STORMWATER MANAGEMENT FACILITY OPERATION AND MAINTENANCE MANUAL

April 2024

Department of Transportation and Infrastructure

Wastewater Management Division

QUICK LINKS

This Manual can be accessed at the City and County of Denver's website at: www.Denvergov.org and searching for "Stormwater O&M Manual."

REFERENCES

1. Southeast Metro Stormwater Authority (SEMSWA) Operations and Maintenance for Permanent Water Quality Control Measure Facilities, SEMSWA, 2019. https://www.semswa.org/water-quality/stormwater-facilities-and-maintenance/
2. Urban Storm Drainage Criteria Manual Vol. 3, Urban Drainage & Flood Control District (UDFCD), 2010. https://mhfd.org/wp-content/uploads/2021/01/01_USDCM-Volume-3.pdf
3. Storm Drainage Design & Technical Criteria, City and County of Denver, 2013. https://www.denvergov.org/files/assets/public/doti/documents/standards/pwes-005.1-storm_drainage_design_and_technical_criteria.pdf
4. City and County of Denver Ultra-Urban Green Infrastructure Guidelines, 2016. https://www.denvergov.org/content/denvergov/en/wastewater-management/stormwater-quality/ultra-urban-green-infrastructure.html
5. Colorado Stormwater Center, Permanent Stormwater Quality Best Management Practice Inspection and Maintenance Field Guide, 2020. http://stormwatercenter.colostate.edu/wp-content/uploads/2020/02/BMP_I-M_Manual.pdf

CONTACTS

For questions regarding Operations and Maintenance plan submittals, modifications to plans, or major maintenance activities, please contact:

Contact	Email	Phone Number
DOTI Engineering Staff	wastewaterpermits@denvergov.org	720-865-2982

For questions regarding Operations and Maintenance inspections, minor maintenance activities, documentation, or to report an illicit discharge, please contact:

Contact	Email	Phone Number
DOTI WMD Inspections	wqinvestigations@denvergov.org	303-446-3659

For questions regarding barrier or sign installation to avoid vehicular traffic, please contact:

Contact	Email	Phone Number
DOTI Right of Way Services	dotipermitoperations@denvergov.org	303-446-3759

ACRONYMS/COMMON PHRASES

- DOTI – Denver Department of Transportation and Infrastructure
- EDB – Extended Detention Basin
- MHFD – Mile High Flood District
- O&M – Operations and Maintenance – Ensuring the function of a stormwater control measure through regular maintenance activities
- Outfall – A point where collected and concentrated surface and stormwater runoff is discharged from the system into a waterbody
- Outlet – A point where stormwater is released from a conveyance or control measure typically into another conveyance or control measure
- PICP – Permeable Interlocking Concrete Pavers
- PPS - Permeable Pavement Systems
- Rip Rap - A facing layer or protective mound of stones placed to prevent erosion or sloughing of a structure of embankment due to the flow of surface and stormwater runoff.
- SCM – Stormwater Control Measure - A structure designed to capture and treat runoff generated during storm events. Previously called BMP's (best management practices)
- Sedimentation – Buildup of (typically) polluted sediment in a control measure that must be removed
- SFB – Sand Filter Basin
- WMD – Denver Department of Transportation and Infrastructure Wastewater Management Division
- WQCV – Water Quality Capture Volume – the amount of runoff that a control measure is designed to treat

TABLE OF CONTENTS

This page intentionally left Blank.

Chapter 1: OVERVIEW

1.1 INTRODUCTION

The purpose of this Stormwater O&M Manual (Manual) is to provide information to the stormwater facility owner and/or the parties responsible for maintenance to ensure that the facility is adequately maintained to function as designed. Denver is required to ensure and enforce maintenance requirements under its Colorado Discharge Permit System (CDPS) Municipal Separate Storm Sewer System (MS4) permit.

A Stormwater Operation and Maintenance Plan (O&M Plan) is required for all stormwater facilities, commonly referred to as stormwater control measures (SCM). The O&M Plan must be created by the facility owner, submitted as part of the project's Drainage Report for review and approval by the City and County of Denver Department of Transportation and Infrastructure (DOTI), and agreed upon by all responsible parties.

The information provided in the O&M Plan will:

- Help the maintenance personnel understand the facility function.
- Provide guidance for inspection and maintenance operations specific to the type of facility.
- Provide mechanisms to ensure long-term maintenance of the facility.

Completed O&M Plans must be provided prior to approval of the Construction Plans for the facility. Checklists of required O&M Plan items can be found in Appendix C and at http://www.denvergov.org/ by searching for "Stormwater O&M Manual." Example O&M Plans are also provided on Denver's website.

1.2 REQUIREMENTS FOR O&M PLAN SUBMITTALS

Denver requires the following information be provided for all permanent stormwater management facilities:

1. Cover Sheet: Provide facility name, address/location, facility type, sheet index, standard notes, approvals, date of drawings
2. Stormwater Facility (SCM) Layout Plan
3. Maintenance Activity Tables for Routine, Minor/Restorative and Major/ Rehabilitation Maintenance: Identify activities, minimum frequencies, items to look for, maintenance actions and responsible parties
4. Landscape Plan
5. Irrigation Plan (if present)
6. Irrigation Details (if present)
7. Structural Details
8. Access locations and easements
9. Inspection Form
10. Maintenance Form

The O&M Plan should include enough construction detail that the facility could be fully rehabilitated (rebuilt) in the future from the O&M Plan. Appendix C provides checklists of information that must be provided in the O&M Plan for Plan and Detail Sheets according to facility type.

For all SCM types, Standard Notes on the Cover Sheet must include:

A. Activities defined in this plan may be amended as agreed upon by all responsible parties. The plan should be updated accordingly.
B. These plans are referenced/copied from the facility design drawings for [facility name] dated [design drawing date]. If substantive changes to design are made during or after construction, then the plan must be resubmitted for approval with as- built drawings.
C. See Denver Stormwater O&M Manual online at denvergov.org for specific information on facility function and maintenance activities associated for this stormwater facility type.

1.3 O&M GUIDANCE FOR STORMWATER FACILITY TYPES IN DENVER

This Manual provides O&M guidance for the most commonly implemented stormwater facility types in the metro Denver area, including extended detention basins, rain gardens, sand filter basins, grass swales/grass buffers, and permeable pavement systems. Other facility types are also implemented in Denver. Table 1 lists facility types and recommended resources for maintenance guidance for these less commonly used stormwater facility types.

Table 1. Resources for O&M Guidance for Stormwater Facility Types in Denver

SCM Type	Recommended O&M Guidance
Extended Detention Basin	Denver O&M Manual*
Rain Garden/Bioretention	Denver O&M Manual*
Sand Filter Basin	Denver O&M Manual*
Grass Buffers/Swales	Denver O&M Manual*
Permeable Pavement	Denver O&M Manual*
Wet Pond/Wetland Basin	USDCM Volume 3 (MHFD) Colorado Stormwater Center Field Guide
Constructed Wetland Channels	USDCM Volume 3 (MHFD)
Green Roofs	USDCM Volume 3 (MHFD)
Manufactured Devices	Manufacturer's Recommendations/O&M Manual

**These facilities also have useful guidance provided in the USDCM Volume 3 and the Colorado Stormwater Center Field Guide.*

1.4 ROLE OF POLLUTANT SOURCE CONTROLS IN STORMWATER FACILITY MAINTENANCE

Although this Manual focuses on maintenance activities for structural stormwater facilities, one of the most effective ways to reduce the maintenance burden and costs is to implement pollutant source controls. Source controls can help to reduce loading of common pollutants such as sediment, trash and debris, chemicals, dog wastes, runoff from stored materials, illicit discharges into the storm drainage system and others. Effective source controls depend on behaviors of property owners/residents and typically require outreach and education to increase awareness of how their actions affect water quality and how they can help reduce maintenance costs over the long-run. Representative topics include:

- Keep properties, streets and gutters, and parking lots free of trash, debris, and lawn clippings.
- Properly dispose of hazardous wastes and chemicals.
- Plan lawn care to minimize the use of chemicals and pesticides.
- Sweep paved surfaces and put the sweepings back on the lawn or dispose of them in appropriate waste containers.
- Be aware of automobiles leaking fluids. Use absorbents such as cat litter to soak up drippings and dispose of waste materials properly.
- Revegetate disturbed and bare areas to maintain vegetative coverage and reduce erosion.
- Clean out the upstream components of the storm drainage system, including inlets, storm sewers and outfalls.
- Do not store pollutant-generating materials outdoors (including certain landscaping materials) unless properly protected from runoff.

1.5 QUALIFICATIONS OF INSPECTION AND MAINTENANCE PERSONNEL

Inspection personnel must be qualified to conduct the facility inspection. Qualifications include knowledge of the facility design features and their function, indicators of conditions requiring maintenance and ability to identify repairs needed.

Maintenance personnel must be qualified to properly maintain stormwater management facilities. Inadequately trained personnel can cause additional problems resulting in additional maintenance costs. For example, special training and qualifications may be necessary for certain landscaped and permeable pavement stormwater facilities. The Colorado Stormwater Center offers training programs related to permanent stormwater SCM inspection and maintenance. For more information, see: http://stormwatercenter.colostate.edu/courses-certifications/.

1.6 CONDUCTING SITE VISITS FOR INSPECTION AND MAINTENANCE

When conducting site visits for inspection and/or maintenance, personnel should be aware of the appropriate access and easement locations for the facility, keep safety at the forefront, and bring appropriate equipment.

1.6.1 Access and Easements

All stormwater management facilities must have both a designated access location as well as a maintenance easement. All access points and easements must be clearly identified on the O&M Plan.

During site visits, facilities must be accessed through appropriate easements and access points identified in the O&M Plan.

1.6.2 Safety

Keep safety at the forefront during inspection and maintenance. Likely hazards should be anticipated and avoided. Representative safety considerations include:

- Report unsafe facility conditions and hazards to Denver 311. For life-threatening conditions and hazardous materials, contact 911.
- Vertical drops may be encountered in areas located within and around the facility. Avoid walking on top of retaining walls or other structures that have a significant vertical drop.
- If inspection and/or maintenance requires confined space entry (e.g., outlet structure, manhole, etc.), then OSHA standards must be adhered to, as described in https://www.osha.gov/SLTC/confinedspaces/index.html.

1.6.3 Field Inspection Equipment

Appropriate equipment must be taken to the field with the inspector(s) to ensure the safety of the inspector and allow inspections to be performed efficiently. Equipment typically required to perform inspections includes:

- Basic safety equipment (e.g., vest, hard hat, safety boots)
- Confined space entry equipment (for OSHA-certified inspectors)
- Communication equipment (e.g., cell phone or radio)
- O&M Plan
- Inspection forms
- Manhole lid remover
- Shovel
- Camera

1.6.4 Maintenance Equipment and Materials

Maintenance equipment will vary by SCM type and the type of maintenance being conducted. For the SCMs described in this Manual, routine maintenance can typically be conducted with ordinary landscape maintenance tools and equipment. For minor/restorative or major/rehabilitative maintenance, specialized (e.g., vactor truck) or heavy equipment (e.g., backhoe) may be needed. If special equipment is needed to conduct maintenance, these equipment requirements should be identified on the O&M Plan.

If vegetation, filter media or other SCM components require replacement or replenishment, the materials used should be consistent with the materials specified in the original SCM design and as documented in the O&M Plan.

1.7 INSPECTING STORMWATER MANAGEMENT FACILITIES

The purpose of stormwater management facility inspections is to determine whether facilities are functioning as intended and to identify maintenance activities needed for the facility. All stormwater management facilities are required to be inspected by a qualified individual at a minimum of twice per year with inspections occurring before and after the rainy summer season. Following significant precipitation events, facilities should be inspected to ensure the facility is draining as designed and to identify damage requiring repairs as a result of major storm events.

Inspections should generally follow the inspection guidelines found for the facility types included in this Manual. For proprietary SCMs, manufacturer's recommendations for inspection frequency must be followed. For other SCM types not included in this Manual, see Volume 3 of the Urban Storm Drainage Criteria Manual (https://mhfd.org/).

The facility inspector must complete an appropriate inspection report for each SCM within the facility as described in this Manual – example reports for common control measures are provided in Appendix A. Facility inspectors may utilize their own report templates if preferred but at a minimum they must cover the same information as the example reports. However, it is recommended to use the example forms provided in this document to ensure adequate documentation is being maintained. The inspection forms serve as documentation of each facility inspection and must be retained by the owner and made available upon request by DOTI inspectors. Photographs showing examples of facilities that represent sites in good condition or that need maintenance can be found at the end of each chapter.

Figure 1. Example Inspection Form

EXTENDED DETENTION BASIN (EDB)
INSPECTION FORM

Subdivision/Business Name: _____ Date: _____

Subdivision/Business Address: _____ Inspector: _____

Weather: _____

Last Date of Rainfall: _____ Amt: _____ Inches

Property Classification: ☐ Residential ☐ Multi-Family ☐ Commercial ☐ Other: _____

Reason for Inspection: ☐ Routine ☐ Complaint ☐ After Significant Rainfall Event

INSPECTION SCORING – For each facility inspection item, insert one of the following scores:

0 = No Deficiencies Identified
1= Monitor (potential for future problem)
2 = Routine Maintenance Required
3= Immediate Repair Necessary
N/A = Not Applicable

FEATURES

1) Inflow Points
____ Riprap Displaced
____ Erosion present/Outfall Undercut
____ Sediment/Debris Accumulation
____ Structural Damage (pipe, end-section, etc.)
____ Woody Growth/Weeds Present

2) Forebay
____ Sediment/Debris Accumulation
____ Concrete Cracking/Failing
____ Drain Pipe/Weir Clogged (not draining)
____ Weir/Drain Pipe Damage

3) Trickle Channel (Low-flow)
____ Sediment/Debris Accumulation
____ Concrete/Riprap Damage
____ Woody Growth/Weeds Present
____ Erosion Outside Channel

4) Bottom Stage (Micropool)
____ Sediment/Debris Accumulation
____ Woody Growth/Weeds Present
____ Bank Erosion
____ Mosquitos/Algae Treatment
____ Petroleum/Chemical Sheen

5) Outlet Works
____ Trash Rack/Well Screen Clogged
____ Structural Damage (concrete, steel, subgrade)
____ Orifice Plate(s) Missing/Not Secure
____ Manhole Access (cover, steps, etc.)
____ Woody Growth/Weeds Present

6) Emergency Spillway
____ Riprap Displaced
____ Erosion Present
____ Woody Growth/Weeds Present
____ Obstruction/Debris

7) Grass Basin Area (Dry Storage)
____ Vegetation Sparse
____ Woody Growth/Undesirable Vegetation
____ Standing Water/Boggy Areas
____ Sediment Accumulation
____ Erosion (banks and bottom)
____ Trash/Debris
____ Maintenance Access

8) Miscellaneous
____ Encroachment in Easement Area
____ Graffiti/Vandalism
____ Public Hazards
____ Burrowing Animals/Pests
____ Other

Inspection Summary/Comments: _____

_____

OVERALL FACILITY RATING (Check One):

0 = No Deficiencies Identified ☐ 2 = Routine Maintenance Required ☐

1 = Monitor (Potential for future problem exists) ☐ 3 = Immediate Repair Necessary ☐

THIS INSPECTION FORM MUST BE KEPT INDEFINITELY AND MADE AVAILABLE TO DOTI UPON REQUEST

Table 2. Inspection Scoring System

Score	Description
0	No deficiencies identified.
1	Monitor – Although maintenance may not be required at this time, a potential problem exists that will most likely need to be addressed in the future. This can include issues like minor erosion, concrete cracks/spalling, or minor sediment accumulation. This item should be revisited at the next inspection.
2	Routine Maintenance Required – Some inspection items can be addressed through the routine maintenance program. Examples include vegetation management or debris/trash removal. Routine maintenance items identified should be addressed as soon as possible, but no later than 6 months following discovery.
3	Immediate Repair Necessary – This item needs immediate attention because failure is imminent or has already occurred. Examples include issues such as structural failure of a feature (outlet structure, forebay, etc.), significant erosion, or significant sediment accumulation. This score should be assigned to a condition that can significantly affect the function of the facility. Items identified should be addressed as soon as possible, but no later than 6 months following discovery.
N/A	Not Applicable – Provide if the feature is not present at the facility. Not all facilities have all of the features identified on the form (e.g., forebay, micropool, etc.).

1.8 MAINTAINING STORMWATER MANAGEMENT FACILITIES

Stormwater management facilities must be properly maintained to ensure that they function correctly and provide the water quality treatment for which they were designed. Routine maintenance performed on a regularly scheduled basis can help avoid more costly major/rehabilitative maintenance that results when facilities are not adequately maintained.

1.8.1 Maintenance Categories (Levels)

Stormwater management facility maintenance programs are separated into three broad categories (levels) of work: routine, minor, and major. The levels are categorized based on the magnitude and type of the maintenance activities performed. Table 3 summarizes the maintenance categories, typical activities, typical frequencies, and coordination requirements with DOTI. Although Table 3 provides general guidance, maintenance should always be done when a facility's performance is compromised, and no later than 6 months following the discovery of need.

For all maintenance activities, appropriate maintenance forms must be completed and retained by the owner for review upon request by DOTI. For major and some minor maintenance activities, prior approval by DOTI is required.

Table 3. Maintenance Categories

Maintenance Category	Description	Typical Frequency	Approval by DOTI Needed?
Routine	Trash and debris removal, mowing, weed control, mosquito/algae management, clean well screens and trash racks.	Multiple Times/Year	No
Minor (Restoration)	Small-scale activities needed to address operational problems. Most of this work can be completed by a small crew and small equipment.	Every Few Years (As Needed)	No
Major (Rehabilitation)	Large-scale maintenance and rehabilitation. Engineering design with construction plans may need to be prepared for review and approval. This work may also require more specialized maintenance equipment, surveying, construction permits, or assistance through private contractors and consultants.	Infrequent	Yes

1.8.2 Maintenance Forms

Maintenance forms for each facility type are provided in Appendix B. These forms are recommended as a tool to document maintenance activities completed for the facility. During site inspections, Denver will request documentation of maintenance.

Figure 2. Example Maintenance Form

EXTENDED DETENTION BASIN (EDB)
MAINTENANCE FORM

Subdivision/Business Name:	_____		Completion Date: _____
Subdivision/Business Address:	_____		Contact Name: _____
Maintenance Category: (check one)	☐ Routine	☐ Restoration (Minor)	☐ Rehabilitation (Major)

MAINTENANCE ACTIVITIES PERFORMED

ROUTINE WORK

- ☐Mowing
- ☐Trash/Debris Removal
- ☐Outlet Works Cleaning (Trash Rack/Well Screen)
- ☐Mosquito Control
- ☐Algae Treatment

MINOR WORK

- ☐Sediment Removal
  - ☐Forebay
  - ☐Trickle Channel
  - ☐Inflow
- ☐Erosion Repair
  - ☐Inflow Point
  - ☐Trickle Channel
- ☐Vegetation Removal/Tree Thinning
  - ☐Inflows
  - ☐Trickle Channel
  - ☐Grass Basin Area
  - ☐Bottom Stage
- ☐Revegetation
- ☐Jet-Vac/Clearing Drains
  - ☐Forebay
  - ☐Outlet Works
  - ☐Inflows

MAJOR WORK

- ☐Sediment Removal (Dredging)
  - ☐Lower stage grass basin area
  - ☐Upper stage grass basin area
- ☐Erosion Repair
  - ☐Outlet Works
  - ☐Lower Stage Grass Basin Area
  - ☐Upper Stage Grass Basin Area
  - ☐Spillway
- ☐Structural Repairs
  - ☐Inflow
  - ☐Outlet Works
  - ☐Forebay
  - ☐Trickle Channel
- Other: _____

Estimated Total Manhours: _____

Equipment/Materials Used: _____

_____

Comments/Additional Info: _____

_____

THIS INSPECTION FORM MUST BE KEPT INDEFINITELY AND MADE AVAILABLE TO DOTI UPON REQUEST

1.8.3 Sediment Disposal

Particularly for major maintenance activities, advanced planning for disposal of dredged sediment is important. In most cases, sediment accumulated in stormwater management facilities is suitable for disposal in solid waste landfills once the sediment is dry and is not considered “hazardous waste.” Sediment should be dewatered before transport and disposal. All sediment transport and disposal must be in accordance with applicable local, state, and federal regulations.

1.9 STORMWATER FACILITY MAINTENANCE RESPONSIBILITY

1.9.1 Maintenance Responsibility for Private Stormwater Facilities

All private property owners are responsible for ensuring that stormwater facilities installed on their property are properly maintained and that they function as designed. In some cases, this maintenance responsibility may be assigned to others through special agreements. The maintenance responsibility for a stormwater facility must be identified on the O&M Plan submittal and clearly identified on any maintenance agreement for the property.

1.9.2 Maintenance Requirements for Denver-Owned Stormwater Facilities

Denver-owned stormwater facilities are subject to the same inspection, maintenance, record-keeping, and annual reporting requirements as privately-owned stormwater facilities. Responsibility for facility maintenance may be shared across multiple city departments. The entity responsible for maintenance must be identified for each maintenance activity in the O&M Plan. The department responsible for the maintenance activity must also ensure that Denver employees and/or contractors have appropriate qualifications and/or training to conduct the maintenance activity.

1.10 REPORTING AND DOCUMENTATION

DOTI requires the facility owner, or its designee to retain and maintain orderly records verifying that stormwater facilities have been properly inspected and maintained. These records must be available to DOTI inspectors upon request. Failure to inspect and maintain stormwater facilities and retain associated documentation may result in an enforcement action in accordance with the requirements of Denver’s Municipal Separate Storm Sewer System (MS4) Permit issued by the Colorado Department of Public Health and Environment (CDPHE).

Chapter 2: EXTENDED DETENTION BASINS

2.1 BACKGROUND

Extended Detention Basins (EDBs) are one of the most common types of stormwater management facilities used in metro Denver. An EDB is a sedimentation basin designed to "extend" the runoff detention time, but to drain completely dry sometime after stormwater runoff ends. The EDB's drain time for the water quality portion of the facility is typically 40 hours. (If part of a flood control detention basin, the drain time may be up to 72 hours.) The basins are considered to be "dry" because the majority of the basin is designed not to have a significant permanent pool of water remaining between runoff events.

EDBs are an adaptation of a detention basin used for flood control, with the primary difference being the typical additions of forebays, micropools, and a slow-release outlet design. Forebays are concrete "pans" located at the inflow point to the basin and are provided to facilitate sediment removal within a contained area prior to releasing runoff into the pond. These forebays collect and briefly hold stormwater runoff, enabling sedimentation. The stormwater is then routed from the forebay into the concrete trickle channel and grassy portion of the basin. The EDB uses a much smaller outlet than a flood control detention basin, extending the emptying time of the more frequently occurring runoff events to facilitate pollutant removal. Ideally, an EDB will have a small micropool just upstream of the outlet. This micropool is designed to hold a small amount of water 2 to 3 feet deep to keep sediment and floatables from blocking the outlet orifices.

Additional design information regarding EDBs can be found in the MHFD Criteria Manual, Volume 3 or by following the link here:

https://mhfd.org/wp-content/uploads/2019/12/06_T-05-Extended-Detention-Basin.pdf

2.2 INSPECTING EXTENDED DETENTION BASINS

Each feature in an EDB is designed for a specific function. The proper function of one feature often depends on another. For example, if a forebay is not properly maintained, it could negatively affect the performance of a feature downstream (trickle channel, micropool, etc.). Therefore, it is critical that each feature of the EDB is properly inspected and maintained to ensure that the overall facility functions as it was intended. Table 4 identifies the most common features and the corresponding maintenance inspection items that can be anticipated for EDBs. Figure 3 provides an example of typical EDB features.

Table 4. Typical Inspection and Maintenance Requirements for EDBs

EDB Features	Sediment Removal	Mowing/ Weed control	Trash & Debris Removal	Erosion	Overgrown Vegetation Removal	Standing Water (mosquito/ algae control)	Structure Repair
Inflow Points (outfalls)	X		X	X	X		X
Forebay	X		X				X
Low-flow channel	X		X	X	X		X
Grass Basin Area (Dry Storage)	X	X	X	X	X	X	
Micropool	X		X		X	X	X
Outlet Structure	X		X				X
Emergency Spillway			X	X	X		X
Embankment		X		X	X		

Figure 3. Typical EDB Features

2.2.1 Inflow Points

Inflow points or outfalls into EDBs are the point source of the stormwater discharge into the facility. An inflow point is commonly a storm sewer pipe with a flared end section that discharges into the EDB. In some instances, an inflow point could be a drainage channel or ditch that flows into the facility.

An energy dissipater (riprap or hard armor protection) is typically installed immediately downstream of the discharge point into the EDB to protect it from erosion. In some cases, the storm sewer outfall can have a toe-wall or cut-off wall immediately below the structure to prevent undercutting of the outfall from erosion

Typical maintenance activities at Inflow Points:

a. ***Riprap Displaced*** – Because the repeated impact/force of water, riprap can shift and settle. If any portion of the riprap apron appears to have settled, soil is present between the riprap, or the riprap has shifted, maintenance may be required to ensure future erosion is prevented.

b. ***Erosion Present/Outfall Undercut*** – In some situations, the energy dissipater may not have been sized, constructed, or maintained appropriately and erosion has occurred. Any erosion within the vicinity of the inflow point will require maintenance to prevent damage to the structure(s) and sediment transport within the facility.

c. ***Sediment Accumulation*** – Because of the turbulence in the water created by the energy dissipater, sediment often deposits immediately downstream of the inflow point. To prevent a loss in hydraulic performance of the upstream infrastructure, sediment that accumulates in this area must be removed in a timely manner.

d. ***Structural Damage*** – Structural damage can occur at any time during the life of the facility. Typically, for an inflow, the structural damage occurs to the pipe's flared end section (concrete or steel). Structural damage can lead to additional operating problems with the facility, including loss of hydraulic performance.

e. ***Woody Growth/Weeds Present*** – Undesirable vegetation can grow in and around the inflow area to an EDB that can significantly affect the performance of the drainage facilities discharging into the facility. This type of vegetation includes trees (typically cottonwoods) and dense areas of shrubs (willows). If woody vegetation is not routinely mowed/removed, the growth can cause debris/sediment to accumulate, resulting in blockage of the discharge. Also, tree roots can cause damage to the structural components of the inflow. Routine maintenance is essential for trees (removing a small tree/sapling is much cheaper and easier than a mature tree). In addition, noxious weeds growing in the facility can result in the loss of desirable native vegetation and impact adjacent open spaces/land.

2.2.2 Forebay

A forebay is a solid surface (pad), typically constructed of concrete, immediately downstream of the inflow point. The forebay is designed to capture larger particles and trash to prevent them from entering the main portion of the EDB. The solid surface is designed to facilitate mechanical sediment removal (e.g., skid steer). The forebay typically includes a small diameter discharge pipe or weir (slot) on the downstream end that is designed to drain the forebay in a specified period of time to promote sedimentation. Forebays vary in size and depth depending on the design and site constraints

Typical maintenance Items for Forebays:

a. **Sediment/Debris Accumulation** – Because this feature of the EDB is designed to provide initial sedimentation, debris and sediment frequently accumulate in this area. If the sediment and debris is not removed from the forebay on a regular basis, it can **significantly** affect the function of other features within the EDB. Routine sediment removal from the forebay can significantly reduce the need for excavation of the main portion of the EDB using specialized equipment (long reach excavators) and **substantially** decrease the long- term sediment removal costs of an EDB.

b. **Woody Growth/Weeds/Cattails** – The presence of plant material not part of the original design should be removed. The forebay should be kept clear of vegetation so that accumulated sediment can be easily removed.

c. **Concrete Cracking/Failing** – The forebay is primarily constructed of concrete, which can crack, spall, and settle. Damage to the forebay can result in deceased performance and impact maintenance efforts.

d. **Drain Pipe/Weir Clogged** – The drainpipe or weir can be clogged with debris, and prevent the forebay from draining properly. If standing water is present in the forebay (and there is not a base flow), the forebay is most likely not draining properly. This can result in decreased performance and create potential nuisances with stagnant water (mosquitoes).

e. **Drain Pipe/Weir Damaged** – Routine maintenance activities, vandalism, or age may cause the weir or drain pipe in the forebay to become damaged. Weirs are typically constructed of concrete, which can crack and spall. The drainpipe is typically smaller in diameter and constructed with plastic, which can fracture.

2.2.3 Trickle Channel (Low-Flow)

The trickle channel conveys stormwater from the forebay to the micropool of the EDB. The trickle channel is typically made of concrete. However, grass lined (riprap sides protected) is also common. The trickle channel is typically 6 to 9 inches in depth and can vary in width. The trickle channel also marks the bottom of an EDB and can be used for reference when dredging the EDB basin

Typical maintenance Items for Trickle Channels:

a. **Sediment/Debris Accumulation –** Trickle channels are typically designed with a relatively flat slope that can promote sedimentation and deposition of debris. Also, if a trickle channel is grass-lined it can accumulate sediment and debris at a much quicker rate. Routine removal of accumulated sediment and debris is essential in preventing flows from circumventing the trickle channel and affecting the dry storage portion of the pond.

b. **Concrete/Riprap Damage –** Concrete can crack, spall, and settle and must be repaired to ensure proper function of the trickle channel. Riprap can also shift over time and must be replaced/repaired as necessary.

c. **Woody Growth/Weeds Present –** Because of the constant moisture in the area surrounding the trickle channel, woody growth (cottonwoods/willows) can become a problem. Trees and dense shrub type vegetation can affect the capacity of the trickle channel and can allow flows to circumvent the feature**.**

d. **Erosion Outside of Channel –** In larger precipitation events, the trickle channel capacity will likely be exceeded. This can result in erosion immediately adjacent to the trickle channel that must be repaired to prevent further damage to the structural components of the EDB.

2.2.4 Micropool

The micropool is a concrete or grouted boulder walled structure directly in front of the outlet structure. At a minimum, the micropool is 2.5 feet deep and is designed to hold water. The micropool is critical in the proper function of the EDB: it allows suspended sediment to be deposited at the bottom of the micropool, thereby preventing sediment from clogging the outlet structure and causing marshy areas in the top and bottom stages of the grassed area of the EDB

Typical maintenance Items for Micropools:

a. **Sediment/Debris Accumulation –** The micropool can frequently accumulate sediment and debris. This material must be removed to maintain pond volume and proper function of the outlet structure.

b. **Woody Growth/Weeds Present -** Because of the constant moisture in the soil surrounding the micropool, woody growth (cottonwoods/willows) can create operational problems for the EDB. If woody vegetation is not routinely mowed/removed, the growth can cause debris/sediment to accumulate outside of the micropool, which can cause problems with other EDB features. Also, tree roots can cause damage to the structural components of the outlet structure. Routine management is essential for trees (removing a small tree/sapling is much cheaper and easier than a mature tree).

c. **Mosquitoes/Algae Treatment** – Nuisances created by stagnant water can result from improper maintenance/treatment of the micropool. Mosquito larvae can be laid by adult mosquitoes within the permanent pool. Also, aquatic vegetation that grows in shallow pools of water can decompose causing foul odors. Chemical/mechanical treatment of the micropool may be necessary to reduce these impacts to adjacent property owners.

d. **Petroleum/Chemical Sheen** – Indicators of illicit discharges into the storm sewer system may be present in the micropool area of the EDB. These indicators can include sheens, odors, discolored soil, and dead vegetation. If it is suspected that an illicit discharge has occurred, Denver 311 immediately. Proper removal/mitigation of contaminated soils and water in the EDB is necessary to minimize environmental impacts downstream.

2.2.5 Outlet Structure

The outlet structure is the feature that is designed to drain the EDB at a specified discharge rate over an allowed period of time. The outlet structure is typically constructed of reinforced concrete into the embankment of the EDB. The concrete structure typically has stainless steel orifice plates anchored/embedded into it to control stormwater release rates. The larger openings (flood control) on the outlet structure typically have trash racks over them to prevent clogging. The water quality orifice plate (smaller diameter holes) will typically have a well screen covering it to prevent smaller materials from clogging it. The outlet structure is the single most important feature in the EDB operation. Proper inspection and maintenance of the outlet structure is essential in ensuring the long-term operation of the EDB

Typical maintenance Items for Outlet Structures:

a. **Trash Rack/Well Screen Clogged –** Floatable material that enters the EDB will most likely make its way to the outlet structure. This material is trapped against the trash racks and well screens on the outlet structure (which is why they are there). This material must be removed on a routine basis to ensure the outlet structure drains in the specified design period.

b. **Structural Damage -** The outlet structure is primarily constructed of concrete, which can crack, spall, and settle. Steel trash racks and well screens are also susceptible to damage.

c. **Orifice Plate Missing/Not Secure –** Residents, property owners, or maintenance personnel sometimes remove or loosen orifice plates if they believe the pond is not draining properly. Any modification to the orifice plate(s) will significantly affect the designed discharge rates for water quality and/or flood control. Modification of the orifice plates is not allowed without approval from DOTI.

d. **Woody Growth/Weeds Present -** Because of the constant moisture in the soil surrounding the outlet structure, woody growth (cottonwoods/willows) can create operational problems for the EDB. If woody vegetation is not routinely mowed/removed, the growth can cause debris/sediment to accumulate around the outlet structure, which can cause problems with other EDB features. Also, tree roots can cause damage to the structural components of the outlet structure. Routine management is essential for trees (removing a small tree/sapling is much cheaper and easier than a mature tree).

2.2.6 Emergency Spillway

An emergency spillway is designed to serve as the overflow of the EDB in the event the volume of the pond is exceeded. The emergency spillway is typically armored with riprap (or other hard armor) and is sometimes buried with soil. The emergency spillway is typically a weir (notch) in the pond embankment. Proper function of the emergency spillway is essential to ensure flooding does not affect adjacent properties.

Typical maintenance Items for Emergency Spillways:

a. **Riprap Displaced –** The emergency spillway is typically armored with riprap to provide erosion protection. Over the life of an EDB, the riprap may shift or dislodge due to flow.

b. **Erosion Present –** Although the spillway is typically armored, stormwater flowing through the spillway can cause erosion damage. Erosion must be repaired to ensure the integrity of the basin embankment and proper function of the spillway.

c. **Woody Growth/Weeds Present –** Management of woody vegetation is essential in the proper long-term function of the spillway. Larger trees or dense shrubs can capture larger debris entering the EDB and reduce the capacity of the spillway.

d. **Obstruction Debris –** The spillway must be cleared of any obstruction (human-caused or natural) to ensure the proper design capacity.

2.2.7 Grass Basin Area (Dry Storage)

The grass basin area of the EDB provides the majority of the water quality and flood detention volume. This area of the EDB is higher than the micropool and typically stays dry, except during storm events. The grass basin area is the largest feature/area of the basin. Sometimes, the grass basin area can be utilized for park space and other uses in larger EDBs. The grass basin bottom elevations (lower stage) should be monitored for sediment accumulation to ensure adequate detention volume is maintained for the facility.

Typical maintenance Items for Grass Basin Area:

a. **Sparse Vegetation –** The grass basin area is the most visible part of the EDB; therefore, aesthetics is important. Adequate and properly maintained vegetation can greatly increase the overall appearance and acceptance of the EDB by the public. Vegetation can also reduce the potential for erosion and sediment transport to the other areas of the pond.

b. **Woody Growth/Undesirable Vegetation –** Although some trees and woody vegetation may be acceptable in the upper portion of the basin, some thinning of cottonwoods and willows may be necessary. Eventually, the basin will have to be dredged to ensure detention volume is maintained, and large trees and shrubs will be difficult to protect during that operation.

c. **Standing Water/Boggy Areas –** Standing water or boggy areas in the grass basin area is typically a sign that some other feature in the basin is not functioning properly. Routine maintenance (mowing, trash removal, etc.) can be extremely difficult if the ground is saturated. If standing water is flagged during the inspection, then the root cause of the problem should also be identified.

d. **Sediment Accumulation –** Although other features within the EDB are designed to capture sediment, the grass basin area will gradually collect sediment over time, resulting in a loss of storage volume. It may be more difficult to determine if this area has accumulated sediment without conducting a field survey. Field indicators of sediment accumulation include:

- Ground adjacent to the trickle channel appears to be several inches higher than concrete/riprap.
- Standing water or boggy areas in grass basin area.
- Uneven grades or mounds.
- Micropool or forebay has excessive amounts of sediment.

e. **Erosion (banks and bottom) –** The bottom grades of the dry storage are typically flat enough that erosion should not occur. However, inadequate vegetative cover may result in erosion of the grass basin area, resulting in increased dredging/maintenance of the micropool.

f. **Trash/Debris –** Trash and debris can accumulate after large events or from illegal dumping. Over time, this material can accumulate and clog the EDB outlet structure.

g. **Maintenance Access –** Most EDBs typically have a gravel/concrete maintenance access path to either the grass basin area or forebay. This access path should be inspected to ensure the surface is still drivable. Some smaller EDBs may not have maintenance access paths; however, the inspector should verify that access is available from adjacent properties.

2.2.8 Miscellaneous

There are a variety of inspection/maintenance issues that may not be attributed to a single feature within the EDB. This category on the inspection form is for maintenance items that are commonly found in the EDB, but may not be attributed to an individual feature

a. **Encroachment in Easement Area –** Private lots/property can sometimes be located very close to the EDBs, even though they are required to be located in tracts with drainage easements. Property owners may place landscaping, trash, fencing, or other items within the easement area that may affect maintenance or operation of the facility.

b. **Public Hazards and Vandalism–** Public hazards such as unknown/suspicious substances, exposed metal/jagged concrete on structures or damage due to vandalism should be reported to Denver 311.

c. **Burrowing Animals/Pests –** Prairie dogs and other burrowing rodents may cause damage to the EDB features and negatively affect the vegetation within the EDB.

d. **Other –** Any miscellaneous inspection/maintenance items not contained on the form should be entered here.

2.3 MAINTAINING EXTENDED DETENTION BASINS

2.3.1 Summary of Routine, Minor and Major Maintenance Activities

A typical EDB Maintenance Program will consist of three broad categories (levels): Routine, Minor and Major. Within each level, a variety of maintenance activities may be necessary. A maintenance activity can be specific to each feature within the EDB, or general to the overall facility. Table 5 highlights the common activities associated with each level.

Table 5. Typical EDB Maintenance Levels and Activities

ROUTINE	MINOR	MAJOR
Mowing	Minor Sediment Removal	Major Sediment Removal
Trash/Debris Removal	Minor Erosion Repair	Major Erosion Repair
Outlet Structure Cleaning	Minor Vegetation Removal	Structural Repair
Sediment Removal from Forebay	Jet Vac / Clearing Drains	
Unwanted Vegetation/Weed Control		
Mosquito Treatment		
Algae Treatment		

A brief description of routine, minor and major activities for EDBs includes:

- Routine Maintenance Activities: The majority of this work consists of regularly scheduled mowing and trash and debris pickups for stormwater management facilities during the growing season. This includes items such as the removal of debris/material that may be clogging the outlet structure well screens and trash racks. It also includes activities such as weed control, mosquito treatment, and algae treatment. These activities normally will be performed multiple times during the year.

- Minor Maintenance Activities: This work consists of a variety of isolated or small-scale maintenance or operational problems. Most of this work can be completed by a small crew, tools, and small equipment.

- Major Maintenance Activities: This work consists of larger maintenance/operational problems and failures of the EDB. This work may also require more specialized maintenance equipment, design/details, surveying, or assistance through private contractors and consultants.

Tables 6 through 8 provide a summary of typical maintenance activities associated with each level of maintenance for EDBs that can be used for developing the O&M Plan for most EDBs; however, maintenance should always be done when a facility's performance is compromised, and no later than 6 months following the discovery of need. Most routine and minor maintenance activities do not require coordination with DOTI; however, coordination with DOTI is required for major maintenance activities. Maintenance activity records should be completed and maintained by the owner, and available upon request by DOTI inspectors. Appendix B provides an example maintenance form for EDBs.
Section 2.3.2 provides a narrative description of activities in tables 6-8

Table 6. Summary of Routine Maintenance Activities for EDBs

Maintenance Activity	Minimum Frequency	Look for:	Maintenance Action
Mowing	Twice annually (more frequent mowing may be desired for aesthetics)	Excessive height that affects the inlet and/or outlet	Trim around structures and/or within facility to ensure facility can perform as intended.
Trash/Debris Removal	Twice annually (2-4 times/year is ideal) and prior to mowing. More frequent removal may be necessary depending on location	Trash & debris in EDB	Remove and dispose of trash and debris
Outlet Structure Cleaning	Twice annually (As needed - after significant rain events)	Clogged outlet structure/well screen; ponding water	Rake well screen; remove and dispose of debris/trash/sediment to allow outlet to function properly
Sediment Removal from Forebay and Trickle Channel	Twice annually (2-4 times/year is ideal; as needed after significant rain events)	Sediment accumulation in forebay and trickle channel; vegetation growing in accumulated sediment	Remove and dispose of sediment
Unwanted Vegetation/ Weed Control	Twice annually (as needed based on inspections)	Noxious weeds; Unwanted vegetation	Hand pull; Consult an authorized herbicide applicator
Mosquito Treatment	As needed	Standing water/mosquito habitat	Treat w/ EPA approved chemicals, typically larvicides
Algae Treatment	As needed	Standing water/ algal growth/green color	Remove mechanically; if needed, treat w/ EPA approved chemicals

Table 7. Summary of Minor Maintenance activities for EDBs

Maintenance Activity	Minimum Frequency	Look for:	Maintenance Action
Sediment Removal from Micropool	As needed based on inspection; may range from 1 –4 years	Sediment buildup in Micropool; depth decreased to 18 inches or sediment accumulation of 12 inches	Remove and dispose of sediment; jet vac may be required
Erosion Repair	As needed, based upon inspection	Rills/gullies forming on side slopes, trickle channel, other areas	Repair eroded areas Revegetate; address source of erosion
Woody Vegetation Removal/Tree Thinning	As needed, based upon inspection	Large trees/wood vegetation in lower portion of basin	Remove vegetation; restore grade and surface
Drain Cleaning/Jet Vac	As needed, based upon inspection	Sediment build-up /non-draining system	Clean drains; Jet Vac if needed

Table 8. Summary of Major Maintenance Activities for EDBs

Maintenance Activity	Minimum Frequency	Look for:	Maintenance Action
Major Sediment Removal	As needed – based upon scheduled inspections (*~15-25 years is typical*)	Large quantities of sediment; reduced pond capacity *(>20% of WQCV capacity lost due to sediment*)	Remove and dispose of sediment. Repair vegetation as needed
Major Erosion Repair	As needed – based upon scheduled inspections	Severe erosion including gullies, excessive soil displacement, areas of settlement, holes	Repair erosion – find cause of problem and address to avoid future erosion
Structural Repair	As needed – based upon scheduled inspections	Deterioration and/or damage to structural components – broken concrete, damaged pipes, outlet structure	Structural repair to restore the structure to its original design

2.3.2 Description of Maintenance Activities

Maintenance activities in Tables 6 through 8 are described below.

2.3.2.1 Mowing

Occasional mowing is necessary to limit unwanted vegetation and to improve the overall appearance and performance of the EDB. Grasses should be mowed to a level which re-establishes the functionality of the facility. The grass height within a 40- to 50-foot radius of the structural components of the facility is particularly important. Grass clippings should be collected and disposed of properly. The desirable grass height can vary from facility to facility and should be coordinated with the owner for aesthetics if there are questions. Typically, grass should not be mowed less than 6 inches high.

2.3.2.2 Trash/Debris Removal

Trash and debris must be removed from the entire EDB area to minimize outlet clogging and to improve aesthetics. This activity must be performed prior to mowing operations.

2.3.2.3 Outlet Structure Cleaning

Debris and other materials can clog the outlet structure's well screen, orifice plate(s) and trash rack. This activity must be performed anytime other maintenance activities are conducted to ensure proper operation.

2.3.2.4 Sediment Removal

Routine sediment removal is focused on the forebay and trickle channel. Forebays are designed to trap sediment for ease of maintenance. Frequent sediment removal from the forebay can help reduce the maintenance burden in other parts of the EDB. Sediment removal from the trickle channel is recommended at least annually.

Minor sediment removal includes sediment removal from the micropool. Minor sediment removal activities can typically be addressed with shovels and smaller equipment, or a Jet-vac.

Major sediment removal is necessary to maintain the original design volume of the EDB and to ensure proper function of the facility and involves removal of large quantities of sediment or removal of sediment from vegetated areas. The frequency of major sediment removal activities varies by site, but can generally be anticipated every 15-25 years. Major sediment removal is needed when the accumulated sediment occupies about 20% of the water quality design volume or when sediment accumulation results in poor drainage in the basin. Major sediment removal activities will require larger and more specialized equipment. Major sediment removal activities will also require surveying with an engineer's level and consultation with DOTI Engineering Staff to ensure design volumes/grades are achieved. Care must be taken when removing large quantities of sediment and sediment deposited in

vegetated areas. Replacement of vegetation may be required if sediment removal damages vegetation.

See Section 1.8.3 for additional guidance on sediment disposal.

2.3.2.5 Unwanted Vegetation/Weed Control

Noxious weeds and other unwanted vegetation must be treated as needed throughout the EDB. This activity can be performed either through mechanical means (mowing/pulling) or with appropriate application of herbicide. Herbicides should be utilized sparingly and as a last resort. All herbicide applications should be in accordance with the manufacturer's recommendations and local requirements. The Colorado Department of Agriculture maintains a list of licensed applicators that be searched at, https://ag.colorado.gov/plants/pesticides/pesticide-applicator-search. Woody vegetation is easier to remove when it is small and should be removed from inlet and outlet areas in particular.

2.3.2.6 Mosquito/Algae Treatment

In some cases, treatment of micropools may be necessary to control mosquitoes and undesirable aquatic vegetation that can create nuisances. Only EPA-approved chemicals/materials can be used when treatment is needed. For algae, mechanical removal is preferred over chemical treatment.

2.3.2.7 Erosion Repair

The repair of eroded areas is necessary to ensure the proper function of the EDB, minimize sediment transport, and to reduce potential impacts to other features. Erosion can vary in magnitude from rilling, which requires minor repairs to inlets, energy dissipaters, and trickle channels, to major gullies in the embankments and spillways. The repair of eroded areas may require the use of excavators, earthmoving equipment, riprap, concrete, erosion control blankets, and turf reinforcement mats. Major erosion repair to basin embankments, spillways, and adjacent to structures requires consultation with DOTI Engineering Staff. Major erosion repair consists of filling and revegetating areas of severe erosion. Determining the cause of the erosion as well as correcting the condition that caused the erosion should also be part of the erosion repair. Care should be given to ensure design grades and volumes are preserved.

2.3.2.8 Woody Vegetation Removal/Tree Thinning

Dense stands of woody vegetation (willows, shrubs, etc.) or trees can create maintenance problems for structures in an EDB. Tree roots can damage structures and invade pipes/channels thereby blocking flows. Also, trees growing in the upper and lower stages of the EDB will most likely have to be removed when sediment/dredging operations occur. A small tree is easier to remove than a large tree, therefore, regular removal/thinning is imperative. All trees and woody vegetation that is growing in the bottom of the EDB or near structures (inflows, trickle channels, outlet structure, emergency spillways, etc.) should be

removed. Any trees or woody vegetation in the EDB should be limited to the upper portions of the pond banks.

2.3.2.9 Clearing Drains/Jet-Vac

An EDB contains many structures, openings, and pipes that can be frequently clogged with debris. These blockages can result in a decrease of hydraulic capacity and create standing water in areas outside of the micropool. The blockage to this infrastructure can be difficult to access and/or clean. Specialized equipment (jet-vac machines) may be necessary to clear debris from these difficult areas.

2.3.2.10 Structural Repair

An EDB includes a variety of structures that can deteriorate, be vandalized or be damaged inadvertently. These structures include items like outlet structure, trickle channels, forebays, inflows and other features. Major repairs to steel and concrete structures may require input from a structural engineer and specialized contractors. Consult with DOTI prior to all major structural repairs.

2.4 EXAMPLE MAINTENANCE PHOTOGRAPHS

Inlet is clogged with trash and debris
Maintenance required

Erosion is present and rip-rap displacement has occurred
Maintenance required

Large, woody debris is growing near inlet
Maintenance required

Clear inlet with no major issues
No immediate maintenance required

Extended Detention Basin – Inflow Points

Forebay is full of sediment, standing water and vegetation
Maintenance required

Trash and sediment accumulation in forebay
Maintenance required

Sediment accumulation and vegetation growth
Maintenance required

Clean, dry forebay with limited sediment accumulation
No immediate maintenance required

Extended Detention Basin – Forebay

Sediment build-up in trickle channel due to snow storage
Maintenance required

Trickle channel clogged with debris and sediment accumulation
Maintenance required

Clear trickle channel
No immediate maintenance required

Extended Detention Basin – Trickle Channel

Micropool with excess sediment buildup and vegetation growth
Maintenance required

Outlet screen in clogged due to debris in micropool
Maintenance required

Micropool is clean – no debris, vegetation, excess sediment
No immediate maintenance required

Extended Detention Basin – Micropool

Trash rack and well screen are clogged with debris
Maintenance required

Well screen is missing from outlet structure
Maintenance required

Orifice plate is not secure/dislodged
Maintenance required

Outlet works clear of debris and properly installed
No immediate maintenance required

Extended Detention Basin – Outlet Works

Excess sediment accumulation in basin area
Maintenance required

Standing water issues in basin area
Maintenance required

Woody debris buildup in basin area
Maintenance required

Basin area has healthy turfgrass
No immediate maintenance required

Extended Detention Basin – Grass Basin Area

Chapter 3: GRASS BUFFERS/GRASS SWALES

3.1 BACKGROUND

Grass Buffers and Grass Swales are common types of Stormwater Management Facilities utilized within the Metro Denver area. Grass Buffers/Swales promote sedimentation, filtration, and infiltration of runoff.

Grass Buffers are uniformly graded and densely vegetated areas of turf grass. They are designed to accommodate sheet flow rather than concentrated or channelized flow. They are typically located adjacent to impervious areas such as parking lots or along highways and roads. Grass Buffers are designed to evenly distribute runoff across the width of the buffer to achieve uniform sheet-flow conditions. A flow spreader may be incorporated for this purpose. In some cases, grass buffers may have underdrain systems.

Grass Swales are densely vegetated drainageways with low-pitched side slopes that collect and convey runoff. Design of their longitudinal slope and cross section forces the flow to be slow and shallow, thereby facilitating sedimentation while limiting erosion. Berms or check dams may be installed perpendicular to the flow to decrease the slope and slow down the flow. Grass swales are used in open space and landscaped areas to collect and convey overland flows, and can be used as an alternative to curb and gutter to collect and convey street flows. Some grass swales are designed with underdrain systems.

Additional design information regarding Grass Swales and Grass Buffers can be found in the MHFD Criteria Manual, Volume 3 or by following these links:

https://mhfd.org/wp-content/uploads/2019/12/09_T-01-Grass-Buffer.pdf

https://mhfd.org/wp-content/uploads/2019/12/T-02-Grass-Swale.pdf

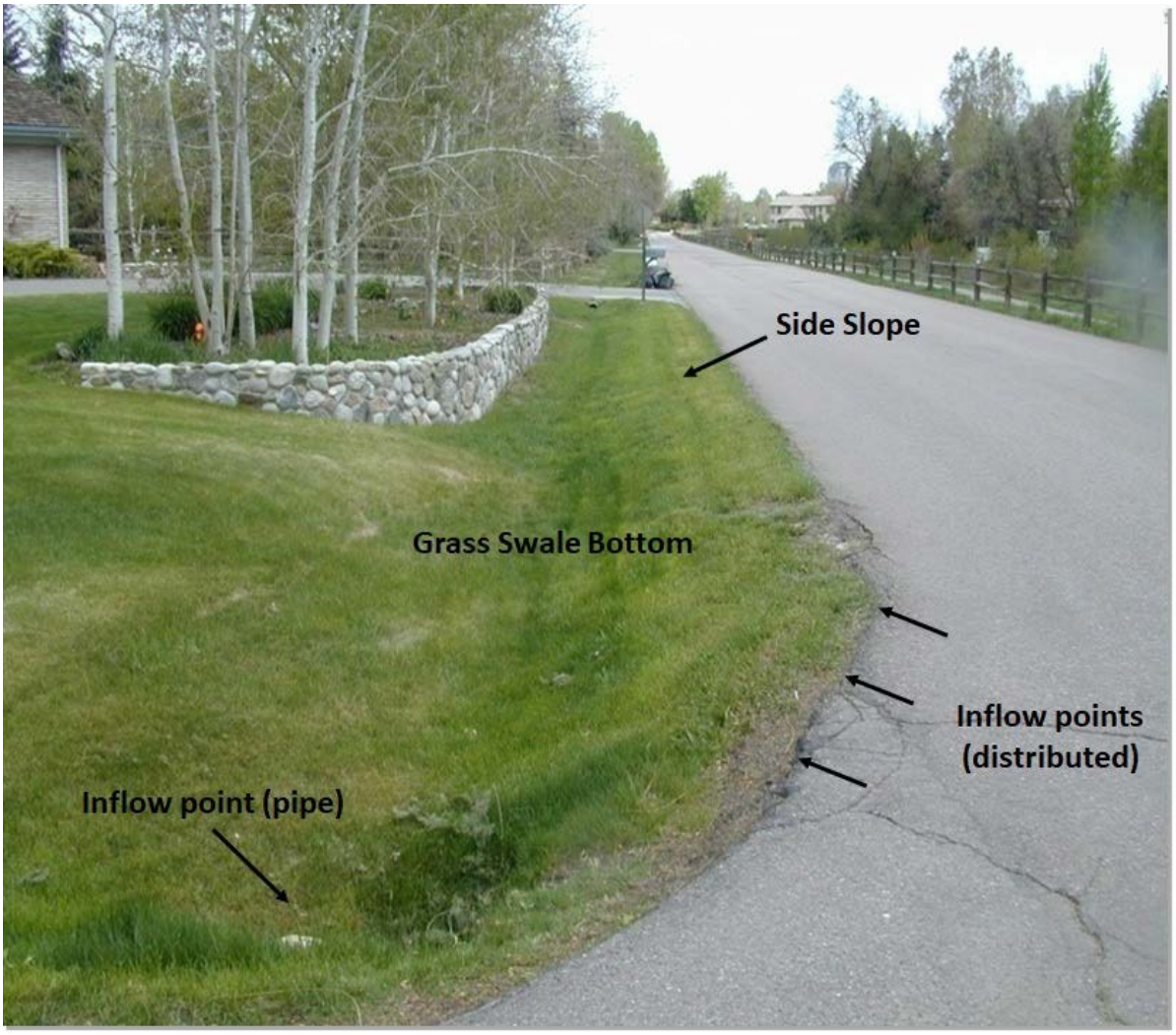
3.2 INSPECTING GRASS BUFFERS AND SWALES

Grass Buffers/Swales are often overlooked as water quality treatment facilities because they blend into common landscaping. Grass Buffers/Swales have various features designed to serve a particular function. It is important for maintenance personnel to understand the function of each of these features. Table 9 summarizes common features of a Grass Buffer/Swale and the corresponding inspection and maintenance items that can be anticipated. Figure 4 provides an example of typical Grass Buffer/Swale features.

Table 9. Typical Inspection and Maintenance Requirements for Grass Buffers & Swales

	Sediment Removal	Mowing/ Weed control	Trash & Debris Removal	Erosion	Removal/ Replacement	Structural Repair
Swale Bottom	X	X	X	X		
Side Slope		X	X	X		
Buffer Strip	X	X	X	X		
Inflows	X	X	X	X	X	X
Underdrain System					X	
Grade Control/Level Spreader				X		X
Irrigation System					X	

Figure 4. Typical Grass/Buffer/Swale Features



3.2.1 Grass Swale Bottom, Side Slopes, and Grass Buffer Strips

Grass Buffers/Swales require general maintenance of the turf grass and repair of any rill or gully development. The bottom and side slopes of Grass Swales and the area of Grass Buffer strips should be maintained with dense vegetative cover and should not be eroded or bare. Particularly during vegetation establishment over the first few years, regular inspection will help to identify and correct erosion problems before they become major issues

Typical maintenance items at the side slopes and bottoms of grass swales and grass buffer areas:

a. **Sediment Accumulation –** The purpose of the grass swale or buffer is to slow down flow and allow sedimentation to occur. To prevent a loss in performance of the swale or buffer, accumulated sediment must be removed a minimum of twice per year, occurring before and after the rainy season and after any significant storm event.

b. **Sparse Vegetation –** Grass Buffers/Swales rely on a healthy, dense cover of grass to decrease the flow velocities and promote sedimentation and infiltration. Grasses that are diseased, dying or otherwise damaged should be replaced. All bare areas should be reseeded or patched. Causes of damaged grass cover such as lack of adequate irrigation, pedestrian or vehicular traffic, uncontrolled weeds, etc., should be identified and remedied.

c. **Erosion Present –** Lack of adequate vegetative cover or excessive flow velocities may result in rill or gully development, and erosion of the swale or buffer strip. Erosion will require maintenance to prevent further damage and to prevent sediment transport.

d. **Standing Water/Boggy Areas –** Grass Buffers/Swales are generally intended to drain and be dry in between rain events. If areas of standing water are present, the swale or buffer may need to be evaluated for proper grade to ensure drainage. In some cases, where underdrains are used, the underdrains should be inspected to ensure that they are not clogged.

3.2.2 Inflow Points

Inflow points are the points of stormwater discharge into the swale or buffer. Inflow points are typically pipe outlets, other grass swales or buffers, or curb cuts from upstream impervious areas, such as parking lots. Some form of energy dissipation is typically provided immediately downstream of the inflow point into the grass swale or buffer. Energy dissipation devices may include riprap aprons, or flow spreaders.

Typical maintenance activities at Inflow Points

a. **Sediment Accumulation –** The purpose of the grass swale or buffer is to slow down flow and allow sedimentation to occur. To prevent a loss in performance of the swale or buffer, accumulated sediment must be removed a minimum of twice per year, occurring before and after the rainy season and after any significant storm event.

b. **Erosion Present/Outfall Undercut** – Erosion in the vicinity of the inflow point will require maintenance to prevent damage to the structure(s) and subsequent sediment transport. In some cases, erosion may be present because energy dissipation features were not provided or may not have been sized, constructed, or maintained appropriately.

c. **Sediment Accumulation –** Sediment often deposits immediately downstream of the inflow point. To prevent a loss in performance, sediment that accumulates in this area must be removed on a timely basis.

3.2.3 Underdrain System

Underdrain systems are sometimes installed for Grass Buffers/Swales that have a flatter slope, compact soils that inhibit infiltration, or a continuous base flow. Underdrains typically consist of a gravel storage area and perforated PVC pipe. The gravel storage area allows for storage of treated stormwater runoff prior to the discharge of the runoff through the perforated PVC pipe.

Typical maintenance activities for an Underdrain System

With proper maintenance of the grass areas, there should be a minimum amount of maintenance required on the underdrain system. Generally, the only maintenance performed on the underdrain system is jet-vac cleaning in the event that it becomes clogged.

3.2.4 Grade Controls and Level Spreaders

Grass Swales that are installed in areas with steep longitudinal slopes often have grade control checks or drop structures. Grade control structures are typically either concrete walls or riprap structures that provide a reinforced drop at specific locations in the channel, reducing the longitudinal slope between the control structures.

Level Spreaders are installed upgradient of Grass Buffers to evenly distribute flows along the design length of the buffer. Level spreaders may consist of slotted curbing, modular block porous pavement, level walls or other spreader devices.

Typical maintenance activities for Grade Control Structures and Level Spreaders

a. **Erosion present –** Grade control structures and level spreaders are provided to reduce the potential for erosion of the Grass Buffer/Swale areas. Erosion within the vicinity of the control structure or level spreader indicates that the structure is not functioning as intended and requires maintenance to prevent future erosion and damage.

b. **Structural damage –** Typically, structural damage of level spreaders or grade control structures occurs with the deterioration of concrete, including cracking, spalling or settling, and the erosion and deterioration of the riprap structures. Level spreaders may settle unevenly creating low areas, which concentrate the flows.

3.2.5 Irrigation System

Grass Buffers/Swales depend on healthy, dense turf grass to function and may require an irrigation system to provide a consistent water supply, particularly if non-native grasses are used. Typically, the condition of the grass cover will provide evidence of the effectiveness and maintenance needs of the irrigation system

Typical maintenance activities for Irrigation Systems

Irrigation systems will generally require routine periodic maintenance and adjustment of irrigation rates throughout the growing season to ensure that proper amounts of water are being applied given the weather conditions, and that they are providing coverage to all areas of the grass to eliminate bare spots. Conversely, over-irrigation should be avoided.

3.2.6 Miscellaneous

There are a variety of inspection/maintenance issues that may not be attributed to a single feature within the Grass Buffer/Swale. This category on the inspection form is for maintenance items that are commonly found in Grass Buffers and Grass Swales, but may not be attributed to an individual feature.

Typical maintenance activities for Grade Control Structures and Level Spreaders

a. **Encroachment in Easement Area –** Denver requires that the Grass Buffer/Swale be located in tracts or drainage easements. Property owners sometimes place landscaping, trash, fencing, or other items within the easement area that may affect maintenance or the operation of the facility. These encroachments should be identified during inspection and removed.

b. **Public Hazards and Vandalism–** Public hazards such as unknown/suspicious substances, exposed metal/jagged concrete on structures or damage due to vandalism should be reported to Denver 311.

c. **Burrowing Animals/Pests–** Prairie dogs and other burrowing rodents may cause damage to the Grass Buffer/Swale features and negatively affect the vegetation. Where burrowing animals are causing damage, contact Denver 311.

d. **Other –** Any miscellaneous inspection/maintenance items not contained on the form should be entered here.

3.3 MAINTAINING GRASS BUFFERS & GRASS SWALES

3.3.1 Maintenance Categories (Levels) and Activities

A typical Grass Buffer/Swale maintenance plan will consist of three broad categories (levels): Routine, Minor and Major. Within each level, a variety of maintenance activities may be necessary. Table 10 highlights the common activities associated with each level.

Table 10. Maintenance Levels & Activities for Grass Buffers and Swales

ROUTINE	MINOR	MAJOR
Mowing and Aeration	Minor Sediment Removal	Major Sediment Removal
Trash/Debris Removal	Minor Erosion Repair	Major Erosion Repair
Sediment Removal	Minor Vegetation Removal	Structural Repair
Weed control		

A brief description of routine, minor and major activities for Grass Buffers and Grass Swales includes:

- Routine Maintenance Activities: The majority of this work consists of scheduled mowing, trash and debris pickups and landscape care for the Grass Buffer/Swale multiple times during the growing season.
- Minor Maintenance Activities: This work consists of a variety of isolated or small-scale maintenance or operational problems. Most of this work can be completed by a small crew, tools, and small equipment.
- Major Maintenance Activities: This work consists of larger maintenance/operational problems and failures. This work may also require more specialized maintenance equipment, design/details, surveying, or assistance through private contractors and consultants.

Tables 11 through 13 provide a summary of typical maintenance activities associated with each level of maintenance for Grass Buffers/Swales that can be used for developing the O&M Plan; however, maintenance should always be done when a facility's performance is compromised, and no later than 6 months following the discovery of need. Most routine and minor maintenance activities do not require coordination with DOTI; however, coordination with DOTI is required for major maintenance activities. Maintenance activity records should be completed and maintained by the owner. Appendix B provides an example maintenance form for Grass Buffers and Grass Swales.

Section 3.3.2 provides a narrative description of the activities in Tables 11 through 13.

Table 11. Summary of Routine Maintenance Activities for Grass Buffers and Swales

Maintenance Activity	Minimum Frequency	Indication Action is Needed:	Maintenance Action
Trash/Debris Removal	Twice annually and before mowing, as needed	Trash & debris present	Remove and properly dispose of trash and debris
Sediment Removal	Annual, as needed	Sediment accumulation at inflow areas	Remove sediment with shovel and properly dispose; repair vegetation if needed
Mowing	Routine – as necessary	Excessive height that affects the inlet and/or outlet	Trim around structures and/or within facility to ensure facility can perform as intended.
Irrigation (Automatic)	Minimum three times annually	Areas of insufficient or excess watering; broken or missing parts	SPRING: start up system; test for even coverage and correct timer settings SUMMER: test for even coverage and correct timer settings FALL: drain and winterize system (follow watering regulations)
Irrigation (Not Automatic)	As needed to maintain healthy grass	Areas of insufficient watering; prolonged dry periods	Water as needed to maintain healthy grass (follow watering regulations)
Weed Control	Minimum twice annually	Noxious weeds; Unwanted vegetation	Hand pull; Consult an authorized herbicide applicator
Mosquito Treatment	As needed, based upon inspections	Standing water/ mosquito habitat	Perform maintenance to eliminate standing water; Treat w/ EPA approved chemicals
Level Spreader (Grass Buffer only)	As needed, based upon inspections	Evidence of uneven flow/localized erosion	Look for cause; repair, fill or revegetate areas of erosion
Rodent Damage	As needed, based upon inspections	Holes, small piles of dirt, raised burrows	Evaluate damage; contact Division of Wildlife for guidance

Table 12. Summary of Minor Maintenance Activities for Grass Buffers and Swales

Maintenance Activity	Minimum Frequency	Indication Action is Needed:	Maintenance Action
Sediment Removal	As needed, based upon inspection	Sediment build-up	Remove and properly dispose of sediment
Erosion Repair	As needed, based upon inspection	Rills and gullies forming on slopes and other areas	Repair eroded areas and revegetate; address cause
Vegetation Removal	As needed, based upon inspection	Trees, willows, shrubs impeding flow	Remove vegetation; restore correct grade and surface
Revegetation	As needed, based upon inspection	Areas without grass	Replace grass by sodding or seeding
Irrigation (Automatic)	As needed, based upon inspection	Evidence of broken or missing parts	Replace parts and test system
Level Spreader (Grass Buffer Only)	As needed, based upon inspection	Evidence of uneven flow, erosion, or rills/gullies	Repair sections of level spreader and address cause
Fertilization or Soil Amendment	As needed, minimize fertilization	Grass with pale color; areas with poor grass growth not due to irrigation problems	Consult with turf specialist; test soil
Vehicle Tracks (Along Roadways)	As needed, based upon inspection	Depressions from vehicle tracks; vegetation damage	Repair and fill depressions; sod or seed damaged areas

Table 13. Summary of Major Maintenance Activities for Grass Buffers and Swales

Maintenance Activity	Minimum Frequency	Look for:	Maintenance Action
Major Sediment/ Pollutant Removal	As needed – based upon scheduled inspections	Large quantities of sediment	Remove and dispose of sediment. Repair vegetation as needed
Major Erosion Repair	As needed – based upon scheduled inspections	Severe erosion including gullies, excessive soil displacement, areas of settlement, holes	Repair erosion – find cause of problem and address to avoid future erosion
Structural Repair	As needed – based upon scheduled inspections	Deterioration and/or damage to structural components – level spreader, grade control structures, irrigation components, and ponding water	Structural repair to restore the structure to its original design
GB/GS Rebuild	As needed – due to complete failure of all or a portion of facility (Turf replacement may be needed every 10-20 years in some areas.)	Failed system; dead vegetation, ponded water not correctable through minor maintenance	Contact DOTI Engineering Staff

3.3.2 Description of Maintenance Activities for Grass Buffers and Swales

Maintenance activities in Tables 11 through 13 are described below.

3.3.2.1 Trash/Debris Removal

Trash and debris must be removed from the Grass Buffer/Swale area to allow for proper functioning and to improve aesthetics. This activity must be performed prior to mowing operations.

3.3.2.2 Mowing

Routine mowing of the turf grass is necessary to maintain an appropriate grass height and to improve the overall appearance and performance of Grass Buffers/Swales. Turf grass should be mowed to a level which re-establishes the functionality and aesthetics of the facility, typically no less than 6 inches in height. The grass height within a 40- to 50-foot radius of the

structural components of the facility is particularly important. Clippings should be collected and disposed of properly. The desirable grass height can vary from facility to facility.

3.3.2.3 Irrigation

Irrigation systems should be maintained in proper working order to provide an adequate water supply to support the grass cover, but without over-irrigating. When automatic irrigation systems are not available, alternate methods for providing a water supply during times of drought must be provided.

Automatic irrigation systems should be maintained routinely throughout the growing season to ensure that they are providing the appropriate amounts of water and uniform coverage of the area. Sprinkler heads should be adjusted as necessary and checked for broken or missing parts.

3.3.2.4 Weed Control

Noxious weeds and other unwanted vegetation must be managed through mechanical means (mowing/pulling) or with appropriate application of herbicide. Herbicides should be utilized sparingly and as a last resort. All herbicide applications should be in accordance with the manufacturer's recommendations and local requirements. The Colorado Department of Agriculture maintains a list of licensed applicators that be searched at, https://ag.colorado.gov/plants/pesticides/pesticide-applicator-search.

3.3.2.5 Level Spreader (Grass Buffer Only)

Evidence of uneven flow and localized erosion downstream of the level spreader indicate that the flow is not evenly distributed along the length of the spreader. For both routine and minor maintenance, areas of erosion should be repaired, filled and revegetated. Causes for the erosion should be investigated and corrected. Buildup of grasses along the edge of the spreader may create an uneven flow distribution that can be corrected as part of routine maintenance.

More significant repairs to the level spreader may be required when the level spreader is no longer level, or has developed damaged areas of cracking or spalling, allowing flows to concentrate in depressed areas instead of being distributed over the length of the structure.

3.3.2.6 Rodent Damage

Small holes, piles of dirt, and raised burrows are evidence of rodent damage. Damaged areas should be repaired and revegetated. Consultation with an animal control specialist or the Division of Wildlife may be required for persistent problems.

3.3.2.7 Sediment Removal

Sediment removal is necessary to ensure proper function of the Grass Buffer/Swale. Care should be taken when removing sediment to prevent damage to the turf grass and surrounding areas. Excessive amounts of sediment are an indication of upstream erosion or

lack of adequate SCMs during construction activities. Causes for contributions of excess sediment should be investigated and addressed.

Major sediment removal consists of removal of large quantities of pollutants, sediment and/or landscaping material. Vegetated areas need special care to ensure design volumes and grades are preserved or may need to be replaced due to the removal activities.

See Section 1.8.3 for additional information on sediment disposal.

3.3.2.8 Erosion Repair

The repair of eroded areas is necessary to ensure the proper functioning of the Grass Buffer/Swale and to minimize sediment transport. Erosion can vary in magnitude from minor repairs to vegetation, to rills and gullies in the swales and inflow points. Extreme care should be taken when utilizing motorized or heavy equipment to ensure damage to the underdrain system does not occur.

Major erosion repair consists of filling and revegetating areas of severe erosion. Major erosion in a Grass Buffer/Swale is generally the result of excessive velocities caused by steep slopes. It may be necessary to make design improvements to the swale or buffer when erosion becomes a major maintenance item. Determining the cause of the erosion as well as correcting the condition that caused the erosion should also be part of the erosion repair. Care should be given to ensure design grades and volumes are preserved.

3.3.2.9 Vegetation Removal

Weeds, shrubs, willows, cattails and other unwanted vegetation that develops in the Grass Buffer/Swale area may impede the flow and cause standing water or backwater problems. Remove unwanted vegetation soon after identification while it is easier to remove and restore the correct grade. Revegetate with seed or sod.

3.3.2.10 Revegetation

Bare areas should be repaired as soon as possible. Repair bare areas with grass or sod. Causes of the problem, such as inadequate water supply or diseased grasses, should be investigated and resolved.

3.3.2.11 Irrigation (Automatic)

Irrigation systems require routine maintenance in accordance with the manufacturer's recommendations (valves, timer, etc.), and maintenance of the pipe and sprinkler heads to ensure that even coverage is being applied, and that there are no missing or broken parts. Timing systems should be checked to verify that the correct amount of water is being applied to the grass areas for the seasonal conditions.

3.3.2.12 Plant Health Care

Grass Buffers/Swales rely on healthy, dense turf in order to function properly. Aeration of the turf area is recommended in the spring and fall. Fertilizers should be applied in the

minimum amounts and frequencies necessary to maintain healthy vegetation in accordance with the grass type. Colorado State University Extension provides fertilizer recommendations for various turfgrass species and maintenance levels (https://cmg.extension.colostate.edu/wp-content/uploads/sites/59/2022/12/LawnCare-Turf-Management.pdf). In some cases, soil amendments with organic matter may be necessary to enable plant growth.

3.3.2.13 Vehicle Tracks

Grass Buffers/Swales that are adjacent to roadway sections may be damaged by vehicle tracks. Rutted areas should be filled in and revegetated as soon as possible. Frequent problems associated with vehicle traffic (such as around corners) may require a barrier or sign to avoid vehicular traffic within the grass areas. Contact DOTI Right of Way services for details and or permitting.

3.3.2.14 Structural Repair

Grass Buffers/Swales may include a level spreader and/or grade control structure that can deteriorate or be damaged during the service life of the facility. These structures are constructed of steel and concrete that can degrade or be damaged and may need to be repaired or re-constructed from time to time. Major repairs to structures may require input from a structural engineer and specialized contractors. Consultation with DOTI Engineering Staff must take place prior to all structural repairs.

3.3.2.15 Rehabilitation/Rebuild

In very rare cases, a Grass Buffer/Swale may need to be rebuilt. Generally, the need for a complete rebuild is a result of improper construction, improper maintenance resulting in structural damage to the underdrain system, or extensive contamination of the Grass Buffer/Swale. Consultation with DOTI Engineering Staff must take place prior to any rebuild project.

3.4 EXAMPLE MAINTENANCE PHOTOGRAPHS

Swale bottom has erosion and excessive sediment build-up
Maintenance required

Inflow Point has erosion and sediment build-up
Maintenance required

Inflow Point with erosion and sediment build-up
Maintenance required

Grass Swale with reasonable vegetation and no major issues
No immediate maintenance required

Grass Buffer/Swale

Chapter 4: RAIN GARDENS

4.1 BACKGROUND

Rain Gardens are a common type of stormwater management facility utilized in the metro Denver area. They are also commonly known as Bioretention and previously as Porous Landscape Detention Basins (PLDs). Rain Gardens consist of a low-lying vegetated area underlain by engineered media (mostly sand) with an underdrain pipe. A shallow surcharge zone exists above the Rain Garden for temporary storage of the Water Quality Capture Volume (WQCV). During a storm, accumulated runoff ponds in the vegetated zone and gradually infiltrates into the underlying media bed, filling the void spaces of the media. The underdrain gradually dewaters the filter media bed and discharges the runoff to a nearby channel, swale, or storm sewer. In some locations, underdrains are not required and the facility infiltrates into the ground. In Denver, most facilities will include underdrains. The Rain Garden provides for filtering, adsorption, and biological uptake of constituents in stormwater and can reduce runoff volumes. The popularity of Rain Gardens has increased because they allow the WQCV to be provided on a site that has little open area available for stormwater management.

Additional design information regarding Rain Gardens can be found in MHFD's Criteria Manual, Volume 3 or by following the link here:
https://mhfd.org/wp-content/uploads/2019/12/05_T-03-Bioretention.pdf

For variations on Rain Garden installations, see City and County of Denver Ultra-Urban Green Infrastructure Guidelines, 2016 by following this link:
https://www.denvergov.org/content/denvergov/en/wastewater-management/stormwater-quality/ultra-urban-green-infrastructure.html

4.2 INSPECTING RAIN GARDENS

Each feature in a Rain Garden is designed for a specific function. The proper function of one feature often depends on another. It is important for maintenance personnel to understand the function of each of these features to prevent damage to any feature during maintenance operations. Table 14 identifies the most common features and the corresponding maintenance inspection items that can be anticipated. Figure 5 shows typical Rain Garden features.

Table 14. Typical Inspection and Maintenance Requirements for Rain Gardens

	Sediment Removal	Mowing /Weed Control	Trash/ Debris Removal	Erosion	Overgrown Vegetation Removal	Removal/ Replacement	Structure Repair
Inflow Points	X		X	X			X
Filter Media	X	X	X	X	X	X	
Forebay	X		X	X			X
Landscaping	X	X	X	X	X		
Underdrain System						X	
Overflow Outlet Structure	X		X				X
Embankment		X	X	X	X		

Figure 5. Typical Rain Garden Features

4.2.1 Inflow Points

Inflow points or outfalls into Rain Gardens are the point of stormwater discharge into the facility. An inflow point is commonly a curb cut with a concrete or riprap rundown. In limited cases, a storm sewer pipe outlet with a flared end section or a storm sewer pipe discharging into a concrete forebay may be the inflow point into the Rain Garden

An energy dissipater (riprap or concrete wall) is typically immediately downstream of the discharge point into the Rain Garden to protect the Rain Garden from erosion. In some cases, the storm sewer outfall can have a toe-wall or cut-off wall immediately below the structure to prevent undercutting of the outfall from erosion

Typical maintenance activities at Inflow Points:

a. **Riprap Displaced** – Because of the repeated impact/force of water, the riprap can shift and settle. If any portion of the riprap rundown or apron appears to have settled, soil is present between the riprap, or the riprap has shifted, maintenance may be required to ensure future erosion is prevented.

b. **Erosion Present/Outlet Undercut** – In some situations, the energy dissipater may not have been sized, constructed, or maintained appropriately and erosion has occurred.

Any erosion within the vicinity of the inflow point will require maintenance to prevent damage to the structure(s) and sediment transport within the facility. It is imperative that material utilized to correct erosion problems within the filter media meets the requirements for filter media as shown on the approved construction drawings.

c. **Sediment Accumulation –** Because of the turbulence in the water created by the energy dissipater, sediment often deposits immediately downstream of the inflow point. To prevent a loss in performance of the upstream infrastructure, sediment that accumulates in this area must be removed on a timely basis.

d. **Structural Damage –** Structural damage can occur at any time during the life of the facility. Typically, for an inflow, the structural damage occurs to the concrete or riprap rundown or pipe flared end section (concrete or steel). Structural damage can lead to additional operating problems with the facility, including loss of hydraulic performance.

4.2.2 Filter Media

The filter media is the main pollutant removal component of the Rain Garden. The filter media consists of 18 inches of an engineered media specified for Bioretention facilities in Volume 3 of the Urban Storm Drainage Criteria Manual. (This mixture is mostly sand.) The filter media removes pollutants through several different processes, including sedimentation, filtration, adsorption, infiltration and microbial uptake.

Sedimentation is accomplished by the slow release of stormwater runoff through the filter media. This slow release allows sediment particles to be deposited on the top layer of the filter media where they are easily removed through routine maintenance. Other pollutants are also removed through this process because many pollutants utilize sediment as a transport mechanism.

Filtration is the main pollutant removal mechanism of Rain Gardens. When the stormwater runoff migrates down through the filter media, many of the particulate pollutants are physically strained out as they pass through the filter bed of sand and are trapped on the surface or among the pores of the filter media.

Adsorption results when pollutants sorb to the filter media, also minimizing export of pollutants from the Rain Garden.

Rain Gardens that are not lined with an impervious liner allow for infiltration into the native soils. This process also allows for additional pollutant removal.

Microbes that naturally occur in the filter media can assist with pollutant removal by breaking down organic pollutants.

Typical maintenance activities for Filter Media:

a. **Infiltration Rate Check –** The infiltration rate of the Rain Garden needs to be checked in order to ensure proper functioning of the Rain Garden. Generally, a Rain Garden should drain completely within 12 hours of a storm event. If drain times exceed the 12-hour drain time, then maintenance of the filter media may be needed. If clogging is suspected, then infiltration testing should be conducted. Several infiltration testing methods can be used to check infiltration rates:

- **Method 1:** Visit the site within 24 hours of 0.5 inches (or more) of rainfall. If water is still ponded on top of the filter media, the filter media may be clogged.
- **Method 2**: Obtain round, metal cylinder at least 12 inches long Insert (pound) cylinder 2-3 inches into filter media. Fill cylinder with 10 inches of water. After 1 hour, measure depth of water remaining in the cylinder. If depth is greater than 5 inches, then filter may be clogged.
- **Method 3**: Use infiltration testing tool (such as "TURF-TEC" Infiltrometer) to measure infiltration rate. If infiltration rate is less than 1 inch/hour, then filter media may be clogged.

b. **Sediment Removal –** Although Rain Gardens should not be utilized in areas where large concentrations of sediment may enter the Rain Garden, it is inevitable that some sediment will enter the Rain Garden. Accumulated sediment on the surface should be removed.

c. **Filter Media Replacement -** The top layers of the filter media are the most susceptible to pollutant loading and therefore may need to be removed and disposed of properly on a semi-regular basis when infiltration rates slow, as evidenced by prolonged standing water. Filter media must be replaced with the media specified in the As-built drawings. No substitutions are allowed without approval of DOTI.

4.2.3 Forebay

A forebay is a solid surface (pad), typically constructed of concrete, immediately downstream of the inflow point. The forebay is designed to capture sediment and trash to prevent them from entering the main portion of the Rain Garden. The solid surface is designed to facilitate mechanical sediment removal (shovel). The forebay typically includes a small diameter discharge pipe or weir on the downstream end and designed to drain the forebay in a specified period of time to promote sedimentation. The forebays vary in size and depth depending on the design and site constraints

Typical maintenance items for Forebays:

a. **Sediment/Debris Accumulation –** Because this feature of the Rain Garden is designed to provide the initial sedimentation, debris and sediment frequently accumulate in this area. If the sediment and debris is not removed from the forebay on a regular basis, it can significantly affect the function of other features within the Rain Garden. Routine sediment removal from the forebay can significantly decrease clogging of the filter media and extend the amount of time before the filter media needs to be replaced. Routine removal of sediment from the forebay can substantially decrease the long-term sediment removal costs of a Rain Garden.

b. **Concrete Cracking/Failing –** The forebay is primarily constructed of concrete, which cracks, spalls, and settles. Damage to the forebay can result in deceased performance and impact maintenance efforts.

c. **Drain Pipe/Weir Clogged –** The drainpipe or weir can be clogged with debris, and prevent the forebay from draining properly. If standing water is present in the forebay (and there is not a base flow), the forebay is most likely not draining properly. This can result in a decrease in performance and create potential nuisances with stagnant water (mosquitoes).

d. **Drain Pipe/Weir Damaged –** Routine maintenance activities, vandalism, or age may cause the weir or drain pipe in the forebay to become damaged. Weirs are typically constructed of concrete, which cracks and spalls. The drainpipe is typically smaller in diameter and constructed with plastic, which can fracture.

4.2.4 Landscaping

The landscaped area consists of specific plant materials and associated landscaping mulch in the bottom of the Rain Garden. Plants improve infiltration rates, provide water and nutrient uptake through plant roots, and generally improve water quality though biological processes. Growing conditions in ultra-urban environments are often harsh and plants require proper maintenance to maintain aesthetics and provide intended functions. The plants are carefully selected for use in the Rain Gardens. Plants utilized in Rain Gardens must be able to grow in dry sandy soils but also be able to withstand frequent inundation by stormwater runoff. These plants also must be able to withstand a variety of pollutants commonly found in stormwater runoff. In addition, plants utilized in Rain Gardens cannot have a deep extensive root system that may cause maintenance difficulty or damage to the facility. If sod must be replaced use sand grown in sandy soils to minimize clogging

Typical maintenance activities for Landscaped Areas:

a. **Woody Growth/Weeds Present –** Undesirable vegetation can grow in and around the landscaped area in the Rain Garden that can significantly affect the performance of the facility. This type of vegetation includes dense areas of shrubs (willows), grasses and noxious weeds. If undesired vegetation is not routinely mowed/removed, the growth can cause debris/sediment to accumulate, resulting in blockage of the filter media. Also, shrub, grass and weed roots can cause damage to the filter media and underdrain system. Routine management is essential to prevent more extensive and costly future maintenance.

b. **Mulch Replacement –** Planting beds may be mulched with 1 to 2 inches of shredded wood mulch to reduce weed growth, or left un-mulched if plant density is sufficient to cover 75% or more of the Rain Garden surface. The wood mulch should be finely shredded in a manner that creates a fibrous mass that meshes together and resists movement.

c. **Irrigation –** Irrigation is necessary to establish the vegetation and sustain plant health during periods of dry weather. Inspections for sufficient moisture are important throughout the growing season (March through October).

d. **Weeding –** All plantings require monthly inspection during the growing season to ward off infestations of deep rooted perennial weeds such as smooth brome, Russian thistle, leafy spurge, bindweed, and bluegrass. Prolifically seeding weeds such as cheatgrass, dandelions, prickly lettuce, spotted spurge, purslane, black medic, alfalfa, yellow and white sweet clover also require monthly policing to prevent them from going to seed and creating long term infestations. Workers taking care of these gardens will need to be professionals highly familiar with weed species, able to recognize them as seedlings to ward off infestation. In most instances, weeds will need to be extracted and physically removed from the site, not sprayed or pulled and left to wither (and scatter seeds).

e. **Debris/Leaf Removal –** Planters require removal of leafy debris each fall (October) and cutting back of perennials and grasses in late winter/early spring (March).

4.2.5 Underdrain System

The underdrain system consists of gravel storage area and perforated PVC pipes. The gravel storage area allows for storage of treated stormwater runoff prior to the discharge of the runoff through the perforated PVC pipe.

Typical maintenance activities for an Underdrain System

With proper maintenance of the landscape areas and filter media, there should be a minimum amount of maintenance required on the underdrain system. Generally, the only maintenance performed on the underdrain system is jet-vac cleaning.

4.2.6 Overflow Outlet Structure

Rain Gardens are designed to treat the water quality capture volume (WQCV) associated with frequently occurring storm events, with larger flow volumes exceeding the WQCV being discharged through the overflow outlet structure without water quality treatment. The outlet structure is typically constructed of a reinforced concrete box in the embankment of the Rain Garden. The concrete structure typically has a steel grate to trap litter and other debris from entering the storm sewer system. Proper inspection and maintenance of the outlet structure is essential in ensuring the long-term operation of the Rain Garden

Typical maintenance activities for Overflow Outlet structure:

a. **Structural Damage -** The overflow outlet structure is primarily constructed of concrete, which can crack, spall, and settle. The steel grate on the overflow outlet structure is also susceptible to damage.

b. **Woody Growth/Weeds Present –** The presence of plant material not part of the original landscaping, such as wetland plants or other woody growth, can clog the overflow outlet structure during a larger storm event, causing flooding damage to adjacent areas. This plant material may indicate a clogging of the filter media and may require additional investigation.

c. **Trash/Debris –** Trash and debris can accumulate in the upper area after large events, or from illegal dumping. Over time, this material can clog the Rain Garden outlet structure.

4.2.7 Embankments

Rain Gardens can be enclosed by low concrete walls or by vegetated embankments. If vegetated embankments are present, then maintenance of vegetation is necessary.

Typical maintenance activities for Embankments:

a. **Vegetation Sparse –** For Rain Gardens with vegetated embankments, adequate and properly maintained vegetation can greatly increase the overall appearance of the Rain Garden. Vegetation can reduce the potential for erosion and subsequent sediment transport to the filter media, thereby reducing the need for more costly maintenance.

b. **Erosion –** Inadequate vegetative cover may result in erosion of the embankments. Erosion that occurs on the embankments can cause clogging of the filter media.

4.2.8 Miscellaneous

There are a variety of inspection/maintenance issues that may not be attributed to a single feature within the Rain Garden. This category on the inspection form is for maintenance items that are commonly found in the Rain Garden but may not be attributed to an individual feature.

a. **Encroachment in Easement Area –** Private lots/property can sometimes be located very close to the Rain Gardens, even though the City and County of Denver requires that Rain Gardens be located in tracts with drainage easements. Property owners may place landscaping, trash, fencing, or other items within the easement that may affect maintenance/operation of the facility.

b. **Public Hazards and Vandalism–** Public hazards such as unknown/suspicious substances, exposed metal/jagged concrete on structures or damage due to vandalism should be reported to Denver 311.

c. **Other –** Any miscellaneous inspection/maintenance items not contained on the form.

4.3 MAINTAINING RAIN GARDENS

4.3.1 Rain Garden Maintenance Categories (Levels) and Activities

A typical Rain Garden maintenance plan will consist of three broad categories (levels): Routine, Minor and Major. Within each level, a variety of maintenance activities may be necessary. Table 15 highlights the common activities associated with each level.

Table 15. Typical Maintenance levels and Activities for Rain Gardens

ROUTINE	MINOR	MAJOR
Mowing	Minor Sediment Removal	Filter Media Replacement
Trash/Debris Removal	Minor Erosion Repair	Major Erosion Repair
Outlet Structure Cleaning	Minor Vegetation Replacement / Removal	Structural Repair
Plant Care / Weed Control	Jet Vac / Clearing Drains	

A brief description of routine, minor and major activities for Rain Gardens includes:

- Routine Maintenance Activities: The majority of this work consists of scheduled plant care, trash and debris pickups and removal of sediment from forebays at regular intervals throughout the year.
- Minor Maintenance Activities: This work consists of a variety of isolated or small-scale maintenance or operational problems, typically determined based on inspection, such as plant replacement and erosion repair. Most of this work can be completed by a small crew, tools, and small equipment. In the event that the Rain Garden needs to be dewatered, care should be given to ensure sediment, filter material and other pollutants are not discharged. All dewatering activities must be coordinated with DOTI.
- Major Maintenance Activities: Major maintenance activities (i.e., facility rehabilitation) include structural repair, filter media replacement, or other significant repairs should typically only happen near the end of the expected life of the facility. This work may also require more specialized maintenance equipment, design/details, surveying, or assistance through private contractors and consultants.

Tables 16 through 18 provide a summary of typical maintenance activities associated with each level of maintenance for Rain Gardens that can be used for developing the O&M Plan for most Rain Gardens; however, maintenance should always be done when a facility's performance is compromised, and no later than 6 months following the discovery of need. Most routine and minor maintenance activities do not require coordination with DOTI; however, coordination with DOTI is required for major maintenance activities. Maintenance activity records should be completed and maintained by the owner. Appendix B provides an example maintenance form for Rain Gardens.

Table 16. Summary of Routine Maintenance Activities for Rain Gardens

Maintenance Activity	Minimum Frequency	Look for:	Maintenance Action
Mowing	Twice annually and as needed	Excessive height that affects the inlet and/or outlet	Trim around structures and/or within facility to ensure facility can perform as intended
Trash/Debris Removal	Twice annually and as needed	Trash & debris	Remove and dispose of trash/debris
Overflow Outlet Structure Cleaning	As needed - after significant rain events–twice annually minimum	Clogged outlet structure; ponding water above outlet elevation	Remove and dispose of debris/trash/sediment to allow outlet to function properly
Weed Control	As needed, based upon inspection	Noxious weeds; Unwanted vegetation	Hand pull; Consult an authorized herbicide applicator

Table 17. Summary of Minor Maintenance Activities for Rain Gardens

Maintenance Activity	Minimum Frequency	Look for:	Maintenance Action
Sediment/Pollutant Removal	As needed, based upon inspection	Sediment build-up; decrease in infiltration rate	Remove and dispose of sediment
Erosion Repair	As needed, based upon inspection	Rills/gullies forming on embankments	Repair eroded areas & revegetate; address cause
Jet Vac/Cleaning underdrain system	As needed, based upon inspection	Sediment build-up/ non-draining system	Clean drains; Jet-Vac if needed

Table 18. Summary of Major Maintenance Activities for Rain Gardens

Maintenance Activity	Minimum Frequency	Look for:	Maintenance Action
Major Sediment/Pollutant Removal	As needed, based upon inspection	Large quantities of sediment; prolonged ponding	Remove and dispose of sediment; replace vegetation as needed
Major Erosion Repair	As needed, based upon inspection	Severe erosion including gullies, excessive soil displacement, areas of settlement, holes	Repair erosion – find cause of problem and address to avoid future erosion
Structural Repair	As needed, based upon inspection	Deterioration and/or damage to structural components – broken concrete, damaged pipes & outlet structure	Structural repair to restore the structure to its original design
Rebuild	As needed – due to complete failure	Removal of filter media and underdrain system	Contact DOTI Engineering Staff

4.3.2 Description of Maintenance Activities for Rain Gardens

Maintenance activities in Tables 16 through 18 are described below.

4.3.2.1 Mowing

When turf grass is part of Rain Garden designs, routine mowing is necessary to improve the overall appearance and performance of the Rain Garden. Turf grass should be mowed to a level which re-establishes the functionality and aesthetics of the facility. Clippings should be collected and disposed of properly. The desirable grass height can vary from facility to facility,

4.3.2.2 Trash/Debris Removal

Trash and debris must be removed from the entire Rain Garden area to minimize outlet clogging and to improve aesthetics. This activity must be performed prior to mowing operations.

4.3.2.3 Overflow Outlet structure Cleaning

Debris and other materials can clog the overflow outlet work's grate. This activity must be performed anytime other maintenance activities are conducted to ensure proper operation.

4.3.2.4 Weed Control

Noxious weeds and other unwanted vegetation must be treated as needed throughout the Rain Garden. This activity can be performed either through mechanical means (mowing/pulling) or with herbicide. Herbicides should be utilized sparingly and as a last resort. All herbicide applications should be in accordance with the manufacturer's recommendations and local requirements. The Colorado Department of Agriculture maintains a list of licensed applicators that be searched at, https://ag.colorado.gov/plants/pesticides/pesticide-applicator-search.

4.3.2.5 Sediment/Pollutant Removal

Two types of sediment removal are needed at Rain Gardens. The first is routine sediment removal from the facility's forebay, if present. The second involves removal of sediment on the filter media surface.

When accumulated sediment clogs the filter media and causes ponding beyond the 12-hour drain time, sediment removal is needed. The infiltration rate of the Rain Garden needs to be checked in order to ensure proper functioning of the Rain Garden.

Generally, the top 3 inches of filter media should be removed when sediment removal is required to address clogging. Additional amounts of filter media may need to be removed if deeper sections of the filter media are contaminated.

If filter media needs to be removed and replaced, replacement media must follow the specifications for bioretention media in MHFD Volume 3. Other types of sand or soil material may lead to clogging of the Rain Garden or export of nutrients.

Minor sediment removal activities can be conducted with shovels, rakes, and smaller equipment. Major sediment removal consists of removal of large quantities of accumulated sediment, filter media and/or landscaping material, typically requiring larger and more specialized equipment. Extreme care should be taken when utilizing motorized or heavy equipment to ensure damage to the underdrain system does not occur and that the infiltrating surface is not compacted. Some Rain Gardens also contain an impermeable liner that can be easily damaged if care is not taken when removing the filter media. Vegetated areas need special care to ensure design volumes and grades are preserved. Plants may need to be replaced due to the removal activities.

Major sediment removal activities will also require surveying with an engineer's level, and consultation with DOTI Engineering Staff to ensure design volumes/grades are achieved.

See Section 1.8.3 for additional guidance on sediment disposal.

4.3.2.6 Erosion Repair

Eroded areas must be repaired to ensure the proper functioning of the Rain Garden, to minimize sediment transport, and to reduce potential impacts to other features. Erosion can vary in magnitude from minor repairs to filter media and embankments, to rills and gullies in the embankments and inflow points. The repair of eroded areas may require the use of excavators, earthmoving equipment, riprap, concrete, and sod.

Major erosion repair consists of filling and revegetating areas of severe erosion. Determining the cause of the erosion as well as correcting the condition that caused the erosion should also be part of the erosion repair. When repairing erosion, design grades and volumes must be preserved in accordance with as-built design drawings. Extreme care should be taken when utilizing motorized or heavy equipment to ensure damage to the underdrain system does not occur. Major erosion repair to the facility embankments, spillways, and adjacent to structures will require consultation with DOTI Engineering Staff.

4.3.2.7 Jet-Vac/Clearing Drains

Most Rain Gardens have an underdrain system that allows treated stormwater runoff to exit the facility. These underdrain systems can develop blockages that decrease hydraulic capacity and create standing water. The blockage to this infrastructure can be difficult to access and/or clean. Specialized equipment (jet-vac machines) may be necessary to clear debris from these difficult areas.

4.3.2.8 Structural Repair

A Rain Garden generally includes a concrete overflow outlet structure that can deteriorate or be damaged during the service life of the facility. Major repairs to structures may require input from a structural engineer and specialized contractors. Consultation with DOTI Engineering Staff must take place prior to all structural repairs.

4.3.2.9 Rebuild

In very rare cases, a Rain Garden may need to be rebuilt. Generally, the need for a complete rebuild is a result of improper construction, improper maintenance resulting in structural damage to the underdrain system, or extensive contamination of the Rain Garden. Consultation with DOTI Engineering Staff must take place prior to any rebuild project.

4.4 EXAMPLE MAINTENANCE PHOTOGRAPHS

Curb-cut inlet with excessive sediment build-up
Maintenance required

Inflow Point with sediment and debris accumulation
Maintenance required

Inflow Point with erosion and sediment build-up
Maintenance required

Inflow Point operating correctly
No immediate maintenance required

Rain Gardens/Sand Filter Basins – Inflow Points

Sand Filter media with excessive sediment build-up
Maintenance required

Rain Garden with dead vegetation on filter media surface
Maintenance required

Clean Sand Filter media
No immediate maintenance required

Rain Garden with healthy vegetation and no sediment
No immediate maintenance required

Rain Gardens/Sand Filter Basins – Filter Media

Outlet of forebay is clogged/blocked causing runoff bypass
Maintenance required

Sediment build-up and forebay outlet is clogged
Maintenance required

Clean forebay
No immediate maintenance required

Clean forebay
No immediate maintenance required

Rain Gardens/Sand Filter Basins – Forebay

Woody/overgrown vegetation in rain garden
Maintenance required

Sparse vegetation in rain garden
Maintenance required

Rain Garden with healthy vegetation
No immediate maintenance required

Rain Garden with healthy vegetation
No immediate maintenance required

Rain Gardens– Landscaping

Outlet Structure with excess vegetation growth
Maintenance required

Outlet Structure installed too low (cross-check with design)
Maintenance required

Outlet Structure clogged with sediment
Maintenance required

Outlet Structure in good condition
No immediate maintenance required

Rain Gardens/Sand Filter Basins – Outlet Works

Chapter 5: SAND FILTER BASINS

5.1 BACKGROUND

Sand Filter Basins are a common type of Stormwater Management facility in Denver. A Sand Filter Basin is a filtering or infiltrating SCM that consists of a surcharge zone underlain by a sand bed with an underdrain system. During a storm, accumulated runoff collects in the surcharge zone and gradually infiltrates into the underlying sand bed, filling the void spaces of the sand. The underdrain gradually dewaters the sand bed and discharges the runoff to a nearby channel, swale, or storm drain. It is similar to a SCM designed for bioretention in that it utilizes filtering but differs in that it is not specifically designed for vegetative growth. The absence of vegetation in a sand filter allows for active maintenance at the surface of the filter, (i.e., raking for removing a layer of sediment). Sand Filter Basins can also be placed in an underground vault. (Underground sand filters have additional maintenance requirements beyond those described here.) Functionally, the primary maintenance concern for Sand Filter Basins is potential clogging, particularly in watersheds with significant sediment loading.

Additional design information regarding Sand Filter Basins can be found in MHFD's Criteria Manual, Volume 3 or by following the link here:

https://mhfd.org/wp-content/uploads/2019/12/07_T-06-Sand-Filter.pdf

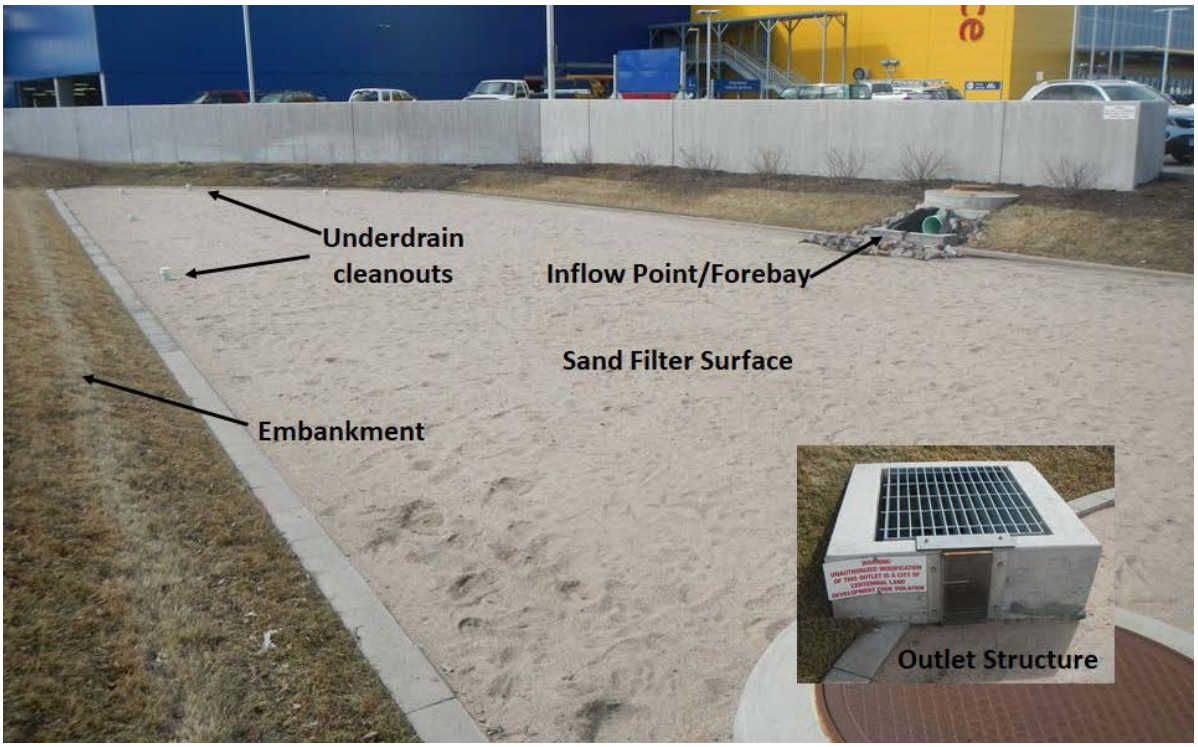
5.2 INSPECTING SAND FILTER BASINS

Each feature in a Sand Filter Basin is designed for a specific function. The proper function of one feature often depends on another. It is important for maintenance personnel to understand the function of each of these features to prevent damage to any feature during maintenance operations. Table 19 identifies the most common features and the corresponding maintenance inspection items that can be anticipated.

Table 19. Typical Inspection and Maintenance Requirements for Sand Filter Basins

	Sediment Removal	Mowing/ Weed control	Trash/ Debris Removal	Erosion	Overgrown Vegetation Removal	Removal/ Replacement	Structure Repair
Inflow Points/Splitter Box	X		X				X
Sedimentation Forebay	X	X	X	X	X		
Filter Media	X	X	X	X	X	X	
Underdrain System						X	
Overflow Outlet Works	X		X				X
Embankment		X	X	X	X		
Emergency Overflow		X	X	X	X		X

Figure 6. Typical Sand Filter Basin Features



5.2.1 Inflow Point/Splitter Box

Inflow points or outfalls into Sand Filter Basins are the point of stormwater discharge into the facility. An inflow point is commonly a curb cut with a concrete or riprap rundown or a storm sewer pipe outfall with a flared end section.

Sand Filter Basins can be designed to treat only the water quality capture volume (WQCV) or to also provide flood detention. Depending on the Sand Filter Basin design, a concrete splitter box may be used to divert volumes above the WQCV around the facility. Proper inspection and maintenance of the splitter box is essential in ensuring the long-term operation of the Sand Filter Basin.

An energy dissipater is typically immediately downstream of the splitter box, at the discharge point into the Sand Filter Basin, to protect the infiltrating surface from erosion. In some cases, the splitter box outlet can have a toe-wall or cut-off wall immediately below the structure to prevent undercutting of the outfall from erosion.

Typical maintenance activities at Inflow Points:

a. **Riprap Displaced –** Because of the repeated impact/force of water, riprap can shift and settle. If any portion of the riprap apron appears to have settled, soil is present between the riprap, or the riprap has shifted, maintenance may be required to ensure future erosion is prevented.

b. **Sediment Accumulation –** Because of the turbulence in the water created by the energy dissipater, sediment often deposits immediately downstream of the inflow point. To prevent a loss in performance of the upstream infrastructure, sediment that accumulates in this area must be removed on a timely basis.

c. **Structural Damage –** Structural damage can occur at any time during the life of the facility. Typically for an inflow, the structural damage occurs to the pipe flared end section (concrete or steel). Structural damage can lead to additional operating problems with the facility, including loss of hydraulic performance.

5.2.2 Forebay

The forebay is located adjacent to the splitter box and generally consists of a concrete area that allows water to be briefly held before being released onto the sand bed surface area. This slowing of runoff allows sediments to be deposited in the forebay and not the filtration surface where they can cause clogging of the filter media.

Typical maintenance activities at a Forebay:

a. **Remove sediment –** Sediment captured in the forebay should be removed on a routine basis to reduce clogging of the sand filter surface area.

b. **Control weeds -** Noxious weeds and other unwanted vegetation must be treated as needed throughout the Sand Filter Basin. This activity can be performed either through pulling or with herbicide. Herbicides should be utilized sparingly and as a last resort. All herbicide applications should be in accordance with the manufacturer's recommendations.

5.2.3 Filter Media

The filter media is the main pollutant removal component of the Sand Filter Basin. The filter media consists of 18 inches of washed sand (CDOT Class B or C Filter Material). The filter media removes pollutants through several different processes, including sedimentation, filtration, infiltration and microbial uptake.

Sedimentation is accomplished by the slow release of stormwater runoff through the filter media. This slow release allows for sediment particles that were not deposited in the sedimentation forebay to be deposited on the top layer of the filter media where they are easily removed through routine maintenance. Other pollutants are also removed through this process because they are attached to sediment.

Filtration is the main pollutant removal mechanism of Sand Filter Basins. When stormwater runoff infiltrates through the filter media, particulate pollutants are trapped on the surface or in the pores of the filter media.

Sand Filter Basins that are not lined with an impervious liner allow for infiltration into the native soils. This process also allows for additional pollutant removal and volume reduction.

Microbes that naturally occur in the filter media can assist with pollutant removal by breaking down organic pollutants.

Typical maintenance activities for Filter Media:

a. **Woody growth control/weeds present -** Noxious weeds and other unwanted vegetation must be treated as needed throughout the Sand Filter Basin. This activity can be performed either through mechanical means (pulling) or with herbicide. Herbicides should be utilized sparingly and as a last resort. All herbicide applications should be in accordance with the manufacturer's recommendations.

b. **Sediment/Pollutant Removal –** Although Sand Filter Basins should not be utilized in areas where large concentrations of sediment and other pollutants will enter the Sand Filter Basin, it is inevitable that some sediment and other pollutants will enter the Sand Filter Basin. Most sediment will be deposited in the sedimentation forebay, however finer suspended particles will migrate to the filter media. These sediments need to be removed to ensure proper infiltration rates.

c. **Filter Replacement -** The top layers of the filter media are the most susceptible to pollutant loading and therefore may need to be removed and disposed of properly on a semi-regular basis when infiltration rates slow.

d. **Infiltration Rate Test -** The sand filter is designed to drain completely within 12 hours of the filling. If the drain time for the basin is prolonged, the filter is in need of maintenance. (See Rain Garden Filter Media for several infiltration test methods.)

5.2.4 Underdrain System

The underdrain system consists of a gravel storage area and perforated PVC pipes. The gravel storage area allows for storage of treated stormwater runoff prior to the discharge of the runoff through the perforated PVC pipe.

Typical maintenance activities for an Underdrain System

With proper maintenance of the filter media and sediment forebay, there should be a minimum amount of maintenance required on the underdrain system. Generally, the only maintenance performed on the underdrain system is jet-vac cleaning.

5.2.5 Overflow Outlet Structure

Some Sand Filter Basins include an overflow outlet structure in place of a splitter box at the inflow. The overflow outlet structure allows runoff amounts that exceed the WQCV to exit the sand filter. The outlet structure is typically constructed of reinforced concrete into the embankment of the Sand Filter Basin. The concrete structure typically has steel orifice plates anchored/embedded into it to control stormwater release rates. The larger openings (flood control) on the outlet structure typically have trash racks over them to prevent clogging. Proper inspection and maintenance of the outlet structure is essential in ensuring the long-term operation of the Sand Filter Basin.

Typical maintenance activities for an Overflow Outlet structure:

a. **Structural Damage -** The overflow outlet structure is primarily constructed of concrete, which can crack, spall, and settle. The steel grate on the overflow outlet structure is also susceptible to damage.

b. **Woody growth control/weeds present –** The presence of plant material not part of the original landscaping, such as wetland plants or other woody growth, can clog the overflow outlet structure during a larger storm event, causing flooding damage to adjacent areas. This plant material may indicate a clogging of the filter media and may require additional investigation

5.2.6 Embankments

Sand Filter Basins can be designed with vertical walls or with vegetated embankments. When vegetated embankments enclose the surface filter area, vegetation-related maintenance is needed.

Typical maintenance activities for Vegetated Embankments

a. **Vegetation Sparse –** When vegetated embankments are present in a Sand Filter Basin, adequate and properly maintained vegetation can greatly increase the overall appearance. Also, vegetation can reduce the potential for erosion and subsequent sediment transport to the filter media, thereby reducing the need for more costly maintenance.

b. **Erosion –** Inadequate vegetative cover may result in erosion of the embankments. Erosion that occurs on the embankments can cause clogging of the filter media.

c. **Trash/Debris –** Trash and debris can accumulate in the Sand Filter Basin after large events, or from illegal dumping. Over time, this material can clog the filter media and outlet structure.

d. **Mowing/woody growth control/weeds present –** The presence of plant material not part of the original landscaping, such as wetland plants or other woody growth, can result in difficulty in performing maintenance activities.

5.2.7 Emergency Overflow

Most Sand Filter Basins have an emergency spillway that is designed to serve as the overflow in the event the volume of the pond is exceeded. The emergency spillway is typically armored with riprap (or other hard armor), and is sometimes buried with soil or may be a concrete wall or other structure. The emergency spillway is typically a weir (notch) in the basin embankment. Proper function of the emergency spillway is essential to ensure flooding does not affect adjacent properties

Typical maintenance activities for an Emergency Overflow

e. **Riprap Displaced –** The emergency spillway is typically armored with riprap to provide erosion protection. Over the life of an Sand Filter Basin, the riprap may shift or become dislodged due to flow.

f. **Erosion Present –** Although the spillway is typically armored, stormwater flowing through the spillway can cause erosion damage. Erosion must be repaired to ensure the integrity of the basin embankment, and proper function of the spillway.

g. **Mowing/weed/woody growth control –** Management of woody vegetation is essential in the proper long-term function of the spillway. Larger trees or dense shrubs can capture larger debris entering the Sand Filter Basin and reduce the capacity of the spillway. These trees and shrubs may also damage the underdrain system of the Sand Filter Basin.

h. **Obstruction/Debris –** The spillway must be cleared of any obstruction (human-caused or natural) to ensure the proper design capacity.

5.2.8 Miscellaneous

There are a variety of inspection/maintenance issues that may not be attributed to a single feature within the Sand Filter Basin. This category on the inspection form is for maintenance items that are commonly found in the Sand Filter Basin, but may not be attributed to an individual feature.

a. **Encroachment in Easement Area –** Private lots/property can sometimes be located very close to the Sand Filter Basins, even though they are required to be located in tracts with drainage easements. Property owners may place landscaping, trash, fencing, or other items within the easement area that may affect maintenance or the operation of the facility.

b. **Public Hazards and Vandalism–** Public hazards such as unknown/suspicious substances, exposed metal/jagged concrete on structures or damage due to vandalism should be reported to Denver 311.

c. **Other –** Any miscellaneous inspection/maintenance items not contained on the form.

5.3 MAINTAINING SAND FILTER BASINS

5.3.1 Sand Filter Basin Maintenance Categories (Levels) and Activities

A typical Sand Filter Basin O&M Plan will consist of three broad categories (levels): Routine, Minor and Major. Within each level, a variety of maintenance activities may be necessary. A maintenance activity can be specific to each feature within the Sand Filter Basin, or general to the overall facility. Typical routine, minor and major maintenance activities for Sand Filter Basins are summarized in Table 20, followed by descriptions of these activities

Table 20. Typical Maintenance Levels and Activities for Sand Filter Basins

ROUTINE	MINOR	MAJOR
Mowing of Embankment	Minor Sediment Removal	Major Sediment Removal
Trash/Debris Removal	Minor Erosion Repair	Major Erosion Repair
Outlet Structure Cleaning	Minor Vegetation Removal	Structural Repair
Weed control	Jet Vac / Clearing Drains	Filter Media Replacement

A brief description of routine, minor and major activities for Sand Filter Basins includes:

- Routine: The majority of this work consists of scheduled mowing of vegetated embankments, trash and debris pickup, and weed control. These activities normally will be performed multiple times during the year.
- Minor: This work consists of a variety of isolated or small-scale maintenance/operational problems. Most of this work can be completed by a small crew, hand tools, and small equipment. In the event that the Sand Filter Basin needs to be dewatered, care should be given to ensure sediment, filter material and other pollutants are not discharged.
- Major: This work consists of larger maintenance/operational problems and failures of the Sand Filter Basin. This work may also require more specialized maintenance equipment, design/details, surveying, or assistance through private contractors and consultants.

Tables 21 through 23 provide a summary of typical maintenance activities associated with each level of maintenance for Sand Filter Basins that can be used for developing the O&M Plan for most Sand Filter Basins; however, maintenance should always be done when a facility's performance is compromised, and no later than 6 months following the discovery of need. Most routine and minor maintenance activities do not require coordination with DOTI; however, coordination with DOTI is required for major maintenance activities. Consultation with DOTI is required prior to any dewatering activity. Maintenance activity records should be completed and maintained by the owner. Appendix B provides an example maintenance form for Sand Filter Basins. Section 5.3.2 provides a narrative description of the activities in Tables 21 through 23.

Table 21. Summary of Routine Maintenance Activities for Sand Filter Basins

Maintenance Activity	Minimum Frequency	Look for:	Maintenance Action
Mowing of Embankment	Twice annually	Excessive height that affects the inlet and/or outlet	Mow grass embankment and grassed areas adjacent to facility, if present
Trash/Debris Removal	Twice annually	Trash/debris in SFB	Remove and dispose of trash and debris
Splitter Box/ Overflow Outlet Structure Cleaning	Twice annually and as needed - after significant rain events	Clogged outlet structure; ponding water	Remove and dispose of debris/trash/ sediment to allow outlet to function properly
Woody growth control /Weed removal	Twice annually	Noxious weeds; Unwanted vegetation growing on filter surface	Hand pull or treat w/herbicide sparingly

Table 22. Summary of Minor Maintenance Activities for Sand Filter Basins

Maintenance Activity	Minimum Frequency	Look for:	Maintenance Action
Scarify Filter Media Surface	Typically every 2-5 years	Caked layer	Scarify top 2 inches of sand every 2-5 years; after this has been done 2- 3 times, replenish with sand to original elevation
Sediment/ Pollutant Removal	As needed; typically every 1 –2 years	Sediment build-up in forebay and filter media; decrease in infiltration rate	Remove and dispose of sediment
Erosion Repair	As needed, based upon inspection	Rills/gullies on embankments	Repair eroded areas & revegetate; address cause
Jet-Vac/ Cleaning Underdrains	As needed, based upon inspection	Sediment build-up/non-draining system	Clean drains; Jet-Vac if needed

Table 23. Summary of Major Maintenance Activities for Sand Filter Basins

Maintenance Activity	Minimum Frequency	Look for:	Maintenance Action
Major Sediment/Pollutant Removal	As needed – based upon scheduled inspections	Large quantities of sediment in the sedimentation forebay and/or filter media; reduced infiltration rate/capacity	Remove and dispose of sediment. Replace any media impacted. Repair vegetation as needed
Major Erosion Repair	As needed – based upon scheduled inspections	Severe erosion including gullies, excessive soil displacement, areas of settlement, holes	Repair erosion – find cause of problem and address to avoid future erosion
Structural Repair	As needed – based upon scheduled inspections	Deterioration and/or damage to structural components – broken concrete, damaged pipes & outlet structure	Structural repair to restore the structure to its original design
Sand Filter Basin Rebuild	As needed – due to complete failure of SFB	Removal of filter media and underdrain system	Contact DOTI Engineering Staff

5.3.2 Description of Maintenance Activities

Maintenance activities in Tables 21 through 23 are described below.

5.3.2.1 Mowing

Although the infiltrating surface of Sand Filter Basins is not vegetated, facility embankments may be vegetated with turfgrass and require mowing to maintain aesthetics. Clippings should be collected and disposed of properly.

5.3.2.2 Trash/Debris Removal

Trash and debris must be removed from the entire Sand Filter Basin area to minimize outlet clogging and to improve aesthetics. This activity must be performed prior to mowing operations.

5.3.2.3 Splitter Box/Overflow Outlet Structure Cleaning

Debris and other materials can clog the splitter box/overflow outlet work's grate. This activity must be performed anytime other maintenance activities are conducted to ensure proper operation.

5.3.2.4 Woody Growth Control/Weed Removal

Debris and other materials can clog the splitter box/overflow outlet work's grate. This activity must be performed anytime other maintenance activities are conducted to ensure proper operation.

5.3.2.5 Sediment Removal/Pollutant Removal

Sediment removal is necessary to ensure proper function of the filter media. The infiltration rate of the Sand Filter Basin needs to be checked in order to ensure proper functioning of the SFB. Generally, a Sand Filter Basin should drain completely within 12 hours of a storm event. If drain times exceed the 12-hour drain time then maintenance of the filter media is likely needed.

At a minimum, the top 3 inches of filter media should be removed at each sediment removal event. Additional amounts of filter media may need to be removed if deeper sections of the filter media are contaminated. The minor sediment removal activities can typically be addressed with shovels, rakes and smaller equipment. New filter media will need to be placed back into the Sand Filter Basin when the total amount of sand removed reaches 9 inches. This may take multiple maintenance events to accomplish. It is critical that only sand that meets MHFD Volume 3 specifications for sand filters be used, which allows CDOT Class B or C filter material. Other types of sand and soil material may lead to clogging of the SFB.

Major sediment/pollutant removal consists of removal of large quantities of sediment/filter media. In very rare cases the filter media of the Sand Filter Basin may be contaminated so badly that the entire 18 inches of the filter media may need to be removed. Extreme care should be taken when utilizing motorized or heavy equipment to ensure damage to the underdrain system does not occur. The sediment/filter media needs to be carefully removed, transported and properly disposed. Vegetated areas need special care to ensure design volumes and grades are preserved or may need to be replaced due to the removal activities. The major sediment removal activities will also require surveying with an engineer's level, and consultation with DOTI Engineering Staff to ensure design volumes/grades are achieved.

See Section 1.8.3 for additional guidance on sediment disposal.

5.3.2.6 Scarify Filter Media Surface

Scarify the top 2 inches of sand on the surface of the filter with a scarifying rake. This may be required once every two to five years depending on observed drain times. After this has been done two or three times, replenish the top few inches of the filter with clean coarse sand (AASHTO C-33 or CDOT Class C filter material) to the original elevation. Maintain a minimum sand depth of 12 inches. Eventually, the entire sand layer may require replacement.

5.3.2.7 Erosion Control

The repair of eroded areas is necessary to ensure the proper functioning of the Sand Filter Basin, to minimize sediment transport, and to reduce potential impacts to other features. Erosion can vary in magnitude from minor repairs to filter media and embankments, to rills and gullies in the embankments and inflow points. Extreme care should be taken when utilizing motorized or heavy equipment for erosion repair to ensure damage to the underdrain system does not occur.

Major erosion repair consists of filling and revegetating areas of severe erosion. Determining the cause of the erosion as well as correcting the condition that caused the erosion should also be part of the erosion repair. Care should be given to ensure design grades and volumes are preserved. Major erosion repair to the basin embankments, spillways, and adjacent to structures will require consultation with DOTI Engineering Staff.

5.3.2.8 Jet-Vac/Clearing Drains

Most Sand Filter Basins have an underdrain system that allows treated stormwater runoff to exit the facility. These underdrain systems can develop blockages that can result in a decrease of hydraulic capacity and also create standing water. These blockages can be difficult to access and/or clean. Specialized equipment (jet-vac machines) may be necessary to clear debris from these difficult areas.

5.3.2.9 Structural Repair

A Sand Filter Basin generally includes a splitter box or concrete overflow outlet structure that can deteriorate or be damaged during the service life of the facility. Major repairs to structures may require input from a structural engineer and specialized contractors. Consultation with DOTI Engineering Staff must take place prior to all structural repairs.

5.3.2.10 Sand Filter Basin Rebuild

In very rare cases, a Sand Filter Basin may need to be rebuilt. Generally, the need for a complete rebuild is a result of improper construction, improper maintenance resulting in structural damage to the underdrain system, or extensive contamination of the Sand Filter Basin. Consultation with DOTI Engineering Staff must take place prior to any rebuild project.

5.4 EXAMPLE MAINTENANCE PHOTOGRAPHS

Curb-cut inlet with excessive sediment build-up
Maintenance required

Inflow Point with sediment and debris accumulation
Maintenance required

Inflow Point with erosion and sediment build-up
Maintenance required

Inflow Point operating correctly
No immediate maintenance required

Rain Gardens/Sand Filter Basins – Inflow Points

Sand Filter media with excessive sediment build-up
Maintenance required

Rain Garden with dead vegetation on filter media surface
Maintenance required

Clean Sand Filter media
No immediate maintenance required

Rain Garden with healthy vegetation and no sediment
No immediate maintenance required

Rain Gardens/Sand Filter Basins – Filter Media

Outlet of forebay is clogged/blocked causing runoff bypass
Maintenance required

Sediment build-up and forebay outlet is clogged
Maintenance required

Clean forebay
No immediate maintenance required

Clean forebay
No immediate maintenance required

Rain Gardens/Sand Filter Basins – Forebay

Outlet Structure with excess vegetation growth
Maintenance required

Outlet Structure installed too low (cross-check with design)
Maintenance required

Outlet Structure clogged with sediment
Maintenance required

Outlet Structure in good condition
No immediate maintenance required

Rain Gardens/Sand Filter Basins – Outlet Works

Chapter 6: PERMEABLE PAVEMENT SYSTEMS (PPS)

6.1 BACKGROUND

Permeable Pavement Systems (PPS) and Permeable Interlocking Pavers (PICP) are an increasingly more common control measure found in Denver. This is an infiltrating SCM that allows water to pass through what is typically an impervious surface by constructing it with porous materials or separations that allow runoff to seep through. These pavement systems are built to replace typical asphalt and concrete to provide a water quality capture volume and reduce the overall amount of impervious surface built for the site – most commonly parking lots and pedestrian walking areas. Permeable pavement systems are often used in Low Impact Development designs. Frequently PPS and PICP's are installed in addition to other control measures to fully achieve WQCV requirements.

Water Quality Capture Volumes are achieved by filter media located underneath the permeable material. In pavement systems not designed to fully infiltrate into the ground, an underdrain can be installed to convey treated water away from the site. Site selection and location of the control measure plays a significant role in the applicability and effectiveness of these pavement systems. Soils must have suitable rates of infiltration and not be used in facilities where infiltrating groundwater could cause contamination of the area – similarly they cannot be built in contaminated soils. As it can be designed as an infiltration SCM, it should not be placed directly adjacent to structures due to expansive soil or bedrock swelling. PPS/PICP must also be located in areas that are well vegetated and not prone to erosion to avoid frequent clogging of the pavement or joint aggregate. The systems can be built in one of three varieties: No infiltration where a subgrade impermeable liner and underdrain are installed, partial infiltration where an underdrain is installed but some infiltration can still occur, and full infiltration where water stored in the pavement and filter material can drain completely into the soil. Full infiltration systems are recommended to have an infiltration rate of 2 times the rate needed to drain the WQCV over 12 hours.

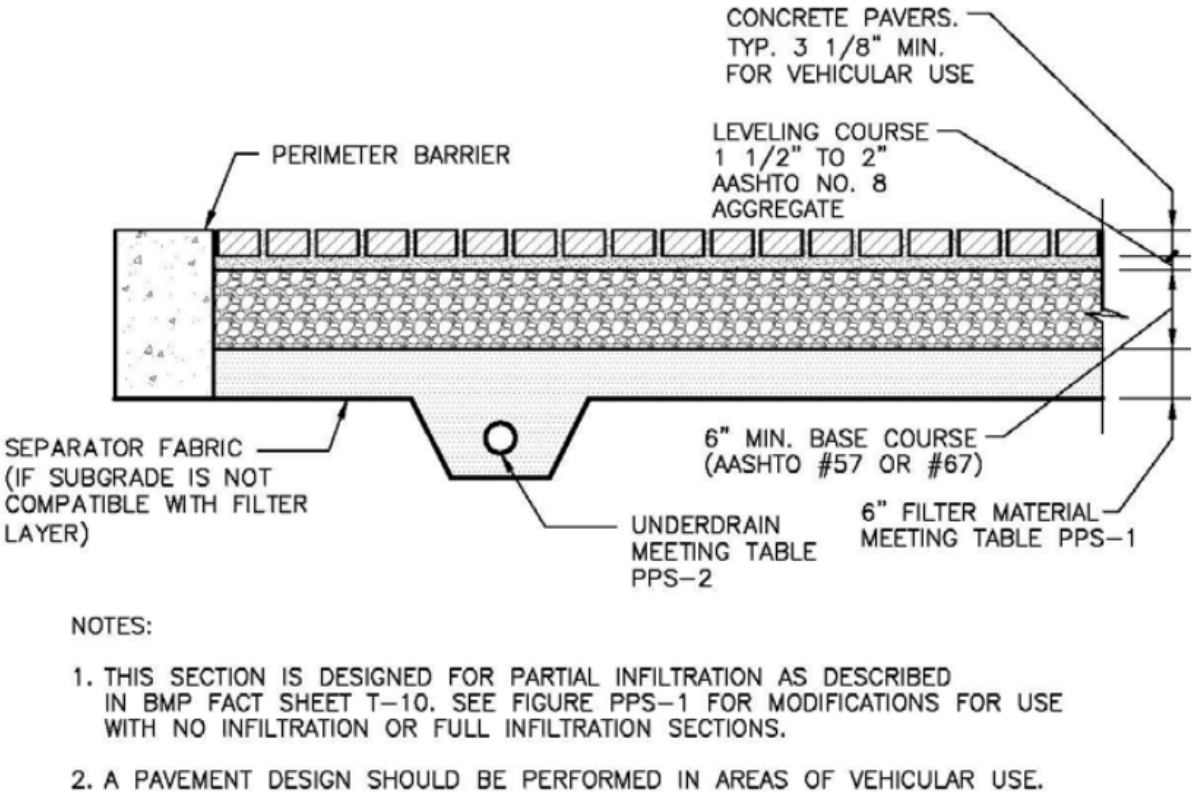
6.2 INSPECTING PERMEABLE PAVEMENT SYSTEMS

Each feature in a Permeable Pavement System or Permeable Interlocking Paver System is designed for a specific function. The proper function of one feature often depends on another. It is important for maintenance personnel to understand the function of each of these features to prevent damage to any feature during maintenance operations. Table 24 identifies the most common features and the corresponding maintenance inspection items that can be anticipated. Figure 7 shows typical Permeable Pavement features.

Table 24. Typical Inspection and Maintenance Requirements for Permeable Pavement & PICP

	Infiltration Rate	Sediment Removal	Trash/ Debris Removal	Weed/Stain Removal	Vacuum/ Sweeping	Removal/ Replacement	Structure Repair
Pavement Surface / Pavers	X	X	X	X	X		X
Underdrain System							X
PICP Aggregate	X	X	X		X	X	X

Figure 7. Typical Permeable Pavement System Cross Section*



** The above cross section shows a PICP system*

6.2.1 Pavement Surface

In permeable pavement systems, the concrete or asphalt surface is made in a way that allows water to penetrate through the surface and enter subsurface filter media where it either infiltrates or is treated then released. This porous surface has voids that allow for water to penetrate through – and as such must be regularly swept to avoid clogging which can lead to more intensive restoration efforts being needed. Typically, this surface is 3-6 inches thick so sediment buildup is not easily visible. If water is not quickly draining through the surface or is pooling on top of the PPS, it is likely in need of maintenance.

Typical maintenance activities for Pavement Surface:

a. **Surface Sweeping –** Proactive vacuuming is recommended for most PPS/PICP systems at least annually. This needs to be done with a regenerative air sweeper truck, vac sweeper truck, or a walk behind vacuums frequently used by landscapers and sidewalk cleaning companies. Do not use pressure washers on PPS/PICP as it can lead to clogging and failure of the system as it further embeds sediment

b. **Weed & Stain removal –** Do not pull weeds as they may remove filter media along with them. Kill weeds using thermal treatment (flame torch) or small amounts of biodegradable, non-toxic chemical treatment. Stains should be removed using spot treatments of biodegradable, non-toxic degreaser – wipe up degreaser using cloth towels and dispose. Do not wash away degreaser using water. Weeds growing from a PPS may indicate excess sediment has accumulated and needs to be removed

c. **Trash/Debris Removal –** Debris and trash can frequently accumulate and should be removed on a regular basis. Mechanical sweeping (brooms or machine sweepers) can be used to remove leaves, trash, and other debris. However, these sweepers will not remove embedded sediment as referenced in *a.* above

d. **Snow and Ice Control & Stockpiles –** Snow removal on PPS systems should be done with plows using rubber blades - Metal blades can cause damage. Never apply sand to any PPS/PCIP system, as it is a form of sediment it will quickly clog the system. Chemical deicers should not be used on porous concrete as it will cause the concrete to crack and fail. Snow should not be stored on PPS/PICP systems due to the sediment in snow piles.

e. **Infiltration Rate Test –** The infiltration rate of the pavement surface needs to be checked to ensure proper functioning of the PPS/PICP. Pour 1 gallon of water over ~30 second onto the pavement surface. The water will infiltrate creating a “wetted area”. Measure the diameter of the wetted area, if it is longer then 10 feet then the surface is likely clogged and needs restorative maintenance. Standing water or pooling after rain events also can indicate clogging. Perform the test in several areas of the PPS as clogging can vary from one location/test to the next

6.2.2 Underdrain System

PPS & PICP systems that are not designed to fully infiltrate into the soil rely on sub-surface underdrains to convey water away from the control measure. If an underdrain is in place, the SCM should drain within 12-24 hours

Typical maintenance activities for an Underdrain System

With proper maintenance of the filter media and sediment forebay, there should be a minimum amount of maintenance required on the underdrain system. Generally, the only maintenance performed on the underdrain system is jet-vac cleaning.

6.2.3 PICP Aggregate

Permeable Interlocking Concrete Paver Systems have small openings (joints) between each individual paver which allow rainfall to infiltrate through. These openings are filled with an aggregate material that is specified in the original design – typically ASTM No. 8, 9, or 89 angular washed aggregate. The aggregate captures sediments close to the surface so the sediment can be more easily removed. If water is pooling at the surface, the aggregate or subsurface infiltration area is clogged or compacted.

Typical maintenance activities for PICP Aggregate:

a. **Add Additional Aggregate –** If the aggregate is over ½ inch below the top of the nearest paver, add more aggregate to the joint area to ensure it is filled. Refer to the design plans or as-builts to determine the type of aggregate to use. Typically this is ASTM No. 8,9 or 89 angular washed stone aggregate

b. **Surface Sweeping –** Regenerative air or vacuum sweeper should be used after any significant landscaping and at minimum once per year to maintain infiltration rates. Do not use pressure washers on joint aggregate. Regularly use mechanical sweepers to remove the upper layer of sediment buildup to minimize the need for more extensive maintenance. After vacuuming, some aggregate may need to be replaced per *a.* above

c. **Trash/Debris Removal –** Debris and trash can frequently accumulate and should be removed on a regular basis. Mechanical sweeping (brooms or machine sweepers) can be used to remove leaves, trash, and other debris. However, these sweepers will not remove embedded sediment and may displace some aggregate that will need to be replaced.

6.3 MAINTAINING PERMEABLE PAVEMENT SYSTEMS

6.3.1 Summary of Routine, Minor and Major Maintenance Activities

A typical PPS/PICP Maintenance Program will consist of three broad categories (levels): Routine, Minor and Major. Within each level, a variety of maintenance activities may be necessary. A maintenance activity can be specific to each feature within the PPS/PICP, or general to the overall facility. Table 25 highlights the common activities associated with each level

Table 25. Typical Maintenance Levels and Activities for Permeable Pavement Systems/PICP

ROUTINE	MINOR	MAJOR
Proactive Surface Sweeping	Stain removal	Restorative vacuuming/ Hydro-scrubbing
Infiltration Testing	Jet Vac / Clearing Underdrain	Damaged pavers or pavement
Trash and debris removal	Add additional Aggregate	Below surface sediment removal
	Weed control (indicates subsurface sediment accumulation)	

A brief description of routine, minor and major activities for Permeable Pavement Systems includes:

- Routine: The majority of this work consists of scheduled sweeping, running infiltration tests, trash/debris removal, and annual vacuuming of built-up sediment. These activities normally will be performed multiple times during the year.
- Minor: This work consists of a variety of isolated or small-scale maintenance/operational problems. Most of this work can be completed by a small crew, hand tools, and small equipment.
- Major: This work consists of larger maintenance/operational problems and failures of the PPS. This work may also require more specialized maintenance equipment, design/details, surveying, or assistance through private contractors and consultants. Only a certified PICP/CGP installer should provide these services

Tables 26 through 28 provide a summary of typical maintenance activities associated with each level of maintenance for Permeable Pavement and PICP systems that can be used for developing the O&M Plan for most designs; however, maintenance should always be done when a facility's performance is compromised, and no later than 6 months following the discovery of need. For PPS/PICP this is typically indicated when runoff builds up on the surface or runoff does not quickly drain into the subsurface. Most routine and minor maintenance activities do not require coordination with DOTI; however, coordination with

DOTI is required for major maintenance activities. Maintenance activity records should be completed and maintained by the owner, and available upon request by DOTI inspectors. Appendix B provides an example maintenance form for PPS/PICP. Section 6.3.2 provides a narrative description of the activities in Tables 26 through 28.

Table 26. Summary of Routine Maintenance Activities for PPS/PICP

Maintenance Activity	Minimum Frequency	Look for:	Maintenance Action
Proactive Surface Sweeping	2-4 times a year; as needed based upon inspection	Buildup of sediment	Use vacuum sweepers or regenerative air sweepers to remove surface level sediment. Do not use power washers
Infiltration Testing	Annually and as needed	Pooling of water, slow drain rate	Perform infiltration testing, see 6.2.1 above
Trash and Debris Removal	Weekly and as needed	Buildup of trash and debris	Remove and dispose of debris and trash

Table 27. Summary of Minor Maintenance Activities for PPS/PICP

Maintenance Activity	Minimum Frequency	Look for:	Maintenance Action
Stain Removal	As needed	Staining on surface	Spot treatment using biodegradable, non-toxic degreaser – wipe up degreaser using cloth towels and dispose.
Add additional aggregate (PICP Systems)	As needed, based upon inspection	Joint aggregate levels 1/2" below the height of the nearest paver	Replace missing aggregate with material listed in designs/plans
Jet-Vac/ Cleaning Underdrains	As needed, based upon inspection	Non-infiltration or semi-infiltration PPS draining slowly	Clean drains; Jet-Vac if needed
Weed Control	As needed, based upon inspection	Weeds growing from joint aggregate areas	Kill weeds using thermal treatment (flame torch) or small amounts of biodegradable, non-toxic chemical treatment

Table 28. Summary of Major Maintenance Activities for Sand PPS/PICP

Maintenance Activity	Minimum Frequency	Look for:	Maintenance Action
Restorative Vacuuming/ Hydro-Scrubbing	As needed – based upon scheduled inspections and/or infiltration tests	Frequent pooling of water, stagnant pools of water, very long drain times	Use vacuum Hydro-Scrubber or pure vacuum sweeper
Paver or pavement repairs	As needed – based upon scheduled inspections	Missing or loose pavers, damage to pavement surface	Make repairs to PPS as needed
Below surface sediment removal	As needed – based upon scheduled inspections	Continued pooling of water, etc. after restorative vacuuming/hydro-scrubbing performed	Bedding course removal and replacement. Pavement section replacement, contact DOTI Engineering Staff

6.3.2 Description of Maintenance Activities

6.3.2.1 Proactive Surface Sweeping

Preventative sweeping is the most common maintenance required by Permeable Pavement Systems. Regular sweeping can reduce the rate that the porous surface and PCIP joints get clogged. Preventative sweeping should occur 2-4 times a year at minimum, depending on the make-up of the drainage area. PICP are the most common permeable pavement systems found in Denver, but Regenerative Air Sweepers are recommended for PICP, pervious concrete, and pervious asphalt for preventative maintenance. Vacuum sweepers are less common but are recommended for restorative maintenance, especially in the case of PICP with aggregate as material can end up being removed by the vacuum.

6.3.2.2 Infiltration Testing

Clogging of permeable pavement systems is not easily visible and is typically indicated by pooling water and slow drain times. Infiltration testing is the best way to determine what areas of your pavement are clogged. A simple infiltration test can be done by doing the following process: Pour 1 gallon of water onto the PPS surface over approximately 30 seconds, the water will infiltrate and create a "wetted area", measure the diameter of the wetted area, if it is longer then 10ft of spread maintenance is most likely needed. Municipal inspectors or certified maintainers may use an infiltrometer to confirm infiltration rates, but this simple test can be done to determine if the PPS is functioning properly during dry periods. The test should be done in several areas of the pavement as clogging is not always the same throughout the entire system

6.3.2.3 Trash and Debris Removal

Trash and debris must be removed from the entire PPS area to minimize surface clogging and to improve aesthetics. This activity should be performed as needed

6.3.2.4 Weed and Stain Removal

In PICP systems weeds may begin to grow up through the joints and may need to be removed. However directly pulling the weeds is not recommended as it can dislodge pavers and impact the PPS's function. Weeds should first be killed using thermal treatment or more likely using small amounts of biodegradable, non-toxic chemical treatments – then once the weeds are dead, they may be removed without risk of damaging the system. It should be noted that if weeds are frequently showing up in a PICP system, sediment has most likely built up underneath the pavers and restorative maintenance may be required.

Since PPS's are frequently traveled and used as parking areas, stains may develop over time. Stains should not be removed using pressure washers to avoid embedding sediment in any porous material. Stains should be removed by using biodegradable, non-toxic degreasers. After being applied the degreasers should be wiped up – not washed away using water.

6.3.2.5 Add Additional Aggregate (PICP Systems)

Permeable Interlocking Concrete Pavers (PICP) have void space between the individual pavers that allow for infiltration. These void spaces are referred to as joints and are filled with stone aggregate that captures sediment at the surface of the permeable pavement system. Over time this aggregate can get displaced or removed during preventative maintenance. If a ½ inch gap from the surface of the pavers or greater is present, then aggregate will need to be readded. This can be done by placing the aggregate on the surface and using a broom to sweep the aggregate into any low spots. The specific type of aggregate should be determined by as-builts or plan sheets for the site – but typically it is ASTM No. 8, 9, or 89 angular washed aggregate.

6.3.2.6 Jet-Vac/Clearing Drains

Many permeable pavement systems have an underdrain system that allows treated stormwater runoff to exit the facility. These underdrain systems can develop blockages that can result in a decrease of hydraulic capacity and also create standing water. These blockages can be difficult to access and/or clean. Specialized equipment (jet-vac machines) may be necessary to clear debris from these difficult areas.

6.3.2.7 Restorative Maintenance/Hydro-Scrubbing

Over time the voids and porous areas of a permeable pavement system will get clogged with sediment from runoff generated during storm events. Regular preventative sweeping can help reduce how often this occurs, but eventually restorative maintenance will be needed to return the PPS to its original level of function. In most cases a "Pure Vacuum Sweeper" will need to be used to remove sediment buried deep in the pours of porous concrete and asphalt. These vacuum trucks are not common and may be hard to locate, alternatively a Vacuum Hydro Scrubber may be easier to source. For PICP a vacuum truck can help remove built up sediment but once fully clogged, the pavers will need to be removed along with the built-up layer of sediment that is preventing proper infiltration. Once the pavers are removed new bedding will need to be added before reinstalling the PICP system.

6.3.2.8 Paver or Pavement Repairs

Over time the pavement surface or pavers may become damaged and need to be replaced. If a section of porous concrete or asphalt must be replaced it should be designed following the initial installation following the facilities accepted as built. Damaged pavers should also be replaced if cracked or otherwise damaged to ensure correct flow through the aggregate material

6.3.2.9 Below Surface Sediment Removal

Over time sediment will build up underneath PICP systems and will prevent proper infiltration and drainage of the system and cannot be easily removed with vacuum systems. To complete restorative maintenance, pavers and existing bedding course may have to be removed. New bedding course must then be placed, and the original pavers can be reinstalled.

6.3.2.10 Snow and Ice Control

Special care needs to be taken when addressing snow on permeable pavement systems. Due to the drainage rates and infiltration that PPS provide snow will often melt quickly on these kinds of surfaces. When snow needs to be removed from permeable pavement and PICP systems rubber plow blades should be used to minimize the risk of damaging the surface material. As sand is a form of sediment it should not be applied to PPS surfaces as the small particulates will quickly clog the system. Do not use deicers on porous concrete as the chemicals can cause the concrete to crack and fail. Snow should not be stored directly on PPS, excess sediment in snow piles will clog the system rapidly

APPENDIX A: INSPECTION FORMS

EXTENDED DETENTION BASIN (EDB)
INSPECTION FORM

Subdivision/Business Name: _____ Date: _____

Subdivision/Business Address: _____ Inspector: _____

Weather: _____

Last Date of Rainfall: _____ Amt: _____ Inches

Property Classification:	☐ Residential	☐ Multi-Family	☐ Commercial	☐ Other: _____
Reason for Inspection:	☐ Routine	☐ Complaint	☐ After Significant Rainfall Event	

INSPECTION SCORING – For each facility inspection item, insert one of the following scores:

0 = No Deficiencies Identified
1= Monitor (potential for future problem)
2 = Routine Maintenance Required
3= Immediate Repair Necessary
N/A = Not Applicable

FEATURES

1) Inflow Points
____ Riprap Displaced
____ Erosion present/Outfall Undercut
____ Sediment/Debris Accumulation
____ Structural Damage (pipe, end-section, etc.)
____ Woody Growth/Weeds Present

2) Forebay
____ Sediment/Debris Accumulation
____ Concrete Cracking/Failing
____ Drain Pipe/Weir Clogged (not draining)
____ Weir/Drain Pipe Damage

3) Trickle Channel (Low-flow)
____ Sediment/Debris Accumulation
____ Concrete/Riprap Damage
____ Woody Growth/Weeds Present
____ Erosion Outside Channel

4) Bottom Stage (Micropool)
____ Sediment/Debris Accumulation
____ Woody Growth/Weeds Present
____ Bank Erosion
____ Mosquitos/Algae Treatment
____ Petroleum/Chemical Sheen

5) Outlet Structure
____ Trash Rack/Well Screen Clogged
____ Structural Damage (concrete, steel, subgrade)
____ Orifice Plate(s) Missing/Not Secure
____ Manhole Access (cover, steps, etc.)
____ Woody Growth/Weeds Present

6) Emergency Spillway
____ Riprap Displaced
____ Erosion Present
____ Woody Growth/Weeds Present
____ Obstruction/Debris

7) Grass Basin Area (Dry Storage)
____ Vegetation Sparse
____ Woody Growth/Undesirable Vegetation
____ Standing Water/Boggy Areas
____ Sediment Accumulation
____ Erosion (banks and bottom)
____ Trash/Debris
____ Maintenance Access

8) Miscellaneous
____ Encroachment in Easement Area
____ Graffiti/Vandalism
____ Public Hazards
____ Burrowing Animals/Pests
____ Other

Inspection Summary/Comments: _____

_____

OVERALL FACILITY RATING (Check One):

0 = No Deficiencies Identified ☐ 2 = Routine Maintenance Required ☐

1 = Monitor (Potential for future problem exists) ☐ 3 = Immediate Repair Necessary ☐

THIS INSPECTION FORM MUST BE KEPT INDEFINITELY AND MADE AVAILABLE TO DOTI UPON REQUEST

GRASS BUFFER – GRASS SWALE (GB/GS)
INSPECTION FORM

Subdivision/Business Name: _____ Date: _____

Subdivision/Business Address: _____ Inspector: _____

Weather: _____

Last Date of Rainfall: _____ Amt: _____ Inches

Property Classification: ☐ Residential ☐ Multi-Family ☐ Commercial ☐ Other: _____

Reason for Inspection: ☐ Routine ☐ Complaint ☐ After Significant Rainfall Event

INSPECTION SCORING – For each facility inspection item, insert one of the following scores:

0 = No Deficiencies Identified
1= Monitor (potential for future problem)
2 = Routine Maintenance Required
3= Immediate Repair Necessary
N/A = Not Applicable

FEATURES

1) Grass Swale Bottom & Side Slopes
____ Sediment/Debris Accumulation
____ Vegetation Cover
____ Erosion Present
____ Standing Water/Boggy Areas

2) Grass Buffer
____ Sediment/Debris Accumulation
____ Vegetation Cover
____ Erosion Present
____ Standing Water/Boggy Areas

3) Inflow Points
____ Rip Rap Displaced/ Rundown or Pipe Damage
____ Erosion Present/Outfall Undercut
____ Sediment/Debris Accumulation

4) Underdrain System
____ Standing Water/Not Draining
____ Evidence of Clogged System

5) Grade Control
____ Erosion Present
____ Structural Damage

6) Level Spreader
____ Erosion Present
____ Structural
____ Unlevel/Uneven Distribution of Flow

7) Irrigation
____ General Grass Condition
____ Bare Spots
____ Broken Sprinkler Heads

8) Miscellaneous
____ Encroachment in Easement Area
____ Public Hazards
____ Burrowing Animals/Pests
____ Other

Inspection Summary/Comments: _____

_____

OVERALL FACILITY RATING (Check One):

0 = No Deficiencies Identified ☐ 2 = Routine Maintenance Required ☐

1 = Monitor (Potential for future problem exists) ☐ 3 = Immediate Repair Necessary ☐

THIS INSPECTION FORM MUST BE KEPT INDEFINITELY AND MADE AVAILABLE TO DOTI UPON REQUEST

RAIN GARDEN (RG)
INSPECTION FORM

Subdivision/Business Name: _____ Date: _____

Subdivision/Business Address: _____ Inspector: _____

Weather: _____

Last Date of Rainfall: _____ Amt: _____ Inches

Property Classification:	☐ Residential	☐ Multi-Family	☐ Commercial	☐ Other: _____
Reason for Inspection:	☐ Routine	☐ Complaint	☐ After Significant Rainfall Event	

INSPECTION SCORING – For each facility inspection item, insert one of the following scores:

0 = No Deficiencies Identified
1= Monitor (potential for future problem)
2 = Routine Maintenance Required
3= Immediate Repair Necessary
N/A = Not Applicable

FEATURES

1) Inflow Points
____ Riprap Displaced/Rundown or Pipe Damage
____ Erosion present/Outfall Undercut
____ Sediment/Debris Accumulation
____ Structural Damage

2) Filter Media
____ Infiltration Rate Check
____ Sediment Removal
____ Filter Replacement

3) Forebay
____ Sediment/Debris Accumulation
____ Concrete Cracking/Failing
____ Drain Pipe/Weir Clogged
____ Drain Pipe/Weir Damaged

4) Landscaping
____ Woody Growth/Weeds Present
____ General Landscape Care

5) Underdrain System
____ Evidence of Clogged system
(Jet-vac cleaning required)

6) Embankments
____ Vegetation Sparse
____ Erosion Present

7) Overflow Outlet Structure
____ Structural Damage
____ Woody Growth/Undesirable Vegetation
____ Trash/Debris

8) Miscellaneous
____ Encroachment in Easement Area
____ Graffiti/Vandalism
____ Public Hazards
____ Other

Inspection Summary/Comments: _____

_____

OVERALL FACILITY RATING (Check One):

0 = No Deficiencies Identified ☐
2 = Routine Maintenance Required ☐
1 = Monitor (Potential for future problem exists) ☐
3 = Immediate Repair Necessary ☐

THIS INSPECTION FORM MUST BE KEPT INDEFINITELY AND MADE AVAILABLE TO DOTI UPON REQUEST

SAND FILTER BASIN (SFB)
INSPECTION FORM

Subdivision/Business Name: _____ Date: _____

Subdivision/Business Address: _____ Inspector: _____

Weather: _____

Last Date of Rainfall: _____ Amt: _____ Inches

Property Classification: ☐ Residential ☐ Multi-Family ☐ Commercial ☐ Other: _____

Reason for Inspection: ☐ Routine ☐ Complaint ☐ After Significant Rainfall Event

INSPECTION SCORING – For each facility inspection item, insert one of the following scores:

0 = No Deficiencies Identified
1= Monitor (potential for future problem)
2 = Routine Maintenance Required
3= Immediate Repair Necessary
N/A = Not Applicable

FEATURES

1) Inflow Points/Splitter Box
____ Riprap Displaced
____ Trash/Debris
____ Sediment/Debris Accumulation
____ Structural Damage (pipe, end-section, etc.)

2) Sedimentation Forebay
____ Sediment/Debris Accumulation
____ Remove Weeds/Woody Growth Control
____ Trash/Debris
____ Erosion Present

3) Filter Media
____ Mowing/Weed/Woody Growth Control
____ Sediment/Pollutant Removal
____ Filter Replacement
____ Infiltration Rate Check

4) Underdrain System
____ Evidence of Clogged System
(Jet-vac cleaning required)

5) Outlet Structure
____ Structural Damage (concrete, steel, subgrade)
____ Mowing/Weed/Woody Growth Control

6) Embankments
____ Vegetation Sparce
____ Erosion Present
____ Trash/Debris
____ Mowing/Weed/Woody Growth Control

7) Emergency Overflow
____ Riprap Displaced
____ Erosion Present
____ Woody Growth/Weeds Present
____ Obstruction/Debris

8) Miscellaneous
____ Encroachment In Easement Area
____ Graffiti/Vandalism
____ Public Hazards
____ Other

Inspection Summary/Comments: _____

_____

OVERALL FACILITY RATING (Check One):

0 = No Deficiencies Identified ☐ 2 = Routine Maintenance Required ☐

1 = Monitor (Potential for future problem exists) ☐ 3 = Immediate Repair Necessary ☐

THIS INSPECTION FORM MUST BE KEPT INDEFINITELY AND MADE AVAILABLE TO DOTI UPON REQUEST

PERMEABLE PAVEMENT SYSTEM (PPS)
INSPECTION FORM

Subdivision/Business Name: _____ Date: _____

Subdivision/Business Address: _____ Inspector: _____

Weather: _____

Last Date of Rainfall: _____ Amt: _____ Inches

Property Classification:	☐ Residential	☐ Multi-Family	☐ Commercial	☐ Other: _____
Reason for Inspection:	☐ Routine	☐ Complaint	☐ After Significant Rainfall Event	

INSPECTION SCORING – For each facility inspection item, insert one of the following scores:

0 = No Deficiencies Identified
1= Monitor (potential for future problem)
2 = Routine Maintenance Required
3= Immediate Repair Necessary
N/A = Not Applicable

FEATURES

1) Pavement Section
- ____ Sediment/Debris Accumulation/Obstructions
- ____ Structural Damage (concrete, pavers, barrier wall, etc.)
- ____ Infiltration Rate Check

2) Underdrain System
- ____ Evidence of clogged system (jet-vac cleaning)
- ____ Cleanouts / caps damaged / missing
- ____ Orifice Plate Missing/Not Secure

3) Miscellaneous
- ____ Trash/Debris
- ____ Encroachment in Easement Area
- ____ Public Hazards
- ____ Woody Growth/Undesirable Vegetation

Inspection Summary/Comments: _____

_____

OVERALL FACILITY RATING (Check One):

0 = No Deficiencies Identified ☐
2 = Routine Maintenance Required ☐
1 = Monitor (Potential for future problem exists) ☐
3 = Immediate Repair Necessary ☐

THIS INSPECTION FORM MUST BE KEPT INDEFINITELY AND MADE AVAILABLE TO DOTI UPON REQUEST

APPENDIX B: MAINTENANCE FORMS

EXTENDED DETENTION BASIN (EDB)
MAINTENANCE FORM

Subdivision/Business Name:	_____	Completion Date: _____	
Subdivision/Business Address:	_____	Contact Name: _____	
Maintenance Category: (check one)	☐ Routine	☐ Restoration (Minor)	☐ Rehabilitation (Major)

MAINTENANCE ACTIVITIES PERFORMED

ROUTINE WORK

☐Mowing
☐Trash/Debris Removal
☐Outlet Structure Cleaning (Trash Rack/Well Screen)
☐Mosquito Control
☐Algae Treatment

MINOR WORK

☐Sediment Removal
- ☐Forebay
- ☐Trickle Channel
- ☐Inflow

☐Erosion Repair
- ☐Inflow Point
- ☐Trickle Channel

☐Vegetation Removal/Tree Thinning
- ☐Inflows
- ☐Trickle Channel
- ☐Grass Basin Area
- ☐Bottom Stage

☐Revegetation
☐Jet-Vac/Clearing Drains
- ☐Forebay
- ☐Outlet Structure
- ☐Inflows

MAJOR WORK

☐Sediment Removal (Dredging)
- ☐Lower stage grass basin area
- ☐Upper stage grass basin area

☐Erosion Repair
- ☐Outlet Structure
- ☐Lower Stage Grass Basin Area
- ☐Upper Stage Grass Basin Area
- ☐Spillway

☐Structural Repairs
- ☐Inflow
- ☐Outlet Structure
- ☐Forebay
- ☐Trickle Channel

Other: _____

Estimated Total Manhours: _____

Equipment/Materials Used: _____

_____

Comments/Additional Info: _____

_____

THIS INSPECTION FORM MUST BE KEPT INDEFINITELY AND MADE AVAILABLE TO DOTI UPON REQUEST

GRASS BUFFER AND GRASS SWALE (GB/GS)
MAINTENANCE FORM

Subdivision/Business Name:	_____		Completion Date: _____
Subdivision/Business Address:	_____		Contact Name: _____
Maintenance Category: (check one)	☐ Routine	☐ Restoration (Minor)	☐ Rehabilitation (Major)

MAINTENANCE ACTIVITIES PERFORMED

ROUTINE WORK

☐Mowing
☐Trash/Debris Removal
☐Outlet Structure Cleaning (Trash Rack/Well Screen)
☐Weed Control (Herbicide Application)

MINOR WORK

☐Sediment Removal
- ☐Inflow Point
- ☐Swale Bottom
- ☐Side Slope
- ☐Buffer Strip

☐Erosion Repair
- ☐Inflow Point
- ☐Swale Bottom
- ☐Side Slope
- ☐Buffer Strip
- ☐Grade Control/Level Spreader

☐Revegetation
- ☐Swale Bottom
- ☐Side Slope
- ☐Buffer Strip
- ☐Bottom Stage

MAJOR WORK

☐Sediment Removal (Dredging)
- ☐Swale Bottom
- ☐Inflow Point

☐Erosion Repair
- ☐Inflow Point
- ☐Swale Bottom
- ☐Side Slope
- ☐Buffer Strip

☐Structural Repairs
- ☐Inflow
- ☐Underdrain
- ☐Level Spreader

Other: _____

Estimated Total Manhours: _____

Equipment/Materials Used: _____

_____

Comments/Additional Info: _____

_____

THIS INSPECTION FORM MUST BE KEPT INDEFINITELY AND MADE AVAILABLE TO DOTI UPON REQUEST

RAIN GARDEN (RG)
MAINTENANCE FORM

Subdivision/Business Name:	_____		Completion Date: _____
Subdivision/Business Address:	_____		Contact Name: _____
Maintenance Category: (check one)	☐ Routine	☐ Restoration (Minor)	☐ Rehabilitation (Major)

MAINTENANCE ACTIVITIES PERFORMED

ROUTINE WORK

☐Mowing
☐Trash/Debris Removal
☐Outlet Structure Cleaning (Trash Rack/Well Screen)
☐Weed Control

MINOR WORK

☐Sediment Removal
- ☐Inflows
- ☐Filter Media
- ☐Forebay
- ☐Outlet Structure

☐Erosion Repair
- ☐Inflows
- ☐Filter Media
- ☐Forebay

☐Re-Vegetation
- ☐Embankments

☐Jet-Vac/Clearing Drains
- ☐Inflows
- ☐Forebay
- ☐Underdrain System
- ☐Outlet Structure

MAJOR WORK

☐Sediment Removal (Dredging)
- ☐Inflows
- ☐Filter Media
- ☐Forebay

☐Erosion Repair
- ☐Outlet Structure
- ☐Embankments

☐Structural Repairs
- ☐Inflows
- ☐Filter Media
- ☐Forebay
- ☐Outlet Structure

Other: _____

Estimated Total Manhours: _____

Equipment/Materials Used: _____

_____

Comments/Additional Info: _____

_____

THIS INSPECTION FORM MUST BE KEPT INDEFINITELY AND MADE AVAILABLE TO DOTI UPON REQUEST

SAND FILTER BASIN (SFB)
MAINTENANCE FORM

Subdivision/Business Name:	_____		Completion Date: _____
Subdivision/Business Address:	_____		Contact Name: _____
Maintenance Category: (check one)	☐ Routine	☐ Restoration (Minor)	☐ Rehabilitation (Major)

MAINTENANCE ACTIVITIES PERFORMED

ROUTINE WORK

☐Mowing
☐Trash/Debris Removal
☐Outlet Structure Cleaning (Trash Rack/Well Screen)
☐Weed Control (Herbicide Application)

MINOR WORK

☐Sediment Removal
- ☐Inflow Point/Splitter Box
- ☐Outlet Structure
- ☐Filter Media
- ☐Sedimentation Forebay
- ☐Emergency Forebay

☐Erosion Repair
- ☐Inflow Point/Splitter Box
- ☐Outlet Structure
- ☐Embankment
- ☐Sedimentation Forebay
- ☐Emergency Overflow
- ☐Filter Media

☐Revegetation
☐Jet-Vac/Clearing Drains
- ☐Inflows
- ☐Outlet Structure
- ☐Underdrain System

MAJOR WORK

☐Sediment Removal (Dredging)
- ☐Filter Media
- ☐Inflow Point

☐Erosion Repair
- ☐Inflow Point/Splitter Box
- ☐Outlet Structure
- ☐Embankment
- ☐Sedimentation Forebay
- ☐Emergency Overflow
- ☐Filter Media

☐Structural Repair
- ☐Inflow/Splitter Box
- ☐Outlet Structure
- ☐Filter Media
- ☐Sedimentation Forebay
- ☐Emergency Overflow

Other: _____

Estimated Total Manhours: _____

Equipment/Materials Used: _____

_____

Comments/Additional Info: _____

_____

THIS INSPECTION FORM MUST BE KEPT INDEFINITELY AND MADE AVAILABLE TO DOTI UPON REQUEST

PERMEABLE PAVEMENT SYSTEM (PPS)
MAINTENANCE FORM

Subdivision/Business Name:	_____		Completion Date: _____
Subdivision/Business Address:	_____		Contact Name: _____
Maintenance Category: (check one)	☐ Routine	☐ Restoration (Minor)	☐ Rehabilitation (Major)

MAINTENANCE ACTIVITIES PERFORMED

ROUTINE WORK

☐Regenerative air or pure vacuum sweeping
☐Trash/Debris Removal
☐Weed Control (thermal treatment or non-toxic herbicide)
☐Stain Removal

MINOR WORK

☐ Jet-Vac/Clearing Drains
- ☐ Inflows
- ☐Outlet Structure
- ☐Underdrain

☐ Joint Aggregate Refill

MAJOR WORK

☐Full or Partial Replacement
- ☐Full Area Replacement
- ☐Partial Area Replacement

☐ Structural Repairs
- ☐ Clean Outs
- ☐ Underdrain
- ☐ Barrier Walls

☐Structural Repairs
- ☐Clean Outs
- ☐Underdrain
- ☐Barrier Walls

☐Restorative Maintenance
- ☐Vacuum Sweeper
- ☐Hydro Scrubber

Other: _____

Estimated Total Manhours: _____

Equipment/Materials Used: _____

_____

Comments/Additional Info: _____

_____

THIS INSPECTION FORM MUST BE KEPT INDEFINITELY AND MADE AVAILABLE TO DOTI UPON REQUEST

APPENDIX C: PLAN SHEET AND DETAIL SHEET CHECKLISTS BY SCM TYPE

OPERATION AND MAINTENANCE PLANS
EXTENDED DETENTION BASIN (EDB)
CHECKLIST FOR REQUIRED ITEMS

COVER SHEET

- facility name, address/location, facility type, sheet index, standard notes, approvals, date of drawings

PLAN AND PROFILE SHEET

Plan view must include:

- Location and labels for all major features of EDB (inflow structure(s), forebay, micropool, trickle channel, access road, outlet work(s), spillway, maintenance access ramps, embankment, etc.)
- Location and label all access and easements pertaining to maintenance of facilities
- Contours
- Other utilities in vicinity of EDB
- Cross-reference to EDB Operation and Maintenance Details sheet
- Linework for right-of-way lines, lot lines, easements, and tracts
- Hatch indicating permanent water elevation in micropool

Profile view must include

- Location and labels for all major features of EDB (inflow structure(s), forebay, micropool, trickle channel, access road, outlet work(s), spillway, maintenance access ramps, embankment, etc.)
- Invert elevations at major features of EDB (inflow structure(s), forebay, micropool, outlet work(s))
- Permanent pool elevation of micropool
- Water quality water surface elevation
- Water surface elevation of all applicable storm events
- Label for upper and bottom stages for EDB

DETAIL SHEET

- Volume provided by the EDB forebay and micropool, including the WQCV
- WQCV drain time
- Seed Mix
- Total mow area including approximate mow boundaries on each side of the EDB
- Tables from Chapter 2 of the O&M Manual
    - Inspection and Maintenance Requirements at Specific EDB Features
    - Summary of Routine Maintenance Activities for an EDB
    - Summary of Minor Maintenance Activities for an EDB
    - Summary of Major Maintenance Activities for an EDB
- Water quality outlet structure detail
- Water quality plate detail
- Maintenance access road detail
- Trickle channel typical section
- Forebay edge detail (or cross section) which includes maximum allowed sediment depth in forebay
- Forebay release structure detail
- Spillway detail(s), including cutoff wall

INSPECTION AND MAINTENANCE FORMS

- Inspection Form from Appendix A
- Maintenance Form from Appendix B

ADDITIONAL DETAILS (if present)

- Landscape Plan
- Irrigation Plan
- Irrigation Details

OPERATION AND MAINTENANCE PLANS
GRASS SWALES/GRASS BUFFERS (GS/GB)
CHECKLIST FOR REQUIRED ITEMS

COVER SHEET

- facility name, address/location, facility type, sheet index, standard notes, approvals, date of drawings

PLAN SHEET

- Location of grass swale(s) and/or buffer(s)
- Contours
- Location and label all access and easements pertaining to maintenance of facilities
- Linework for right-of-way lines, lot lines, easements, and tracts
- Labels for streets adjacent to grass swale(s)/buffer(s)
- Linework for all storm sewer structures
- Cross-reference to Grass Swale/Buffer Operation and Maintenance Details sheet

DETAIL SHEET

- Tables from Chapter 3 of the O&M Manual:
  - Typical Inspection and Maintenance Requirements Matrix
  - Summary of Routine Maintenance Activities
  - Summary of Minor Maintenance Activities
  - Summary of Major Maintenance Activities
- Typical grass swale and/or buffer section including typical horizontal and vertical dimensions, sideslopes, type of fill/media materials, subgrade material, and underdrain (if applicable).
- Underdrain details (if applicable) including trench dimensions, perforated PVC dimensions, and trench fill material.

INSPECTION AND MAINTENANCE FORMS

- Inspection Form from Appendix A
- Maintenance Form from Appendix B

ADDITIONAL DETAILS (if present)

- Landscape Plan
- Irrigation Plan
- Irrigation Details

OPERATION AND MAINTENANCE PLANS
RAIN GARDEN (RG)
CHECKLIST FOR REQUIRED ITEMS

COVER SHEET

- facility name, address/location, facility type, sheet index, standard notes, approvals, date of drawings

PLAN SHEET

- Location and labels for all major rain garden features (inlet pipe, overflow outlet structure, outlet pipe, etc.)
- Location and label all access and easements pertaining to maintenance of facilities
- Linework for underdrains
- Linework for right-of-way lines, lot lines, easements, and tracts
- Contours
- Other utilities in vicinity of facility
- Cross reference to Rain Garden Operation and Maintenance Details sheet

DETAIL SHEET

- WQCV provided by the RG
- WQCV drain time
- Tables from Chapter 4 of the O&M Manual:
  - Inspection and Maintenance Requirements at Specific Features
  - Summary of Routine Maintenance Activities
  - Summary of Minor Maintenance Activities
  - Summary of Major Maintenance Activities
- Overflow outlet box detail/typical cross section
- Typical cross section (include label for depth of WQCV)
- Underdrain detail including labels for the depth and type of fill materials and diameter of perforated pipe
- Rundown cross section and details (if applicable).

INSPECTION AND MAINTENANCE FORMS

- Inspection Form from Appendix A
- Maintenance Form from Appendix B

ADDITIONAL DETAILS (if present)

- Landscape Plan
- Irrigation Plan
- Irrigation Details

OPERATION AND MAINTENANCE PLANS
SAND FILTER BASIN (SFB)
CHECKLIST FOR REQUIRED ITEMS

COVER SHEET

- facility name, address/location, facility type, sheet index, standard notes, approvals, date of drawings

PLAN SHEET

- Location and labels for all major features of SFB (inlet pipe, energy dissipation structures, maintenance access road, overflow outlet structure, outlet pipe, spillway, etc.)
- Location and label all access and easements pertaining to maintenance of facilities
- Linework for underdrains
- Linework for right-of-way lines, lot lines, easements, and tracts
- Contours
- Other utilities in vicinity of SFB
- Cross references to detail sheets

DETAIL SHEET

- WQCV provided by the SFB
- WQCV drain time
- Tables from Chapter 5 of the O&M Manual:
  - Inspection and Maintenance Requirements at Specific SFB Features
  - Summary of Routine Maintenance Activities for a SFB
  - Summary of Minor Maintenance Activities for a SFB
  - Summary of Major Maintenance Activities for a SF
- Overflow outlet box detail/typical section
- Typical SFB cross section (include label for depth of WQCV)
- Underdrain detail including labels for the depth and type of fill materials and diameter of perforated pipe

INSPECTION AND MAINTENANCE FORMS

- Inspection Form from Appendix A
- Maintenance Form from Appendix B

ADDITIONAL DETAILS (if present)

- Landscape Plan
- Irrigation Plan
- Irrigation Details

OPERATION AND MAINTENANCE PLANS
PERMEABLE PAVEMENT SYSTEM (PPS)
CHECKLIST FOR REQUIRED ITEMS

COVER SHEET

- facility name, address/location, facility type, sheet index, standard notes, approvals, date of drawings

PLAN SHEET

- Location and labels for all major features of PPS (paving system area, barrier walls, underdrains, clean outs, etc.)
- Location and label all access and easements pertaining to maintenance of facilities
- Linework for underdrains
- Linework for right-of-way lines, lot lines, easements, and tracts
- Contours
- Other utilities in vicinity of PPS
- Cross references to detail sheets

DETAIL SHEET

- Type of PPS utilized (concrete grid pavement, PICP, etc.)
- Manufactures information for any replacement
- Tables from Chapter 6 of the O&M Manual:
    - Inspection and Maintenance Requirements at Specific PPS Features
    - Summary of Routine Maintenance Activities for a PPS
    - Summary of Minor Maintenance Activities for a PPS
    - Summary of Major Maintenance Activities for a PPS
- Typical PPS cross section (include label for aggregate grading)
- Underdrain detail including labels for the depth and type of fill materials and diameter of perforated pipe

INSPECTION AND MAINTENANCE FORMS

- Inspection Form from Appendix A
- Maintenance Form from Appendix B

OPERATION AND MAINTENANCE PLANS
OTHER STORMWATER CONTROL MEASURES (SCM)
(E.G. WETLAND BASIN, GREEN ROOF, MANUFACTURED DEVICES)
CHECKLIST FOR REQUIRED ITEMS

COVER SHEET

- facility name, address/location, facility type, sheet index, standard notes, approvals, date of drawings

PLAN SHEET

- Location and labels for all major features of SCM (inlet pipe(s), overflow outlet structure, outlet pipe, etc.)
- Location and label all access and easements pertaining to maintenance of facilities
- Linework for right-of-way lines, lot lines, easements, and tracts
- Contours
- Other utilities in vicinity of SCM
- Cross references to detail sheets

DETAIL SHEET

- Details of major features of SCM (inlet pipe, overflow outlet structure, outlet pipe, control plate, etc.)
- Manufactures information for any replacement
- Manufactures information for inspection and maintenance
- Tables adapted from Chapters of the O&M Manual (if not included from a manufacturer must be developed individually):
    - Inspection and Maintenance Requirements at Specific SCM Features
    - Summary of Routine Maintenance Activities for a SCM
    - Summary of Minor Maintenance Activities for a SCM
    - Summary of Major Maintenance Activities for a SCM
- Typical SCM cross sections (if applicable)
- Water quality water surface elevation (if applicable)

INSPECTION AND MAINTENANCE FORMS

- Inspection Form (if not included from a manufacturer must be developed individually)
- Maintenance Form (if not included from a manufacturer must be developed individually)

ADDITIONAL DETAILS (if present)

- Landscape Plan
- Irrigation Plan
- Irrigation Detail