgrade should be checked and accepted by the General Contractor or designated party, with written certification presented to the paver installation subcontractor prior to starting work.

A. Acceptance of Site Verification of Conditions

1. General Contractor shall inspect, accept and certify in writing to the paver installation subcontractor that site conditions meet specifications for the following items prior to installation of interlocking concrete pavers.

Note: Compaction of the soil subgrade is optional and should be determined by the project engineer. If the soil subgrade requires compaction, compact to a minimum of 95% standard Proctor density per ASTM C698. Compacted soil density and moisture should be checked in the

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field with a nuclear density gauge or other test methods for compliance to specifications. Stabilization of the soil and/or base material may be necessary with weak or continually saturated soils, or when subject to high wheel loads. Compaction will reduce the permeability of soils. If soil compaction is necessary, estimate the infiltration rate per ASTM D3385 for hydrologic design after compacting the test area(s) and measuring density. Reduced infiltration may require drain pipes within the open-graded subbase to conform to local storm drainage requirements.

- a. Verify that subgrade preparation, compacted density and elevations conform to specified requirements.
 - b. Provide written density test results for soil subgrade to the Owner, General Contractor and paver installation subcontractor.
 - c. Verify location, type, and elevations of edge restraints, [concrete collars around] utility structures, and drainage pipes and inlets.
2. Do not proceed with installation of bedding and interlocking concrete pavers until subgrade soil conditions are corrected by the General Contractor or designated subcontractor.

3.3 PREPARATION

- A. Verify that the soil subgrade is free from standing water.
- B. Stockpile joint/opening filler, base and subbase materials such that they are free from standing water, uniformly graded, free of any organic material or sediment, debris, and ready for placement.
- C. Edge Restraint Preparation
 1. Install edge restraints per the drawings [at the indicated elevations].

3.4 INSTALLATION

Note: The minimum slope of the soil subgrade is typically 0.5%. Actual slope of soil subgrade will depend on the drainage design and exfiltration type. All drain pipes, observation wells, overflow pipes, and (if applicable) geotextiles or impermeable geomembrane liner, berms, and baffles should be in place per the drawings prior to or during placement of the subbase and base, depending on their location. Care must be taken not to damage drainpipes during compaction and paving. Base/subbase thicknesses and drainage should be determined using ICPI's Permeable Interlocking Concrete Pavements manual and Permeable Design Pro software.

- A. General
 1. Any excess thickness of soil applied over the excavated soil subgrade to trap sediment from adjacent construction activities shall be removed before application of the [geotextile] [impermeable geomembrane liner] and subbase materials.
 2. Keep area where pavement is to be constructed free from sediment during entire job. [Geotextiles] [Impermeable Geomembrane Liner] Base and bedding materials contaminated with sediment shall be removed and replaced with clean materials.
 3. Do not damage drainpipes, overflow pipes, observation wells, or any inlets and other drainage appurtenances during installation. Report any damage immediately to the project engineer.

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B. Geotextiles or Impermeable Geomembrane Liner

1. Any excess thickness of soil applied over the excavated soil subgrade to trap sediment from adjacent construction activities shall be removed before application of the [geotextile] [impermeable geomembrane liner] and subbase materials.
2. Keep area where pavement is to be constructed free from sediment during entire job. [Geotextiles] [Impermeable Geomembrane Liner] Base and bedding materials contaminated with sediment shall be removed and replaced with clean materials.
3. Do not damage drainpipes, overflow pipes, observation wells, or any inlets and other drainage appurtenances during installation. Report any damage immediately to the project engineer.

C. Open-graded subbase with coarse sand media around underdrain pipes at low points for additional water quality treatment

1. Install No. 3 subbase stone under, around and over the top of the underdrain pipe.
2. Fill and water jet the coarse sand media to fill the voids between the No. 3 subbase stone below, around, and over the top of the underdrain pipe until the coarse sand has filled the voids and is stable without additional settlement.

D. Open-graded subbase and base

1. Moisten, spread and compact the No. 3 subbase in maximum 8 in. (200 mm) lifts [without wrinkling or folding the geotextile. Place subbase to protect geotextile from wrinkling under equipment tires and tracks.] Do not place subbase aggregate on a subgrade [or geotextile] with water ponded on it.
2. For each lift, make at least two (2) passes in the vibratory mode then at least two (2) in the static mode with a minimum 10 t (8 T) vibratory roller until there is no visible movement of the No. 3 stone. Do not crush aggregate with the roller.
3. Use a minimum 13,500 lbf (60 kN) plate compactor with a compaction indicator to compact areas that cannot be reached by the vibratory roller. Do not crush the aggregate with the plate compactor.
4. The surface tolerance of the compacted No. 3 subbase shall be $\pm 2 \frac{1}{2}$ in. (± 65 mm) over a 10 ft (3 m) straightedge.
5. Moisten, spread and compact the No. 57 base layer in one 4 in. (100 mm) thick lift. On this layer, make at least two (2) passes in the vibratory mode then at least two (2) in the static mode with a minimum 10 t (8 T) vibratory roller until there is no visible movement of the No. 57 stone. Do not crush aggregate with the roller.
6. The surface tolerance the compacted No. 57 base should not deviate more than. ± 1 in. (25 mm) over a 10 ft (3 m) straightedge.

Note: At the option of the designer, this supplemental test method bracketed in item D7 describing the use of a lightweight deflectometer (LWD) can be used for in-situ deflection testing of the compacted base layer (typically ASTM No. 57 stone). This test method can assist contractors in reaching adequate job site compaction and offer an additional level of confidence for the project owner and designer. This test method is appropriate for pavement subject to consistent vehicular traffic such as parking lots and roads. This test protocol is not needed for pedestrian areas and residential driveways. The LWD test method should comply with ASTM E2835.

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[

7. *Note: If No. 8 stone is not available, No. 89 can be used as a bedding course if choke criteria in the ICPI Permeable Interlocking Concrete Pavement manual (current edition) are met.*

- a. After three preloading drops, the maximum average deflection from three additional drops shall be no greater than 0.5 mm.

Note: Adjust tonnage quantity based on anticipated daily tons installed and compacted.

- b. Conduct LWD tests on every [800 tons (725 T)] of remaining area of compacted subbase and base aggregates.

8. Test Report:

- a. The test report shall include the following:
 - 1) Project description.
 - 2) Sketch of test area and numbered test locations.
 - 3) Aggregate type and layer thicknesses.
 - 4) Aggregate characteristic properties: gradation, porosity, bulk density.
 - 5) Compaction equipment type and weight.
 - 6) Static and/or vibratory compaction.
 - 7) Number of passes of the compaction equipment.
 - 8) Average of three deflections for each location.]
 - 9)

Note: If No. 8 stone is not available, No. 89 can be used as a bedding course if choke criteria in the ICPI Permeable Interlocking Concrete Pavement manual (5th edition) are met.

E. Bedding layer

1. Moisten, spread and screed the No. 8 stone bedding material. Maintain a consistent 2 in. (50mm thickness prior to compaction with the pavers.
2. Fill voids left by removed screed rails with No. 8 stone.
3. The surface tolerance of the screeded No. 8 bedding layer shall be $\pm 3/8$ in (10 mm) over a 10 ft (3 m) straightedge.
4. Do not subject screeded bedding material to any pedestrian or vehicular traffic before paving unit installation begins.

F. Permeable interlocking concrete pavers and joint/opening fill material

1. Lay the paving units in the pattern(s) and joint widths shown on the drawings. Maintain straight pattern lines.
2. Fill gaps at the edges of the paved area with cut units. Cut pavers subject to tire traffic shall be no smaller than 1/3 of a whole unit.
3. Cut pavers and place along the edges with a [double-bladed splitter or] masonry saw.
4. Fill the openings and joints with [No. 8] stone.

Note: Some paver joint widths may be narrow and not accept most of the No. 8 stone. Use joint material that will fill joints such as washed ASTM No. 89 or No. 9 stone.

5. Remove excess aggregate on the surface by sweeping pavers clean.

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6. Compact and seat the pavers into the bedding material using a low-amplitude, 75-90 Hz plate compactor capable of at least 5,000 lbf (22 kN). This will require at least two passes with the plate compactor.
7. Do not compact within 6 ft (2 m) of the unrestrained edges of the paving units.
8. Apply additional aggregate to the openings and joints if needed, filling them completely. Remove excess aggregate by sweeping then compact the pavers. This will require at least two passes with the plate compactor.
9. All pavers within 6 ft (2 m) of the laying face must be left fully compacted at the completion of each day.
10. The final surface tolerance of compacted pavers shall not deviate more than $\pm 3/8$ (10 mm) under a 10 ft (3 m) long straightedge.
11. The surface elevation of pavers shall be 1/8 to 1/4 in. (3 to 6 mm) above adjacent drainage inlets, concrete collars or channels.

3.5 REPAIR/RESTORATION

A. Repairs

1. Repair or replace any damaged work to the original specified condition prior to final acceptance.
2. Where lateral displacement of the concrete pavers has occurred adjacent to edge restraints the cut concrete pavers shall be replaced with new concrete pavers of the correct size to comply with the specified joint widths and the surface shall be re-established.

3.6 RE-INSTALLATION [IF NEEDED]

3.7 FIELD QUALITY CONTROL

- A. After sweeping the surface clean, check final elevations for conformance to the drawings.
- B. Lippage: No greater than 1/8 in. (3 mm) difference in height between adjacent pavers.

Note: The surface of the pavers may be 1/8 to 1/4 in. (3 to 6 mm) above the final elevations after compaction. This helps compensate for possible minor settling normal to pavements.

- C. The surface elevation of pavers shall be 1/8 to 1/4 in. (3 to 6 mm) above adjacent drainage inlets, concrete collars or channels.
- D. Bond lines for paver courses: $\pm 1/2$ in. (± 15 mm) over a 50 ft (15 m) string line.
- E. Verify the surface infiltration at a minimum of 100 in./hour using test method C 1781.

3.8 ADJUSTING [IF NEEDED]

3.9 CLEANING / CLEAN-UP

- A. All materials generated by construction work in this section shall be removed at the end of each section of work and the site shall be left in a clean and safe condition.

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- B. After completion of any repair work, clean all exposed surfaces with clean water and stiff brushes until all stains and dirt are removed. Use cleaning solutions only that are recommended by the concrete paver manufacturer and do not use wire brushes.
- C. The Worksite shall be thoroughly cleaned of all waste materials and all unused or salvaged materials, equipment, tools, etc. and left in an orderly condition.

3.10 CLOSEOUT ACTIVITIES [IF NEEDED]

3.11 PROTECTION

- A. After work in this section is complete, the General Contractor shall be responsible for protecting work from sediment deposition and damage due to subsequent construction activity on the site.
- B. PICP installation contractor shall return to site after six (6) months from the completion of the work and provide the following as required: fill paver joints with stones, replace broken or cracked pavers, and re-level settled pavers to initial elevations. Any additional work shall be considered part of original bid price and with no additional compensation.

3.12 WARRANTY

- A. One Year Warranty and Maintenance: PICP installation contractor shall return to the site at the Owner's request over a period of one (1) year from final acceptance to rectify any problems in the work caused by its failure to adequately align the concrete pavers, compact the base course or fill the void joints.
- B. Any additional work shall be considered part of original bid price and with no additional compensation.

3.13 MAINTENANCE

- A. Winter Sanding **should not** be used in area of Permeable Interlocking Concrete Pavement (PICP), or in adjacent surface areas that drain to the pavers. Sand will enter the joints between the pavers and reduce the system permeability. Deicing chemical such as sodium or calcium chloride can be used, but the quantity will likely be less for PICP because of thermal gain and the ability of PICP to infiltrate meltwater and the associated reduction in ice formation.
- B. Recommended Maintenance Guidelines (Example)

Note: Edit as appropriate for the specific project's applications or conditions.

Activity	Frequency												Per
	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Yr.
Review maintenance & operations records & incidences to determine if there have been any changes													1
Minimally 1 time per year													

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Activity	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Per Yr.
Document general site features (take photographs, etc.)					Minimally 1 time per year								1
Note any surface contamination or clogging					Minimally 1 time per year								1
Note obvious source of surface contaminants					Minimally 1 time per year								1
Identify the extent & severity of any damage or deficiencies (e.g., settlement, ponding, cracked pavers, etc.)					Minimally 1 time per year								1
Repair & replace cracked or broken pavers					once every 20 years upon inspection/determination								0.05
Repair & replace damaged pavements					once every 20 years upon inspection/determination								0.05
Repair & level pavers if ½" in parking or if ¼" for ADA access					once every 20 years upon inspection/determination								0.05
Replenish paver jointing aggregate					once every 20 years upon inspection/determination								0.05
Replace or add to subbase of pavers					once every 20 years upon inspection/determination								0.05
Inspect edge restraints to ensure that they are performing their required function					Minimally 1 time per year								1
Remove weeds and moss					Minimally 1 time per year								1
Remove trash & gently clean off with blower					12 times a year minimally								12
Regenerative air machine vacuum cleaning of pavements / pavers in street or sidewalks					Adjust cleaning intervals as based on infiltration test results – possibly one every 2-3 years								0.5
Check observation wells to confirm the maximum allowable storage time					Minimally 1 time per year								1
Underdrain system & observation wells – inspect, remove debris, & cleanout; make sure system is still performing				1	1						1		3

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Activity	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Per Yr.
Sand removal from paver areas after ice storm													1
After adjacent street sanding event to remove sands from joints													
Inspection & testing surface infiltration rate at different locations & applications per ASTM C1781													1
1 time per year													

Note:

Duration of project work and from adjacent construction: Inspect and Repair BMP's until adjacent construction is complete to prevent siltation of paver system; remove BMP's.

One initial visit for regenerative air machine vacuum cleaning of pavers / pavements within the first year of service.

3.14 ATTACHMENTS [IF NEEDED]

END OF SECTION

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SECTION 33 46 24
BIORETENTION (RAIN GARDEN)

[Text in Blue is for information or guidance. Remove all blue text in the final project document.]

The text that follows is a draft of sample specifications that will need to be edited to suit specific project requirements by a Licensed Qualified Professional Designer.

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes

1. Bioretention (Rain Garden) areas
2. Excavation
3. [Impermeable Geomembrane liner]
4. Drainage system
5. Underdrain system
6. Coarse sand media storage area
7. Plant materials and related items
8. Expanded shale
9. Screened cushion sand
10. Washed sand
11. Organic fully mature compost
12. Bioretention planting media
13. Testing
14. Installation of media
15. Finished grading
16. Plant materials
17. Mulches for topdressing
18. [Jute matting (mesh)]
19. [Tree ground anchoring frame]
20. Organic herbicide and organic fungicide
21. Organic insecticides
22. Silt and sedimentation protection at curb cut openings and splash pad/forebay curb openings
23. Irrigation: Watering with water-wise practices to establish and not over-water plants
24. Warranty and replacements
25. Maintenance

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26. Furnish all work and materials, appliances, tools, equipment, facilities, transportation, and services necessary for and incidental to performing all operations in connection with the installation of the bioretention (rain garden) areas.

B. Related Specification Sections include, but are not necessarily limited to:

1. Division 0 – Bidding Requirements, Contract Forms, and Conditions of the Contract
2. Division 1 – General Requirements
3. Section 33 46 26 – Sand Filters

C. Other Related Specification Standards

Note: It is the responsibility of the Licensed Qualified Professional Designer to determine all applicable standards that relate to this section. For example: Section 33 05 10 – Utility Trench Excavation, Embedment, and Backfill as per the City of Fort Worth.

1.2 PRICE AND PAYMENT PROCEDURES

A. Measurement and Payment

1.3 REFERENCES

- A. American Association of State Highway and Transportation Officials (AASHTO)
 1. AASHTO T194 – Determination of Organic Matter in Soils by Wet Combustion
- B. American Society for Testing and Materials International (ASTM); use all active and updated standards
 1. ASTM C131 Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
 2. ASTM C136 Method for Sieve Analysis for Fine and Coarse Aggregate
 3. ASTM C33/C33M Standard Specification for Concrete Aggregates
 4. ASTM C88 Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate
 5. ASTM C535 Standard Test Method for Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
 6. ASTM D448 Standard Classification for Sizes of Aggregate for Road and Bridge Construction
 7. ASTM D3385 Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer
 8. ASTM D4972 Standard Test Method for pH of Soils
 9. ASTM D5093 Standard Test Method for Field Measurement of Infiltration Rate Using Double-Ring Infiltrometer with Sealed-Inner Ring
 10. ASTM D6391 Standard Test Method for Field Measurement of Hydraulic Conductivity Using Borehole Infiltration
 11. ASTM F949 Standard Specification for Poly (Vinyl Chloride) (PVC) Corrugated Sewer Pipe with a Smooth Interior and Fittings

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- C. American Standard for Nursery Stock (under the American National Standard Institute (ANSI)), Edition approved April 14, 2014 by American Nursery and Landscape Association (ANSI Z60.1-2014) - plant materials.
- D. Environmental Protection Agency (EPA)
- E. Hortus Third, The Staff of the L.H. Bailey Hortorium. 1976. MacMillan Publishing Con., New York. Plant nomenclature.
- F. Organic Materials Review Institute (OMRI)
- G. Texas Department of Transportation (TXDOT) Standard Specification for Construction and Maintenance of Highways, Streets, and Bridges.
- H. USDA and US Composting Council. 2002. Test Methods for the Examination of Compost and Composting (TMECC)
 - 1. TMECC 02.02-B Sample Sieving for Aggregate Size Classification
 - 2. TMECC 04.03-A Total Phosphorus
 - 3. TMECC 04.04-A Total Potassium
 - 4. TMECC 04.05-Mg Magnesium
 - 5. TMECC 04.06 Heavy Metals and Hazardous Elements
 - 6. TMECC 04.10-A 1:5 Slurry Method, Mass Basis (Soluble Salts)
 - 7. TMECC 04.11-A 1:5 Slurry pH
 - 8. TMECC 05.05-A Seedling Emergence and Relative Growth
 - 9. TMECC 05.07-A Loss on Ignition Organic Matter Method
 - 10. TMECC 05.08-B Carbon Dioxide Evolution Rate
 - 11. TMECC 05.08-E Solvita® Maturity Index
 - 12. TMECC 07.01-B Fecal Coliforms

1.4 ADMINISTRATIVE REQUIREMENTS

- A. Permitting

1.5 DEFINITIONS

- A. Weeds: Any plant not specified on the drawings or accepted as a substitute.

1.6 SUBMITTALS

- A. Samples shall be submitted no less than sixty (60) days prior to installation for approval by Owner's Authorized Representative.
- B. Attach product name, address of manufacturer and/or supplier and appropriate literature and composition of material for each of the items as listed below. Literature or Product Data shall consist of manufacturer's current specifications, with catalog cuts, data sheets, safety data sheets, test results, installation instructions, and samples as noted.
 - 1. [Impermeable Geomembrane Liner: 12" x 12" sample]
 - 2. Expanded Shale: 1 gallon plastic bag or container
 - 3. Screened Cushion Sand: 1 gallon plastic bag or container

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4. Washed Sand: 1 gallon plastic bag or container
 5. Organic Compost: 1 gallon plastic bag or container
 6. Bioretention Planting Media: 1 gallon plastic bag or container
 7. Rustic Cut Mulch: 1 gallon plastic bag or container
 8. Single Grind Mulch: 1 gallon plastic bag or container
 9. [Jute Matting (Mesh): 12" x 12" sample]
 10. [Tree Ground Anchoring Frame]
 11. Organic Herbicide(s)
 12. Organic Fungicide(s)
 13. Organic Insecticide(s)
- C. Plant Material: Submit documentation no less than sixty (60) days prior to installation that all plant materials have been located and are ready to be secured. Arrange specific review procedure of plant materials at time of submission. Submittals and review shall be organized as follows:
1. Preliminary Review: Submit representative photographs for review of all plant materials in the required sizes and in available quantity at no less than sixty (60) working days prior to shipment to the site.
 2. Submittal shall include each of these items per plant: 1) a minimum of one (1) high quality color bond image or 2) one (1) color digital image. Include one (1) set for each plant type and size required for the project. The 8-1/2" x 11" sheet/image is to include the name and address of the supplier/grower, size of the plant in the picture and Botanical and English name of the plant and variety/cultivar name. Digital submittals are preferred due to expediting time and for reduction in the carbon footprint.
 3. Tree photographs shall include a person or device to determine scale, and shall include two (2) photographs of each tree type or group. The two (2) photographs shall be taken at approximately 90 degrees from each other. One (1) additional photograph shall be taken at the base of each tree to show root flare and root conditions at the soil surrounding the root flare.
 4. Provide any additional tree groups and specimen photographs as required to illustrate the quality and/or quantity of material.
 5. Poor quality photographs, photographs that are not in color, not labeled, or photographs which do not adequately represent the plant material will be rejected.
 6. Photograph Acceptance and Nursery Review: Acceptance of material through photographs/digital images does not preclude rejection of unsatisfactory material upon delivery. The Owner's Authorized Representative reserves the right to refuse review from photographs or at the grower if, in his judgment suitable material or sufficient quantities are not available. Contractor shall insure a sufficient quantity of plants will be available whenever trips are arranged to a nursery for the purposes of tagging material for the project.
 7. Specific sources of materials may be listed in the plant schedule for availability, size, quality control of plant character and for matching of specific plant growing conditions.

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8. Representative samples of smaller containerized or plug plant materials.
 9. Unavailable Material: If proof is submitted that any plant specified is not obtainable, a proposal will be considered for use of the nearest equivalent size or variety with corresponding adjustment of Contract price. Substantiate such proof in writing no later than sixty (60) days prior to installation.
- D. Sources: Within at least sixty (60) days prior to delivery to site, notify Owner and Owner's Authorized Representative in writing of source materials required for the project.

1.7 ACTION SUBMITTALS/INFORMATIONAL SUBMITTALS

- A. Organic Compost: submit for approval in accordance with 2.7.
- B. Bioretention Planting Media Mix Design: submit for approval in accordance with 2.8.

1.8 CLOSEOUT SUBMITTALS [IF NEEDED]

1.9 MAINTENANCE MATERIAL SUBMITTALS

- A. Maintenance Instructions: Submit to Owner's Authorized Representative for approval. Submit two (2) copies and one (1) electronic copy of revised instructions prior to expiration of Contractor's maintenance period(s) required under the contract.

1.10 QUALITY ASSURANCE AND QUALITY CONTROL

- A. General: Test and inspect materials and operations as work progresses as described in this section: Failure to detect defective Work or materials at any time will not prevent rejection if a defect is discovered after installation, nor shall it constitute final acceptance.
- B. Testing Agency Qualification
 1. General: Agencies that perform testing on bioretention soil media and related materials, including permeability/infiltration testing, shall be accredited by STA, ASTM, AASHTO, or other designated recognized standards organization. All certifications shall be current. Testing agency shall be capable of performing all tests to the designated and recognized standards specified and shall provide test results with an accompanying Manufacturer's Certificate of Compliance. The following information shall be provided for all testing laboratories used:
 - a. Name of lab(s) and contact person(s)
 - b. Address(es) and phone numbers
 - c. Email address(es)
 - d. Qualifications of laboratory and personnel including the date of current certification by STA, ASTM, AASHTO, or approved equivalent.
 2. Compost: Laboratory that performs testing shall be independent, enrolled in the US Composting Council's (USCC) Compost Analysis Proficiency (CAP) program, and perform testing in accordance with USCC Test Method for the Examination of Composting and Compost (TMECC).
 3. Qualified Lab.

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C. Contractor/Installer Qualification

1. Company: Specialized in performing the Work of this Section with minimum seven (7) years documented experience installing projects with bioretention (rain garden) basins of similar size and scope. The Contractor shall furnish a list of references or previous work experience on similar projects as requested by the Owner's Authorized Representative.
2. Personnel: Submit qualifications of qualified/experienced personnel who shall provide adequate supervision to ensure installation of the BMP/iSWM/LID/GSI features. Perform work only with qualified personnel familiar with required landscaping methods and materials.

D. Product Manufacturer Qualifications

1. Company specializing in manufacturing Products specified with minimum seven (7) years documented experience.

E. Plant Materials

1. Source quality control: Furnish certificates of inspection of landscape materials, to accompany shipments, as required by governmental authorities or as requested for inspection by Owner. Comply with applicable federal, state, county and local regulations governing landscape materials.
2. Growing location: Furnish certificates showing where materials have been grown or balled and burlapped.
3. Observation at growing site does not preclude right of rejection at the Worksite. Plants damaged in transit or at the Worksite shall be rejected.
4. Substitutions: Not permitted unless approved by the Owner's Authorized Representative when specified planting material is not obtainable.
 - a. Submit proof of non-availability together with proposal for use of equivalent material.
 - b. Substitutions of larger size or better grade than specified will be allowed upon approval by the Owner's Authorized Representative, but with no increase in unit price.

F. Mock-Ups

1. Demonstrate excavation, media barrier installation (if required), underdrain installation, bioretention planting media installation for bioretention (rain garden) planting areas for one (1) of each different application or depth condition on site at locations selected with Owner and Owner's Authorized Representatives to show compliance with Section 3 – Execution.
2. Coordinate with General Contractor for sequencing of mock-ups to demonstrate bioretention media installation for bioretention (rain garden) areas.
3. Contractor shall demonstrate installation of the topdressing with planting to prevent erosion, stabilize soils and prevent silting.
4. Refer to 3.19 for BMP's and Cap and Seal procedures, and to 3.3 Preparation.

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1.11 ANALYSES AND TESTING OF SAMPLES

- A. All testing specified herein is the responsibility of the Contractor and shall be conducted by the independent testing agency, retained by the Contractor. The Owner's Authorized Representative reserves the right to conduct additional testing on all materials submitted, delivered, or in-place to ensure compliance with Specifications.

Note: Batch-specific test results and certifications shall be required for projects installing more than 500 cubic yards of Bioretention Planting Media.

- B. Material for Testing: Bioretention Planting Media - pre-mixed proportions of soil per specification or for adjustment of proportions based on test results.
- C. Sampling of Media: Pre-mixed samples shall be pulled from approved submitted project stockpile mix for testing.
- D. Infiltration Rate Test: Pre-mixed media to provide minimum of fifty (50) inches per hour rate. Submit required quantity of Contractor selected media for Infiltration Test at independent testing agency selected by Owner, or as noted below, and paid for by Contractor. Repeat test as necessary at Contractor's cost.
- E. Hydraulic Conductivity Test: Submit required quantity of Contractor selected pre-mixed media for Infiltration Test at independent testing agency selected by Owner and paid for by Contractor. Repeat test as necessary at Contractor's cost.
- F. Testing: Pay cost of testing of materials not meeting specifications.

1.12 DELIVERY, STORAGE, AND HANDLING

- A. Products
1. Deliver packaged materials in sealed containers showing weight, analysis and name of manufacturer, supplier or grower. Protect materials from deterioration during delivery and while stored at the site.
 2. Storage: Store products and materials with protection from weather or other conditions which would damage or impair the effectiveness of the product. Protect metal containers from sun during summer months with temperatures above 80 degrees F.
- B. Bioretention Planting Media, Mulches and Aggregates
1. Protect the bioretention planting media, mulches and aggregates from contamination and sedimentation, and all sources of additional moisture at supplier site, during transport, and at the project site, until incorporation into the Work.
 2. The Contractor is required to coordinate delivery of bioretention planting media, mulches, impermeable geomembrane liners, and aggregates with bioretention (rain garden) cell excavation and soil installation. Bioretention planting media should not be stockpiled onsite for any length of time. In no case shall the bioretention planting media be stockpiled onsite for more than 24 hours without prior written approval by the Owner's Authorized Representative. If stockpiled onsite for any length of time, the bioretention planting media shall meet the following requirements:

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- a. Locate piles away from drainage courses, inlets, sewer cleanout vents, and concentrated stormwater flows.
- b. Place stockpiles on geotextile fabric.
- c. Cover stockpiles with plastic or comparable materials.
- d. Contain stockpiles (and prevent contamination from adjacent stockpiles) with temporary perimeter barrier (e.g., sand bags, wattles, silt fence).

C. Plant Materials

1. Preparation
 - a. Balled and Burlapped (B&B) Plants: Dig and prepare shipment in a manner intended to protect roots, foliage and branches from damage and protect the shape, and future development.
 - b. Plants should bear label from the grower certifying genus and species. Labels should be securely attached and waterproof bearing legible designation of botanical and common name. Plants not labeled may be rejected.
2. Deliver trees, shrubs, ornamental grasses, perennials, forbs, and groundcover plants after preparation for planting have been completed and plant immediately.
3. Damage: Protect plant material in transit and at the site. Material not properly protected, and which is damaged, will be rejected.
4. Unloading, Handling and Staging of Trees
 - a. Staging systems shall be prepared in advance to adequately hold trees above ground for optimum tree health prior to planting. Many times, even with the best planning and coordination, trees cannot be planted when they are delivered.
 - b. Use extreme caution when handling trees. Use a strap cradle, adequate for weight and size of tree and root ball, attached to the root ball to unload and move trees. Strapping and wire baskets can break or loosen. Never move, lift, or handle by attaching to or by putting pressure on the trunk. Be very careful not to damage or scar trunks and branches.
 - c. Prior to unloading, proper moisture shall be maintained in root balls. Trucks shall be staged in the shade prior to unloading. Unloading time shall be no more than two (2) hours per trunk.
 - d. Immediately after unloading, no more than one hour after unloading, stand the trees up to reduce risk of sun scald. Properly staged trees shall be standing, untied and spaced.
 - e. Remove cardboard trunk protector within forty-eight (48) hours of trees being stood upright to reduce the risk of damage.
 - f. Monitor moisture in the root ball by probing the soil with a soil probe and manage supplemental irrigation accordingly. Be careful not to over or under irrigate.
 - g. During cold weather periods, root balls must be protected from freezing temperatures.
 - h. Storage is at Contractor's own risk.

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5. Handling of Plant Materials

- a. Do not deliver plants until the site conditions are ready for planting. If planting is delayed, heel-in bare rooted or freshly dug plants in a bed containing adequate mulch to keep roots moist. Separate bundles and trim roots, if long or damaged, using sharp pruning shears. Place plants in flats, pots, or other containers in a sheltered spot protected from sun, wind and mechanical damage and keep roots moist. Storage is at Contractor's own risk.
- b. Do not lift or handle any plants by tops, stems or trunks at any time. Do not bind or handle plants with wire or rope at any time.

1.13 SEQUENCING

- A. Pre-Placement Conference: A mandatory pre-placement conference will take place, including a minimum the Engineer/Landscape Architect, resident Engineer, the Owner's Authorized Representative, Installer, and General Contractor, to review schedule, products, soil testing, permeability testing, and installation. The Contractor shall notify all parties a minimum of two (2) days prior to conference.

Note: Pre-placement conference is mandatory for all projects within the public right-of-way, or on other public property, and is strongly recommended for privately-owned parcel projects.

- B. Coordinate with General Contractor for sequencing for bioretention (rain garden) excavation, [impermeable geomembrane liner installation], underdrain system, coarse sand media storage installation, and bioretention media installation. Must occur after all other site work disturbance is complete.
- C. All surrounding site areas draining into bioretention (rain garden) areas must be stabilized prior to any work for excavation or installation of raingardens and bioswale areas. Sand bags or curb inlet blocks must be placed at curb drainage openings to prevent initial runoff from entering the bioretention (rain garden) areas until plant materials have had time to root in place for approximately three (3) to nine (9) months depending on growing season.

Note: Design of system using impermeable geomembrane liner is dependent on elevation of subsurface ground water.

- D. Coordinate irrigation, finished grading, planting, topdressing, and other related units of Work specified in other Sections to ensure plant material can be supported and installed as indicated.

1.14 SCHEDULING

- A. Submit a written proposed work schedule to the Owner's Authorized Representative for approval at least sixty (60) days prior to start of work under this Section. Modifications shall be made to this schedule only with written authorization from the Owner's Authorized Representative(s).
- B. Provide schedule to reflect sequencing issues for bioretention (rain garden) areas as noted in 1.13.
- C. In general, the work shall proceed as rapidly as the site becomes available, consistent with normal seasonal limitations for planting work.

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1.15 WARRANTY

- A. General: Warranties specified in this Section shall not deprive the Owner of other rights the Owner may have under other provisions of the Contract Documents and shall be in addition to and run concurrent with other warranties made by the Contractor under requirements of the Contract Documents.
- B. Plant Materials
 - 1. In accordance with the General Provisions, warrant that all shrubs, ornamental grasses, perennials, forbs, and groundcover planted under this Contract will be healthy and in flourishing condition of active growth shall be valid for one (1) year from date of Substantial Completion/Final Acceptance.
 - 2. Replacement Quantities: Contractor shall be held responsible for a maximum of two (2) replacements for each failed tree, shrub, ornamental grass, forb, and same area of groundcover planting after final acceptance during the Warranty Period.
 - 3. Replace dead trees or trees not in vigorous, thriving condition as soon as weather permits. Replace trees, which have partially died thereby damaging shape, size, or symmetry. The opinion of the Owner's Authorized Representative as to what constitutes a dead plant shall be final.
 - 4. Replace plants and trees with same kind and size as originally planted at no cost to the Owner. Provide one (1) year warranty on replacement plants. Trees should be replaced at start of next planting or digging season. In such cases, remove dead trees immediately. Protect irrigation system, other piping conduit, or other work during replacement. Repair any damage immediately.
 - 5. Plant materials exhibiting conditions which are determined as being unacceptable due to workmanship by the Contractor shall be repaired and/or replaced at no additional cost to the Owner.
 - 6. As soon as weather conditions permit, replace, without cost to Owner all dead plants and all plants not in a vigorous, thriving condition, as determined by Owner's Authorized Representative during and at the end of Warranty Period.
 - 7. Closely match replacements to adjacent specimens of the same species. Apply all requirements of this Specification to all replacements.
 - 8. Replacement plants will be guaranteed to be true to species, variety or cultivar as specified.
 - 9. Warranty excludes replacement of plants after final acceptance because of injury by storm, drought, drowning, hail, freeze, insects, or diseases.
 - 10. Warranty: Warrant that all trees, shrubs, ornamental grasses, perennials, forbs, and groundcover planted under this Contract will be healthy and in flourishing condition of active growth one (1) year from date of Substantial Completion.
- C. Special Warranty: Submit written special warranty registered with manufacturer as specified in this Section.

1.16 SOURCE QUALITY CONTROL [IF NEEDED]

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PART 2 - PRODUCTS

2.1 OWNER FURNISHED PRODUCTS [IF NEEDED]

2.2 IMPERMEABLE GEOMEMBRANE LINER – refer to Section 33 46 26 – Sand Filter.

2.3 COARSE SAND MEDIA – refer to Section 33 46 26 – Sand Filter.

2.4 EXPANDED SHALE

- A. Rotary kiln expanded shale and clay lightweight aggregate: horticultural grade (G Pile).
- B. Size: 3/8 inch conforming to gradation as shown below:

<u>Sieve Size</u>	<u>Percent Passing</u>
1/2" (12.5 mm)	100
3/8" (9.5 mm)	90-100
No. 4 (4.75 mm)	40-90
No. 8 (2.36 mm)	0-20
No. 16 (1.18 mm)	0-10

- C. Manufacture
 - 1. Arcosa Lightweight, Arlington, TX, (817-635-8541), www.acrosa.com.
 - 2. Equivalent manufacturer as determined by the Owner's Authorized Representative.

2.5 SCREENED CUSHION SAND

- A. Blend of Deep Loamy Sand excavated from a minimum of twenty (20) feet below ground level, minimizing the chances of nut sedge, weeds or grass traces.
- B. Use a three-eighths (3/8) inch screen to screen out oversized particles, rock and debris.
- C. Gradation requirements per ASTM C33, Standard Specification for Concrete Aggregates.
- D. Cleaned and washed to remove sediment.
- E. This screened material helps keep the bioretention soil media open and helps improves drainage.

2.6 WASHED SAND

- A. Media porosity minimum of 0.32.
- B. Gradation requirements per TXDOT Fine Aggregate Grade No. 1.
- C. Alternate: Gradation requirements per ASTM C33, Standard Specifications for Concrete Aggregates.
- D. Clean and washed to remove sediment.

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Note: Use of washed sand as an alternate to expanded shale or screened cushion sand for Bioretention Planting Media design mix shall meet all test requirements per 1.11 as approved from the Licensed Qualified Professional Designer.

2.7 COMPOST

- A. Organic Compost: 100% plant based; Class 1; shall be finished, fully composted, stabilized and mature compost that has been produced by aerobic (biological) decomposition of organic matter and meets or exceeds the requirements set forth by the United States Department of Agriculture, the United States Composting Council (USCC) and their Test Methods for the Examination of Compost and Composting (TMECC), and State composting requirements. Compost feedstock shall include fully composted cotton burs, local grass trimmings, leaves, brush and processed wood fiber and shall add an average of 1.1 lbs. N¹, 0.13 lbs. P¹, and 0.8 lbs. K¹ of pure consumable organic nutrients per one (100) square feet for each inch depth added plus minerals and trace elements.
- B. Compost shall not include food waste, stable waste, treated lumber, pallets, pine bark, raw manure or mushroom compost waste. Compost shall not include any man-made materials or chemicals.
- C. Do not use mixed municipal solid waste compost since it varies from season to season. Ensure compost does not contain any visible inorganic refuse, other physical contaminants, or any substance considered to be harmful to plant growth.
- D. Compost material shall have no pungent smell, but rather an earthy smell.
- E. The compost must be turned a minimum of five (5) times and not achieve a temperature greater than 160 degrees Fahrenheit. Each turning cycle should not be shorter than fourteen (14) days minimum.
- F. Compost used must meet the parameters shown below:

Compost for use in Bioretention Planting Media Physical Requirements		
<u>Parameter</u>	<u>Value</u>	<u>Analysis Method</u>
Particle Size % Passing 3/4 inch sieve	≥99%	TMECC 02.02-B
Particle Size % Passing 1/2 inch sieve	97%	TMECC 02.02-B
Heavy Metals & Hazardous Elements	Pass	TMECC 04.06
Soluble Salts	5.0dS/m Max ²	TMECC 04.10-A
pH range	7.9 - 8.9	TMECC 04.11-A
Maturity (Germination and Vigor)	≥90%	TMECC 05.05-A
Organic Matter Content	25 - 65% (dry mass)	TMECC 05.07-A
Stability	≤8	TMECC 05.08-B
Solvita® Compost Maturity Test	≥7	TMECC 05.08-E
Fecal Coliform	<1,000 MPN/g Max	TMECC 07.01-B
Composting Time	6 - 12 Months	n/a

- G. A copy of the producer's STA certification.

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- H. The contractor shall provide a copy of the lab analysis, performed by an STA-certified lab, verifying that the compost from the project stockpile to be used for the bioretention planting media meets the requirements noted above.
- I. Acceptable Manufacturer and Supplier: Soil Building Systems, 2101 Walnut Hill Lane, Dallas, Texas 75229, (972-831-8181), attention: Baron Ablon.
- J. Equivalent high-quality material meeting requirements of compost as noted above as determined by the Owner's Authorized Representative.

2.8 BIORETENTION PLANTING MEDIA

- A. Bioretention Planting Media (pre-mixed, engineered soil).
 - 1. Proportions (Percentages) by Volume: Fully Mature Compost – 50%, Expanded Shale - 25%, and Screened Cushion Sand – 25%.
- B. Mix must be tested prior to delivery to site to show compliance in meeting all compost requirements, material component requirements, infiltration rates, proportions and testing criteria as noted in 1.11.

Bioretention Planting Media (Soil Mix) Testing Parameter Requirements		
<u>Parameter</u>	<u>Value</u>	<u>Analysis Method</u>
pH Range	7.6 - 8.8	TMECC 05-07-A, ASTM D4972
Organic Matter Content	40 - 50%	AASHTO T194
Phosphorus (P2O5)	X	TMECC 04.03-A
Potassium (K2O)	X	TMECC 04.04-A
Magnesium	X	TMECC 04.05-Mg
Soluble Salts	5.0dS/m Max	TMECC 04.10-A
Testing Equipment Infiltration Rate Precision	0.25 inches/hour (min.)	ASTM D3385

- C. Acceptable Manufacturer and Supplier: Soil Building Systems, 2101 Walnut Hill Lane, Dallas, Texas 75229, (972-831-8181), www.soilbuildingsystems.com, attention: Baron Ablon.
- D. Equivalent Manufacture or Supplier providing high-quality designed mix with each component meeting properties, source and testing requirements as listed in 2.4, 2.5, 2.6 and 2.7, and design mix testing requirements per 1.11 as determined by the Owner's Authorized Representative.

2.9 PRE-EMERGENCE AND POST-EMERGENCE FOR WEED REMOVAL - ORGANIC HERBICIDE AND HAND PULLING

- A. Chemical Herbicides will not be used due to detrimental effects on the soils and BMP/iSWM/LID due to runoff effects.
- B. For site bed treatments: initial during bed preparation, prior to planting, and for spot treatment with a wick after planting.

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- C. Nonselective organic herbicide: Mirimichi Green Pro Weed Control, EPA approved and OMRI listed, as manufactured by Mirimichi Green Express, 418 Hermitage Road, Castle Hayne, NC 28429, (910-602-1681); as supplied by San Jacinto Environmental Supplies, Houston, TX (713-957-0909), local representative: Lanse Fullinwider, cell: (214-534-2317), or other suppliers.
- D. Nonselective organic herbicide, such as Agricultural grade (20%) vinegar. Vinegar can be mixed with citrus oil.
- E. Hand weeding or plant specific application of organic herbicide shall be used to control weeds during plant establishment.

2.10 PLANTS

- A. General: Provide healthy, field-grown ball and burlapped plants or nursery-grown container General: Provide healthy, field-grown ball and burlapped plants or nursery-grown container and boxed plants, well-formed No. 1 grade from a recognized, local nursery, and of the species and variety shown on the drawings, well-developed branches conforming to and complying with the last edition of American Standard for Nursery Stock, Edition approved April 14, 2014 by American Nursery and Landscape Association (ANSI Z60.1-2014). Listed plant heights are from tops of root balls to nominal tops of plants.
- B. Provide only healthy, vigorous stock, grown under climatic conditions similar to conditions in the locality of the project and free of disease, insects, eggs, larvae, and defects such as knots, sun-scald, injuries, abrasions, disfigurement, borers and infestations.
- C. Vigor: Plants shall be sound, healthy and vigorous, well branched and densely foliated when in leaf. They shall be free of disease, insect pests, eggs, or larvae. They shall have healthy, well-developed, vigorous and fibrous root systems. Plants shall be free from physical damage or adverse conditions which would prevent thriving growth.
- D. Container and Boxed Stock material
 - 1. Verify that all container stock has been grown in the containers in which delivered for at least six (6) months, but not over two (2) years.
 - 2. Plants shall have a root ball size of minimum of ten (10) inches in diameter for each one (1) inch caliper, measured six (6) inches above root ball.
 - 3. Root system development:
 - a. Samples must prove to be free of kinked, circling or girdling roots and with no evidence of a pot-bound condition.
 - b. Trees shall have been grown in heavy or heavy clay soil and irrigated with drip irrigation. Loose potting soils are not acceptable since root mass will flex with trunk sway and allow potential overturn of tree.
 - c. Field grown plants recently planted into containers will be accepted if roots have developed into new soils.
 - 4. Root flare of plant material shall be visible at nursery prior to delivery, and after transplanting into the landscape.
 - 5. Root balls shall not be cracked or broken prior to shipment.

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6. Do not remove self-locking tags prior to delivery to site.
7. Remove all weeds and other invasive plants from the base of the nursery plant's root container prior to delivery to site.

E. Nursery grown B&B material

1. Plants shall have a root ball size of minimum of ten (10) inches in diameter for each one (1) inch caliper, measured six (6) inches above root ball.
2. Root system development:
 - a. All named cultivars shall be own root clones; no grafted or bud-grafted trees will be accepted.
 - b. 100% mechanically root-pruned at least once and transplanted a minimum of three (3) times during the first three (3) years of the tree's life.
 - c. Trees shall have been grown in heavy clay soil and irrigated with drip irrigation.
 - d. Plants shall be well healed in for a minimum of thirty (30) days with a flush of new roots at the edge of the burlap prior to shipping. Recently dug plants will not be accepted.
 - e. Trees shall have no girdling roots, have no "J" shaped roots, and the trunk flare shall be visible.
3. Ensure balls are firm, neat, slightly tapered, and well burlapped.
4. Root balls shall not be cracked or broken prior to shipment.
5. Root flare of plant material must be above ground and visible at nursery before harvest, prior to delivery, and after transplanting into the landscape.
6. Root liner grown trees shall have been planted such that their root flare is visible above the finished grade of the liner. No buried tree flares will be submitted or accepted.
7. Do not remove self-locking tags prior to delivery to site.
8. Remove all weeds and other invasive plants from the base of the nursery plant's root ball prior to delivery to site.

F. Medium Shade and Ornamental Trees - Canopy development

1. No. 1 grade nursery stock healthy, vigorous, full-branched, well-shaped, trunk diameter, and height requirements as specified
2. There shall be a strong central leader to the top of the canopy. The tip of the leader on the main trunk must be intact and it's terminal bud must be the highest part of the tree.
3. No branch can have a diameter greater than 2/3 the trunk diameter measured directly above the branch crotch. The tree will have no inclusions or co-dominant branches.
4. The tree crown shall be structurally uniform. Branches shall be evenly distributed around the trunk. The crown shall be full of foliage which is evenly distributed around the tree.
5. Trees that have had branches tipped or cropped will not be accepted.

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6. Provide trees with full rounded crowns, meeting height and spread standards after pruning. No flat sided trees or trees with open areas on any side will be acceptable. Trees shall be consistently superior in form and branching, and typical of the growth habit of their species unless otherwise specified.
- G. Tree Caliper Measurement Requirements: for a single stem tree, the diameter (caliper) of the trunk shall be measured twelve (12) inches above the top of the root ball for a tree having a diameter up to and including eight (8) inches, and measured at four and one-half feet above the top of the root ball for a tree having a diameter of more than eight (8) inches. For multi-stem trees, the diameter of the trunk measured at the narrowest point below branching when branching occurs higher than twelve (12) inches above the top of the root ball. When branching occurs at or lower than twelve (12) inches above the top of the root ball, caliper means the diameter of the largest stem plus the average diameter of the remaining stems, measured at four and one-half (4.5) feet above the top of the root ball.
- H. Ornamental grasses, forbs, perennials and groundcover: Nursery grown, healthy, vigorous, of normal habit of growth for species. Specified sizes are before pruning and measured with branches in normal position. Plants to be well rooted and established in the container.
- I. Plants shall conform to the sizes and quality notes in the plant list and/or as indicated, with the exception of that larger plants than those specified may be used if approved by the Owner's Authorized Representative. Use of larger plants shall not increase the contract price. Specified sizes shall be after pruning, and plants shall be measured with their branches in normal position.
- J. Pruning: Do not prune plants before delivery. If pruning is necessary, prune with direction from Owner's Authorized Representative.
- K. Plant protection during shipping: Wrap canopy of plants prior to loading to ensure that branch structures are protected and that wind damage is minimized. Shrubs and smaller plant material will be handled and loaded to protect character and form of each plant. Removal of protection strapping and wrapping shall be handled with care to prevent damage to the plant material once it is delivered to the site. Damaged materials will be subject to rejection.
- L. Upon delivery to site:
 1. Reject trees with cracked, loose or broken balls when frame or burlap is removed at time of planting.
 2. Trees will be individually approved or rejected by the Owner's Authorized Representative on site.
 3. Trees: Free of physical damage such as scrapes, bark abrasions, or split branches.
 4. Trees for planting adjacent to pavement surfaces for pedestrian required clearances shall be pruned and branched up to seven (7) foot height above the finished grade of the pavement as directed by the Owner's Authorized Representative.

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2.11 TOPDRESSING

- A. Rust Cut Hardwood Mulch (bottom layer) for Bioretention (Rain Garden) Planting Areas
 - 1. Native hardwood mulch; free from: man-made foreign material, lumber, treated materials, woodmill sawdust or pine bark; hammer mill processed, decomposed - heat sterilized two (2) times to remove latent weed seeds, aged for minimum two (2) to four (4) months, screened to remove fines. No soft green or unprocessed materials allowed. 96% of material will pass through a one (1) inch screen with additional screening down to three-eighths (3/8) inch, 98% of material will not exceed eight (8) inches in length. Material shall have no pungent odors, but will have an earthy smell. As manufacture and supplied by: Soil Building Systems, 2101 Walnut Hill Lane, Dallas, TX 75229 (972-831-8181), attention: Baron Ablon.
 - 2. Tree Mulch (once ground native hardwood mulch) custom screened material to match properties of mulch noted above and to not exceed eight (8) inches in length. Product must have been heat sterilized (2) times to remove latent weed seeds and aged for minimum two (2) months. No soft green or unprocessed materials allowed. As processed and supplied by Living Earth (LETCO), Dallas, TX, if submitted material is determined to be an equivalent by the Owner's Authorized Representative.
 - 3. Equivalent mulch product as approved by the Owner's Authorized Representative.
- B. Single Grind Mulch (top or full layer) for Bioretention (Rain Garden) Planting Areas
 - 1. Blend of native woods; free of man-made foreign matter, manure or pine bark; rough-cut hammer mill processed to achieve materials that will interlock, heat sterilized to address potentially harmful diseases in event they are present, screened to remove fines, coarse textured. 95%+ of material will pass through a four (4) inch screen with additional screenings down to a three-quarters (3/4) inch, 98% of material will not exceed sixteen (16) inches in length.
 - a. Manufacture and supplier meeting requirements above: Soil Building Systems, 2101 Walnut Hill Lane, Dallas, TX 75229 (972-831-8181), attention: Baron Ablon.
 - b. Equivalent mulch product as approved by the Owner's Authorized Representative.

3.1 JUTE MATTING (MESH) [IF NEEDED]

- A. Provide jute matting of a uniform, plain weave with warp, and woof yarns of approximately the same size.
- B. The physical requirements shall be:
 - 1. Width: 45 inches to 48 inches, (\pm) 1 inch.
 - 2. 1 inch square openings (\pm)
 - 3. 78 warp ends per width
 - 4. 41 weft ends per yard
 - 5. Weight - 1.80 lbs. (average) per running yard
- C. Provide staples to secure fabric to slope per manufacturer's recommendations.

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2.12 ANCHORING FRAME FOR MEDIUM AND ORNAMENTAL TREES (where no impermeable geomembrane liner is used, and where depth allows)

A. For anchoring of tree root balls: adjustable below-grade root ball anchoring system with ground anchors and tightening straps.

1. Below Grade Safety Stakes as manufactured by Tree Stake Solutions, re-bar anchoring ring with three (3) six (6) inch U brackets, color: natural metal or painted, and three (3) separate anchors with S-hook and tightening straps. Manufacturer's local representative: Jeff Tuley, (903-676-6143), www.treestakesolutions.com.

<u>Item #</u>	<u>Description</u>
15-BG	10-15 gal. or 17" root ball with 3 – V68 Anchors
30-BG	20-30 gal. or 22" root ball with 3 – V68 Anchors
45/65BG	45-65 gal. or 27-30" root ball with 3 – V68 Anchors
100-BG	95-100 gal. or 36" root ball with 3 – V68 Anchors
150-BG	150 gal. or 42" root ball with 3 – V68 Anchors
200-BG	200 gal. or 48" root ball with 3 – V88 Anchors

2. Duckbill® Root Ball System using Duckbill Root Ball Kit consisting of 3 Duckbill anchors, D-ring, and 1 strap with hand ratchet. Manufacturer: Duckbill Earth Anchors, Maclean Civil Products, 481 Munn Road, Suite 300, Fort Mill, SC 29715, (800-325-5360).

2.13 ORGANIC FUNGICIDES

- A. As needed for specific conditions.
- B. No chemical fungicides shall be used.
- C. MicroGro Granular Root Protector - Biological Fungicide as supplied by San Jacinto Environmental Supplies, Houston, TX (713) 957-0909, local representative: Lanse Fullinwider, cell: (214-534-2317), or equivalent product as approved by the Owner's Authorized Representative.
- D. Contractor shall recommend products for submittal and approval by the Owner's Representative depending on final plant selections and their susceptibility to certain fungi.

2.14 ORGANIC INSECTICIDES

- A. Soft Bodied Insects (aphids, mites, thrips, white flies, lace bugs, etc.)
 1. EcoSMART® Organic Insecticides as manufactured by a division of the Kittrich® Corporation, Atlanta, GA 30336, (714-736-1011).
 2. Neem Oil.
- B. Scale: Use 2 ounces of Orange Oil mixed with 1 ounce of Neem Oil to a gallon of water. Spray weekly for 3 weeks.
- C. Caterpillars, Army Worms, Sod Webworms: Use Bacillus Thuringiensis (BT) biological agent.

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D. Chinch Bugs

1. EcoSMART® Granular, as manufactured by a division of the Kittrich® Corporation, Atlanta, GA 30336, (714-736-1011), or approved equivalent product as approved by the Owner's Authorized Representative.

2.15 ORGANIC INSECTICIDE - FIRE ANTS

A. Fire Ant Bait

1. PayBack® Fire Ant Bait with Conserve® Insecticide (spinosad 0.015%) granular form as manufactured by Southern Agricultural Insecticides, Inc., Palmetto, FL 34220, (941-722-3285).
2. Ferti-lome Come and Get It! Fire Ant Killer with Conserve® Insecticide (spinosad 0.015%) granular form as manufactured by Ferti-lome – Voluntary Purchasing Groups, Inc., 230 FM 87, Bonham, TX 75418.

- B. Dusting Powder: Perma-Guard® Commercial Insecticide D-20 (pyrethrins 0.02%, technical piperonyl butoxide 1.0%, silicon dioxide from diatomaceous earth 88.0%) as manufactured by Perma-Guard, Inc., Albuquerque, NM 87102, (505-243-1460), or equivalent product as approved by the Owner's Authorized Representative.

2.16 WATER – Permanent or Temporary Irrigation System

- A. Potable. Available on site.

Note: Refer to the irrigation specifications and plans as provided separately for the project application and in compliance with all state and local codes.

2.17 MACHINERY AND EQUIPMENT

- A. Machinery requirements listed under this Section are NOT intended to be restrictive of specific manufacturers or models, unless so stated. Specific mention of the manufacturers is intended as a guide to illustrate the final product of the maintenance operations desired. All equipment used shall be and maintained in top working condition at all times.
- B. Excavation and pruning tools shall be maintained in safe, working condition, cutting edges shall be sharp at all times.
- C. Insecticide and fungicide sprayers (for organic products) shall be of the hand-held, backpack, or vehicle-mounted type. Sprayers shall be in a safe working condition at all times.
- D. The Contractor shall be responsible for any grade, plant material (trees, shrubs, ornamental grass, forbs, perennials, groundcover, etc.), or hardscape amenity (building, forebay, pavement, edging, walls, etc.) damage caused by the sprayer and the application process.

2.18 ACCESSORIES [IF NEEDED]

2.19 SOURCE QUALITY CONTROL [IF NEEDED]

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PART 3 - EXECUTION

3.1 INSTALLERS [IF NEEDED]

3.2 EXAMINATION

- A. Acceptance of Site Verification of Conditions
 - 1. General Contractor shall inspect, accept and certify in writing to the bioretention (rain garden) installation subcontractor that site conditions meet specifications for the following items prior to installation of bioretention (rain garden) areas.

3.3 PREPARATION

- A. Coordinate for scheduling and sequencing of excavation and installation of bioretention (rain garden) areas with all related work.
- B. Prevent runoff from adjacent pervious and impervious surfaces from entering the bioretention (rain garden) cell (e.g. sand bag inlet curb cuts, stabilize adjacent areas, flow diversion) until authorization is given by the Owner's Authorized Representative.
- C. Exclude equipment from bioretention (rain garden) facilities. No equipment shall operate within the area of the cell(s) once bioretention (rain garden) excavation has begun, including during and after excavation, installation of underdrain and coarse sand media storage, irrigation installation, backfilling, planting and mulching.
- D. Prevent foreign materials and substances, such as silt laden run-off, construction debris, paint, paint washout, concrete slurry, concrete layers of chunks, cement, plaster, oils, gasoline, diesel fuel, paint thinner, turpentine, tar roofing compound, or acid from entering or being stored in or adjacent to the cell(s) at any point during construction.
- E. Utilities:
 - 1. Determine locations of underground utilities and perform work in a manner which is intended to avoid possible damage. Hand excavate, where required, to minimize possibility of damage to underground utilities.
 - 2. Water is available on site. *Refer to irrigation system drawings for proposed underground irrigation system.*
- F. By beginning Work, Contractor accepts conditions and assumes responsibility for correcting unsuitable conditions encountered at no additional cost to the Owner.

3.4 EXCAVATION AND GRADING

- A. The Contractor shall not start bioretention (rain garden) cell(s) excavation and grading until all areas draining to the cell(s) are stabilized and authorization has been given by the Owner's Authorized Representative.
- B. Construct bioretention (rain garden) cell(s) subgrade to +/- 3/4 inch of the grades and slopes specified on the Drawings.
- C. Excavation within six (6) inches of final soil grade shall not be permitted if cell(s) have standing water, or have been subjected to more than one-half (1/2) inch of precipitation within the previous forty-eight (48) hours.

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- D. Excavation of each bioretention (rain garden) cell
 - 1. Infiltrative Cell (Permeable)
 - a. Excavation shall be provided with a long arm excavator from the sides of the cell. No equipment will be allowed in the cell as this will cause soil compaction. The long arm excavator shall excavate with a drag technique by pulling with the teeth to rip the soils and open the soils for infiltration. Do not use the scoop technique as this will compact the soils.
 - 2. Non-infiltrative Cell (Impermeable)
 - a. Excavation shall provide depth of bed per Drawings with compacted subbase soils and impermeable or geomembrane liners (or clay liner).
- E. Examine rough excavated grade/subgrade for each type of cell and verify conditions under which work is to be performed.

3.5 SUBGRADE PREPARATION AND PROTECTION

- A. Protect the bioretention (rain garden) cell area excavation from over compaction and/or contamination.
 - 1. Cell areas which have been over compacted by equipment or vehicle traffic or by other means and which need to be ripped, over excavated, receive additional scarification, or other restorative means shall be done at the Contractor's expense and at the direction of the Owner's Authorized Representative.
 - 2. Excavated areas contaminated by sediment laden (silt) runoff prior to placement of underdrain with coarse sand media storage and bioretention planting media shall be remediated at the Contractor's expense by removing the contaminated soil (top three (3) inches minimum) and replacing with a suitable material as determined by the Owner's Authorized Representative.
- B. Remove all trash, debris, construction waste, cement dust and/or slurry, or any other materials that may impede infiltration into prepared subgrade.
- C. The subgrade shall be inspected and accepted by the Owner's Authorized Representative prior to placement of any materials or final subgrade scarification or compaction.
- D. For infiltrative cells (permeable): scarify the surface of the subgrade to a minimum of three (3) inches immediately prior to placement of underdrain system with coarse sand media for storage and bioretention planting media. Acceptable methods of scarification include use of excavator bucket teeth in dragging method or a rototiller to loosen the surface of the subgrade.
- E. For non-infiltrative cells (impermeable): install the impermeable or geomembrane prior to the placement of the underdrain system with coarse sand media storage and bioretention planting media.
- F. Place coarse sand media storage material below and around underdrain system, where shown on drawings, with conveyor belt or with an excavator or loader from a height no higher than six (6) feet unless otherwise approved by the Owner's Authorized Representative (i.e., do not dump material directly from truck into cell).

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- G. Coarse Sand Media Storage areas contaminated by sediment-laden runoff prior to placement of bioretention planting media shall be remediated at the Contractor's expense by removing the contaminated coarse sand media storage material (top three (3) inches minimum or as directed by the Owner's Authorized Representative) and replacing with clean washed coarse sand media storage material per Section 2.5, to the lines and grades on the Drawings.
- H. Coarse Sand Media Storage material shall be inspected and accepted for placement and finished grade by the Owner's Authorized Representative prior to the installation of the bioretention planting media. Any material that does not conform to this Specification shall be removed and replaced with acceptable material or remediated to the satisfaction of the Owner's Authorized Representative, at the Contractor's expense.

3.6 INSTALLATION OF BIORETENTION PLANTING MEDIA

- A. Coordinate installation and placement of irrigation mainline at edges of cell(s) prior to bioretention media placement. Lateral irrigation lines for bubblers and drip lines shall be provided per irrigation plans.
- B. Inspection of the coarse sand media storage layer, underdrain, cleanout, and overflow structure installation, where included on the Drawings.
- C. The bioretention planting media may not be stored on site, but shall be scheduled for delivery when the cells have been inspected, accepted, and the material has been tested and is ready to be installed into the cells.
- D. The Contractor shall not place the bioretention planting media until the Owner's Authorized Representative has reviewed and confirmed the following:
 - 1. Bioretention Planting Media delivery ticket(s): Delivery tickets shall show that the full delivered amount of bioretention planting media matched the product type, volume and manufacturer named in the submittals. Each delivered batch of bioretention planting media shall be accompanied by a certification letter from the supplier verifying that the material meets specifications and is supplied from the approved bioretention planting media stockpile.
 - 2. Visual match with submitted samples: Delivered product will be compared to the submitted 1-gallon sample, to verify that it matches the submitted sample. The Owner's Authorized Representative may inspect any loads of bioretention planting media on delivery and stop placement if the soil does not appear to match the submittals; and require sampling and testing of the delivered soil to determine if the soil meets the requirements of Section 2.10 before authorizing placement.

Note: On larger projects, it may be appropriate to require that the testing specified in Section 2.10 be performed on samples taken at the supplier's yard from the stockpile to be used for the project; Section 1.11 A.

- E. Placement, grading and consolidation shall not occur when the bioretention planting media is excessively wet, or has been subjected to more than one-half (1/2) inch of precipitation within forty-eight (48) hours prior to placement. Excessively wet is defined as being at or above 22 percent soil moisture by a General Tools & Instruments DSMM500 Precision Digital Soil Moisture Meter with Probe (or equivalent). A minimum of three (3) readings with the soil moisture probe will be used to determine

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the average percent soil moisture reading per each truck load. There should be no visible free water in the material.

- F. The Contractor may place the bioretention planting media loosely with a conveyor belt or with an excavator or loader from a height no higher than six (6) feet, unless otherwise approved by the Owner's Authorized Representative (i.e., do not dump material directly from truck into cell). Soil shall be placed upon a prepared subgrade or coarse sand media storage in accordance with these Specifications and in conformity with the lines, grades, depth, and typical cross-section shown in the Drawings or as established by the Owner's Authorized Representative.
- G. Excessively dry bioretention planting media may be lightly and uniformly moistened, as necessary, to facilitate placement and workability.
- H. Compact bioretention planting media using non-mechanical compaction methods (e.g., boot packing, hand tamping, or water consolidation) to 83 percent (+/- 2 percent) of the maximum dry density per modified Proctor test (ASTM D1555). Determination of in-place density shall be made using a nuclear gauge per ASTM D6938. Moisture content determination shall be conducted on a soil sample taken at the location of the nuclear gauge reading per ASTM D2216.
- I. Grade bioretention planting media to a smooth, uniform surface plane with loose, uniformly fine texture. Rake, remove ridges, and fill depressions to meet finished grades.
- J. Final media depth shall be measured and verified only after the media has been compacted. If after consolidation, the media is not within +/- 3/4 inch of the grades and slopes specified on the Drawings, add material to bring it up to final grade and raked.
- K. Final inspection and acceptance for placement and finished grades is by the Owner's Authorized Representative.
- L. Any media that does not conform to this Specification shall be remediated to the satisfaction of the Owner's Authorized Representative, or removed and replaced with acceptable bioretention planting media, at the Contractor's expense.
- M. Set beds to finished grade of media to allow for mulch topdressing installation depth.

3.7 PLANT PREPARATION AT HOLDING AREA PRIOR TO INSTALLATION

- A. Contractor shall completely remove all weeds, vines or plant seedlings, including their root system, growing at top of container or on top of the root ball to ensure that these invasive non-specified plants do not gain foothold to establish in the bioretention (rain garden) beds and cause additional maintenance to remove.
- B. Removal and disposal of all weeds, vines or plant seedlings shall occur prior to any plant moving for installation or placement in the planting beds.

3.8 PLANTING

- A. Planting Restrictions: Perform actual planting only when weather and soil conditions are suitable in accordance with locally accepted practice. Do not install plant life when ambient temperatures may drop below 35 degrees F or above 100 degrees F.

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- B. Do not plant when bioretention planting media is excessively wet.
- C. Place prepared plants in position on bed areas before containers have been removed.
- D. The Owner's Authorized Representative reserves right to interchange or shift locations of plants prior to planting.
- E. Plant in pits two (2) times greater in diameter than root balls or container diameter. Remove all burlap, ropes, wires and strings from the rootball prior to planting.
- F. Remove the container from the prepared plant. Do not dump or rinse out excess soil from planting containers into the bioretention (rain garden) area.
- G. Score the root ball vertically at four (4) equal points around the edge prior to planting or tease the roots to eliminate circling roots.
- H. Excavate hole and set plant depth such that the top of the root flare of the shrub/large ornamental grass/groundcover plant at the soil is one and one half (1 1/2) inch above finished grade for plants in 2 gallon and up sized containers, and one (1) inch above the top of the finished grade for plants in containers 1 gallon and smaller
- I. Backfill to depths of root balls with bioretention planting media. Carefully settle by watering to prevent air pockets. Water in thoroughly.
- J. Carefully prune plants to remove dead or broken branches and remove waste from planting area.

3.9 MEDIUM CANOPY AND ORNAMENTAL TREE PLANTING

- A. General Planting Requirements for all Canopy Shade and Ornamental Trees:
 - 1. Handling trees: Use extreme caution. Use a strap cradle (adequate for weight and size of root ball) attached to root ball to unload and move trees. Strapping and wire basket can break or loosen. Never move, lift or handle by attaching to or by putting pressure on the trunk. Be certain that equipment, including straps, chains, and cradles, are rated for the weights of the trees being lifted.
 - 2. Face tree to give best appearance and to allow for required branching height clearance above walks and streets. Provide branching orientation turned to provide for best growth pattern to prevent conflict with vehicles or adjacent structures. Receive approval from the Owner's Authorized Representative prior to final installation to prevent further handling or damage to the root system.
 - 3. Remove any plastic wrap and any circling roots from the root ball. Handle tree only by root ball.
 - 4. Maintain tree in a straight and plumb position.
 - 5. Position tree anchoring frame, if applicable, over top of root ball and install ground anchors to align to frame above. Connect anchoring hooks and adjust tree to ensure it is plumb and anchored securely to the subgrade per manufacturer's directions prior to starting backfill. Refer to tree anchoring details for further information.
 - 6. Saturate the planting hole with water after backfilling is one half (1/2) complete to aid removal of air from the backfill.

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7. After initial backfill, tamping/watering, and the tree is plumb, then add balance of bioretention planting media backfill to edge of root ball allowing for mulch topdressing.
8. After above items have been completed, remove synthetic wrap, cardboard packaging, and cut/remove the entire side of the wire basket down the base of the root ball. Remove the burlap from the top portions of the root ball.
9. Remove all remaining shipping straps, tags, tapes, ties, stakes and other items from the trunk and canopy of the tree.

3.10 [TREE ROOT BALL ANCHORING

- A. Anchor trees prior to backfilling to ensure ground anchors are firmly into existing subbase, or anchoring frame is connected to embeds or other forms of anchor support to prevent tree from overturning.
- B. Anchor all trees as detailed and per manufacturer's requirements, unless shown otherwise.
- C. Take precautions during staking operation to prevent damage or injury to roots and irrigation, impermeable or geomembranes, underdrain system, or other underground utility lines.]

3.11 TOP DRESSING

- A. After finished grade has been approved.
- B. Do not mulch when bioretention planting media is excessively wet.
- C. Top dress with rustic cut hardwood mulch to a depth of one (1) inch compacted depth, and then top off with single grind mulch at three (3) inches.
- D. Extend mulching to edge of planting area and to forebays.
- E. Extend mulching to base of overflow inlet structure.
- F. This top dressing occurs after plant installation. Delay this operation until near final acceptance.
- G. Top dressing must achieve specified depth to attain final acceptance.
- H. Hold mulches back to expose the root flare of the plant. Do NOT cover the root flares of trees or the crown root of plants and ornamental grasses.
- I. Where heavy drainage impact may occur, provide overlap layer of jute matting (mesh) over top of rustic cut mulch and then topdress with the large single grind mulch.
- J. All mulch shall be inspected and accepted by the licensed qualified professional designer to ensure appropriate depth and material prior to facility commissioning (e.g., unblocking of inlets).

3.12 PRUNING OF NEW TREES

- A. Prune trees to preserve natural character of plant. Remove sucker growth, broken or badly bruised branches, and crossed branches.

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- B. Trees: Pruning will be carried out by experienced pruning personnel.
 - 1. Receive approval in the field for extent of pruning from Owner's Authorized Representative.
 - 2. Sterilize pruning tools between individual plants, especially in the genus *Quercus*.
 - 3. Raise limbs to an acceptable height as approved by the Owner's Authorized Representative. Raise limbs to seven (7) foot height for trees within ten (10) feet of sidewalk.
- C. Spray paint all wounds of plants of the genus *Quercus* as soon as possible. Spray paint deliberate wounds on genus *Quercus* within one (1) hour and accidental wounds due to storms, etc. as soon as possible.
- D. Spray type paints that are non-latex or non-petroleum based and are dark brown, dark gray or black in color are acceptable for use only on genus *Quercus*.
- E. Wounds on other species shall be allowed to compartmentalize naturally, unless determined otherwise by Owner's Authorized Representative or Arborist.
- F. Dispose of all waste and removed material off site per requirements of local codes.

3.13 MONITORING OF NEW TREES

- A. Trees shall be continuously and routinely inspected for distress caused by construction activities. Notify Owner's Authorized Representative at first sign of distress.
- B. Any Fire Ant mounds around or on top of a new tree root zone shall be treated immediately and the mound removed physically. Do not allow the mound to build on the tree trunk as this will cover the tree root flare and possibly cause injury or death. Ensure that any chemical application to the Fire Ant mound is safe for application atop tree root zones.
- C. Dispose of all waste and removed material off site per requirements of local codes.

3.14 WEED REMOVAL

- A. Contractor shall hand-remove foreign or invasive grass, weeds and immature weeds with root systems prior to formation of seed heads.
- B. Contractor shall monitor and continue to remove weeds, vines and invasive plants from top of nursery grown plants and tree root balls to prevent competition for plant growth.
- C. Contractor shall obtain prior approval from the Owner's Authorized Representative before applying the approved organic herbicides.
- D. The Contractor shall be held solely responsible for plant loss due to the application of organic herbicides. Any loss of plant material shall be replaced at Contractor's sole expense and all plant replacements shall be of the same species and size of the existing plant materials.
- E. Hand weeding or plant specific application of organic herbicide shall be used during plant establishment.

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3.15 DEEP ROOT WATERING

- A. Deep root water all trees within the construction limits of the project once every two (2) weeks during the summer and once (1) a month during the winter, during the duration of the project and until final acceptance. This should be adjusted to the amount of rain. However, unless it has rained at least one-half (1/2) inch since the last watering, continue to deep root water. Complete deep root watering by watering root ball zone of tree.
- B. Water new plantings to provide optimum soil moisture level for plant germination and root development and not to exceed watering requirements.

3.16 PLANT CARE UNTIL FINAL ACCEPTANCE

- A. Water: When irrigation system is not operational, provide necessary hoses and other watering equipment required to complete landscaping.
- B. Maintain plantings and trees by watering, weeding, raking, controlling diseases and pests, cleaning, and replacing plants as necessary to keep landscape in a vigorous, healthy condition as needed until final acceptance. Maintenance until final acceptance includes but is not limited to the following:
 - 1. Watering Trees: Tree balls to be kept moistened to the depth of the tree ball.
 - 2. Weeding: Remove weeds and foreign grass over plant areas at least once (1) a week and dispose off-site per local code requirements.
 - 3. Application of approved organic insecticides, organic herbicides and organic fungicides shall be in accordance with manufacturer's instructions per Owner and Owner's Authorized Representative approval. Remedy damage from use of insecticides.
 - 4. Trimming and pruning includes only removal of dead or broken branches, and treatment of pruned areas and other wounds. Do not shear any plants. Dispose trimmings off site per local code requirements.
 - 5. Disease control.
 - 6. Tree straightening: Best for the health of the trees to wait until dormancy to straighten or reset the trees that have started to root into the backfill. Straighten by carefully digging out around the root ball, attaching seat belt strap to the part of the wire basket that is still intact around the root ball, and lifting with appropriate equipment. Never pull, push or put pressure on the trunk. Then repeat applicable planting instructions 3.8.
- C. Coordinate watering schedules during installation and until final acceptance. Provide deep root watering to keep root balls moist on newly installed trees at a minimum of once (1) every two (2) weeks during summer months or as weather conditions indicate.

3.17 CLEANING/CLEAN-UP

- A. Keep premises neat and orderly including organization of storage areas.
- B. Remove trash and debris from excavated areas, underdrain installation, bioretention media installation, planting plants, and mulching beds from Work site daily as work progresses.
- C. Clean faces of building, walls, and other architectural features to remove sediments.

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- D. Keep paved areas clean by sweeping or hosing.

3.18 SITE ENVIRONMENTAL PROCEDURES

- A. Waste Management: Comply with requirements of local codes for recycling and reusing waste.
- B. Waste Disposal: Disposal of waste, including accessories and used items, by recycling or reusing waste to the extent practical. When washing containers for recycling, do not permit runoff to enter storm drains or sewer systems or penetrate soils.

3.19 MONITORING OF BMP'S AND "CAP AND SEAL"

- A. Monitor all BMP's or "Cap and Seal" measures to ensure the stability and structural durability of the curb opening block integrity.
- B. Opening blocks are to remain secure in place and closed to prevent site runoff from entering the bioretention (rain garden) cells until establishment of plant root systems during maintenance warranty period and per the requirements of the Flood Testing for one-hundred and twenty (120) day plant grow-in period depending on growing season.
- C. Removal of BMP's and "cap and seal" at curb openings shall only occur during maintenance warranty period by maintenance warranty Contractor after plants root systems are established and stable. Owner's Authorized Representative shall review and approve time of removal of opening blocks to allow entry of runoff.

3.20 FLOOD TESTING

- A. Inlets shall be constructed per the Plans and free from all obstructions prior to commencing the flow testing.
- B. Testing shall be conducted at the conclusion of the one-hundred and twenty (120) day plant grow-in period, depending on growing season. Protection and flow diversion measures installed to comply with BMP's and Cap and Seal shall be removed in their entirety prior to commencing the flow testing.
- C. Underdrains shall be plugged at the outlet structure to minimize water consumption during the testing.
- D. Prior to testing, broom sweep gutter and other impervious surfaces within the test area to remove sediments and other objectionable materials.
- E. The Owner's Authorized Representative shall be present during the demonstration. The Contractor shall notify the Owner's Authorized Representative a minimum of two (2) working days prior to the testing.
- F. The Contractor shall water test each facility to demonstrate that all inlet curb openings are capturing and diverting all water in the gutter to the facility, outlet structures are engaging at the elevation specified, and the designed ponding depth is achieved. Testing shall include application of water from a hydrant or water truck, at a minimum rate of ten (10) gallons per minute, into the gutter a minimum of fifteen (15) feet upstream of the inlet curb opening being tested. Each inlet shall be tested individually. If erosion occurs during testing, restore soils, plants, mulch, and other related affected materials.

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Note: The Licensed Qualified Professional Designer should update test flow rate for inlets to reflect project-specific design, as needed.

- G. The Owner's Authorized Representative will identify deficiencies and required corrections, including but not limited to relocating misplaced plants, adjusting energy dissipation material, mulch, adjusting inlets, splash aprons, energy dissipation sump or forebays, removing and replacing inlets, and removing debris.
- H. Once adjustments are made, the Contractor shall re-test to confirm all test water flows into the facility from the gutter and correct and remaining deficiencies identified by the Owner's Authorized Representative.
- I. Inlet, outlets, and other bioretention facility appurtenances shall not be accepted until testing and any required correction and retesting is complete and accepted by the Owner's Authorized Representative.

Note: The Owner/Owner's Authorized Representative may, at any time, conduct additional testing on all materials submitted, delivered, or in-place, to ensure compliance with the specifications. Additional tests may be required if the Licensed Qualified Professional Designer suspects the facility does not conform to the specifications (e.g., as evidenced by lower than anticipated infiltration capacity).

3.21 FINAL ACCEPTANCE

- A. Due to seasonal requirements, final acceptance of this section may not coincide with that of the remaining contract work.
- B. Request inspection for final acceptance before the end of the plant care and maintenance as described in 3.16, and per flood testing requirements as described in 3.20.
- C. Final acceptance shall be considered the time at which planting, testing, related work and clean-up are one hundred (100%) percent completed.

3.22 PROTECTION

3.23 MAINTENANCE

- A. Maintenance Instructions: Submit two (2) copies and one (1) electronic copy of typewritten instructions recommending procedures to be established by the Owner for the maintenance of bioretention (rain garden) features prior to expiration of Contractor's maintenance period(s) required under the contract. Submit to Owner's Authorized Representative for approval.

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B. Recommended Maintenance Guidelines (Example)

Note: Edit as appropriate for the specific project's applications or conditions.

Activity	Frequency												Per Yr.
	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	
Tree straightening – first year after installation	*	*	*	*	*	*	*	*	*	*	*	*	*
Tree pruning to provide canopy clearance over sidewalks, roads & structures	*	*	*									*	*
Trees - removal of dead wood & suckers	*	*	*	*	*	*	*	*	*	*	*	*	*
Trees – remove excess mulch, soil & ant beds to maintain exposure of tree root flare	*	*	*	*	*	*	*	*	*	*	*	*	*
Trees – treat damage to trunks by vandalism or natural event	*	*	*	*	*	*	*	*	*	*	*	*	*
Hand weed beds - do not allow weeds or seedling trees to establish & mature, remove & dispose of	1	1	2	4	4	5	4	4	5	4	2	1	37
Muhly grasses – comb & pull dried seed stalks from crown of plant by hand with rubber gloves, only cut back once every 2 to 3 years only as necessary, remove all trimmings from beds		1											0.5 to 0.3
Trim / cut back warm season ornamental grasses to 1/3 rd of the plant height – 1 time every 2 to 3 years, only as necessary, remove all trimmings from beds		1											0.5
Trim / cut back cool season sedges to 1/3 rd of the plant height - 1 time every 2 years, only as necessary, remove all trimmings from beds									1				0.5
Trim/Dead head perennials – pick prune by hand or use pruning tools, remove all trimmings from beds	*	*	*	*	*	*	*	*	*	*	*	*	*

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Activity	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Per Yr.
Curb Inlet/Splash Pad/Forebay – sand bag removal at curb opening (end of 120 days) and maintenance to remove all trash and sediment from basin and openings	1	1	1	1	1	1	1	1	1	1	1	1	12
Trim back dead stalks of perennials after plant becomes dormant to 6 inch height above grade to mark where plant will come up in Spring, removal all trimmings										*	*	*	*
Pick prune shrubs, only if necessary, to maintain natural character – no shearing or topping is allowed	*	*	*	*	*	*	*	*	*	*	*	*	*
Remove all debris, trimmings, fallen branches & thatch from planting bed areas	*	*	*	*	*	*	*	*	*	*	*	*	*
Organic Insecticide - Ant control	*	*	*	*	*	*	*	*	*	*	*	*	*
Applications & treatment with organic: insecticides, herbicides, & fungicides	*	*	*	*	*	*	*	*	*	*	*	*	*
Remove decomposed mulch and apply fresh single grind / interlocking hardwood mulch to maintain full 3 inch depth for first year until plants are established			1							1			2
Remove decomposed mulch & apply fresh single grind / interlocking hardwood mulch around bases of drain structures			1							1			2
Curb Inlet/ Energy Dissipation Sump/Forebay – sand bag removal at curb opening (end of 120 days) and maintenance to remove all trash and sediment from basin and openings	1	1	1	1	1	1	1	1	1	1	1	1	12
Irrigation check	5	4	4	4	5	4	5	4	5	4	4	4	52

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Activity	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Per Yr.
Irrigation inspection & repair				1	1	1	1	1	1			1	7
Clean, repair & restore aggregate surfaces – remove sediments from aggregates with stormwater inflow	5	4	4	4	5	4	5	4	5	4	4	4	52
Remove trash from, repair & restore large aggregate surfaces	*	*	*	*	*	*	*	*	*	*	*	*	*
Litter & leaf removal	5	4	4	4	5	4	5	4	5	4	4	4	52
Remove debris, pull back mulch, cleanout & inspect surface drain grates & area drains	1		1		1		1		1		1		6
Inspect & cleanout subdrain system	1		1		1		1		1		1		6
Inspect & cleanout sedimentation basins	1		1		1		1		1		1		6
Inspect & clean out drain pipe outfall openings to ensure they are free of debris & functioning	1		1		1		1		1		1		6
Remove Snow, Ice and Sand after ice storm event	*	*	*	*							*	*	*
Inspection & testing surface infiltration rate at different locations & applications (hydraulic conductivity test)					1 time per year								1
Visit w/ Contracting Officer	1	1	1	1	1	1	1	1	1	1	1	1	12

* as needed

NOTE: This table is not comprehensive and is intended as a guideline. Refer to project documents for further information.

Duration of project work and from adjacent construction: Inspect and Repair BMP's until adjacent construction is complete to prevent siltation of Drainage Storage Features; remove BMP's.

3.24 ATTACHMENTS [NOT USED]

END OF SECTION

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SECTION 33 46 26 SAND FILTER

[Text in Blue is for information or guidance. Remove all blue text in the final project document.]

The text that follows is a draft of sample specifications that will need to be edited to suit specific project requirements by a Licensed Qualified Professional Designer.

PART 1 – GENERAL

1.1 SUMMARY

A. Section Includes

1. Sand
2. Coarse sand media
3. Edge restraints
4. [Impermeable Geomembrane liner]
5. Drainage system
6. Underdrain pipe system

B. Related Specification Sections include, but are not necessarily limited to:

1. Division 0 - Bidding Requirements, Contract Forms, and Conditions of the Contract
2. Division 1 - General Requirements
3. Section 33 46 24 - Bioretention (Rain Garden)

C. Other Related Specification Standards

Note: It is the responsibility of the Licensed Qualified Professional Designer to determine all applicable standards that relate to this section. For example: Section 33 49 20 – Curb and Drop Inlets as per the City of Fort Worth.

1.2 PRICE AND PAYMENT PROCEDURES

A. Measurement and Payment

1.3 REFERENCES

A. American Society for Testing and Materials International (ASTM); use all active and updated standards

1. ASTM C131 Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
2. ASTM C136 Method for Sieve Analysis for Fine and Coarse Aggregate
3. ASTM C33/C33M Standard Specification for Concrete Aggregates
4. ASTM D448 Standard Classification for Sizes of Aggregate for Road and Bridge Construction.
5. ASTM D1004 Standard Test Method for Tear Resistance (Graves Tear) of Plastic Film and Sheeting

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6. ASTM D1505 Standard Test Method for Density of Plastics by the Density-Gradient Technique
 7. ASTM D2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
 8. ASTM D3385 Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer
 9. ASTM F949 Standard Specification for Poly (Vinyl Chloride) (PVC) Corrugated Sewer Pipe with a Smooth Interior and Fittings
- B. Federal Test Method Standard (FTMS)
1. Puncture Test FTMS 101C - Method 2065
- C. Texas Department of Transportation (TXDOT)
1. Standard Specification for Construction and Maintenance of Highways, Streets, and Bridges: Item 421 - Hydraulic Cement Concrete - 2.6.2 - Fine Aggregate Grade No. 1.
 2. Special Specification 5056: Impermeable Liner.

1.4 ADMINISTRATIVE REQUIREMENTS

- A. Permitting

1.5 SUBMITTALS

- A. In accordance with Conditions of the Contract and Division 1 Submittal Procedures Section.
- B. Installation subcontractor's drawings and details: Indicate perimeter conditions, junction with other materials, details.
- C. Impermeable Geomembrane liner sample at 12" x 12" and manufacturer's literature (if applicable).
- D. Soils report indicating density test reports, classification, and infiltration rate measured on-site under compacted conditions, and suitability for the intended project.
- E. Erosion and sediment control plan.
- F. Filter Installation Subcontractor
1. Job references from projects of a similar size and complexity. Provide Owner/Client/General Contractor names, postal address, phone, fax, and email address.
 2. Written Method Statement and Quality Control Plan that describes material staging and flow, installation procedures, including representative reporting forms that ensure conformance to the project specifications.

1.6 ACTION SUBMITTALS/INFORMATIONAL SUBMITTALS

- A. Sand: submit for approval in accordance with 2.2.

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1.7 CLOSEOUT SUBMITTALS [IF NEEDED]

1.8 MAINTENANCE MATERIAL SUBMITTALS

- A. Maintenance Instructions: Submit to Owner's Authorized Representative for approval. Submit two (2) copies and one (1) electronic copy of revised instructions prior to expiration of Contractor's maintenance period(s) required under the contract.
- B. Extra materials: Provide [Specify area] [Specify percentage] additional material for use by owner for maintenance and repair.
- C. Sand shall be from the same production run, size and type, or excavated area of quarry as installed materials.

1.9 QUALITY ASSURANCE AND QUALITY CONTROL

- A. General: Test and inspect materials and operations as work progresses as described in this section: Failure to detect defective Work or materials at any time will not prevent rejection if a defect is discovered after installation, nor shall it constitute final acceptance.
- B. Testing Agency Qualification
 - 1. General: Agencies that perform testing on bioretention soil media and related materials, including permeability/infiltration testing, shall be accredited by ASTM, AASHTO, or other designated recognized standards organization. All certifications shall be current. Testing agency shall be capable of performing all tests to the designated and recognized standards specified and shall provide test results with an accompanying Manufacturer's Certificate of Compliance. The following information shall be provided for all testing laboratories used:
 - a. Name of lab(s) and contact person(s)
 - b. Address(es) and phone numbers
 - c. Email address(es)
 - d. Qualifications of laboratory and personnel including the date of current certification by ASTM, AASHTO, or approved equivalent.
- C. Contractor/Installer Qualification
 - 1. The installer shall have a minimum of seven (7) years successful experience in the installation of sand filters, similar to the filters required for this project.
 - 2. Utilize an installer having successfully completed sand filter installation similar in design, material and extent indicated on this project.
 - 3. The installer shall have suitably experienced personnel and a management capability sufficient to execute the work shown on the Drawings and specified herein.
 - 4. The installer's foreman/supervisor shall have a minimum of five (5) years experience in the installation of sand filter systems similar in size and nature to this project. The contractor shall ensure that the foreman/supervisor is on site for the entire duration of the work.

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- D. Regulatory Requirements and Approvals: [Specify applicable licensing, bonding or other requirements of regulatory agencies.].
- E. Review the Quality Control Plan with a pre-construction meeting of representatives from the installation subcontractor, general contractor, engineer and/or owner's representative.
- F. Mock-Ups: Use materials, methods and workmanship to show the standard of appearance and makeup of the final filter.
 - 1. Install a 10 ft x 10 ft (3 x 3 m) filter area.
 - 2. This area will be used as the standard by which the work will be judged.
 - 3. Subject to acceptance by owner, mock-up may be retained as part of finished work.
 - 4. If mock-up is not retained, remove and properly dispose of mock-up.

1.10 ANALYSES AND TESTING OF SAMPLES

- A. All testing specified herein is the responsibility of the Contractor and shall be conducted by the independent testing agency, retained by the Contractor. The Owner's Authorized Representative reserves the right to conduct additional testing on all materials submitted, delivered, or in-place to ensure compliance with Specifications.
- B. Material for Testing: Sand and Coarse Sand Media.
- C. Sampling of Sand and Coarse Sand Media: Samples shall be pulled from approved submitted project stockpile for testing.
- D. Infiltration Rate Test: Submit required quantity of Contractor selected sand for Infiltration Test at independent testing agency selected by Owner, or as noted below, and paid for by Contractor. Repeat test as necessary at Contractor's cost.
- E. Testing: Pay cost of testing of materials not meeting specifications.

1.11 DELIVERY, STORAGE, AND HANDLING

- A. General: Comply with Division 1 Product Requirement Section.
- B. Comply with supplier's ordering instructions and lead-time requirements to avoid construction delays.
- C. Delivery: Deliver materials from supplier such that they are protected from deterioration during delivery and while stored at the site.
- D. Rate of supply: Deliver materials to the construction site in such quantities and at such times as will assure the continuity of the installation.
- E. Storage and Protection: Store materials with protection from weather or other conditions which would damage or impair the effectiveness of the material. Store materials at job site in such a manner that no damage occurs to the existing conditions.
- F. The contractor is responsible for providing fencing or other methods to prevent theft of vandalism of stored materials.

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1.12 ENVIRONMENTAL REQUIREMENTS

- A. Do not install in rain, sleet, or snow.
- B. Do not install frozen materials.

1.13 SEQUENCING

- A. Pre-Placement Conference: A mandatory pre-placement conference will take place, including a minimum the Engineer/Landscape Architect, resident Engineer, the Owner's Authorized Representative, Installer, and General Contractor, to review schedule, products, sand testing, and installation. The Contractor shall notify all parties a minimum of two (2) days prior to conference.

Note: Pre-placement conference is mandatory for all projects within the public right-of-way, or on other public property, and is strongly recommended for privately-owned parcel projects.

- B. Coordinate with General Contractor for sequencing for sand filter excavation, impermeable geomembrane liner installation, underdrain system, coarse sand media installation, and sand media installation. Must occur after all other site work disturbance is complete. All surrounding site areas draining into sand filter areas must be stabilized prior to any work for excavation or installation of sand filter areas. Sand bags or curb inlet blocks must be placed at curb/inlet drainage openings to prevent initial runoff from entering the sand filters until they have been accepted.
- C. Coordinate finished grading, and other related units of Work specified in other Sections to sand filter can perform as designed.

1.14 SCHEDULING

- A. Submit a written proposed work schedule to the Owner's Authorized Representative for approval at least sixty (60) days prior to start of work under this Section. Modifications shall be made to this schedule only with written authorization from the Owner's Authorized Representative(s).
- B. Provide schedule to reflect sequencing issues for sand filter areas as noted in 1.13.
- C. In general, the work shall proceed as rapidly as the site becomes available.

1.15 WARRANTY

- A.

1.16 SOURCE QUALITY CONTROL [IF NEEDED]

PART 2 – PRODUCTS

2.1 OWNER FURNISHED PRODUCTS [IF NEEDED]

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2.2 SAND

- A. Provide fine aggregate consisting of clean, hard, washed, durable particles of natural or manufactured sand.
- B. Provide fine aggregate free from frozen material and from injurious amounts of salt, alkali, vegetation matter, or other objectionable material.
- C. Porosity: minimum of 0.32.
- D. Size: conforming to gradation as shown below:

<u>Sieve Size</u>	ASTM C33/C33M Fine Aggregate <u>Percent Passing</u>	TXDOT Fine Aggregate <u>Percent Passing</u>
3/8"	100	100
#4	95-100	95-100
#8	80-100	80-100
#16	50-85	50-85
#30	25-60	25-65
#50	5-30	10-35 ¹
#100	0-10	0-10
#200		0-3 ²

- 1. 6-35 when sand equivalent value is greater than 85.
- 2. 0-6 for manufactured sand.

2.3 COARSE SAND MEDIA – SEPARATING SAND AND UNDERDRAIN

- A. Provide coarse sand consisting of clean, hard, washed, durable particles of natural or manufactured sand.
- B. Provide coarse sand free from frozen material and from injurious amounts of salt, alkali, vegetation matter, or other objectionable material.
- C. Size: conforming to gradation as shown below:

<u>Sieve Size</u>	Coarse Sand Aggregate <u>Percent Passing</u>
3/4"	100
#4	60-100
#50	10-30
#100	0-10
#200	0-3

2.4 IMPERMEABLE GEOMEMBRANE LINER [IF NEEDED]

- A. Synthetic material with a very low permeability.
- B. Shall be free of holes, blisters, undispersed raw materials, or any sign of contamination by foreign matter.

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- C. Shall minimally meet TXDOT Special Specification 5056: Impermeable Liner values as shown below:

<u>Property</u>	<u>Value</u>	<u>Test Method</u>
Nominal Thickness	30 mil (mm)	N/A
Density	0.033 oz/cm ³	ATSM D1505
Tensile Strength at Break	240 lbs/in-width	N/A
Tensile Strength at Yield	140 lbs/in-width	N/A
Elongation at Break	700%	N/A
Elongation at Yield	13%	N/A
Tear Resistance Initiation	45.0 lbs	ASTM D1004
Puncture Resistance	80 lbs	FTMS 101C Method 2065
Carbon Black Content	2-3%	N/A

2.5 CLAY LINER [IF NEEDED]

- A. Compacted clays with a very low permeability.
- B. Soil physical characteristics
 - 1. ≥50 percent fines
 - 2. Liquid limit between 35 and 60
 - 3. Plasticity index versus liquid limit above the A-line
 - 4. USCS Soil Classification of CH, CL MH are recommended.
- C. Field compaction should achieve 95 percent standard max density as determined by ASTM D698. Proctor testing to determine the optimum moisture content for compaction should be performed and result retained.

2.6 UNDERDRAIN PIPE

- A. Use PVC or HDPE slotted pipe
 - 1. Do Not Use pipe with circular perforations with coarse sand filter media
 - 2. Do Not Use pipe wrapped in geotextile fabric (can clog quickly)
- B. Minimum Schedule 40 pipe wall thickness (or equivalent pipe stiffness)
 - 1. 4" diameter pipe: 0.237 in.
 - 2. 6" diameter pipe: 0.280 in
 - 3. Maximum slot width: 0.032 in. (0.81 mm)
- C. Minimum slot open area per foot of pipe length
 - 1. 4" diameter pipe: 1.90 in.2 (12.6 mm2)
 - 2. 6" diameter pipe: 1.98 in.2 (12.8 mm2)
 - 3. If thicker wall pipe than in #2, increase slot area by 50%
- D. Distance between slot centers **
 - 1. 4" diameter pipe: 0.413 in. (10.5 mm)
 - 2. 6" diameter pipe: 0.516 in. (13.1 mm)

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*Note: ** Some variation in these values is acceptable. However, any increased slot length and/or decreased slot centers must not be detrimental to pipe's strength and rigidity.*

- E. All joints heat or cement welded
- F. Acceptable Pipe Brands that meet above specified minimums
 - 1. CertainTeed PVC Underdrain Pipe
 - 2. CONTECH® A-2000™ (PVC)
 - 3. ADS N-12® Dual Wall (HDPE)

2.7 SOURCE QUALITY CONTROL [IF NEEDED]

PART 3 – EXECUTION

3.1 INSTALLERS [IF NEEDED]

3.2 EXAMINATION

- A. Acceptance of Site Verification of Conditions
 - 1. General Contractor shall inspect, accept and certify in writing to the sand filter installation subcontractor that site conditions meet specifications for the following items prior to installation of sand filter system.

3.3 PREPARATION

- A. Coordinate for scheduling and sequencing of excavation and installation of rain garden and/or bioretention areas with all related work.
- B. Prevent runoff from adjacent pervious and impervious surfaces from entering the sand filter cell (e.g. sand bag inlet curb cuts, stabilize adjacent areas, flow diversion) until authorization is given by the Owner's Authorized Representative.
- C. Exclude equipment from sand filter facilities. No equipment shall operate within the area of the cell(s) once sand filter area excavation has begun, including during and after excavation, installation of underdrain and coarse sand media, backfilling with sand and finished grading.
- D. Prevent foreign materials and substances, such as silt laden run-off, construction debris, paint, paint washout, concrete slurry, concrete layers of chunks, cement, plaster, oils, gasoline, diesel fuel, paint thinner, turpentine, tar roofing compound, or acid from entering or being stored in or adjacent to the cell(s) at any point during construction.
- E. Utilities:
 - 1. Determine locations of underground utilities and perform work in a manner which is intended to avoid possible damage. Hand excavate, where required, to minimize possibility of damage to underground utilities.

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- F. By beginning Work, Contractor accepts conditions and assumes responsibility for correcting unsuitable conditions encountered at no additional cost to the Owner.

3.4 EXCAVATION AND GRADING

- A. The Contractor shall not start sand filter cell(s) excavation and grading until all areas draining to the cell(s) are stabilized and authorization has been given by the Owner's Authorized Representative.
- B. Construct sand filter cell(s) subgrade to +/- 3/4 inch of the grades and slopes specified on the Drawings.
- C. Excavation within six (6) inches of final soil grade shall not be permitted if cell(s) have standing water, or have been subjected to more than one-half (1/2) inch of precipitation within the previous forty-eight (48) hours.
- D. Excavation of each Non-infiltrative Cell (Impermeable) sand filter cell
 - 1. Excavation shall provide depth of bed per Drawings with compacted subbase soils and impermeable geomembrane liners (or clay liner).
- E. Examine rough excavated grade/subgrade for each type of cell and verify conditions under which work is to be performed.

3.5 SUBGRADE PREPARATION AND PROTECTION

- A. Protect the sand filter cell area excavation from over compaction and/or contamination.
 - 1. Cell areas which have been over compacted by equipment or vehicle traffic or by other means and which need to be ripped, over excavated, receive additional scarification, or other restorative means shall be done at the Contractor's expense and at the direction of the Owner's Authorized Representative.
 - 2. Excavated areas contaminated by sediment laden (silt) runoff prior to placement of underdrain with coarse sand media and sand shall be remediated at the Contractor's expense by removing the contaminated soil (top three (3) inches minimum) and replacing with a suitable material as determined by the Owner's Authorized Representative.
- B. Remove all trash, debris, construction waste, cement dust and/or slurry, or any other materials that may impede infiltration into prepared subgrade.
- C. The subgrade shall be inspected and accepted by the Owner's Authorized Representative prior to placement of any materials or final subgrade scarification or compaction.
- D. For non-infiltrative cells (impermeable): install the impermeable geomembrane liner, or clay liner, prior to the placement of the underdrain system with coarse sand media and sand.
- E. Thermal weld the impermeable geomembrane liner and water test for twenty-four (24) hours prior to placement of piping or sands. Owner's Authorized Representative shall be on site to review results. If any leaks are detected, then repairs shall be made prior to proceeding with balance of work. Re-testing may be required by Owner's Authorized Representative prior to acceptance.

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- F. Place coarse sand media material below and around underdrain system, where shown on drawings, with conveyor belt or with an excavator or loader from a height no higher than six (6) feet unless otherwise approved by the Owner's Authorized Representative (i.e., do not dump material directly from truck into cell).
- G. Coarse sand media areas contaminated by sediment-laden runoff prior to placement of sand shall be remediated at the Contractor's expense by removing the contaminated coarse sand media material (top three (3) inches minimum or as directed by the Owner's Authorized Representative) and replacing with clean washed coarse sand media material per Section 2.5, to the lines and grades on the Drawings.
- H. Coarse sand media material shall be inspected and accepted for placement and finished grade by the Owner's Authorized Representative prior to the installation of the sand. Any material that does not conform to this Specification shall be removed and replaced with acceptable material or remediated to the satisfaction of the Owner's Authorized Representative, at the Contractor's expense.

3.6 INSTALLATION OF SAND

- A. Inspection of the coarse sand media layer, underdrain, cleanout, and overflow structure installation, where included on the Drawings.
- B. The sand may not be stored on site, but shall be scheduled for delivery when the cells have been inspected, accepted, and the material has been tested and is ready to be installed into the cells.
- C. The Contractor shall not place the sand until the Owner's Authorized Representative has reviewed and confirmed the following:
 - 1. Sand delivery ticket(s): Delivery tickets shall show that the full delivered amount of sand matched the product type, volume and manufacturer/supplier named in the submittals. Each delivered batch of sand shall be accompanied by a certification letter from the supplier verifying that the material meets specifications and is supplied from the approved sand stockpiles for each gradation of sand.
 - 2. Visual match with submitted samples: Delivered product will be compared to the submitted 1-gallon sample, to verify that it matches the submitted sample. The Owner's Authorized Representative may inspect any loads of sand on delivery and stop placement if the sand does not appear to match the submittals; and require sampling and testing of the delivered soil to determine if the sand meets the requirements of Section 2.2 before authorizing placement.

Note: On larger projects, it may be appropriate to require that the testing specified in Section 2.2 and 2.3 be performed on samples taken at the supplier's yard from the stockpile to be used for the project; Section 1.10 A.

- D. Placement, grading and consolidation shall not occur when the sand is excessively wet, or has been subjected to more than one-half (1/2) inch of precipitation within forty-eight (48) hours prior to placement. Excessively wet is defined as being at or above 22 percent soil moisture by a General Tools & Instruments DSMM500 Precision Digital Soil Moisture Meter with Probe (or equivalent). A minimum of three (3) readings with the soil moisture probe will be used to determine the average

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- percent soil moisture reading per each truck load. There should be no visible free water in the material.
- E. The Contractor may place the sand loosely with a conveyor belt or with an excavator or loader from a height no higher than six (6) feet, unless otherwise approved by the Owner's Authorized Representative (i.e., do not dump material directly from truck into cell). Sand shall be placed upon a prepared subgrade or coarse sand media in accordance with these Specifications and in conformity with the lines, grades, depth, and typical cross-section shown in the Drawings or as established by the Owner's Authorized Representative.
 - F. Excessively dry sand may be lightly and uniformly moistened, as necessary, to facilitate placement and workability.
 - G. Compact sand using non-mechanical compaction methods (e.g., boot packing, hand tamping, or water consolidation) to 83 percent (+/- 2 percent) of the maximum dry density per modified Proctor test (ASTM D1555). Determination of in-place density shall be made using a nuclear gauge per ASTM D6938. Moisture content determination shall be conducted on a sand sample taken at the location of the nuclear gauge reading per ASTM D2216.
 - H. Grade sand to a smooth, uniform surface plane with loose, uniformly fine texture. Rake, remove ridges, and fill depressions to meet finished grades.
 - I. Final sand depth shall be measured and verified only after the sand has been compacted. If after consolidation, the sand is not within +/- 3/4 inch of the grades and slopes specified on the Drawings, add material to bring it up to final grade and raked.
 - J. Final inspection and acceptance for placement and finished grades is by the Owner's Authorized Representative.
 - K. Any sand that does not conform to this Specification shall be remediated to the satisfaction of the Owner's Authorized Representative, or removed and replaced with acceptable sand, at the Contractor's expense.
 - L. Set finished grade of sand relative to all drainage structures.

3.7 RE-INSTALLATION [IF NEEDED]

3.8 FIELD QUALITY CONTROL [IF NEEDED]

3.9 SYSTEM STARTUP [IF NEEDED]

3.10 ADJUSTING [IF NEEDED]

3.11 CLEANING / CLEAN-UP

- A. All materials generated by construction work in this section shall be removed at the end of each section of work and the site shall be left in a clean and safe condition.
- B. The Worksite shall be thoroughly cleaned of all waste materials and all unused or salvaged materials, equipment, tools, etc. and left in an orderly condition.

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3.12 CLOSEOUT ACTIVITIES [IF NEEDED]

3.13 PROTECTION

- A. After work in this section is complete, the General Contractor shall be responsible for protecting work from sediment deposition and damage due to subsequent construction activity on the site.

3.14 MAINTENANCE

- A. Maintenance Instructions: Submit two (2) copies and one (1) electronic copy of typewritten instructions recommending procedures to be established by the Owner for the maintenance of bioretention (rain garden) features prior to expiration of Contractor's maintenance period(s) required under the contract. Submit to Owner's Authorized Representative for approval.
- B. Recommended Maintenance Guidelines (Example)

Note: Edit as appropriate for the specific project's applications or conditions.

Activity	Frequency												Per Yr.
	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	
Remove the weeds, preferably by hand, or if an herbicide is used, wick it onto the plant, do not spray - do not allow weeds or seedling trees to establish & mature, remove & dispose of	1	1	2	4	4	5	4	4	5	4	2	1	37
Grasses that naturalize on surface - mow & bag grass clippings, remove & dispose of		1	1	2	2	2	2	2	2				14
Applications & treatment with organic: insecticides, herbicides, & fungicides	*	*	*	*	*	*	*	*	*	*	*	*	*
Curb Inlet/ Energy Dissipation Sump/Forebay – remove all trash and sediment from basin and openings	1	1	1	1	1	1	1	1	1	1	1	1	12
Clean, repair & restore aggregate surfaces – vacuum or sweep remove sediments from aggregates with stormwater inflow	5	4	4	4	5	4	5	4	5	4	4	4	52
Remove trash from energy dissipation (aggregate) surfaces	*	*	*	*	*	*	*	*	*	*	*	*	*
Litter & leaf removal	5	4	4	4	5	4	5	4	5	4	4	4	52

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Activity	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Per Yr.
Organic Insecticide - Ant control	*	*	*	*	*	*	*	*	*	*	*	*	*
Remove debris, cleanout & inspect surface drain grates & area drains	1		1		1		1		1		1		6
Inspect & cleanout subdrain system	1		1		1		1		1		1		6
Inspect & cleanout sedimentation basins	1		1		1		1		1		1		6
Inspect & clean out drain pipe outfall openings to ensure they are free of debris & functioning	1		1		1		1		1		1		6
Inspection & testing surface infiltration rate at different locations & applications (hydraulic conductivity test)					1 time per year								1
Visit w/ Contracting Officer	1	1	1	1	1	1	1	1	1	1	1	1	12
* as needed													

NOTE: This table is not comprehensive and is intended as a guideline. Refer to project documents for further information.

Duration of project work and from adjacent construction: Inspect and Repair BMP's until adjacent construction is complete to prevent siltation of Drainage Storage Features; remove BMP's.

3.15 ATTACHMENTS [IF NEEDED]

END OF SECTION

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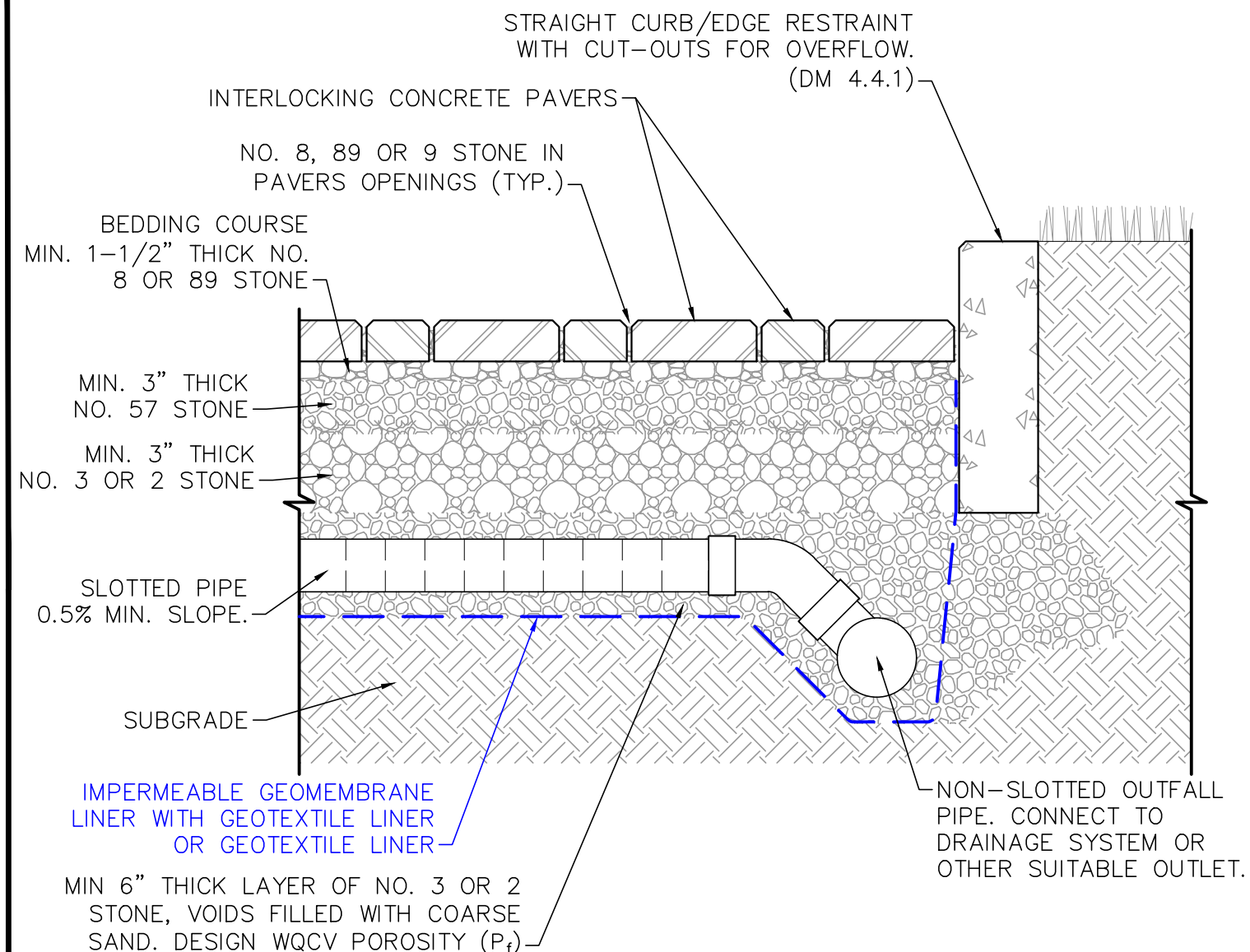


TRWD WATER QUALITY MANUAL

PLANNING AND IMPLEMENTING STORMWATER QUALITY PRACTICES

Appendix H

Example Typical Details



PERMEABLE PAVEMENT

AVAILABLE WQV STORAGE

$$V_{AVAIL} = L * W * [((h_1 + h_2) / 2) * P_1 + h_f + P_f]$$

WHERE:

L = CELL LENGTH (20' MAX BETWEEN PIPES)

W = WIDTH OF PAVEMENT

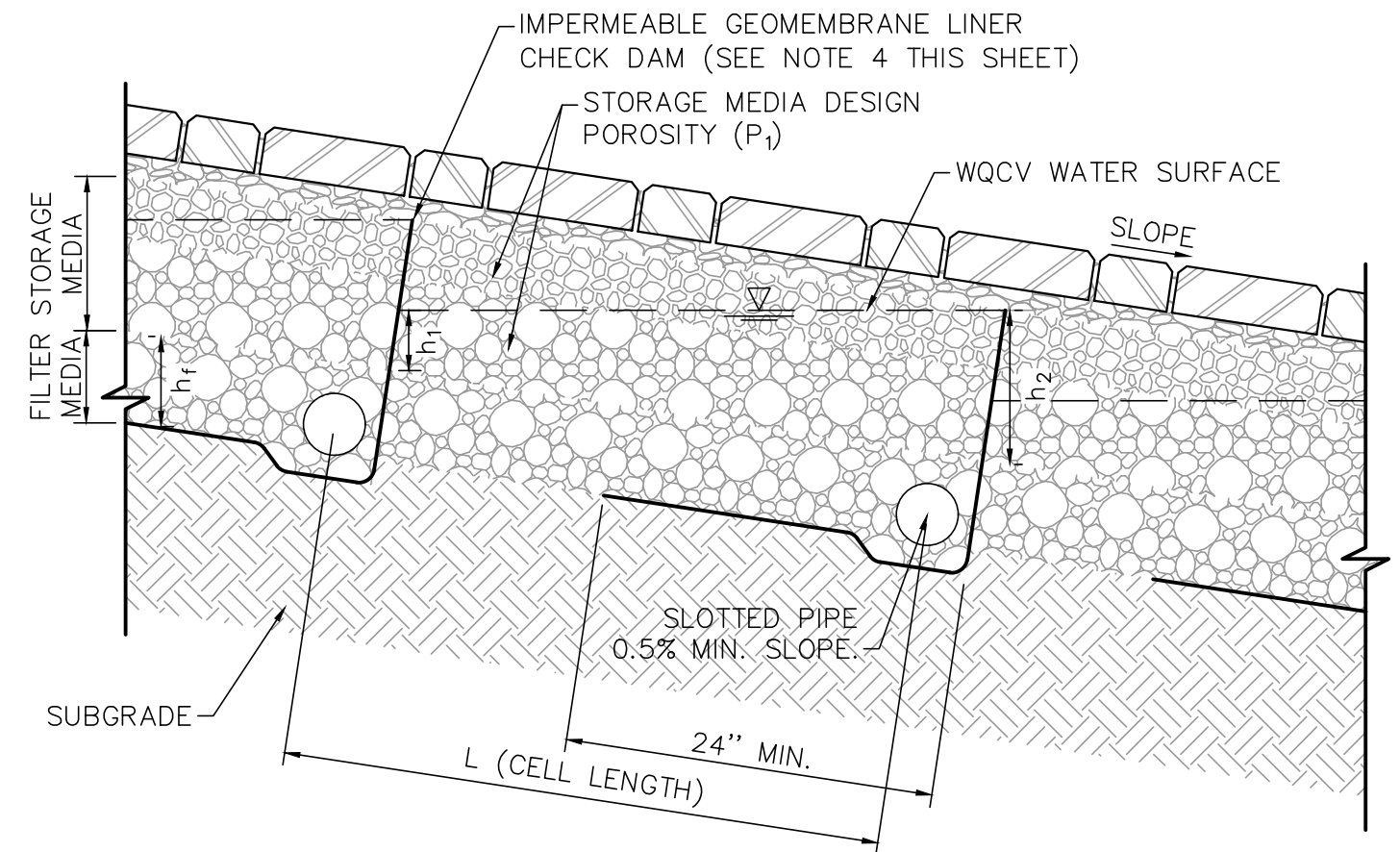
h_1 = UPHILL STORAGE MEDIA DEPTH

h_2 = DOWNHILL STORAGE MEDIA DEPTH

h_f = DEPTH OF FILTER MEDIA (6" MIN.)

P_1 = STORAGE MEDIA DESIGN POROSITY, 0.3 (MAX.)

P_f = FILTER MEDIA DESIGN WQCV POROSITY, 0.1 (MAX.)



NOTES:

- CHECK DAMS RECOMMENDED IF SUBGRADE SLOPE EXCEEDS 0.005 FT/FT.
- LOCATION AND DEPTH OF CHECK DAMS TO BE SPECIFIED IN THE DESIGN PLANS.
- IF UNDERDRAIN TO PASS THROUGH IMPERMEABLE MEMBRANE, ATTACH USING A WATERTIGHT COLLAR.
- IMPERMEABLE GEOMEMBRANE LINER WITH WITH GEOTEXTILE LINER TOP AND BOTTOM FOR PROTECTION AGAINST DAMAGE DURING AGGREGATE COMPACTION.
- CONSULT WITH PAVEMENT ENGINEER TO INSURE TOTAL SECTION WILL SUPPORT EXPECTED TRAFFIC LOADS

CHECK DAMS IN SLOPED PAVEMENT PROFILE VIEW

SEE SHEET
4 OF 4
FOR NOTES.

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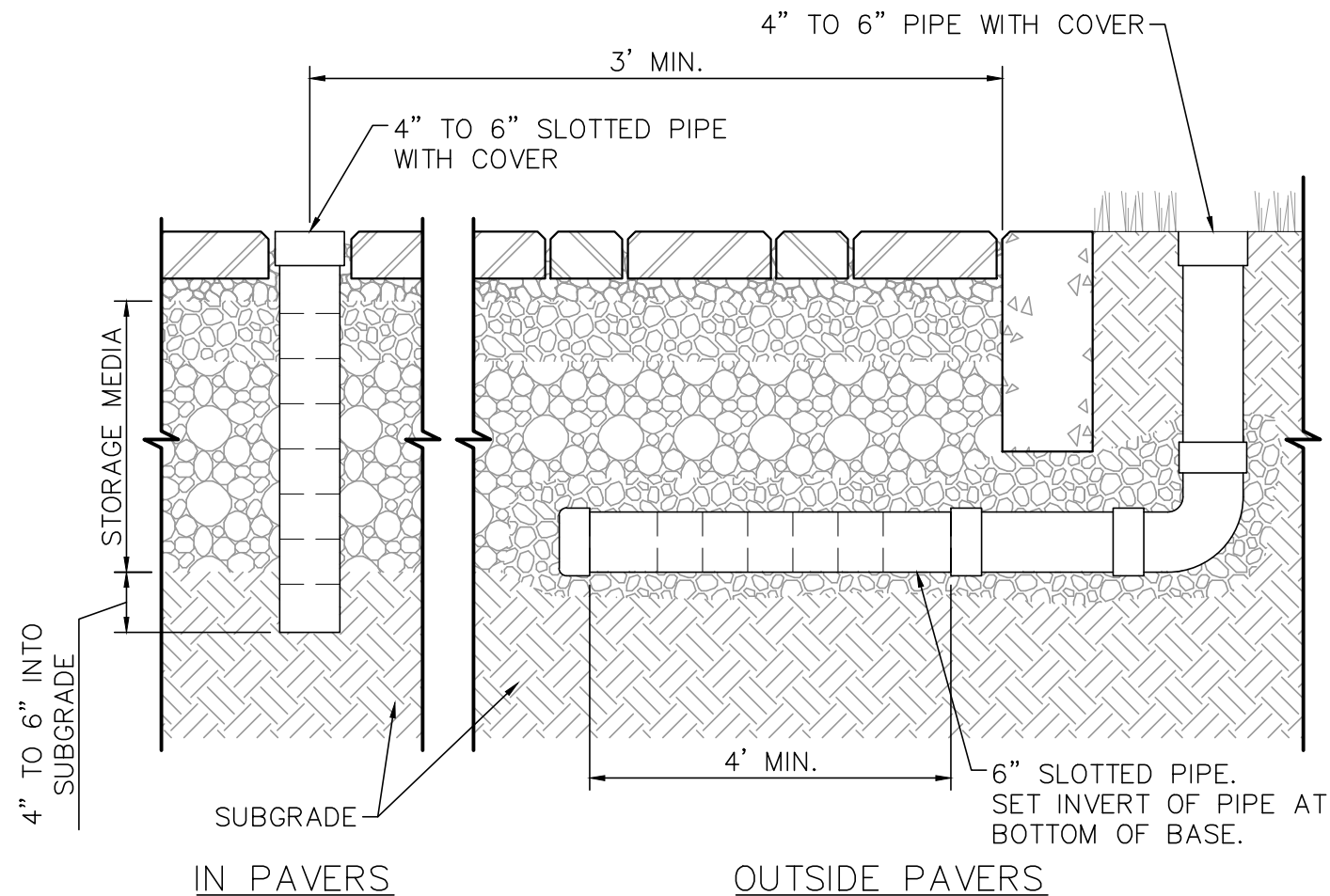
1 OF 4

TARRANT REGIONAL WATER DISTRICT

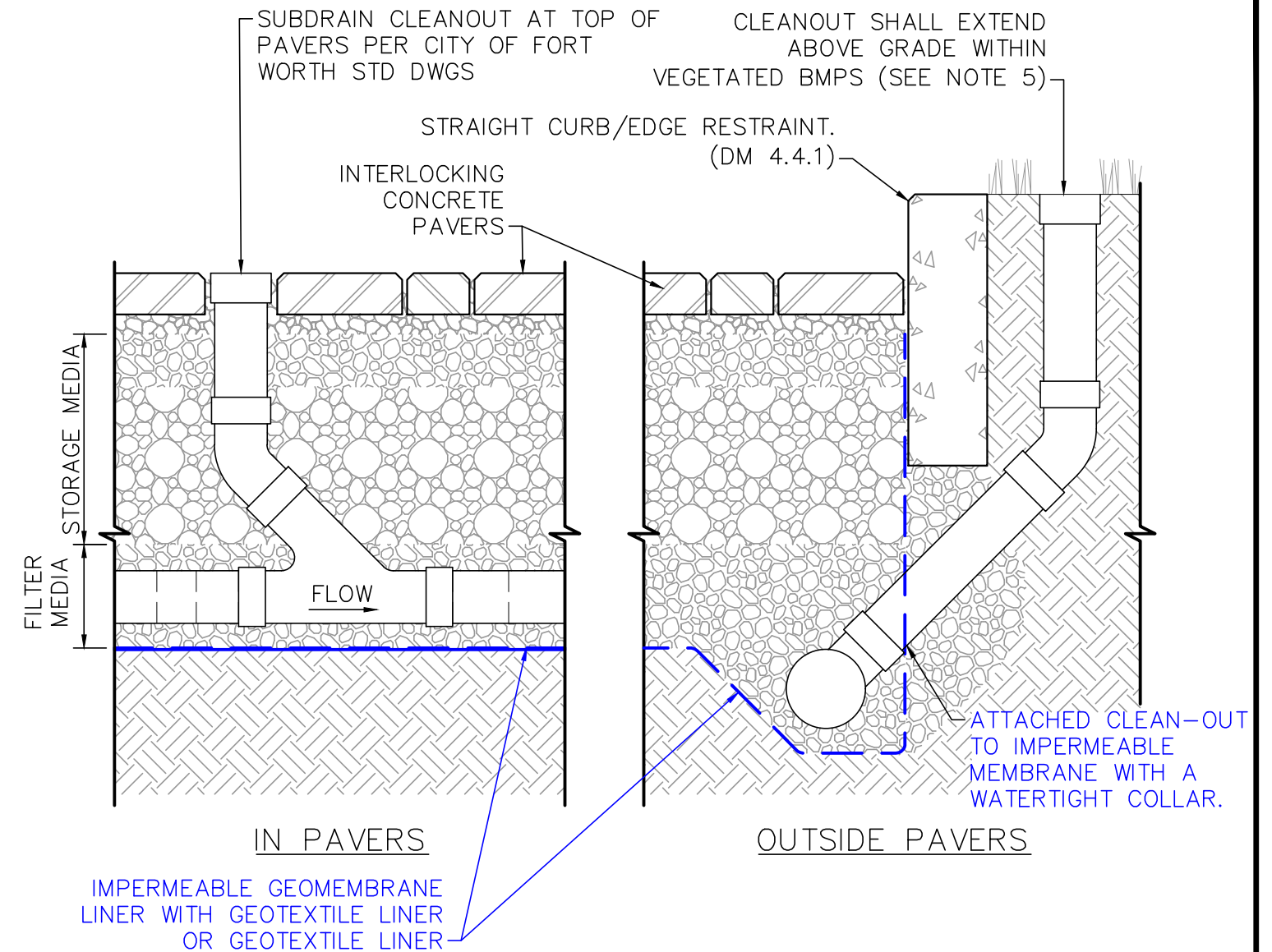
**TYPICAL DETAILS FOR
PERMEABLE PAVEMENT**

REVISED: 07/24/2020

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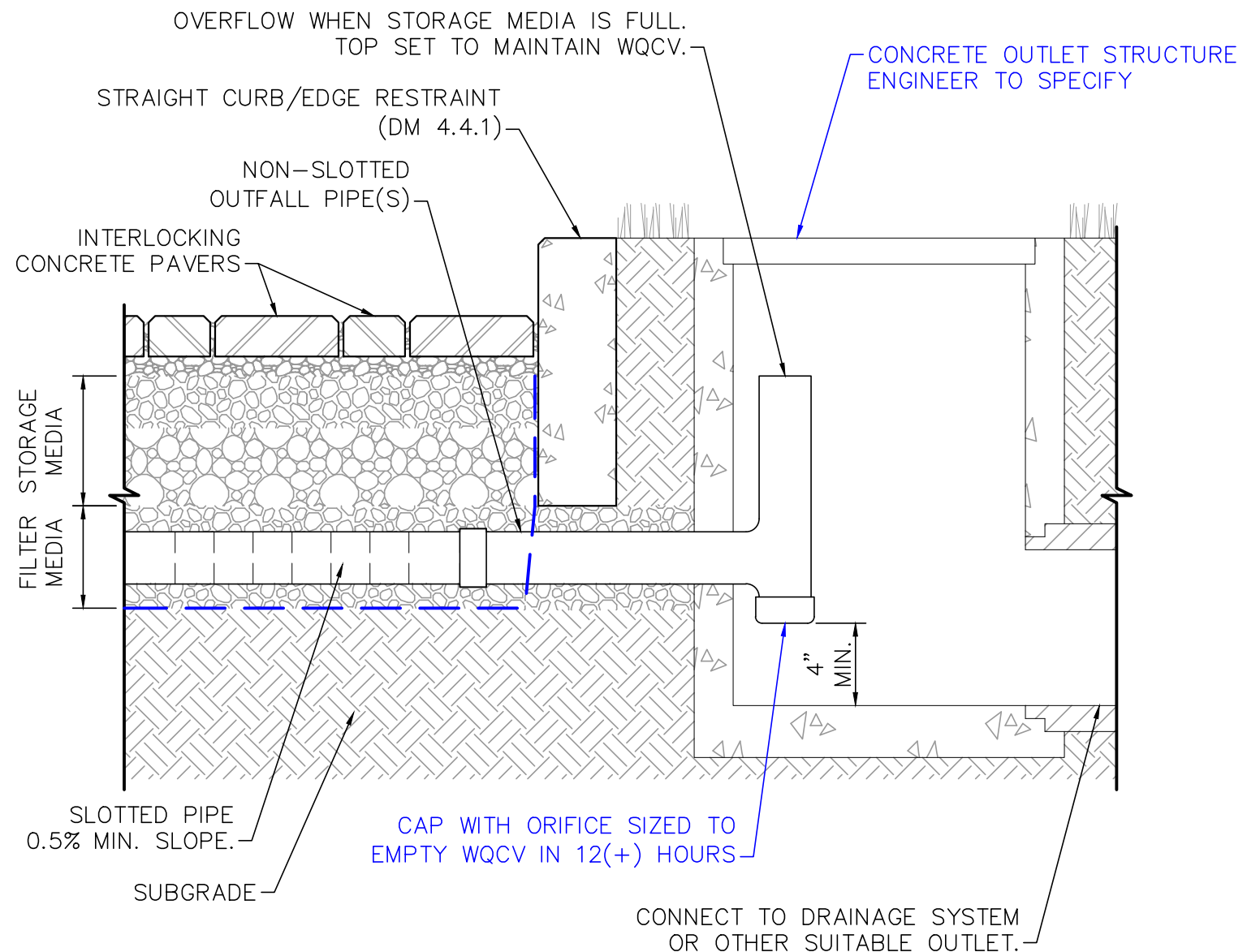
OBSERVATION WELLS



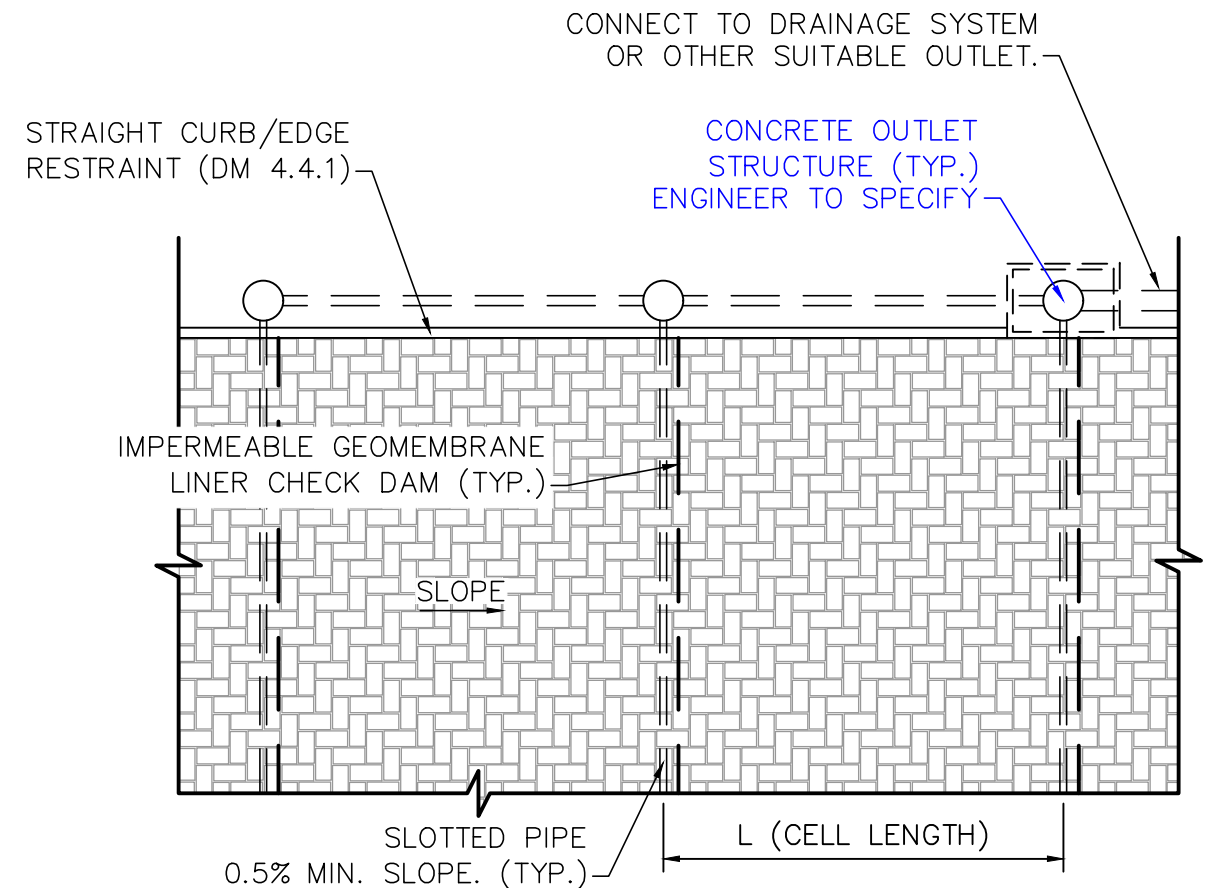
CLEANOUTS

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SEE SHEET 4 OF 4 FOR NOTES.



CONTROLLED OUTFALL



CHECK DAMS IN SLOPED PAVEMENT
PLAN VIEW

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SEE SHEET
4 OF 4
FOR NOTES.

3 OF 4

TARRANT REGIONAL WATER DISTRICT

**TYPICAL DETAILS FOR
PERMEABLE PAVEMENT**

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GENERAL NOTES:

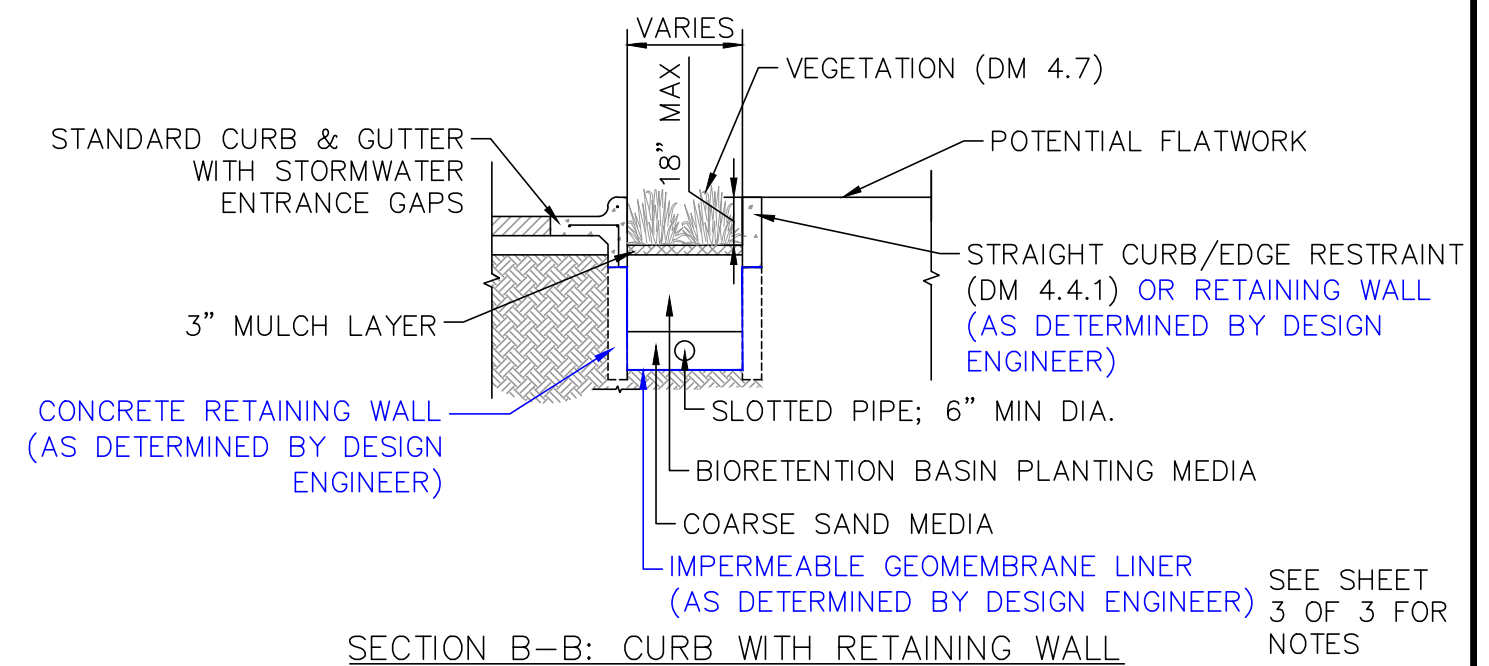
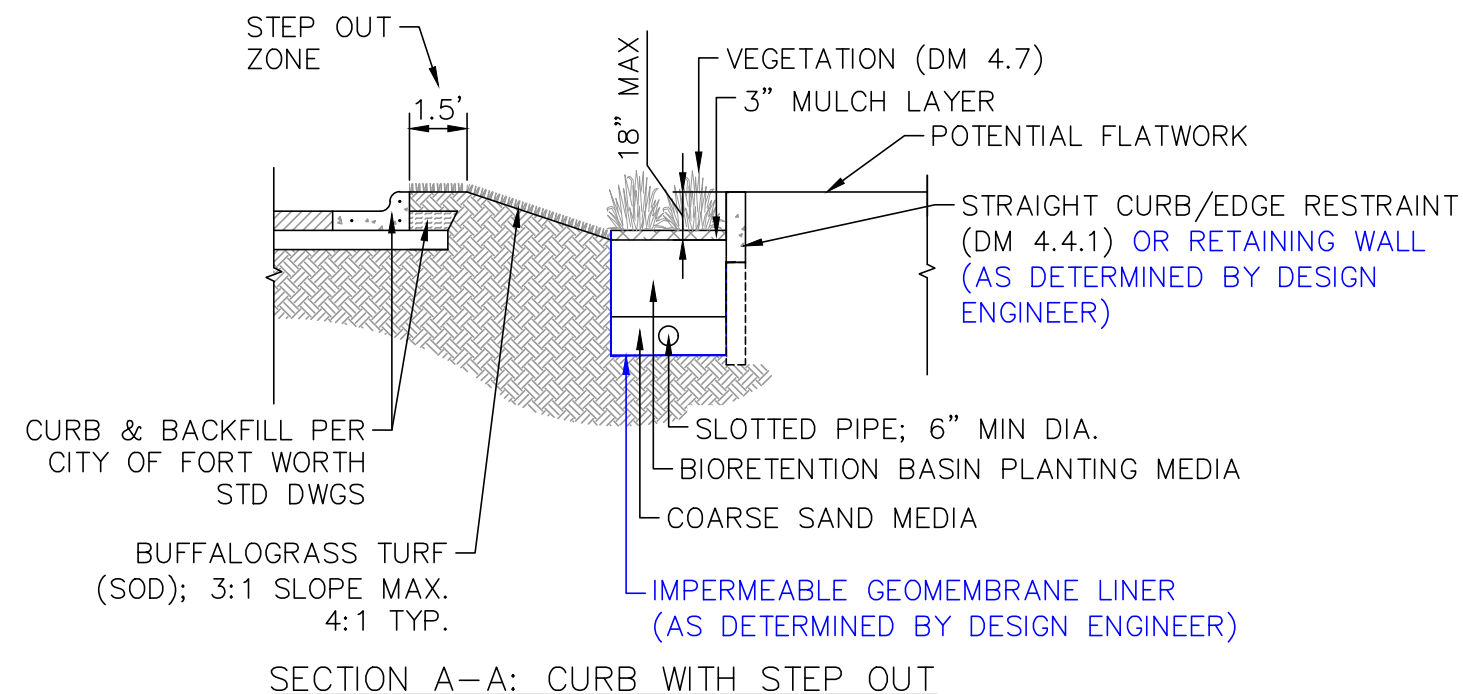
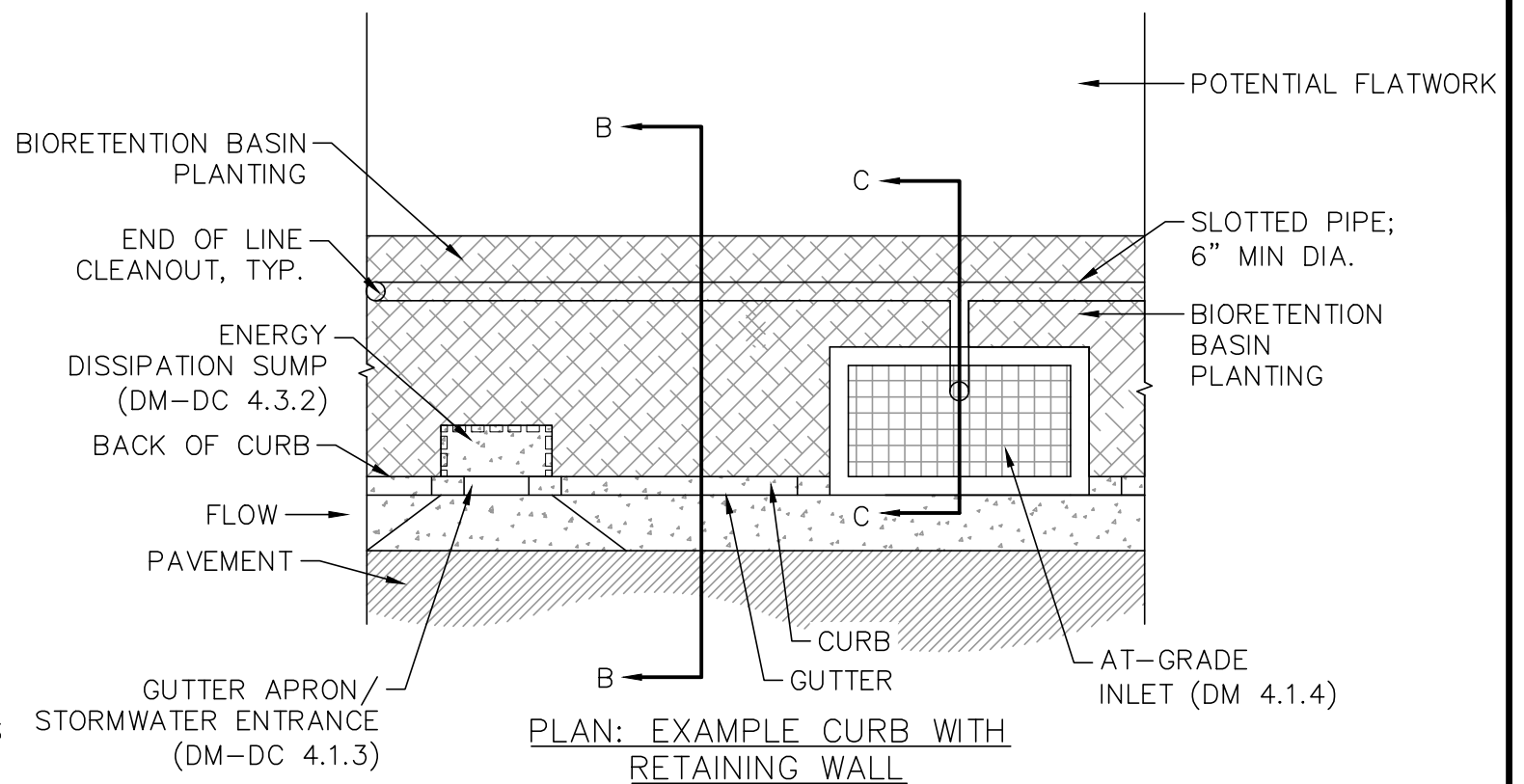
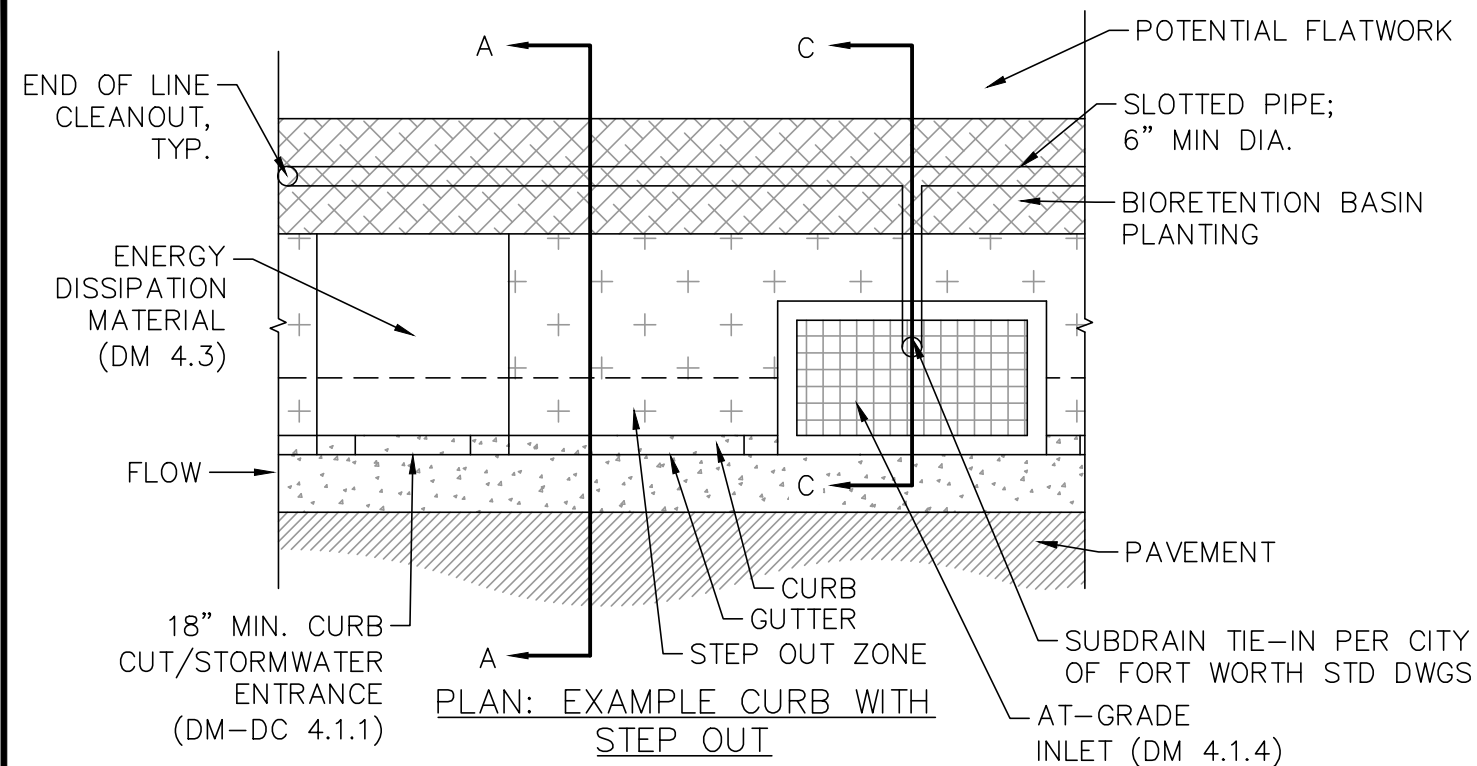
- 1. ALL PEDESTRIAN FEATURES SHALL COMPLY WITH CURRENT APPLICABLE TEXAS ACCESSIBILITY STANDARDS.
- 2. CONSULT PAVEMENT ENGINEER FOR LOAD BEARING DESIGN NEEDS.
- 3. ALL AGGREGATE USED IN GREEN INFRASTRUCTURE SHALL BE WASHED PRIOR TO INSTALLATION.

PERMEABLE PAVERS:

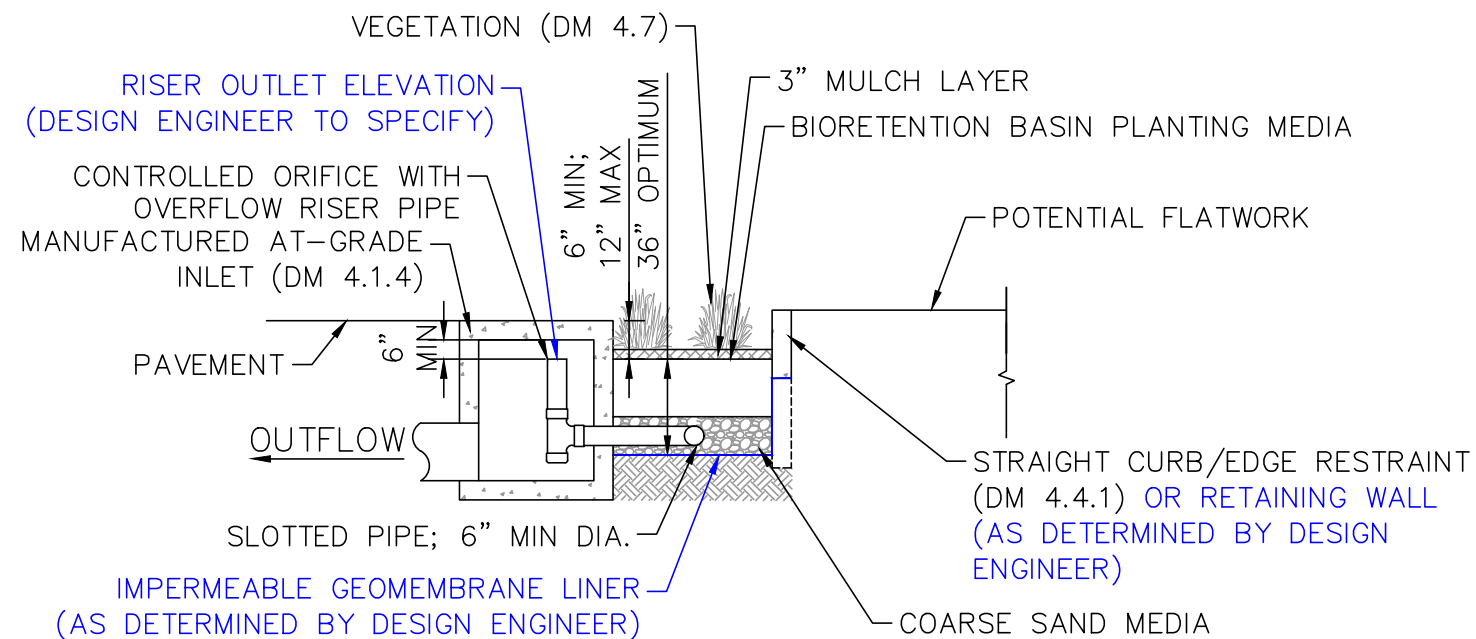
- 4. PERMEABLE PAVER MATERIAL SHALL BE EITHER BRICK PAVER PER CITY OF FORT WORTH STD SPECIFICATIONS OR PERMEABLE INTERLOCKING CONCRETE PAVER PER ASTM C936. ALL PAVERS SHALL BE LAID IN AN INTERLOCKING PATTERN FOR INCREASED STABILITY. ATTENTION SHALL BE PAID TO JOINT MATERIAL TO ENSURE UNIFORM SPACING IS ACHIEVED FOR APPLICATION THAT DO NOT USE INTERLOCKING PAVERS.
- 5. CLEANOUTS:
 - 5.1. CLEANOUTS IN VEGETATED BMPS SHALL EXTEND A MINIMUM 6” ABOVE FINISHED GRADE. CLEANOUTS IN PAVED AREAS SHALL BE FLUSH WITH THE PAVED SURFACE.
 - 5.2. CLEANOUTS ARE REQUIRED ON ALL UNDERDRAIN INSTALLATIONS.
 - 5.3. CLEANOUTS SHALL BE PROVIDED AT THE UPSTREAM AND DOWNSTREAM ENDS OF AN UNDERDRAIN OR DISTRIBUTION PIPE SYSTEM, WITH A MAXIMUM SPACING OF 200 FEET BETWEEN CLEANOUT. ADDITIONAL CLEANOUTS SHALL BE INSTALLED AT ALL 90 DEGREE BENDS AND AS NEEDED TO ACCESS THE SYSTEM FOR MAINTENANCE.
 - 5.4. CLEANOUTS SHALL BE LOCATED OUTSIDE OF DRIVING LANE WITHIN EITHER THE PARKING LANE, BIKE LANE, SIDEWALK OR NON–PAVED RIGHT–OF–WAY WHENEVER POSSIBLE.
 - 5.5. MINIMUM CLEANOUT SIZE SHALL BE 4 INCHES.
- 6. ACCEPTABLE PIPE MATERIAL SHALL BE IN ACCORDANCE WITH CITY OF FORT WORTH STD SPECIFICATIONS.
- 7. THICKNESS OF BRICK PAVER BE A MINIMUM OF 2.25” UNLESS SPECIFIED PER CITY OF FORT WORTH STD SPECIFICATIONS. THICKNESS OF A PERMEABLE INTERLOCKING CONCRETE PAVER SHALL BE DEPENDENT ON USAGE(MINIMUM OF 3.125” FOR VEHICULAR USE AND 2.25” FOR PEDESTRIAN USE).
- 8. JOINT MATERIAL SHALL EITHER BE SAND PER SECTION 4.6.1 OR NO. 8, 89, OR 9 PER ASTM C33. FOR INTERLOCKING CONCRETE PAVER SYSTEMS, OPEN JOINTS NO JOINTING MATERIAL MAY BE ACCEPTABLE PER MANUFACTURER REQUIREMENTS. OPEN JOINTS SHALL NOT EXCEED 1/2” OPENINGS PER TEXAS ACCESSIBILITY STANDARDS.
- 9. PAVERS SHALL HAVE CHAMFERED EDGES.

- 10. SEE TRWD SECTION 3 FOR FULL PAVEMENT SECTION REQUIREMENTS FOR PERMEABLE PAVERS.
- 11. MINIMUM OF ONE UNDERDRAIN PER PERVIOUS PAVEMENT INSTALLATION IS REQUIRED. HORIZONTAL AND VERTICAL LOCATION OF UNDERDRAIN AND UNDERDRAIN BEDDING VARIES. BOTTOM OF BASE LAYER SHALL BE SLOPED FOR POSITIVE DRAINAGE TOWARDS THE UNDERDRAIN AND OUTLET. MINIMUM UNDERDRAIN SIZE SHALL BE 6 INCHES.
- 12. UNDERDRAIN BEDDING TRENCH MUST MAINTAIN A MINIMUM OFFSET OF 4” FROM THE OUTSIDE DIAMETER OF THE UNDERDRAIN. TRENCH SIDES MAY BE VERTICAL OR SLOPED.
- 13. AVERAGE GROUND WATER TABLE MUST BE AT OR BELOW INVERT OF UNDERDRAIN.
- 14. AT–GRADE CONCRETE EDGE RESTRAINT REQUIRED FOR ALL PERMEABLE PAVER INSTALLATIONS AT THE INTERFACE WITH EXISTING PAVEMENT. EDGE RESTRAINT FOR PEDESTRIAN APPLICATIONS MAY BE AT–GRADE CONCRETE BAND. EXTEND THE EDGE RESTRAINT DOWN TO THE DEPTH AND WIDTH TO BE DETERMINED BY THE DESIGN ENGINEER.
- 15. END PERMEABLE PAVER SECTION BEFORE CURB RETURN WHEN INTERSECTION IS RAISED. ALLOW FOR TYPICAL PAVEMENT TRANSITION SECTION TO RETURN TO NORMAL CROWN OF EXISTING STREET.
- 16. IMPERMEABLE BARRIERS ARE REQUIRED WHEN PERMEABLE PAVER INSTALLATION IS WITHIN 10’ OF A BUILDING FOUNDATION, NON–PERMEABLE PAVEMENT SUBGRADE OR IS PLACED ON AN EXPANSIVE CLAY.
- 17. WHERE IMPERMEABLE BARRIER NOT PRESENT, NON–WOVEN GEOTEXTILE FABRIC IS REQUIRED AROUND THE AGGREGATE COURSE AND PIPE BEDDING FOR STABILIZATION AND TO MINIMIZE MATERIAL MIGRATION.
- 18. THE DESIGNER MUST CONSIDER THE ANTICIPATED TRAFFIC LOADS, IN–SITU SOIL STRENGTH, ENVIRONMENTAL ELEMENTS AND PLANNED RESERVOIR DESIGN IN DETERMINING THE APPROPRIATE THICKNESS FOR A GIVEN INSTALLATION.

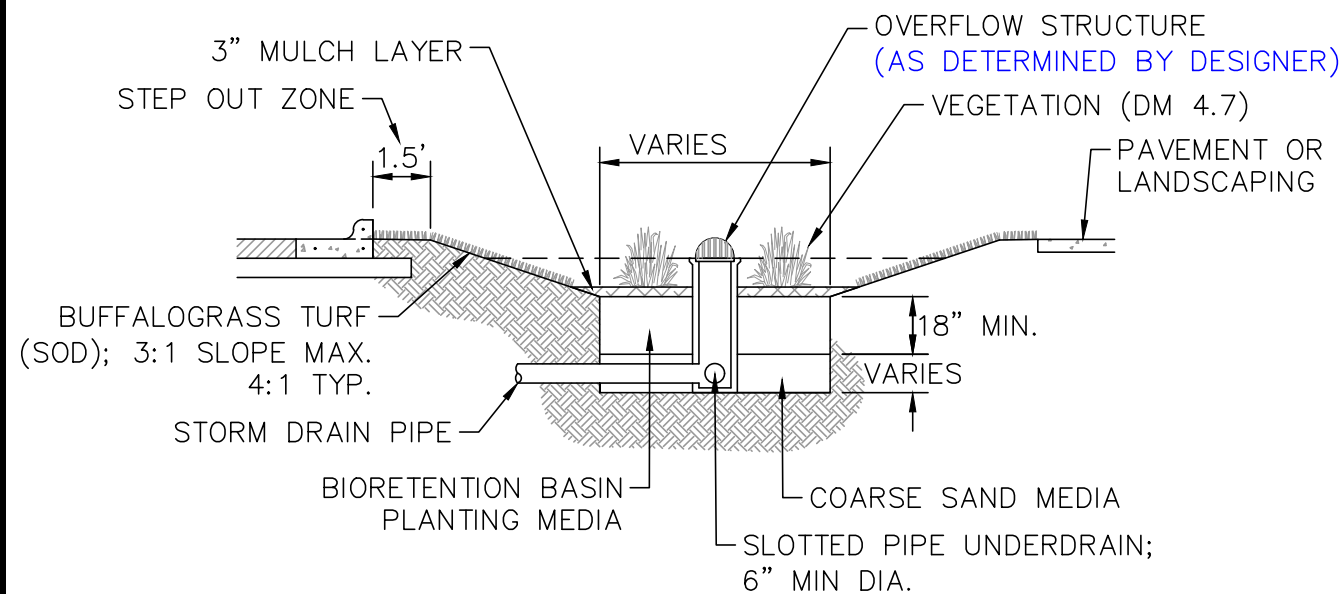
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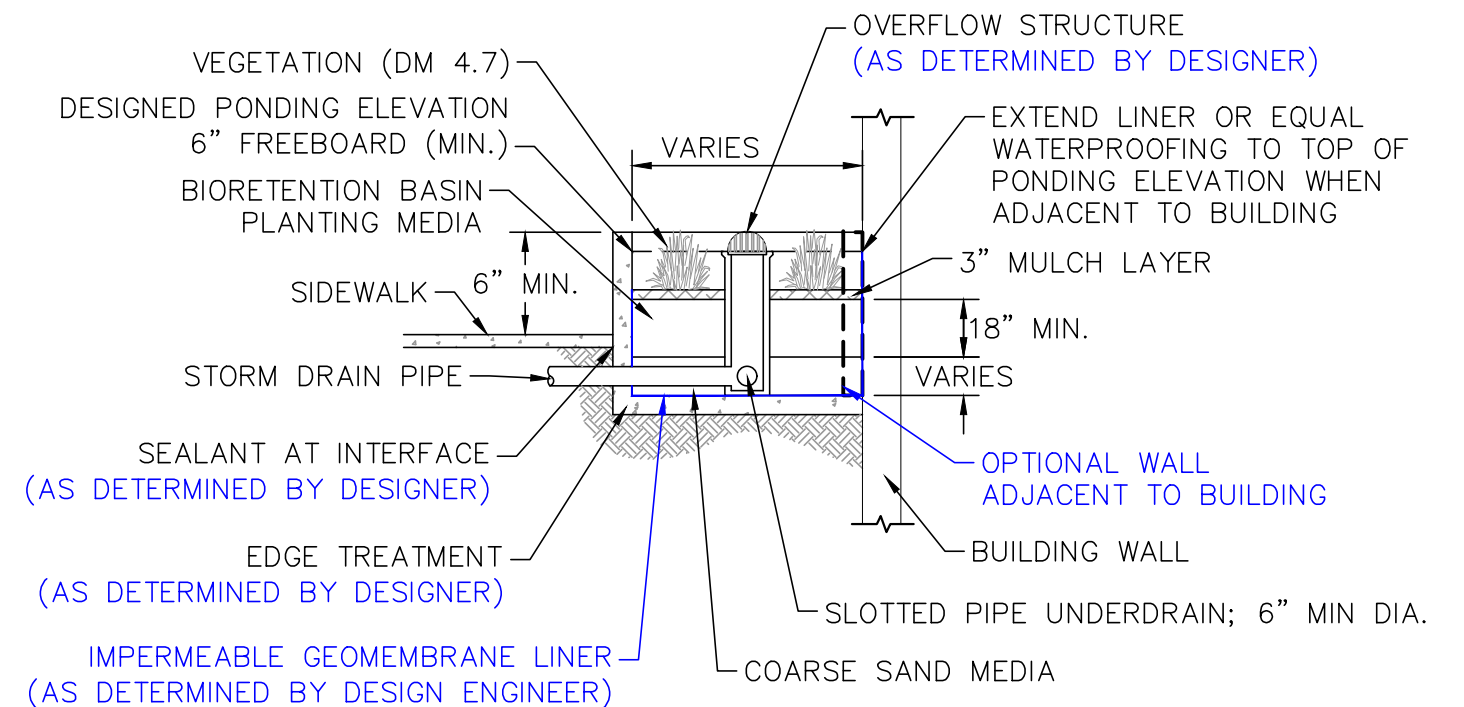
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SECTION C-C: SUBDRAIN INLET TIE-IN



BIORETENTION BASIN



NOTES:

1. INSTALL DOWNSPOUT OR OTHER CONVEYANCE CONNECTION FROM BUILDING TO DRAIN ABOVE DESIGN PONDING ELEVATION.

BIORETENTION PLANTER

SEE SHEET
3 OF 3 FOR
NOTES

2 OF 3

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TARRANT REGIONAL WATER DISTRICT
**TYPICAL DETAILS FOR
BIORETENTION BASIN**

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BIORETENTION BASIN:

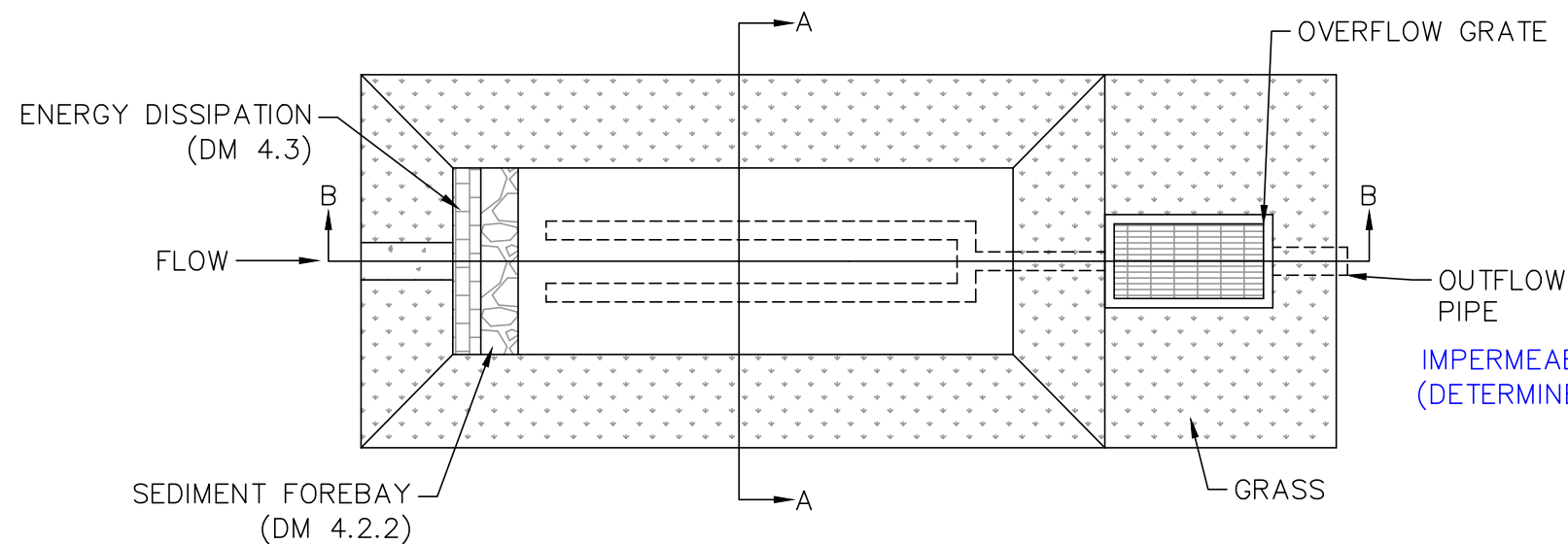
- 18 INCH STEP OUT ZONE REQUIRED WHERE STREET PARKING IS PROVIDED. INSTALLATION MAY BE STANDARD CONCRETE SIDEWALK, TURF, GRAVEL, OR OTHER MATERIAL BASED ON SURROUNDING CONDITIONS.
- RETAINING WALLS ARE REQUIRED WHEN BIORETENTION BASIN IS WITHIN THE BASE OF THE ROADWAY, WHICH TYPICALLY EXTENDS 12 INCHES FROM THE BACK OF THE CURB.
 - RETAINING WALL TO BE DESIGNED BASED ON SITE SPECIFIC CONDITIONS AND LOAD REQUIREMENTS. ALTERNATIVE DESIGNS TO PROTECT THE ROADWAY BASE MAY BE CONSIDERED.
 - OPTION TO PROVIDE A TOE CURB WHEN BIORETENTION BASIN IS ADJACENT TO A SIDEWALK AND WHEN THERE IS A DROP THAT IS GREATER THAN 6 INCHES FROM THE TOP OF SIDEWALK TO THE TOP OF THE BIORETENTION BASIN MEDIA.
- OPTION TO PROVIDE ROOT BARRIER WHEN TURF STEP OUT IS USED ADJACENT TO A SHRUB PLANTED BIORETENTION BASIN TO PREVENT TURF MIGRATION.

2.3. RETAINING WALL TO EXTEND TO DEPTH AS DETERMINED BY DESIGN ENGINEER.

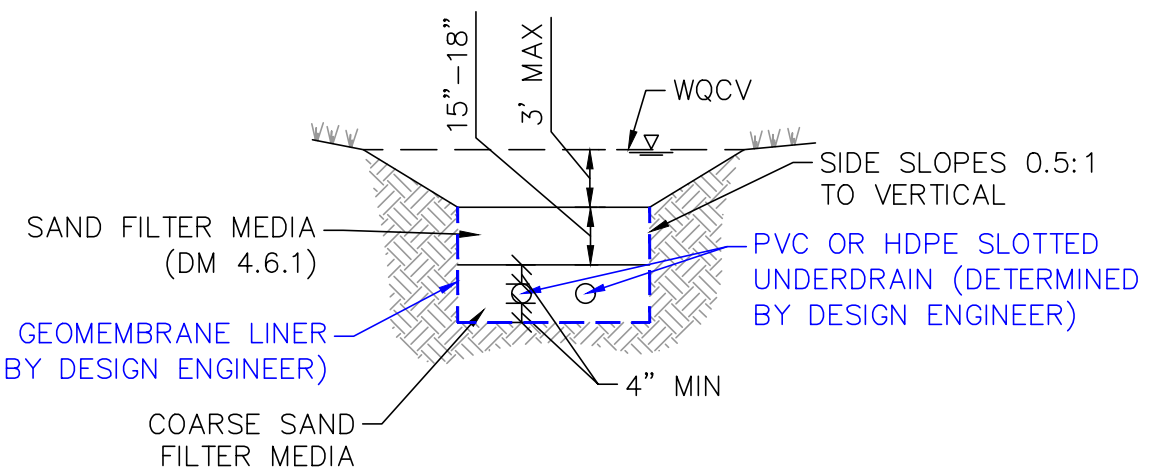
NOTES:

- ALL PEDESTRIAN FEATURES SHALL COMPLY WITH CURRENT APPLICABLE TEXAS ACCESSIBILITY STANDARDS.
- REFER TO TRWD WQ GUIDANCE MANUAL SECTION 3.2 – BIORETENTION BASINS.
- PIPE SIZES WILL VARY. MINIMUM SLOTTED PIPE SIZES SHALL BE 6 INCHES.
 - SUBSURFACE SLOTTED PIPE SHALL HAVE A MINIMUM SLOPE OF 0.5%.
 - SLOTTED PIPE SHALL HAVE A MINIMUM OF 4 INCHES OF COARSE SAND MEDIA ON ALL SIDES OF THE PIPE.
- CLEANOUTS:
 - CLEANOUTS IN VEGETATED BMPS SHALL EXTEND A MINIMUM 6” ABOVE FINISHED GRADE. CLEANOUTS IN PAVED AREAS SHALL BE FLUSH WITH THE PAVED SURFACE.
 - CLEANOUTS ARE REQUIRED ON ALL UNDERDRAIN INSTALLATIONS.
 - CLEANOUTS SHALL BE PROVIDED AT THE UPSTREAM AND DOWNSTREAM ENDS OF AN UNDERDRAIN OR DISTRIBUTION PIPE SYSTEM, WITH A MAXIMUM SPACING OF 200 FEET BETWEEN CLEANOUT. ADDITIONAL CLEANOUTS SHALL BE INSTALLED AT ALL 90 DEGREE BENDS AND AS NEEDED TO ACCESS THE SYSTEM FOR MAINTENANCE.
 - CLEANOUTS SHALL BE LOCATED OUTSIDE OF DRIVING LANE WITHIN EITHER THE PARKING LANE, BIKE LANE, SIDEWALK OR NON–PAVED RIGHT–OF–WAY WHENEVER POSSIBLE.
 - MINIMUM CLEANOUT SIZE SHALL BE 4 INCHES.
- ALL WOOD FORMS, BOTH ABOVE AND BELOW FINISHED GRADE, SHALL BE REMOVED PRIOR TO CONSTRUCTION COMPLETION.
- AVOID COMPACTION OF EXISTING SUBGRADE BELOW BIORETENTION BASIN DURING CONSTRUCTION.
- CURB GAP WIDTHS ARE DETERMINED BY THE SIZE OF THE WATERSHED, IN ORDER TO MAXIMIZE WATER FLOW INTO THE FACILITY. MINIMUM GAP SIZE SHALL BE 18 INCHES.
- SIDE SLOPES SHALL NOT BE GREATER THAN A 3:1 TYPICAL SLOPE. WITH ADDITIONAL EROSION CONTROL MEASURES INCORPORATED, STEEPER SLOPES MAY BE UTILIZED ON A SITE SPECIFIC BASIS.

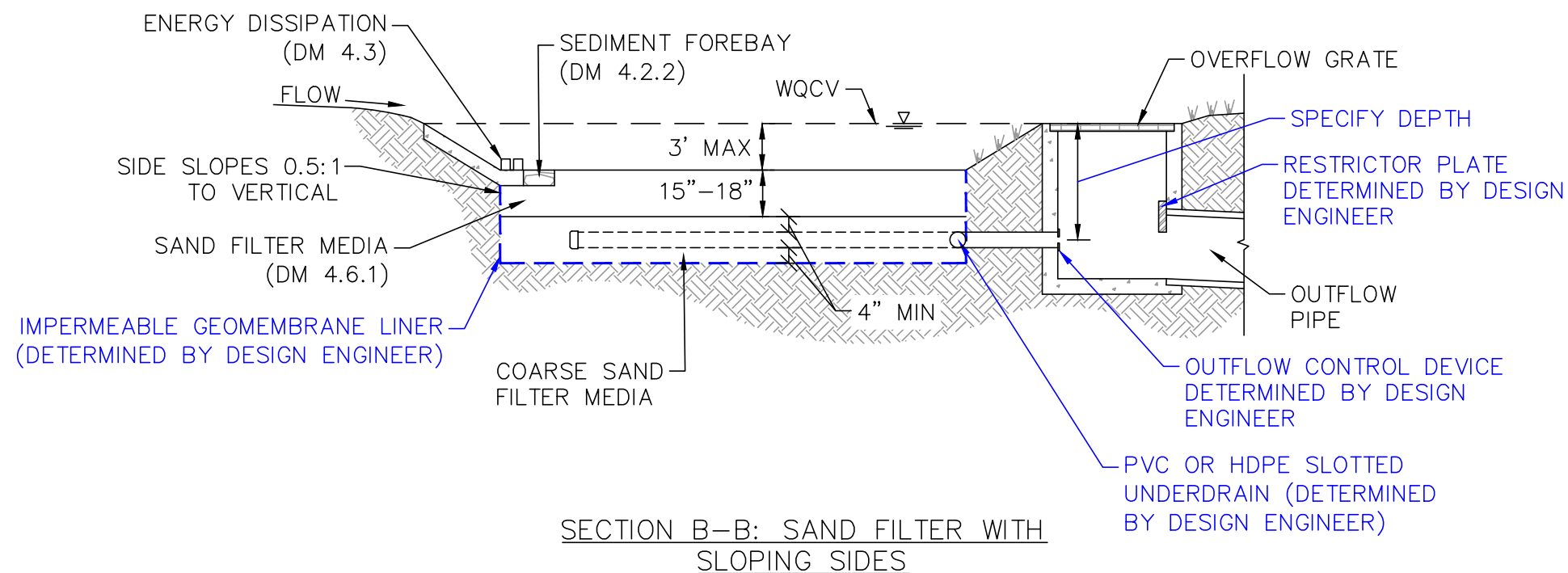
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PLAN: SAND FILTER WITH SLOPING SIDES



SECTION A-A



SECTION B-B: SAND FILTER WITH SLOPING SIDES

NOTES:

1. REFER TO TRWD WQ GUIDANCE MANUAL SECTION 3.1 - SAND FILTERS. .
2. PIPE MATERIALS SHALL BE IN ACCORDANCE WITH CITY OF FORT WORTH STD SPECIFICATIONS.
3. PIPE SIZES WILL VARY. MINIMUM SLOTTED PIPE SIZES SHALL BE 6 INCHES MINIMUM.

SAND FILTER:

1. PROVIDE A FLOW CONTROL ORIFICE AT DISCHARGE END OF UNDERDRAINS SYSTEM TO EMPTY THE WQV IN 12 TO 24 HOURS.

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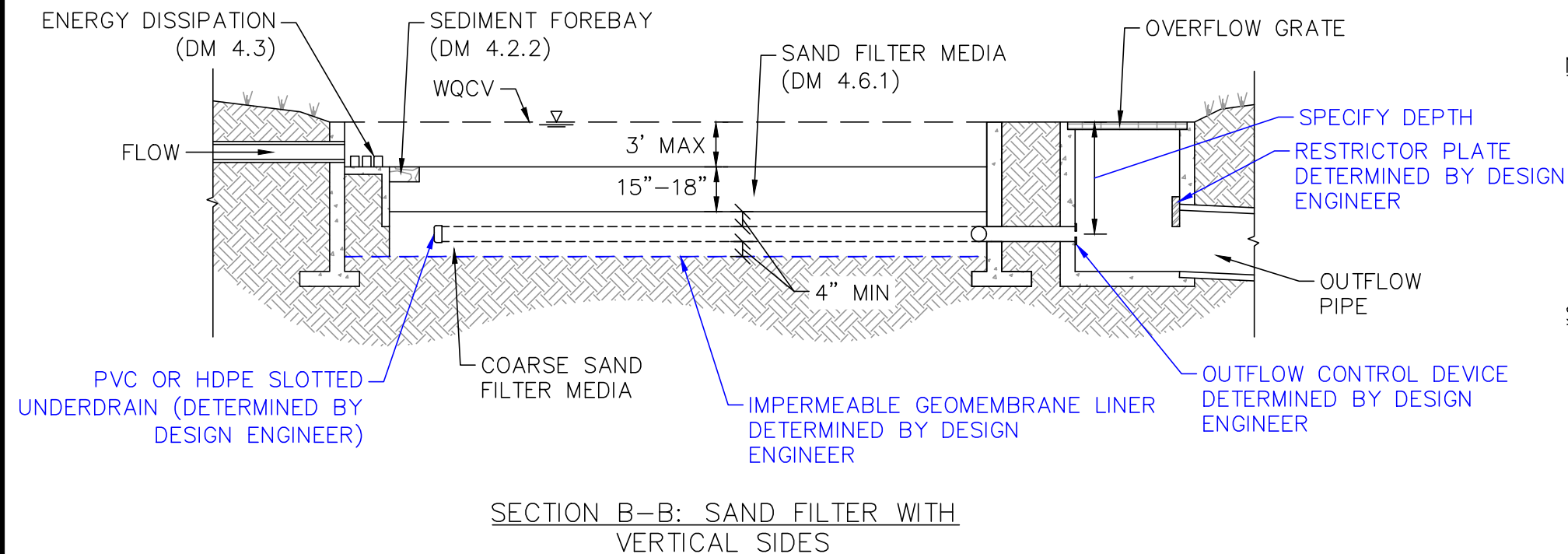
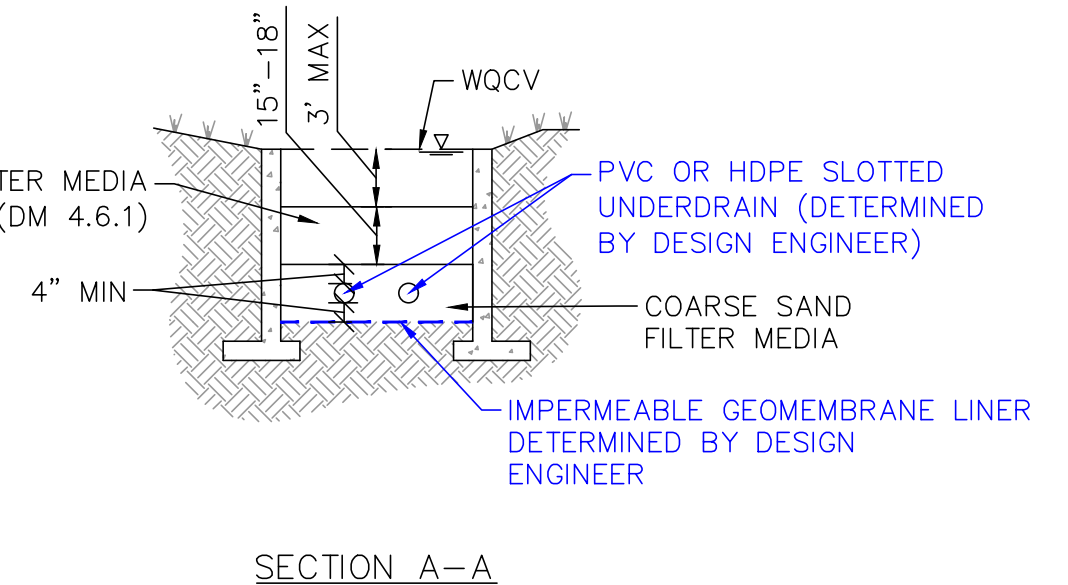
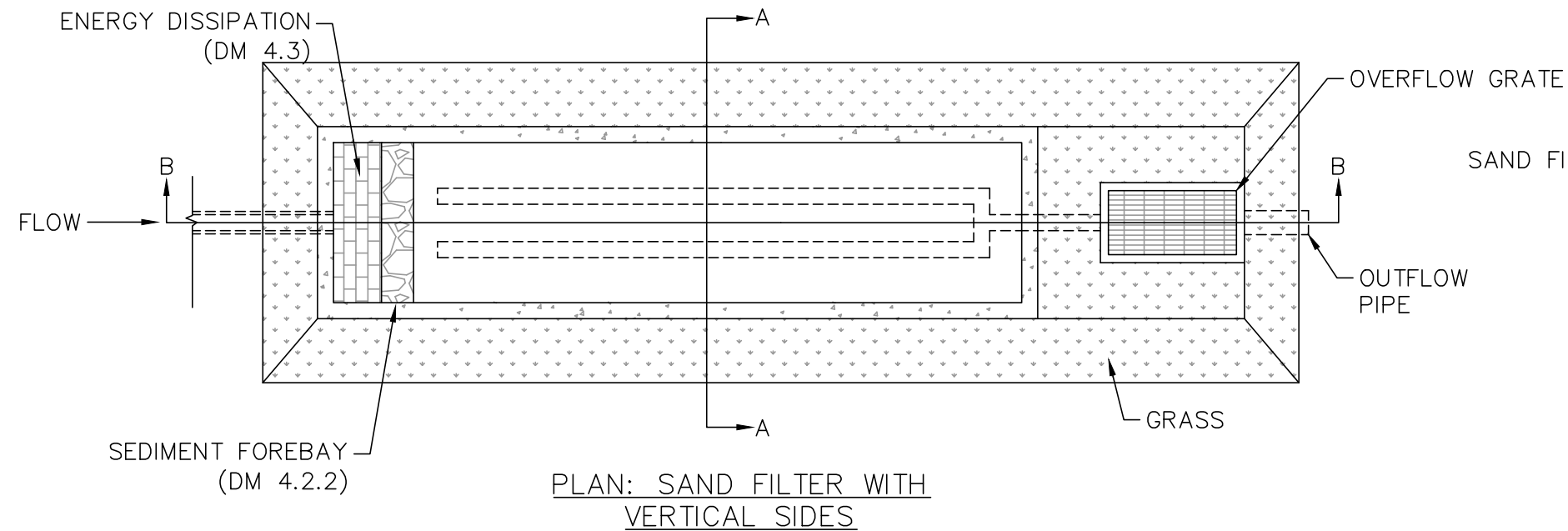
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TARRANT REGIONAL WATER DISTRICT

**TYPICAL DETAILS FOR
SAND FILTER**

REVISED: 07/24/2020

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TARRANT REGIONAL WATER DISTRICT
**TYPICAL DETAILS FOR
SAND FILTER**

REVISED: 07/24/2020

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