Operations, Maintenance, and Inspections for Post Construction BMPS Appendix

1.0 Overview of OMI for Post Construction BMPS Appendix

1.1 Introduction

This supplemental appendix for the iSWM Criteria manual is intended to be used as a reference for understanding the recommended operations, maintenance, and inspections practices for some of the most commonly used post construction stormwater management BMPs in the North Texas region. These practices are categorized within the following three areas each having similar frequencies and requiring similar levels of expertise and effort:

- Routine Maintenance: High frequency, regular maintenance activities that are generally lower cost and lower effort. These activities may or may not require specialized knowledge of the BMP's
- Restorative Maintenance: Low frequency maintenance activities that are generally higher cost and higher effort. These activities typically require specialized knowledge of the BMP's, require specialized equipment and staffing and have higher cost implications.
- Rehabilitative Maintenance: These activities are lower frequency events but are associated with risk of much higher costs associated with potential damages and costs.

1.2 Trash and Debris Management

Management of trash and debris collection and disposal is a substantial cost component that must be considered and will become even more important as permit requirements are likely to become more stringent. Establishing a baseline trash generation rate based on a volume per unit area basis is the first step in developing a sufficient plan and budget for this management activity. Many municipalities and other permit holders have already established detailed baseline trash generation rates based on factors that significantly affect trash generation including land use, population density, and economic profile. While many of these permit holders have expended significant capital to create models that estimate annual trash generation rates, others rely on benchmarking with existing studies to estimate reasonable trash generation rates per land use category for budgeting purposes. Establishment of baseline trash generation rates is also required to create a trash load reduction and monitoring plan that is imperative for tracking progress when required under certain TMDL related requirements associated with trash and debris management. There are many examples of baseline trash load and reduction plans publicly available that have established loading rates based on land use categories. One example of a plan created as a requirement for trash and debris management for a permit holder under TMDL requirements is available from San Bruno, California:
https://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/stormwater/MRP/02-2012/Counties/San_Mateo/San_Bruno.pdf

Planning for restorative and rehabilitative maintenance activities is best approached by establishing a baseline scenario for evaluation of potential damages and failures along with estimation of the costs associated with each. Once these baseline costs are evaluated the risk of occurrence must be considered. It is recommended that two levels of risk be considered (high frequency and low frequency) and an annualized net present value associated with each level of risk is established for the baseline. With this relatively simple analysis completed, an annualized average NPV for restorative and rehabilitative maintenance unit cost can be established for the overall jurisdiction for planning and budgeting purposes.

2.0 Dry Detention and Extended Dry Detention

2.1 Description

Dry Detention and Extended Detention Basins (EDBs) are some of the most common types of stormwater BMPs utilized today. Dry detention is typically a simple grassed area with embankments or a more compact depressed area created with structural walls in areas with limited open space that temporarily stores stormwater above ground and controls the release rate to the downstream conduit or stream. EDBs are an adaptation of a detention basin used for flood control, with the primary difference being the addition of forebays, micropools, and a slow release outlet design. Forebays are shallow and typically concrete lined storage areas located at the inflow point to the basin and are provided to facilitate sediment removal within a contained area prior to releasing into the pond. These forebays collect and briefly hold stormwater runoff resulting in a process called sedimentation, dropping sediment out of the stormwater. Forebays also provide for the capture of larger floatable debris for collection and disposal following storm events. The stormwater is then routed from the forebay into the concrete trickle channel and upper basin, the large grassy portion of the basin. The EDB uses a much smaller outlet that extends the emptying time of the more frequently occurring runoff events to facilitate pollutant removal. An EDB should have a small micropool just upstream of the outlet. This micropool is designed to hold a small amount of water to keep sediment and floatables from blocking the outlet orifices.

The micro-pools in EDBs can frequently accumulate sediment and debris. This material must be removed to maintain pond volume and proper function of the outlet structure. Additionally, trash and debris can accumulate after large events, or from illegal dumping. Over time, this material can accumulate and clog the EDB outlet works. Periodic trash and debris removal is necessary for proper operation of EDBs.

Stagnant water, resulting from improper maintenance/treatment of the EDB micro-pool can create a nuisance because mosquito larvae can be laid within the permanent pool. Also, aquatic vegetation that grows in shallow pools of water can decompose causing foul odors. To reduce these impacts, chemical/mechanical treatment of the micro-pool may be necessary.

Many problems concerning Dry Detention and Extended Dry Detention Basin BMPs can be avoided through applying routine maintenance activities. 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 numerous times during the year. It is ideal to ensure that completed inspection and maintenance forms shall are submitted for each inspection and maintenance activity, so that there are reliable records of maintenance activities.

Structural damage can occur at any time during the operational life of the facility. Structural damages that should be routinely inspected for include but are not limited to:

- Damage to forebay flow control and debris collection structures.
- Erosion along low flow pilot channel structures and damage to joints along concrete pilot channels.
- Damage to and erosion adjacent to outflow structures including weirs and risers on both upstream and downstream sides.
- Erosion of embankments upstream and downstream.
- Damage to structural energy dissipation controls at system outfalls.
- Failure of joints in outfall pipes from riser structures.
- Damage to trash racks and connections to riser structures.

2.2 Routine Maintenance Requirements

The majority of this work consists of scheduled mowings during the growing season and trash and debris pickups for stormwater management facilities conducted on a regular basis. 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 numerous times during the year. These items do not require prior correspondence with the City for privately maintained systems but do require that completed inspection and maintenance forms shall are submitted for each inspection and maintenance activity, so that there are reliable records of maintenance activities. These activities and the frequency of each should be detailed in the operations and maintenance plan for privately maintained systems or integrated into the overall plan for permittee operated and maintained systems.

O&M Practices	Frequency	Action
Trash/Debris Removal and Disposal	Twice annually and after significant rain events (should be done before mowing).	Removal of all trash and debris from the main detention area, forebays, micropools, and outfall structures.
Mowing	Monthly during growing season.	Manage excessive grass height/aesthetics. Mow grass height to 4"-6".
Outlet Works Cleaning	Twice annually minimum, as needed. After significant rain events.	Inspect for clogged outlet structures; ponding water above lowest outlet elevation and remove and dispose of debris/trash/sediment to allow proper outlet function.
Weed Control	As needed, based upon inspection.	Inspect for noxious weeds and unwanted vegetation. Can treat with herbicide or hand pull. Possibly consult local weed inspector.
Mosquito Treatment	As needed.	Inspect for standing water/mosquito habitat. Treat with EPA approved chemicals.
Algae Treatment	As needed.	Inspect for standing water/algal growth/green color. Treat with EPA approved chemicals.

2.3 Restorative Maintenance Requirements

This work consists of a variety of isolated or small-scale maintenance and work needed to address moderate operational problems. Most of this work can be completed by a small crew, with minor tools, and small equipment. These items generally do not require prior correspondence with the City for private systems but do require that completed inspection and maintenance forms are filed on-site for each inspection and maintenance activity so that there are reliable records of maintenance activities. It is recommended to include inspection of forebays, embankments, and outflow controls including upstream and downstream conditions during routine maintenance activities with more comprehensive inspections completed and documented during annual inspections.

2.4 Rehabilitative Maintenance Requirements

This work consists of large-scale maintenance and major improvements needed to address failures within the stormwater BMP. This work requires consultation with the appropriate staff at the city staff level for privately owned systems and may require an engineering design with construction plans to be prepared for review and approval by the city. This work may also require more specialized maintenance equipment, surveying, construction permits or assistance through private contractors and consultants. It is recommended that the municipality includes proactive inspection and reporting requirements within the approved operations and maintenance plan for the structure that will trigger notification of the municipality of the potential need for rehabilitative maintenance.

2.5 Program Budgeting Guidance

Establishing a reliable annual budget for maintenance of these BMPs should be a requirement for the development of an approved operations and maintenance plan for privately and publicly maintained systems. It can be time consuming to establish an annual budget for the maintenance of an entire system of these BMPs that are owned and operated by the permittee but it can be simplified by using established cost databases and applying unit costs for specific activities such as mowing or trash collection and disposal from other established maintenance activities within the permit holder's jurisdiction.

The recommended approach for establishing a system for projecting annual operations and maintenance costs for dry detention and extended dry detention BMPs is provided below:

1. Establish a comprehensive database of dry detention and extended dry detention systems within the managed jurisdiction that includes the following information:
    a. Geographic location of BMP and general description
    b. Drainage area serviced and description of managed area land use
    c. Estimated annual loading of trash and debris based on land use serviced
        i. This can be modeled or estimated using established simplified methodologies
    d. Age of BMP
    e. BMP size (surface area and volume)
    f. Description of forebay if applicable
    g. Outfall type and material (eg. concrete weir, corrugated riser with orifice, concrete box with weir, etc)
    h. Pilot channel type and material including length and size
    i. Description of outfall location (eg. closed pipe connection, open channel, major/minor creek, river, etc)
2. Establish a baseline menu of routine maintenance activities for dry detention basins and link to field units linked to data from the system such as:
    a. Routine Inspections
        i. Annual Frequency (each)
    b. Routine Maintenance Activities
        i. Annual Frequency (each)
        ii. Trash/Debris Removal and Disposal (weight based on annual loading/frequency)
        iii. Mowing (surface area, crew size)
        iv. Outlet Works Cleaning (each)
        v. Weed Control (surface area)
        vi. Mosquito Treatment (surface area)
        vii. Algae Control (surface area)
    c. Restorative Maintenance Activities
        i. Estimate Frequency (eg. every 5 years, every 10 years)
            1. Slope stabilization of embankments (% of surface area)
            2. Pilot channel repairs (% of pilot channel surface area)
            3. Outfall repairs (reference history of repair costs for similar structures and estimate unit cost for size of BMP)
    d. Rehabilitative Maintenance Activities
        i. Risk based estimate using a baseline BMP considering:
            1. Potential onsite and offsite damages due to failure
            2. Initial response costs
            3. Structural replacement costs

4. Risk of failure

Collection of inventory and establishment of projected costs for routine and restorative maintenance is a fairly straight forward process which can draw upon available inventory and cost data for the general activities that make up the maintenance program. Where inventory data is not available it is recommended that a system for collecting and managing the data for all new developments is prioritized. The data management system should then be updated with information about existing dry detention and extended dry detention systems located within the jurisdiction which could potentially require significant effort and expense and should also be considered when budgeting for the overall operations and maintenance plan. Please refer to Section 1.2 Trash and Debris Management for additional guidance for building a comprehensive strategy to address floatable debris and impacts to post construction BMPs.

3.0 Bioretention

3.1 Description

Bioretention is a common stormwater BMP that consists of a low-lying vegetated area underlain by a permeable media typically with an underdrain system when installed in low permeability native soils. A shallow surcharge zone exists above the bioretention basin for temporary storage of the water quality volume. During a storm, accumulated runoff ponds in the vegetated zone and gradually infiltrates into the underlying filter media, filling the void spaces of the sand. The underdrain gradually dewaters the filter media and discharges the runoff to a nearby channel, swale, or storm sewer. Bioretention BMPs provide filtering, absorption, and biological uptake of constituents in stormwater. Bioretention basins are a popular option because they allow the water quality volume to be provided on a site that has limited open area available for stormwater management. Bioretention is often installed to provide a landscaping amenity.

The underdrain system may consist of a layer of geotextile fabric, gravel storage area and perforated PVC pipes. Underdrain systems vary with design but similar maintenance programs for similar elements of the system should be anticipated. There should be a minimum amount of maintenance required on the underdrain system if there is proper maintenance of the landscape areas and filter media. Generally, the only maintenance performed on the underdrain system is routine flushing via cleanout appurtenances.

The embankments of bioretention basins are one of the most visible parts of this BMP, therefore aesthetics is important. Adequate and properly maintained vegetation enhance the overall appearance of the bioretention basin. Stabilized vegetation can reduce the potential for erosion and subsequent sediment transport into the filter media, thereby reducing the need for more costly maintenance. Inadequate vegetative cover may result in erosion of the embankments. Erosion that occurs on the embankments and other areas draining to the BMP can cause clogging of the filter media.

Common problems associated with bioretention can be avoided with routine maintenance activities. The majority of this work consists of scheduled mowings, trash and debris pickups and general landscape care for the bioretention basin. It also includes activities such as weed control and mulch redistribution. These activities normally should be performed numerous times during the year. It is ideal to ensure that completed inspection and maintenance forms are completed and filed for each inspection and maintenance activity.

Structural damage can occur at any time during the operational life of the facility. Structural damages that should be routinely inspected for include but are not limited to:

- Damage to outflow control structures.
- Erosion at primary discharge outfalls into the bioretention system.
- Joint failures in underdrain pipes due to expansion and contraction of underlying soils.
- Clogging of underdrain systems due to excessive sedimentation into system.

3.2 Routine Maintenance Requirements

Maintenance of bioretention systems will be more intensive during the first year of operation than should be expected for the years that follow. During the first six months of operation it is important to plan to inspect systems after each significant rainfall over ½". Plan for spot reseeding to address bare and eroding areas and ensure that areas draining to the system have been stabilized with adequate vegetation. Routine watering of the plant material during the establishment period as recommended by a qualified landscape architect is very important during the first several months of operation and during the first growing season. These activities normally will be performed numerous times during the year. These items do not require prior correspondence with the City for privately maintained systems but do require that completed inspection and maintenance forms shall are submitted for each inspection and maintenance activity, so that there are reliable records of maintenance activities. These activities and the frequency of each should be detailed in the operations and maintenance plan for privately maintained systems or integrated into the overall plan for permittee operated and maintained systems.

O&M Practices	Frequency	Action
Trash/Debris Removal	Twice annually (should be done before mowing).	Remove and dispose of trash and debris
Mowing	Twice annually.	Looking for excessive grass height/aesthetics. Aim to maintain 2"-4" grass height.
Overflow Outlet Works Cleaning	Twice annually minimum, as needed. After significant rain events > ½".	Looking for clogged outlet structure; ponding water above outlet elevation and remove and dispose of debris/trash/sediment to allow proper outlet function.
Mulch removal and replacement	Once every 2-3 years.	Mulch accumulation can reduce available water storage volume. Removal of mulch increases the infiltration rate.
Weed Control and Rake Mulch	As needed, based upon inspection. At least twice during the growing season.	Looking for noxious weeds and unwanted vegetation. Can treat with herbicide or hand pull. Possibly consult local weed inspector.
Pruning	1-2 times per year.	Looking for standing water/mosquito habitat. Treat with EPA approved chemicals.
Watering	Once per week for first 2 months and then as recommended by landscape architect.	Newly planted plants need suitable water quantities.
Fertilization	As recommended by landscape architect.	Newly planted plants need necessary nutrients for proper growth.
Remove and Replace Dead Plants	As needed.	More than 10% of plants may die, survival rates increase over time.

3.3 Restorative Maintenance Requirements

This work consists of a variety of isolated or small-scale maintenance and work needed to address operational problems. Most of this work can be completed by a small crew, with minor tools, and small equipment. Restorative maintenance of bioretention basins that should be anticipated over the operational life of the system may include full replacement of filter media and repair/replacement of underdrain system appurtenances, pipes, joints, cleanouts, and outfalls. Restorative maintenance needs can be greatly reduced when routine maintenance programs are in place.

3.4 Rehabilitative Maintenance Requirements

This work consists of large-scale maintenance and major improvements needed to address failures within the stormwater BMP. This work requires consultation with the appropriate staff at the city staff level for privately owned systems and may require an engineering design with construction plans to be prepared for review and approval by the city. This work may also require more specialized maintenance equipment, surveying, construction permits or assistance through private contractors and consultants. It is recommended that the municipality includes proactive inspection and reporting requirements within the approved operations and maintenance plan for the structure that will trigger notification of the municipality of the potential need for rehabilitative maintenance. Bioretention basins typically manage runoff from drainage areas less than 2 acres and system failure will not likely create significant risk of downstream or onsite damages. Large scale maintenance and major improvements to bioretention systems that are routinely maintained are rarely required.

3.5 Program Budgeting Guidance

Establishing a reliable annual budget for maintenance of these BMPs should be a requirement for the development of an approved operations and maintenance plan for privately maintained systems. It can be time consuming to establish an annual budget for the maintenance of an entire system of these BMPs that are owned and operated by the permittee but it can be simplified by using established cost databases and applying unit costs for specific activities such as mowing or trash collection and disposal from other established maintenance activities within the permit holder's jurisdiction.

The recommended approach for establishing a system for projecting annual operations and maintenance costs for dry detention and extended dry detention BMPs is provided below:

1. Establish a comprehensive database of bioretention systems within the managed jurisdiction that includes the following information:
    a. Geographic location of BMP and general description
    b. Drainage area serviced and description of managed area land use
    c. Estimated annual loading of trash and debris based on land use serviced
        i. This can be modeled or estimated using established simplified methodologies
        ii. Require that trash and debris removal and disposal is part of any approved private system maintenance agreement
    d. Age of BMP
    e. BMP size (surface area and volume)
    f. Description of forebay if applicable
    g. Underdrain and overflow system type
    h. Description of outfall location of underdrain (eg. closed pipe connection, open channel, major/minor creek, river, etc)
2. Establish a baseline menu of routine maintenance activities for bioretention systems and link to field units linked to data from the system such as:
    a. Routine Inspections
        i. Annual Frequency (each)
    b. Routine Maintenance Activities
        i. Annual Frequency (each)

    ii. Trash/Debris Removal and Disposal (weight based on annual loading/frequency)
    iii. Mowing (surface area, crew size)
    iv. Mulch redistribution (surface area)
    v. Vegetation management (planted surface area)
    vi. Outlet Works Cleaning (each)
    vii. Weed/Invasives Control (surface area)
c. Restorative Maintenance Activities
    i. Estimate Frequency (eg. every 5 years, every 10 years)
        1. Mulch replacement (surface area)
        2. Filter media replacement (volume)
        3. Underdrain/Pipeworks (assume percentage of total system replacement at time of filter media replacement)
d. Rehabilitative Maintenance Activities
    i. Risk based estimate using a baseline BMP considering:
        1. Potential onsite and offsite damages due to failure
        2. Initial response costs
        3. Structural replacement costs
        4. Risk of failure

Collection of inventory and establishment of projected costs for routine and restorative maintenance is a fairly straight forward process which can draw upon available inventory and cost data for the general activities that make up the maintenance program. Where inventory data is not available it is recommended that a system for collecting and managing the data for all new developments is prioritized. The data management system should then be updated with information about existing dry detention and extended dry detention systems located within the jurisdiction which could potentially require significant effort and expense and should also be considered when budgeting for the overall operations and maintenance plan. Please refer to Section 1.2 Trash and Debris Management for additional guidance for building a comprehensive strategy to address floatable debris and impacts to post construction BMPs.

Planning for restorative and rehabilitative maintenance activities is best approached by establishing a baseline scenario for evaluation of potential damages and failures along with estimation of the costs associated with each. Once these baseline costs are evaluated the risk of occurrence must be considered. It is recommended that two levels of risk be considered (high frequency and low frequency) and an annualized net present value associated with each level of risk is established for the baseline. With this relatively simple analysis completed, an annualized average NPV for restorative and rehabilitative maintenance unit cost can be established for the overall jurisdiction for planning and budgeting purposes.

4.0 Vegetated Swales

4.1 Description

Vegetated Swales are common types of stormwater BMPs that promote filtration, infiltration, and settling of stormwater runoff. Vegetated swales are typically installed with low-pitched side slopes that collect and convey runoff. Low-pitched side slopes facilitate routine maintenance such as mowing or trimming and also reduce erosive velocities of runoff conveyed by the swale. 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. Vegetated Swales are used in open space and landscaped areas to collect and convey overland flows, and it can be used as an alternative to curb and gutter to collect and convey street flows. Some Vegetated Swales are designed with underdrain systems to provide for treatment of the water quality volume of runoff in addition to treatment provided by existing soils, surface vegetation, and root systems.

Vegetated Swales require general maintenance of the turf grass or native grasses (preferred) and repair of any rill or gully development. The bottom and side slopes of vegetated swales should be maintained with dense vegetative cover, and it should not be eroded or bare. Inspection over the first few years will help to determine if any problems are developing.

The purpose of the vegetated swale is to slow down flow, allow sedimentation to occur, and allow sufficient time for nutrient uptake by the plant material for water quality improvement. To prevent a loss in performance of the swale, sediment that accumulates must be removed on a timely basis. Vegetated 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 which contribute to the damaged grass cover, including lack of adequate irrigation, traces of pedestrian or vehicular traffic, uncontrolled weeds etc., should be identified and remedied.

Vegetated 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.

Some vegetated swales that have a flatter slope or soils which do not allow adequate percolation or are in areas with a continuous base flow may have been installed with an underdrain system. Underdrains typically consist of a layer of geotextile fabric, gravel storage area and perforated PVC pipe. The geotextile fabric is utilized to prevent the filter material from entering the underdrain system. The gravel storage area allows for storage of treated stormwater runoff prior to the discharge of the runoff through the perforated PVC pipe or other outflow control appurtenance.

Structural damage can occur at any time during the operational life of the facility. Structural damages that should be routinely inspected for include but are not limited to:

- Rill erosion along flowline and side slopes of the swale.
- Washout of check dams.
- Erosion upstream and downstream of check dams.

4.2 Routine Maintenance Requirements

Routine maintenance of vegetated swales can typically be integrated easily with standard landscape maintenance programs. Routine maintenance activities mostly consist of routine mowing, trash and debris removal, and reestablishment of vegetation as necessary. These items do not require prior correspondence with the City but do require that completed inspection and maintenance forms shall are submitted for each inspection and maintenance activity, so that there are reliable records of maintenance activities. These items do not require prior correspondence with the City for privately maintained systems but do require that completed inspection and maintenance forms shall are submitted for each inspection and maintenance activity, so that there are reliable records of maintenance activities. These activities and the frequency of each should be detailed in the operations and maintenance plan for privately maintained systems or integrated into the overall plan for permittee operated and maintained systems.

O&M Practices	Frequency	Action
Trash/Debris Removal	Twice annually (should be done before mowing).	remove and dispose of trash and debris.
Mowing	Routine - Twice annually.	Maintain grass height of 2" - 4" (native grasses can be 4" - 6"). Inspect for excessive grass heights or poor aesthetics.
Irrigation (Automatic)	Three times annually.	Inspect for areas of insufficient or excess watering; broken or missing parts. During the Spring season - maintenance on start up system; test for even coverage and correct timer settings. Summer season - test for even coverage and correct timer settings. Fall - Drain and winterize system. (follow irrigation regulations)
Irrigation (Not Automatic)	As needed to maintain healthy grass.	Inspect for areas of insufficient or excess watering. (follow irrigation regulations)
Weed Control	As needed, based upon inspection.	Inspect for noxious weeds and unwanted vegetation. Can treat with herbicide or hand pull. Possibly consult local weed inspector.
Mosquito Treatment	1-2 times per year. As needed, based on inspections.	Inspect for standing water/mosquito habitat. Perform maintenance to eliminate standing water; treat with EPA approved chemicals.
Level Spreader (Grass Buffer only)	As needed, based on inspections.	Inspect for evidence of uneven flow/localized erosion. Identify the cause of erosion and repair, fill, or revegetate areas of erosion.
Rodent Damage	As needed, based on inspections,	Inspect for holes, small piles of dirt, raised burrows. Evaluate damage; contact parks department or division of wildlife for guidance.

4.3 Restorative Maintenance Requirements

This work consists of a variety of isolated or small-scale maintenance and work needed to address operational problems. Most of this work can be completed by a small crew, with minor tools, and small equipment. These items do not require prior correspondence with the City but do require that completed inspection and maintenance forms shall are submitted for each inspection and maintenance activity, so that there are reliable records of maintenance activities. Expected restorative maintenance activities include small area regrading, stabilization of minor erosion of banks and flowlines, and repair/replacement of minor check dam, flow control and energy dissipating structures.

4.4 Rehabilitative Maintenance Requirements

This work consists of large-scale maintenance and major improvements needed to address failures within the stormwater BMP. This work requires consultation with City/Stormwater Team and may require an engineering design with construction plans to be prepared for review and approval by the City. This work may also require more specialized maintenance equipment, surveying, construction permits or assistance through private contractors and consultants. These items require prior correspondence with the City and require that completed maintenance forms be submitted to City with the annual report forms. Rehabilitative maintenance activities include major re-grading of banks and flowlines, major erosion stabilization due to threatened adjacent structures, and major flow control and energy dissipating structure repairs and replacement.

4.5 Program Budgeting Guidance

Establishing a reliable annual budget for maintenance of these BMPs should be a requirement for the development of an approved operations and maintenance plan for privately maintained systems. It can be time consuming to establish an annual budget for the maintenance of an entire system of these BMPs that are owned and operated by the permittee but it can be simplified by using established cost databases and applying unit costs for specific activities such as mowing or trash collection and disposal from other established maintenance activities within the permit holder's jurisdiction.

The recommended approach for establishing a system for projecting annual operations and maintenance costs for vegetated swale BMPs is provided below:

1. Establish a comprehensive database of vegetated swale systems within the managed jurisdiction that includes the following information:
    a. Geographic location of BMP and general description
    b. Drainage area serviced and description of managed area land use
    c. Estimated annual loading of trash and debris based on land use serviced
        i. This can be modeled or estimated using established simplified methodologies
        ii. Require that trash and debris removal and disposal is part of any approved private system maintenance agreement
    d. Age of BMP
    e. BMP size (surface area and volume)
    f. Description of outfall type and location.
    g. Description and number of check dams, flow control, and energy dissipating structures including identification code and location
    h. Underdrain and/or aggregate storage description
    i. Description of outfall location of underdrain (eg. closed pipe connection, open channel, major/minor creek, river, etc)
2. Establish a baseline menu of routine maintenance activities for bioretention systems and link to field units linked to data from the system such as:
    a. Routine Inspections
        i. Monthly Frequency (each)
    b. Routine Maintenance Activities
        i. Annual Frequency (each)
        ii. Trash/Debris Removal and Disposal (weight based on annual loading/frequency)
        iii. Mowing (surface area, crew size)
        iv. Flow control and energy dissipation cleaning and repairs (each)
        v. Weed Control (surface area)
    c. Restorative Maintenance Activities

i. Estimate Frequency (eg. every 5 years, every 10 years)
   1. Slope stabilization of embankments (% of surface area)
   2. Flow line repairs and stabilization (% of pilot channel surface area)
   3. Outfall repairs (reference history of repair costs for similar structures and estimate unit cost for size of BMP)

d. Rehabilitative Maintenance Activities
   i. Risk based estimate using a baseline BMP considering:
      1. Potential offsite damages due to failure
      2. Initial response costs
      3. Structural replacement costs
      4. Risk of failure

Collection of inventory and establishment of projected costs for routine and restorative maintenance is a fairly straight forward process which can draw upon available inventory and cost data for the general activities that make up the maintenance program. Where inventory data is not available it is recommended that a system for collecting and managing the data for all new developments is prioritized. The data management system should then be updated with information about existing vegetated swale systems located within the jurisdiction which could potentially require significant effort and expense and should also be considered when budgeting for the overall operations and maintenance plan. Please refer to Section 1.2 Trash and Debris Management for additional guidance for building a comprehensive strategy to address floatable debris and impacts to post construction BMPs.

Planning for restorative and rehabilitative maintenance activities is best approached by establishing a baseline scenario for evaluation of potential damages and failures along with estimation of the costs associated with each. Once these baseline costs are evaluated the risk of occurrence must be considered. It is recommended that two levels of risk be considered (high frequency and low frequency) and an annualized net present value associated with each level of risk is established for the baseline. With this relatively simple analysis completed, an annualized average NPV for restorative and rehabilitative maintenance unit cost can be established for the overall jurisdiction for planning and budgeting purposes.

5.0 Permeable Pavements

5.1 Description

Permeable pavement functions like traditional concrete or asphalt surfaces but allows water to infiltrate through the pavement surface. Common permeable pavement systems that have been used in North Texas include: paver blocks, turf pavers, porous asphalt, porous concrete, and expanded shale mix. In soils that are conducive to infiltration, permeable pavements allow water to soak into the ground, replenishing groundwater. Most soils in North Texas have very low permeability and are highly expansive. Installation of permeable pavement systems in expansive clay soils will require the installation of engineered underdrain and storage layers. These layers are typically composite systems consisting of bridging layer materials to manage infiltrating sediments and coarser aggregate based layers that maximize porosity and storage capacity while also providing structural support. Permeable pavement works best in areas of pedestrian traffic or low automobile traffic such as sidewalks and parking lots.

The primary challenge of maintaining permeable paving systems is the control of sediment deposition and infiltration into the system. Fine sediment can infiltrate into the underdrain layers and build up overtime reducing the storage capacity of the composite layers. Coarser sediment tends to accumulate in the top layers of the system and in between joints of interlocking pavers. Permeable pavement systems should not be located where overland flow from landscaped areas are likely to transport and deposit sediments into the system. Sediment and debris deposited onto the systems from pedestrian and vehicular traffic is easier to manage and maintain and sediment deposited from the air is much finer and generally will not significantly reduce system performance.

Periodic vacuuming and low-pressure washing should be used to clear out voids and extend the paver's functional life. In commercial installations, conventional street sweepers should be used with vacuums, brushes and water ideally four times a year and at least 1 time a year, but the actual required frequency will be determined by local conditions. In residential installations, vacuuming can be performed by loosening sediment with a pick if necessary and vacuuming with a shop-vac type of product. Additional aggregate filler material may also need to be added after cleaning. Recent maintenance with all of these systems, snow removal operations should be carefully considered, and the use of sand or ash should be avoided as it may cause clogging of the pavement.

Structural damage can occur at any time during the operational life of permeable pavement systems. Structural damages that should be routinely inspected for include but are not limited to:

- Cracked or broken pavers.
- Cracks in continuous surface system such as porous concretes and asphalt which are typically associated with subgrade preparation and expansive soils
- Shifting of pavers due to loading, subgrade issues, and loss of aggregates between pavers

5.2 Routine Maintenance Requirements

Permeable pavements must be inspected to ensure that it operates in good working condition and in accordance with the approved design and specifications. Items in need of repair must be immediately addressed. Regular visual inspections should be conducted monthly to ensure that the system is clean of debris, adequately infiltrates water, and is clean of sediments and settleable solids.

O&M Practices	Frequency	Action
Street sweeping and vacuuming	1 - 2 times annually or as warranted per	Vacuum surface, adjust vacuuming schedule per sediment loading and/or any sand deposits from

	inspection results (typically spring/fall).	winter.
Replenish Aggregate	As needed, based upon inspection and post vacuuming.	Replenish aggregate if more than 1/2 inch from chamfer bottoms on paver surfaces.
Oil, grease and organics cleaning	As needed, based upon inspection	
Inspect and repair pavers	As needed, based upon inspection.	Repair all paver surface deformations exceeding 1/2 inch.
Repair pavers	As needed, based upon inspection.	Repair pavers offset by more than 1/4 inch above/below adjacent units or curbs, inlets, etc.
Replace cracked paver units	As needed, based upon inspection.	Replace cracked paver units impairing surface structural integrity.
Check drains outfalls	Occasionally during storm events.	Check drains outfalls for free flow of water and outflow from observation well after a major storm event.
Remove snow	Winter: as needed, based on inspections.	Winter: Remove snow with standard plow/snow blowing equipment; monitor ice on surface for reduced salt use than typically used on impervious pavements.

5.3 Restorative Maintenance Requirements

This work consists of a variety of isolated or small-scale maintenance and work needed to address operational problems. Most of this work can be completed by a small crew, with minor tools, and small equipment. These items do not require prior correspondence with the City but do require that completed inspection and maintenance forms shall are submitted for each inspection and maintenance activity, so that there are reliable records of maintenance activities. Restorative maintenance activities include: replacement of damaged pavers or small sections of problematic continuous surface pavements, management and stabilization of upland flow areas, and installation of oil and grease separating systems to address problematic accumulation from specific upland sources.

5.4 Rehabilitative Maintenance Requirements

This work consists of large-scale maintenance and major improvements needed to address failures within the stormwater BMP. This work requires consultation with City/Stormwater Team and may require an engineering design with construction plans to be prepared for review and approval by the City. This work may also require more specialized maintenance equipment, surveying, construction permits or assistance through private contractors and consultants. These items require prior correspondence with the City and require that completed maintenance forms be submitted to City with the annual report forms. Rehabilitative maintenance generally refers to replacement of large portions of the permeable pavement system including underdrain layers and appurtenances to address subgrade conditions or excessive sediment and organic material accumulation that severely limits infiltration into and dewatering from the system.

5.5 Program Budgeting Guidance

Establishing a reliable annual budget for maintenance of these BMPs should be a requirement for the development of an approved operations and maintenance plan for privately maintained systems. It can be time consuming to establish an annual budget for the maintenance of an entire system of these BMPs that are owned and operated by the permittee but it can be simplified by using established cost databases and applying unit costs for specific activities such as mowing or trash collection and disposal from other established maintenance activities within the permit holder's jurisdiction.

The recommended approach for establishing a system for projecting annual operations and maintenance costs for dry detention and extended dry detention BMPs is provided below:

1. Establish a comprehensive database of dry detention and extended dry detention systems within the managed jurisdiction that includes the following information:
    a. Geographic location of BMP and general description
    b. Drainage area serviced and description of managed area land use
    c. Estimated annual loading of trash and debris based on land use serviced
        i. This can be modeled or estimated using established simplified methodologies
    d. Age of BMP
    e. BMP size (surface area and volume)
    f. Description of service activities that may impact BMP performance (eg. parking, trash containers, roof drainage, food sales/distribution, overland flow from landscaped areas)
    g. Description of subgrade and drainage layer
    h. Outfall type and material (underdrain outfall to daylight or pipe)
    i. Description and coordinates of outfall location (eg. closed pipe connection, open channel, major/minor creek, river, etc)
2. Establish a baseline menu of routine maintenance activities for dry detention basins and link to field units linked to data from the system such as:
    a. Routine Inspections
        i. Monthly Frequency (each)
    b. Routine Maintenance Activities
        i. Annual Frequency (each)
        ii. Sediment, Debris, and Organics Removal and Disposal (weight based on annual loading/frequency)
        iii. Vacuuming (surface area, crew size)
        iv. Outlet Works Cleaning (each)
        v. Surface Adjustments/Replacements for Pavers (surface area)
        vi. Surface Aggregate Replenishment
    c. Restorative Maintenance Activities
        i. Estimate Frequency (eg. every 5 years, every 10 years)
            1. Surface Repairs/Replacements (% of surface area)
            2. Surface Aggregate Replacement (% of pilot channel surface area)
            3. Underdrain Cleanout and Outfall Repairs (reference history of repair costs for similar structures and estimate unit cost for size of BMP)
    d. Rehabilitative Maintenance Activities
        i. Risk based estimate using a baseline BMP considering:
            1. Potential offsite damages due to failure
            2. Initial response costs
            3. Structural replacement costs
            4. Risk of failure

Collection of inventory and establishment of projected costs for routine and restorative maintenance is a fairly straight forward process which can draw upon available inventory and cost data for the general activities that make up the maintenance program. Where inventory data is not available it is recommended that a system for collecting and managing the data for all new developments is prioritized.

The data management system should then be updated with information about existing dry detention and extended dry detention systems located within the jurisdiction which could potentially require significant effort and expense and should also be considered when budgeting for the overall operations and maintenance plan. Please refer to Section 1.2 Trash and Debris Management for additional guidance for building a comprehensive strategy to address floatable debris and impacts to post construction BMPs.

Planning for restorative and rehabilitative maintenance activities is best approached by establishing a baseline scenario for evaluation of potential damages and failures along with estimation of the costs associated with each. Once these baseline costs are evaluated the risk of occurrence must be considered. It is recommended that two levels of risk be considered (high frequency and low frequency) and an annualized net present value associated with each level of risk is established for the baseline. With this relatively simple analysis completed, an annualized average NPV for restorative and rehabilitative maintenance unit cost can be established for the overall jurisdiction for planning and budgeting purposes.

6.0 Program and Asset Management Tools

6.1 Description

Management of post construction BMPs should be carefully integrated into the MS4 permit holder's overall stormwater system program. Post construction BMPS should be considered as assets within the stormwater system and should be inventoried and tracked in the same way that common stormwater system elements such as pipes, inlets, and manholes. A robust asset management program for stormwater systems including post construction BMPs helps address and reduce the amount and frequency of unexpected, expensive, and reactive repairs to the system while also enhancing overall system performance. Developing an asset management program for stormwater systems can be challenging for utilities that manage older systems due to undocumented system information. Because post construction BMPS are relatively new systems that are typically located at the surface level they can be valuable building blocks for an overall stormwater asset management program. The major critical steps and factors to be considered while planning and implementing a stormwater asset program are summarized in the EPA Document "Asset Management Programs for Stormwater and Wastewater Systems: Overcoming Barriers to Development and Implementation, March 6, 2017) as:

1. Identifying overall asset management program scope
2. Establishing the desired level of service
3. Choosing and implementing asset management software
4. Cataloging assets
5. Scoring assets
6. Continuing asset management program development.

The referenced document is a valuable resource for communities considering development of or improving an existing stormwater asset management program. It is available from the EPA at this link: https://www.epa.gov/sites/production/files/2018-01/documents/overcoming-barriers-to-development-and-implementation-of-asset-management-plans.pdf

6.2 Inspection Data Collection and Management

The efficiency and completeness of collection and management of inspection data for stormwater systems will determine the effectiveness of the stormwater asset management program. The development of standardized data collection forms, preferably web based, should be created for each type of post construction BMP implemented throughout the community. These forms should be identical for both privately and publicly owned systems to facilitate consolidation of inspection results into a centralized asset management program database. Integration of the inspection data collection and management system into a community's stormwater utility program is recommended to improve overall system efficiencies and allow for asset management program improvements and adjustments that may be required over time.

6.3 Inventory Data Management, System Performance Monitoring, and Maintenance Management

Recommendations for inventory data that should be collected for post construction BMPS are provided in sections 2 through 5 of this document under the program budgeting guidance. The recommended data to be collected is best managed using a geographic information system (GIS) to allow for helpful spatial analysis of system ages, volume managed, inspection and maintenance tracking, and watershed specific distribution. The inventory data can also be managed using spreadsheet based software if GIS and/or asset management software is not being used. Tracking the recommended data within a spreadsheet will facilitate the transfer and use of data in more robust systems in the future.

Integration of inventory data management into stormwater utility management systems can facilitate tracking and scheduling of routine inspections and maintenance based on recommended schedules for specific post construction BMPS. The integrated system allows for notification of system owners of required/recommended maintenance activities linked to the drainage charge billing system. Linking these notifications to standardized inspection and maintenance forms can catalyze proactive management of stormwater management systems and can potentially be linked to incentives to reduce drainage charges. Ultimately, a robust asset management program will enhance system performance, facilitate permit reporting with quantified results, and ultimately reduce unit costs associated with ongoing operations and maintenance.