United States
Environmental Protection
Agency

# Operation and Maintenance of Green Infrastructure Receiving Runoff from Roads and Parking Lots

## Technical Memorandum

**September 2016**

Great Lakes RESTORATION

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**Operation and maintenance is a challenge that when not addressed properly can lead to failure of green infrastructure and high costs associated with restoration. This memorandum addresses common operation and maintenance questions and provides recommendations for evaluating the need and providing maintenance for green infrastructure, specifically bioretention and bioswales, that serves highly impervious roadways and parking lots.**

Green infrastructure (GI) involves the use of vegetation and porous materials to restore some of the natural processes required to treat stormwater runoff at the source. GI tends to have vegetation, be relatively small and distributed, and contain fewer structural components than more conventional stormwater practices. GI requires routine operation and maintenance to uphold the desired performance and aesthetic quality as well as ensure performance throughout its expected lifetime.

Runoff from roads and parking lots often contains high nutrient loads compared to other impervious surfaces and is also a source of sediment, heavy metals, and organic compounds (e.g., polycyclic aromatic hydrocarbons, or PAHs). Concentrated flow from roads and parking lots causes stream degradation, flooding, and other hydrologic impacts. These conditions emphasize the importance of maintaining GI receiving runoff from these surfaces.

Stormwater managers have been installing vegetated infiltration practices such as bioswales and bioretention for decades now. While some studies exist, limited research is available on how operation and maintenance affects performance of these practices. Key issues and challenges include:

- How to determine if maintenance is needed
- Inspection frequency
- Triggers for maintenance
- Disposal of materials

The purpose of this memorandum is to illustrate what is known about each challenge listed above and provide operation and maintenance recommendations. All stormwater control measures (SCMs)—not just GI—need operation and maintenance. If not properly operated and maintained, performance can decline, eventually leading to failure. The following series of photos provides several examples of failure due to insufficient operation and maintenance.


*Tetra Tech*

**Bioswale treating runoff from urban parking lot (Cleveland, OH).**




*All photos: Bill Lord, NCSU BAE Stormwater Engineering Group*

**Examples of failing bioretention and swales due to insufficient operation and maintenance.**
**A) Sediment has filled entire basin and is level with the drop inlet**
**B) Presence of cattails indicate wetland conditions and failure to drain properly**
**C) Use of non-selective herbicide led to swale erosion**

**Regulated Municipal Separate Storm Sewer Systems (MS4s)** are required to address maintenance as part of their Storm Water Pollution Prevention Program, as described in two of the required minimum control measures:

- *Post-Construction Runoff Control Minimum Control Measure*
  Ensure adequate long-term operation and maintenance of controls
- *Pollution Prevention/Good Housekeeping Minimum Control Measure*
  Develop and implement an operation and maintenance program with the ultimate goal of preventing or reducing pollutant runoff from municipal operations into the storm sewer system

## Performance

Inadequate operation and maintenance of vegetated GI can affect performance in a number of ways:

- When vegetation dies and is not replaced, bioretention, bioswales, and other practices lose the pollutant uptake and evapotranspiration benefits provided by the plants.
- Mulch layers provide some direct pollutant removal, help retain soil moisture for plants, and protect the soil media from clogging by fine sediment particles. Mulch is an organic material that decomposes over time and therefore requires periodic replacement.
- Clogged soil media prevents infiltration and can lead to a complete failure of a practice, requiring replacement of the media.

It is important to consider that pollutants removed from stormwater are typically retained in the bioretention system; therefore, their ultimate fate remains a concern. Triggers for replacing soil media, as well as thresholds for reuse versus disposal, are discussed in later sections.

*Tetra Tech*

**Lack of vegetation in bioretention area (Beachwood, OH)**

While there are several examples of how operation and maintenance can affect performance, the literature currently lacks comprehensive research on how performance relates to operation and maintenance. Blecken et al. (2015) state that future research should focus on how operation and maintenance affects the long-term function of SCMs. While some practices have been operating for at least 20 years, they have not been studied to determine how performance changed over time or how operation and maintenance has affected performance. Lessons learned from this research could be applied to new installations in the future and prevent further loss of function. In general, if a practice is clogged or vegetation lost, performance is expected to deteriorate.

### Benefits of Restorative Maintenance

Brown and Hunt (2012) studied clogged bioretention cells that drained an asphalt parking lot and had become clogged by fines from the gravel layer during parking lot construction. Beginning one month after construction, the cells were monitored for hydrology and water quality. After the first year, the monitoring indicated that the cells were both clogged and undersized. To increase surface storage and repair the infiltration function, the side slopes were steepened and the top 75 mm of soil media were removed. The cells were monitored for a year following this repair. Storage, infiltration rate, and nutrient and sediment removal were compared between the pre-repair and post-repair timeframes. Brown and Hunt (2012) found that the repair substantially decreased overflow events and allowed a greater volume of stormwater treatment. Peak outflow rates decreased, and the duration of higher flow rates was reduced by factors of 2 to 3. Also during post-repair, pollutant load reductions improved for most constituents measured except ortho-phosphorus for all cells and total phosphorus for some of the cells. The study results emphasize both the importance of inspection and maintenance as well as correct design and installation.

## Aesthetics

GI is often used to enhance the aesthetics of a public space. The value of GI in the beautification of a site is often discussed as a reason to choose GI over other more conventional approaches. As with any landscaped feature, GI requires maintenance to uphold its intended appearance, and more frequent maintenance is often required than for performance alone. Common aesthetic problems include overgrown or undergrown vegetation, trash accumulation, and nuisance vegetation (e.g., invasive species).

The aesthetics of a site should be maintained with performance goals in mind. Establishing specific goals and objectives for the "look" of a practice can help in planning for the correct frequency of maintenance. The public may prefer a more manicured look at some sites while elsewhere a more natural look may be preferred. The public may also raise safety concerns with overgrown vegetation. Strategies to address these issues include setting measurable targets that trigger maintenance tasks and training operation and maintenance staff on invasive species identification.

Where vegetation is lacking or overgrown, investigation into the causes can sometimes point to more serious performance concerns. Mazer et al. (2001) found that excessive inundation in bioswales was limiting vegetation growth in King County, Washington bioswales. The cause of inundation was not specified; however, design and soils were both suggested as contributing factors to the performance issues. Among several design and operation and maintenance recommendations, the study recommended that bioswale managers minimize inundation during the dry season and ensure appropriate soil drainage and stability. In some cases, maintenance based on aesthetic goals may lead to excessive use of fertilizer, which negates the water quality benefits of the practice. The need for fertilizer can be avoided by selecting native plants or other species that are adapted to a variety of conditions.

## The Effect of Land Use

For bioswales and bioretention adjacent to paved areas, understanding the importance of operation and maintenance starts at the source. In many communities, most impervious cover is related to the transportation system. Material and pollutants accumulate on roadways and parking lots during dry weather conditions, forming a highly concentrated first flush of pollutants during rainfall events. Streets and parking lots are often among the land uses with the highest pollutant loads and concentrations.

Bioretention systems are stressful environments for plant growth due to periods of flooding and pollutant loading, followed by long dry periods. Certain plant species are more capable of thriving in these hydraulic and pollutant loading extremes than others and can help to minimize the amount of maintenance needed due to plant die off.

The major categories of pollutants in urban stormwater include metals, organic chemicals, pathogens, nutrients, biochemical oxygen demand, sediment, and salts. Once these pollutants are deposited onto road and parking surfaces, they are available for transport in runoff to receiving waters during storm events. The table on the next page summarizes common contaminants and sources of pollutants in roadway and parking lot runoff.

In a meta-analysis, Cave et al. (1994) listed highways among the higher polluting land uses for many sediment, nutrient, and heavy metal constituents. Metals loading (copper, lead, zinc, etc.) has been shown to increase with traffic and human activity occurring on streets or parking lots, especially for commercial, industrial, and high density residential land uses (Bannerman et al. 1993, Sanger et al. 1999, Stein et al. 2008).

A nationwide study by the US Federal Highway Administration found that event mean concentrations of pollutants in highway runoff were appreciably higher for sites with average daily traffic greater than 30,000 vehicles per day (Driscoll et al. 1990). Traffic above this threshold produced higher concentrations of total suspended solids, volatile suspended solids, total organic carbon, chemical oxygen demand, nitrate-nitrite, total Kjeldahl nitrogen, phosphate, copper, lead, and zinc (see table).

**Pollutant concentration in highway runoff (urban highways with average traffic more than 30,000 vehicles per day) (source: Driscoll et al. 1990)**

| Pollutant | 10% of Sites LESS Than | Median Site | Corrective Measure |
|---|---|---|---|
| | mg/L | | |
| TSS | 68 | 142 | 295 |
| VSS | 20 | 39 | 78 |
| TOC | 12 | 25 | 52 |
| COD | 57 | 114 | 227 |
| $NO_2$+$NO_3$ | 0.39 | 0.76 | 1.48 |
| TKN | 1.05 | 1.83 | 3.17 |
| $PO_4$-P | 0.15 | 0.40 | 1.07 |
| Copper | 0.025 | 0.054 | 0.119 |
| Lead | 0.102 | 0.400 | 1.564 |
| Zinc | 0.192 | 0.329 | 0.564 |

**Common contaminants and sources of pollutants in roadway and parking lot runoff**

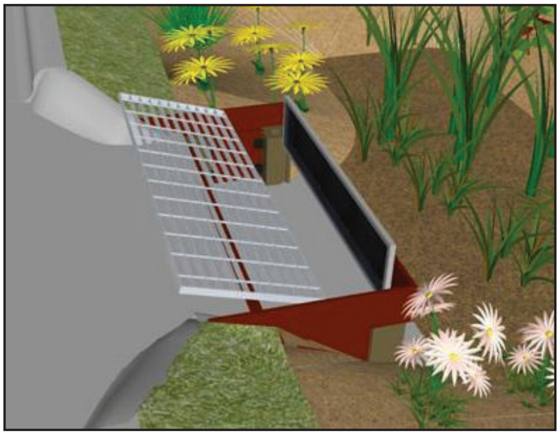
| | |
|---|---|
| **Sediment** | Sources of sediment in urban runoff include construction activities, erosion of unvegetated areas, and winter sand application. Sediment also accumulates on impervious surfaces whether from atmospheric deposition or wind erosion and deposition. Sediment that is routed to bioretention areas can build up at inlets, clog soil media, and smother plants. |
| **Nutrients** | Phosphorus and nitrogen are the primary nutrients in stormwater runoff, originating from sources such as lawn fertilizers, leaf litter, grass clippings, unfertilized soils, detergents, atmospheric deposition, and rainfall. Highways and other transportation corridors can increase atmospheric nutrient deposition from the by-products of vehicle exhaust. |
| **Heavy Metals** | The primary source of heavy metals in stormwater runoff is wear of motor vehicle parts, such as brake pads and tires. Gasoline, motor oil, brake linings, rubber, and asphalt all contribute heavy metals to roadway surfaces. Roadway stormwater runoff may contain trace metals such as copper, lead, and zinc. Where runoff is allowed to infiltrate, these metals may accumulate in soil and potentially leach into the groundwater once the soil sorption capacity is reached. |
| **Petroleum Hydrocarbons and Organic Chemicals** | Many sources of petroleum hydrocarbons exist in urban catchments, including leaky storage tanks, parking lot and roadway runoff, automotive emissions, elicit dumping, spills, and tire particles. Petroleum hydrocarbons in stormwater, particularly oil, grease, and organic compounds (e.g., benzene, toluene), can be traced to transportation activities such as fuel spills and engine oil leaks. Organic chemicals can also be found in runoff—high concentrations of polycyclic aromatic hydrocarbons (PAHs) have been found in runoff from roads and parking lots that use sealcoats. |
| **Salt** | In cold climates, salt usage is common to mitigate icy streets, sidewalks, and paved areas during winter months. Salt (e.g., sodium chloride) can build up on paved surfaces between melt events but will eventually be washed off into nearby SCMs and downstream to receiving waters. Salt can also accumulate in soils and can be transferred to the shallow groundwater system over time. High salt concentrations in soils can hinder a plant's access to water and cause declines or loss of vegetation in bioretention cells and bioswales. Early spring is the most critical period for managing salt concentrations when plant leaves are emerging and rains have not yet flushed the soil media of excess salts. |

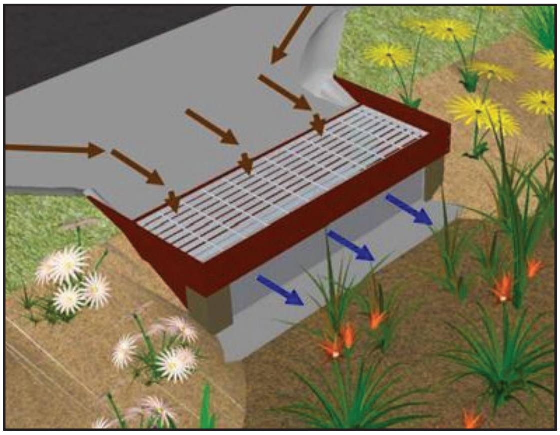
## Start with Design

During the design phase of a project, two key elements that will enhance a successful maintenance program include (1) access to the practice and (2) design and construction that includes pretreatment.

Access is critical to both inspect and conduct maintenance activities in the bioretention area. During the design and permitting phase of a project, mechanisms can be put in place (e.g., easements, agreements) to ensure access to the practices for the purposes of inspection and maintenance. The design should ensure that adequate space is provided for maintenance equipment. GI that is placed near roads or in parking lots likely will not have physical access issues, but working with private landowners to ensure safe access is important. In addition, communicating maintenance activities to local landowners can provide education and outreach opportunities.

Dedicated pretreatment can simplify maintenance activities and help to focus inspections. For example, a grass filter strip can be used to catch sediment and other particulates that may enter a bioretention area. These grass filter strips can tend to build up with sediment and cause runoff to bypass the GI practice. Regular inspection of filter strips is critical to ensure the bioretention areas function as needed. Rock inlets are also commonly used. These inlets capture sediment well but require labor-intensive maintenance to remove sediment build-up. Structural pretreatment practices are becoming more common and can be used to capture sediment and particulates at the inlet. There are several designs that have been used such as the Rain Guardian, available from the Anoka Conservation District (http://www.rainguardian.biz/index.php). These inlets were designed by practitioners who recognized the challenges of maintenance activities with the goal of minimizing the labor and intensity of maintenance activities typically needed for filter strips or rock inlets. Trench or channel drains can also be used to capture sediment at bioretention inlets. Other types of structural pretreatment practices include grit chambers, sumps, and sediment forebays.





**The Rain Guardian, images courtesy of Anoka Conservation District and rainguardian.biz.**

Materials selected for use in bioretention and bioswales can also reduce maintenance needs. Non-floating mulch helps maintain functionality and reduce the need for premature replacement of mulch. The selection of low-maintenance plants (correct hardiness zone, tolerate wet and dry conditions, etc.) can also reduce maintenance needs.

## Inspection and Assessment

Maintenance typically begins with a regular inspection or assessment program. Inspections by qualified staff can identify and prioritize maintenance needs. These inspections should occur at least once per year. While inspection frequencies can vary, local governments tend to rely on visual inspections to determine whether higher levels of assessment are needed. For example, if visual inspection observes that standing water is present 48 hours after a rainfall event, then the practice may not be infiltrating at the desired rate, triggering further evaluation of the infiltration rate. Schedules may need to be adjusted over time as issues arise. Frequencies of inspection and maintenance also depend on drainage area, land use, activities in the watershed, and rainfall magnitude and intensity. Determining when more infrequent, restorative maintenance is needed can be less straightforward.

Visual inspections often include observations of vegetation growth and health, ponded water, clogged inlet and outlet structures, sediment accumulation, and other conditions. Several tests, such as infiltration rates, soil texture, and inflow/outflow monitoring, can be conducted as part of a site visit or visual inspection that can help inform maintenance needs. As part of the University of Minnesota On-Line Assessment and Maintenance Manual (Erickson et al. 2010), a series of inspection checklists describes the observations necessary for an effective visual inspection (see Attachment A). Simpler approaches to inspection are also common, such as the guidance provided below.

**Bioretention Basin Maintenance Guide**

Ramsey-Washington Metro Watershed District

| Inspection Checklist | Y/N | | If yes, perform the following maintenance. |
|---|---|---|---|
| Are weeds or invasive plants present? | Yes ☐ | No ☐ | Pull weeds and invasive plants out by the roots to prevent them from returning. Spot treat perennial weeds with appropriate herbicide if necessary. |
| Is there sediment accumulation? | Yes ☐ | No ☐ | Remove sediment that has accumulated in the inlets, outlets, and bottom of the basin with a shovel or other appropriate tool. |
| Are trash, excessive leaves, grass clippings, or other debris present? | Yes ☐ | No ☐ | Remove any debris present. |
| Is anything blocking or clogging inlets or outlets? | Yes ☐ | No ☐ | Remove any debris or sediment that may be preventing the water from flowing into or out of the bioretention basin. |
| Are there areas of bare soil or erosion? | Yes ☐ | No ☐ | Add mulch where it has been depleted and add additional plants where necessary. Use appropriate erosion control methods for more serious cases of erosion. |
| Is there standing water 48 or more hours after a rainfall? | Yes ☐ | No ☐ | This is an indication that your bioretention basin is not functioning as designed, likely due to a larger problem that will require further study and action. |
| If underdrain is present, is there standing water 48 or more hours after a rainfall? | Yes ☐ | No ☐ | Remove any trapped sediment present. If sediment does not appear to be blocking flow, this may be an indication that your underdrain is not functioning as designed and will require further study and action. |

## Infiltration Rates

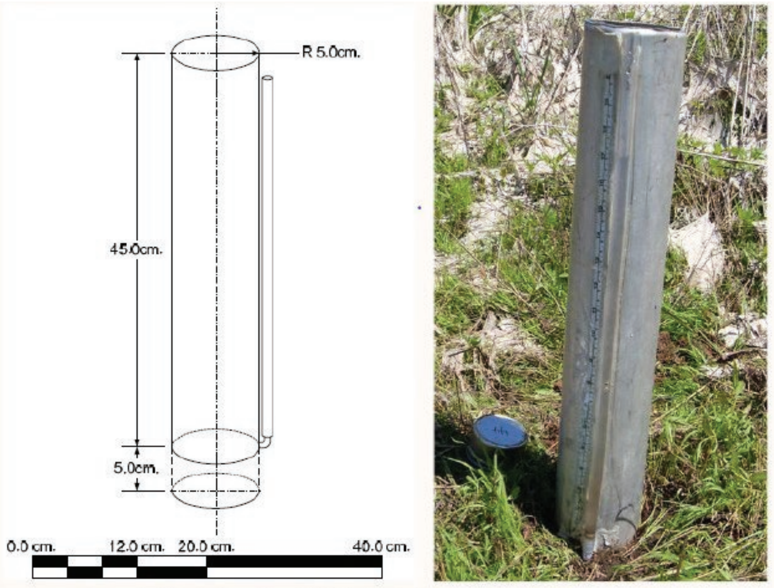
Bioretention and bioswales are often designed to meet a specific infiltration rate following installation. Some states and municipalities require or recommend minimum infiltration rates that can be used as benchmarks to determine when restorative maintenance is needed. Tracking infiltration rates over time can help to identify declined performance and trigger maintenance activities. Studies have indicated that bioretention infiltration rates appear to drop immediately following installation and then level off (Jenkins et al. 2010; MPCA 2016a). Plant roots help maintain the infiltration rate by forming macropores, and planted bioretention areas have shown slight increased infiltration rate after the initial decrease (MPCA 2016a).

Infiltration rate monitoring can be accomplished in several ways:

- A staff gage or other type of level measurement can be used to monitor decline in water levels over time. Ideally these measurements are taken hourly or several times a day, but daily observations may also be sufficient to determine an infiltration rate.

- Point measurements of infiltration rate at the bottom of the practice can be made and compared against other point measurements over time using an infiltrometer or permeameter. Multiple point measurements are needed to characterize the infiltration rate.

If the monitored infiltration rate falls below the design rate, the practice should be investigated to determine the cause of the reduced rate. Quick, approximate soil texture tests can also be easily incorporated into a visual inspection to help determine whether the soil media might be clogged. If the soil media texture has become more silty or clayey, further investigation is warranted into potential replacement of the soil media. Additional assessment of the contributing drainage area should be conducted to determine if there are existing activities that could be contributing to the lower rate (e.g., construction activities releasing sediment).




**Example of infiltrometer (Erickson et al. 2010)**



**Examples of bioswales in downtown Indianapolis, IN. Left bioswale is in need of maintenance and revegetation; right bioswale is well vegetated and appears to be working properly.**

## Soil Chemistry Testing

Soil testing can be used to assess whether a bioretention area requires restorative maintenance, specifically media replacement, by determining if pollutant concentrations in the soil affect performance. Soil testing is most effective in combination with inflow/outflow monitoring so that the soil conditions can be linked to a measured decline in performance. Soils and media can become saturated with a particular pollutant and soil testing will vary by pollutant. While soil conditions are a concern for all constituents, soil phosphorus content more often affects removal efficiencies of bioretention and should be given particular attention. Salts are also a common issues in cold weather states.

Some communities set requirements for phosphorus concentrations in soil media; in these cases, the soil media must be tested prior to installation. A Phosphorus-Index (P-Index) between 10 and 30 mg/kg is commonly used as a requirement or guideline for bioretention soil media, especially in watersheds with high phosphorus loads (NCDEQ 2009, MPCA 2016b, and ODNR 2006). Phosphorus net export is likely to occur when soil media is above this range.

Salt accumulation in roadside bioretention and bioswales can affect vegetation health and survival. If visual inspections indicate that vegetation has declined, soils should be tested for salt concentrations. Plants are most vulnerable to high salt concentrations in early spring when leaves emerge and before rains flush salt from the soil media. Several states recommend maximum salinity levels, which can be used as a benchmark for when more management is needed. Some states require or recommend that soluble salts (soil/water 1:2) should not exceed 500 parts per million (MPCA 2016b, ODNR 2006).

In addition to vegetation effects, preliminary research suggests that high sodium concentrations in soil media may decrease bioretention infiltration rates and increase mobilization of dissolved organic carbon if the soil media contains swelling clays (Barak 2012). These findings suggest that communities should use caution with de-icing applications that drain to bioretention and bioswales, conduct further studies, and explore management techniques that decrease potential sodium concentrations in soil.

Management to reduce soil salinity and its effects include planting salt tolerant vegetation, using alternatives to sodium chloride (e.g., calcium chloride, sand, or cinders), and avoiding late season applications near the devices (Perry 2016). The Transportation Association of Canada (TAC 2013) has published extensive guidance on designing and managing roadside areas to protect vegetation from salt damage: http://tac-atc.ca/sites/tac-atc.ca/files/site/doc/resources/roadsalt-6.pdf.

## Inflow/Outflow Monitoring

Comparing the inflow and outflow pollutant concentrations and loads directly measures the pollutant reduction performance of the practice. For most communities, this type of monitoring would not be practical for every bioretention area or bioswale, but managers could select a subset of practices for more detailed study, which would help provide triggers for maintenance.

## Example Assessment Program

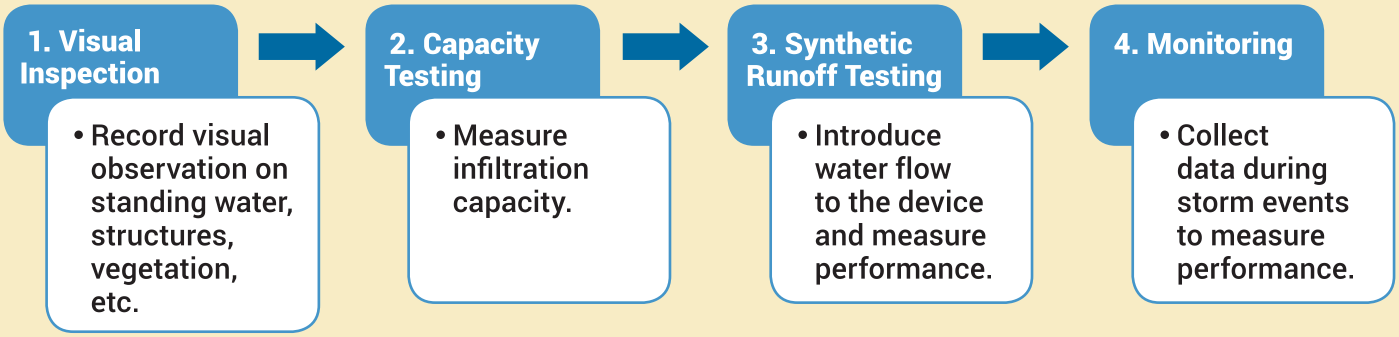
Erickson et al. (2010) describe how an assessment program can be developed based on a community's specific information needs, budgetary constraints, time frames, and legal requirements. The first step in developing an assessment program is defining the goals. Relating to bioretention and bioswales, examples of assessment objectives include:

- System-wide visual examination of stormwater treatment practices to determine if they are malfunctioning
- Identification of maintenance needs and scheduling

- Determination of effects in reducing runoff volumes, phosphorus, and sediment loading rates
- Optimization of life expectancy by scheduling appropriate and timely maintenance procedures

Once the objectives have been established, information is compiled on the location and design specifications, receiving waters, past maintenance schedules (if any), seasonal treatment needs, and limitations on schedule, budget, and personnel. This information is evaluated with the goals to determine whether and how often the assessment should or can be performed. Four assessment levels are provided, in order of increasing effort. The four assessment levels help establish a process for visual inspection, can help point out the need for higher levels of assessment, and can help determine maintenance needs. In the table below adapted from Erickson et al. (2010), each level is compared in terms of objectives, effort, frequency (elapsed time), advantages, and disadvantages.

**The Four Maintenance Assessment Levels (Erickson et al. 2010), defined for bioretention and bioswales**




**Comparison of four levels of assessment (adapted from Erickson et al. 2010)**

| | Visual Inspection | Capacity Testing | Synthetic Runoff Testing | Monitoring |
|---|---|---|---|---|
| **Objectives** | Determine if stormwater BMP is malfunctioning | Determine infiltration or sedimentation capacity and rates | Determine infiltration rates, capacity, and pollutant removal performance | Determine infiltration rates, capacity, and pollutant removal performance |
| **Typical Elapsed Time** | 1 day | 1 week | 1 week to 1 month | 14+ months |
| **Advantages** | Quick, inexpensive | Less expensive, no equipment left in field | Controlled experiments, more accurate with fewer tests required for statistical significance compared to monitoring, no equipment left in field | Most comprehensive, assesses stormwater BMP within watershed without modeling |
| **Disadvantages** | Limited knowledge gained | Limited to infiltration and sedimentation capacity/rates, uncertainties can be substantial | Cannot be used without sufficient water supply, limited scope | Uncertainty in results due to lack of control, equipment left in field |

## Operation and Maintenance Activities and Schedule

A maintenance program is critical to the long-term effectiveness of GI practices, particularly those that rely on vegetation, such as bioretention and bioswales. Maintenance can be conducted by a public agency or by a private landowner; mechanisms should be put in place to ensure maintenance is being conducted on all practices. Maintenance needs can be aesthetic in nature (e.g., overgrowth of plants, weeds, trash) or can require partial or full restoration.

**Aesthetic maintenance** of bioretention areas often consists of weeding, trash removal, clipping and pruning vegetation, and mulch replacement. This type of maintenance typically can be accomplished by landowners, residents, and non-technical staff.

**Partial restoration** may require sediment removal from the inlet or bottom of practice or replacement of plants. This type of maintenance is typically performed by public works staff or similar.

**Full restoration** is needed when an inspection identifies that performance does not meet the original project goals. For example, the presence of ponded water or wetland vegetation may indicate that the bioretention area no longer infiltrates. Adjustments might also be needed for inlets and outlets. Prior to any significant restoration activities, a survey of the watershed is recommended to identify activities that may be contributing to the practice failure (e.g., inadequate erosion control).

Operation may include protecting GI from construction runoff, enforcing rules for surrounding activities, and preventing inappropriate use of the practice. To avoid vegetation damage, salt buildup, and other issues, GI should be avoided for snow storage areas if possible.

Proper operation and maintenance involves performing multiple tasks at recommended time intervals (first year, semi-annually, annually, etc.) as well as regular inspection to determine further maintenance needs. Operation and maintenance tasks serve to uphold an expected level of performance, prevent more expensive operation and maintenance needs, and extend the life of the GI.

Measurable targets for operation and maintenance often serve to maintain both performance and regular maintenance. Some maintenance tasks are regularly scheduled to sustain performance and prevent damage. Other maintenance tasks occur as needed and may be triggered by an extreme weather event. In the latter case, properly timed inspections help identify maintenance needs beyond the regularly scheduled tasks. While the importance of maintenance is clear from a pollutant source perspective, the timing of maintenance needs can vary and is often specific to geography, climate, and site conditions. Feehan (2013) emphasizes that a number of factors should be considered in maintenance schedules, including practice type, runoff volume, traffic loading, sediment loading, litter/debris loading, seasonal variations, adjacent construction, and irregular weather events.

### When to Weed?

- When sunlight no longer reaches the surface of the soil
- When invasive species are present
- When desirable views are obstructed
- As needed to achieve performance and aesthetic goals

Existing stormwater management literature provides guidance on how to develop appropriate maintenance programs and schedules. The text box below provides an example operation and maintenance schedule. Some stormwater manuals recommend that vegetation density be limited so that sunlight can reach the soil and promote bacteria removal, which also prevents overgrowth from an aesthetic perspective. Other triggers for controlling vegetation include the presence of invasive species or obstruction of desirable views. Structural components, such as outlets, can be damaged over time if woody vegetation is allowed to grow in cracks. Proper operation and maintenance, as described in Mazer et al. (2001), also involves ensuring that the design provides a balanced inundation frequency over the life cycle of a practice. Too much flow could cause excessive erosion, leading to malfunction and costly repairs.

Even when maintenance schedules are followed adequately, variables such as climate patterns, weather variability, public use of the devices, etc. can lead to unforeseen maintenance needs. Inspection and adaptive management are critical components to any maintenance program.

## Recommended Maintenance Activities for Bioretention Areas

From the Minnesota Stormwater Manual Wiki, accessed May 2016
http://stormwater.pca.state.mn.us/index.php/Operation_and_maintenance_of_bioretention

**First year after planting**

- Adequate water is crucial to plant survival, and temporary irrigation will be needed unless rainfall is adequate until plants mature

**As needed**

- Prune and weed to maintain appearance
- Stabilize or replace mulch when erosion is evident
- Remove trash and debris
- Mow filter strip
- Renew mulch to replace that which has broken down into organic matter
- Replace vegetation whenever percent cover of acceptable vegetation falls below 90 percent or project specific performance requirements are not met; if vegetation suffers for no apparent reason, consult with horticulturist and/or test soil as needed

**Semi-annually**

- Inspect inflow points for clogging (off-line systems) and remove any sediment
- Inspect filter strip/grass channel for erosion or gullying and sod as necessary
- Inspect herbaceous vegetation, trees, and shrubs to evaluate their health and replant as appropriate to meet project goals
- Remove any dead or severely diseased vegetation

**Annually in fall**

- Inspect and remove any sediment and debris build-up in pretreatment areas
- Inspect inflow points and bioretention surface for build-up of road sand associated with spring melt period; remove as necessary and replant areas that have been impacted by sand/salt build up
- Cut back and remove previous year's plant material and remove accumulated leaves if needed (or controlled burn where appropriate)

For proper nutrient control, bioretention cells must not be fertilized unless a soil test from a certified lab indicates nutrient deficiency. The one exception is a one-time fertilizer application during planting of the cell, which will help with plant establishment. Irrigation is also typically needed during establishment.

### Recommended Maintenance Activities for Bioretention Areas (continued)

Pretreatment devices need to be maintained for long-term functionality. Accumulated sediment in the forebay will need to be cleaned out at a minimum when it is half-full, which should be approximately every 10 to 20 years. In an especially dirty watershed, the frequency may be increased to every 2 to 3 years. Sediment should also be cleaned out of rip rap and sumps. A vacuum truck is typically used for sediment removal. If a grassed filter strip or swale is used as pretreatment, it should be mowed as frequently as a typical lawn. Depending on the contributing watershed, grassed BMPs may also need to be swept before mowing. All grassed BMPs should also be swept annually with a stiff bristle broom or equal to remove thatch and winter sand. The University of Minnesota's Sustainable Urban Landscape Series website provides guidance for turf maintenance, including mowing heights.

Maintenance of vegetation after establishment is similar to adjacent gardens (except for application of fertilizer). Weeding is especially important during the plant establishment period, when vegetation cover is not 100 percent yet, but some weeding will likely always be needed. It is also important to budget for some plant replacement (at least 5 to 10 percent of the original plantings) during the first few years after planting, in case some of the plants that were originally planted die. Rubbish and trash removal will likely be needed more frequently than in the adjacent landscape, since the hydraulic loading ratio is high. Trash removal is important for prevention of mosquitoes. Mulch renewal will be needed two or three times after establishment (first five years). After that, the plants are typically dense enough to make it difficult to mulch, and the breakdown of plant material will provide enough organic matter to the infiltration/filtration device. It is recommended that bioretention performance evaluations follow the four level assessment system in *Stormwater Treatment: Assessment and Maintenance* (Gulliver et al. 2010). More detailed information about maintenance procedures, a maintenance schedule, and estimated maintenance costs are also available in Gulliver et al. (2010).

The following are minimum requirements for plant coverage.

- At least 50 percent of specified vegetation cover at end of the first growing season
- At least 90 percent of specified vegetation cover at end of the third growing season
- Supplement plantings to meet project specifications if cover requirements are not met
- Tailoring percent coverage requirements to project goals and vegetation; for example, percent cover required for turf after one growing season would likely be 100 percent, whereas it would likely be lower for other vegetation types

Owner's Representatives may wish to consider deducts and liquidated damages for bad construction practices. Regulating authorities may wish to consider fines for bad construction practices.

The following photos compare the same bioretention site just after installation, after several years of vegetation growth, and following routine maintenance. The aesthetics of the site changed dramatically across these three stages. An open, natural aesthetic was achieved at this site while controlling overgrowth and ensuring access to the outlet structure for other maintenance tasks.


*All photos: Tetra Tech*

**Comparison of three stages of vegetation maintenance at one bioretention practice: A) Shortly after installation; B) After several years of vegetation growth; C) After routine maintenance**

## When Restoration and Disposal Are Needed

While the majority of routine bioretention maintenance is focused on maintaining aesthetic features, removal of sediment or bioretention media may be needed periodically. Li and Davis (2008) found that sediment and heavy metals concentrate in the top 5- to 10 cm of bioretention media, so that removal and replacement of surface layers may revitalize water quality performance. As bioretention and bioswales are used more frequently and accumulate sediment over greater time periods, restoration is likely to become a more important consideration.

Limited research is available on the management and maintenance of bioretention in order to enhance performance and reduce lifecycle costs. Brown and Hunt (2012) repaired two sets of bioretention cells by excavating the top 75 mm of fill media to remove accumulated fine sediments. This increased the surface storage volume by nearly 90 percent and the infiltration rate by up to a factor of 10. Overflow volume also decreased. For most constituents, the effluent pollutant loads exiting the post-repair cells were lower than their pre-repair conditions. This outcome showed that clogging was limited to the surficial media layer, and maintenance was critical to performance (Liu et al. 2014).

### Maintenance Costs

Houle et al. (2013) evaluated different types of stormwater control and found that more distributed measures required higher percentages of "predictive or proactive" maintenance activities but tended to have lower maintenance costs per load removed overall compared to devices that required less frequent but more expensive repairs or rehabilitation (see table below).

**Operation and Maintenance Costs per Load Removed (Houle et al. 2013)**

| Operational Costs | Vegetated Swale | Wet Pond | Dry Pond | Sand Filter | Gravel Wetland | Bio-retention | Porous Asphalt |
|---|---|---|---|---|---|---|---|
| Total Suspended Solids ($/kg/year) | 6 | 17 | 11 | 21 | 8 | 8 | 4 |
| Total Phosphorus Performance ($/g/year) | NT | NT | NT | 7 | 3 | 6 | 2 |
| Dissolved Inorganic Nitrogen ($/g/year) | NT | 0.89 | 0.93 | NT | 0.28 | 0.64 | NT |

NT = No treatment; values are incalculable as lack of SCM pollutant treatment results in infinite costs.

## Process and Best Practices

Stormwater collection and conveyance systems collect and concentrate pollutants to prevent them from reaching surface waters and impacting water quality, aquatic life, or human health. Maintaining these systems often includes regular clean out and disposal of contaminated sediment and soil. Sampling is typically required prior to disposal to determine proper management. Sediment disposal from bioretention cells and bioswales presents a similar need to determine whether disposal or re-use of media is appropriate.

Sediment that accumulates in stormwater collection systems varies greatly with regard to contaminant concentrations and chemistry, and may differ among samples from the same system. Collection systems also vary in size and shape, as well as design. For example, some may have multiple inlets and outlets, and the types of media may differ. Land uses in the drainage areas can also influence contaminant concentrations in sediments.

The Minnesota Pollution Control Agency (MPCA 2015) outlines important procedures and steps when planning for sediment removal:

- Inventory and maintenance needs
- Evaluating and testing sediment
- Engineering and contracting
- Excavating sediment
- Site restoration
- Records and documentation to keep on file
  - Volume of sediment removed in cubic yards
  - Evaluation, testing, and/or laboratory results
  - Place of disposition/disposal
  - Employee training records and certifications

Feasibility of sediment removal can be improved by intentionally designing bioswales and bioretention for equipment access.

## Handling Considerations

Maintenance staff should use caution when handling soil media that is potentially hazardous. When taking soil samples, staff should wear protective gloves and avoid any bodily contact with the soil. Soil samples should be collected in a consistent manner, and the sampling device should be decontaminated between samples. Samples should be submitted to an accredited laboratory for analysis. Typical laboratory accreditations include the National Environmental Laboratory Accreditation Program certification and state-based certification programs.

If the soil in the practice is potentially hazardous, the soil should not be disturbed until test results are received. In the event that soil is disturbed prior to testing, this soil should be contained using drums, tarps, or other appropriate containment device that prevents leaching, airborne dust particles, or other release until testing can be completed. If soil media is determined to be non-hazardous, then specialized staff would not be required for soil handling.

If soil testing determines that soil media is hazardous, then trained professionals should be used for the removal and disposal of the media. The removal may require air monitoring, dust suppression, and other specialized procedures.

State regulatory agencies post lists of approved contractors for hazardous materials handling. Prior to disposal in a landfill, it is likely that samples will need to be collected for waste characterization analysis. Waste characterization allows landfills to ensure that they properly handle and dispose of hazardous materials and aids in determining the type of landfill that can accept the hazardous material.

## Ultimate Disposal

If inspections and monitoring lead to findings that soil media contains too much phosphorus or other pollutants of concern, the next step is to determine whether that soil media can be re-used or if disposal is needed. Disposal of sediment removed from GI generally falls within two categories: regulated and unregulated. Unregulated sediment is characterized as sediment that does not have contamination exceeding residential soil reference values or residential soil screening levels. Unregulated sediment may be managed locally and without disposal restrictions. However, disposal of contaminated sediment is more challenging and more expensive. Excavated sediment that is considered regulated fill is generally sent to a solid waste landfill. Depending on the types and concentrations of contaminants, sediment may need to be disposed of at a landfill that has an industrial solid waste management plan. Coordination with state agencies that regulate contaminated sediment is recommended.

Research conducted on stormwater pond sediments in the Minneapolis–St. Paul, Minnesota metropolitan area showed that polycyclic aromatic hydrocarbons (PAHs) are the primary contaminants of concern affecting disposal decisions (Polta et al. 2006).

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# Middle St. Croix Watershed Management Organization Inspection and Maintenance Program

*Case Study Contact: Mike Isensee, Administrator of the Middle St. Croix Watershed Management Organization*

The Middle St. Croix Watershed Management Organization (MSCWMO) is a watershed group tasked with cooperatively managing water resources in a 19.8 square mile watershed located along the pristine St. Croix River in Minnesota. There are ten member communities that have signed a joint powers agreement and have contracted staff from the Washington Conservation District to conduct watershed planning and implementation. The MSCWMO is overseen by a board made up of locally elected or appointed representatives from each member community.


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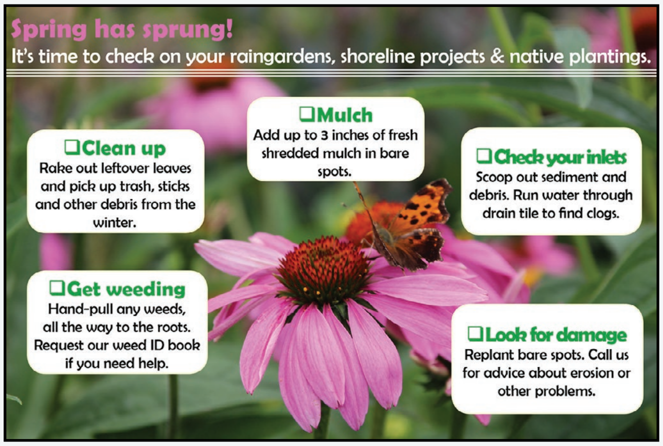


MSCWMO

The MSCWMO conducts a comprehensive inspection and maintenance program for the many best management practices (BMPs) in the watershed. As of 2015, there were over 200 BMPs installed in the watershed, most of the BMPs are bioretention areas that receive runoff from streets via curb cuts and range in size from 200-300 square feet. These BMPs include four types of projects with varying maintenance strategies:

## Residential Raingardens and Native Shoreline Restoration Projects

90 small scale residential raingardens and shoreline restoration projects located on private property.

*Maintenance Strategy:* Send annual maintenance post card reminder with MSCWMO contact information to provide assistance if requested.

## Retrofit Projects Installed and Maintained by MSCWMO and/or Member Communities

Since 2007 the watershed and cities have installed 88 BMPs, primarily bioretention basins, on public property or within right-of-ways.

*Maintenance Strategy:* Annual inspections and maintenance. Maintenance has been provided by the Minnesota Conservation Corps through an annual grant program since 2012. The MSCWMO directs the crews and the member communities provide funding for materials such as mulch and plant replacement.

## Retrofit Projects Installed by MSCWMO and Maintained by Landowners

Beginning in 2012, the MSCWMO required landowner maintenance agreements prior to the installation of voluntary projects. The MSCWMO provides maintenance for the first two years, then in the third year provides onsite maintenance consultation to landowners. The watershed then conducts annual inspections of these 23 projects.

Inspection letters are sent to landowners and they are encouraged to contact the MSCWMO for further on site consultation if they have any questions.

*Maintenance Strategy:* For new voluntary projects, the MSCWMO provides maintenance for the first two years, after which the private landowner is responsible for maintenance.

## New and Redevelopment Stormwater Projects

During the review process project applicants are required to submit a legal agreement with the City identifying maintenance items and responsibilities. Currently, there are 16 permitted permanent stormwater volume control facilities in the MSCWMO.

*Maintenance Strategy:* These BMPs are not part of the annual inspections program at this time.

MSCWMO inspections identify three types of potential maintenance activities needed:

1. Aesthetics (weeding, inlet clean-out, invasive plant management)
2. Restore partially functioning BMP (replacing plants, mulching, minor grading)
3. Restore non-functioning BMP (full restoration)

For those practices requiring aesthetic maintenance, the MSCWMO currently contracts with the Minnesota Conservation Corps. Aesthetic maintenance typically includes inlet clean-out and weeding. Other maintenance needs include mulching every three years or plant replacement are conducted on an as needed basis. Projects requiring repairs such as excavation or larger scale fixes are prioritized and addressed sequentially as part of the annual capital improvements projects.

Most practices identified as partially or non-functioning are due to sod or rock inlets that have filled with sediment and cause stormwater to bypass the bioretention basin. Because of this issue, the watershed requires the use of pretreatment devices that have capacity to remove at least 50 percent of the annual sediment load (Figure 1). This has increased function and decreased maintenance of practices installed since 2014. The other primary cause of failure in this watershed is due to the presence of marginal soils. The MSCWMO now requires at least one soil boring at the location of each proposal BMP. Underdrains suspended in engineered soil media with a gate valve are required for all BMPs constructed in soils that are not hydrologic soil group A (i.e., sandy or sandy loam).

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**Figure 1. Two types of street raingarden inlets: Left – Rock inlet; Right – Pretreatment inlet. The pretreatment inlet is now required for all new street raingardens to aid in collection of gross solids (sediment, leaves, trash, etc.) and maintenance. Rock inlets are no longer allowed due to difficulty maintaining the effectiveness of the inlet for pretreatment.**

The MSCWMO also provides technical review for new and redevelopment projects in the watershed and in particular reviews proposed stormwater management for adherence with MSCWMO-specific watershed standards and other regulations. Per state statute and a joint powers agreement, the member communities must implement the MSCWMO

## Middle St. Croix Watershed Management Organization Inspection and Maintenance Program

standards. As part of the review process, the MSCWMO now requires pretreatment on all infiltration BMPs and a signed legal maintenance agreement with the community.

The MSCWMO funds the majority of inspection and maintenance through member fees provided by cities and townships within the watershed. Member fees are typically allocated from general funds. Member communities also pay directly for any needed materials (e.g., plants, mulch, etc.). A grant from Minnesota's Clean Water Fund was obtained by the MSCWMO to fund in part of the maintenance work conducted by the Minnesota Conservation Corps.

The MSCWMO estimates that typical maintenance costs which reflect two visits per year are between $200–$300 per BMP, resulting in an annual cost of $16,000–$24,000 per year for the practices they are currently maintaining. These costs do not take into consideration repairs needed for partially or non-functioning BMPs.

In 2014, the MSCWMO partnered with the Washington Conservation District and other nearby watershed organizations to develop an interactive Conservation Project Map to track the pollutant load reduction, location, condition, and maintenance needs for the growing number of practices within the watershed. The Map is updated annually with new BMP information. The geospatial maps and inspection forms are accessible on mobile devices and streamline the inspection process and annual maintenance and repair prioritization projects.

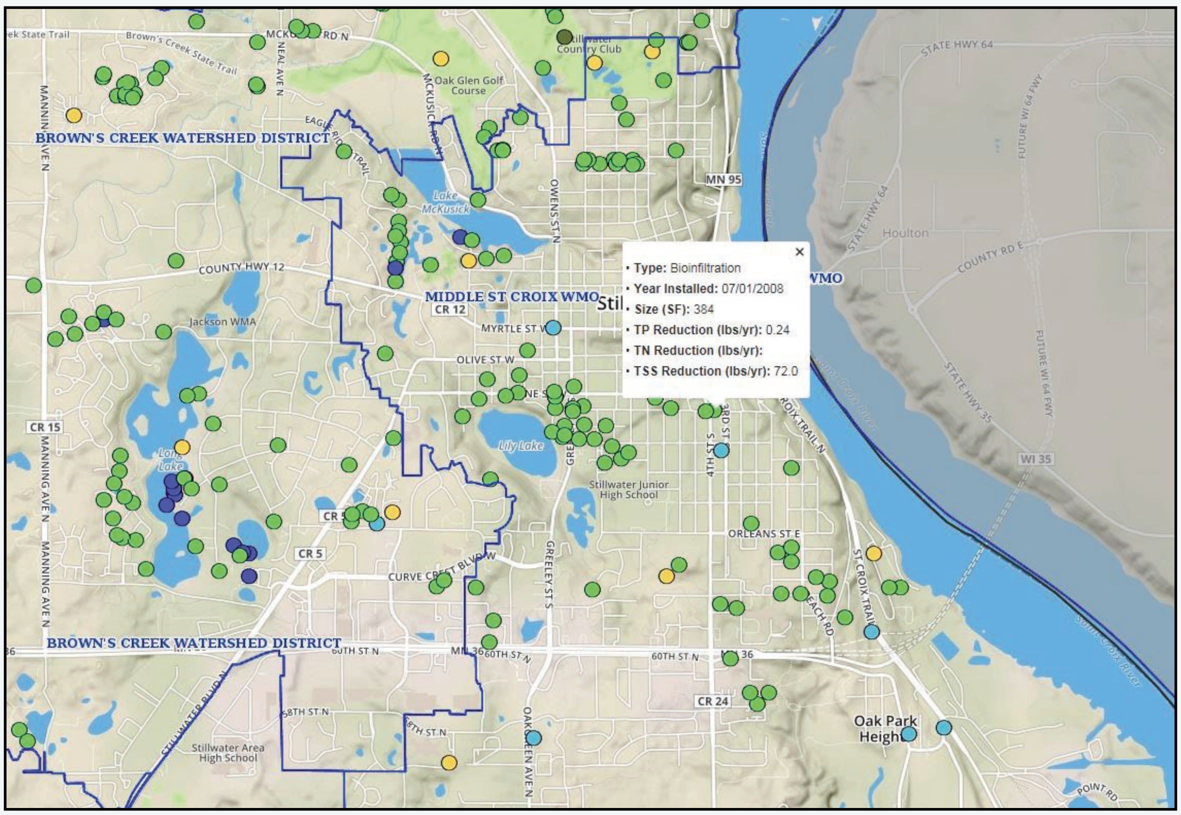


**Figure 2.Screen shot from Conservation Practice Map webpage**

The inspection and maintenance program has adapted as the number of BMPs has increased in the watershed. Initially, inspection and maintenance activities were conducted by MSCWMO staff; as the number of BMPs increased the MSCWMO contracted with the Minnesota Conservation Corps for aesthetic maintenance. Now, as the number of BMPs has reached a critical number, the MSCWMO is partnering with other government entities to either hire dedicated seasonal staff or use a contractor to carry out maintenance activities.

*"Maintenance Begins with Design"*

**Middle St. Croix Watershed Management Organization Inspection and Maintenance Program**

## 2013 Landowner Agreement Template

**MIDDLE ST. CROIX WATERSHED MANAGEMENT ORGANIZATION**
455 Hayward Avenue N. Oakdale, MN 55128
Phone 651.330.8220 x22 fax 651.330.7747 www.mscwmo.org


**RAINGARDEN INSTALLATION AND MAINTENANCE AGREEMENT BETWEEN LANDOWNER AND THE MIDDLE ST. CROIX WATERSHED MANAGEMENT ORGANIZATION**

The following agreement has been prepared for the proposed raingarden project in the catchment discharging urban stormwater directly to Lily Lake.

The raingarden located at this property will infiltrate or filtrate urban stormwater that is currently discharging into Lily Lake. The owner agrees to the following guidelines/statements in regards to the raingarden/stormwater treatment facility to be installed in the right-of-way adjacent to their property.

1. The landowner has agreed to have a raingarden installed in the City right-of-way adjacent to their property.
2. The landowner agrees to keep the raingarden in place for period of (10) years for the date of installation.
3. The landowner understands that some land area may be disturbed outside of the City right-of-way as part of this project and that the contractor installing the raingardens will restore these areas.
4. After the two-year maintenance period provided by the Middle St. Croix Watershed Management Organizations, the landowner agrees to maintain the raingarden in the City right-of-way adjacent to their property. Raingarden maintenance activities for the homeowner to perform include:
   a. Remove litter, debris, and accumulated sediment from the raingarden area, including the entrance to the raingarden off of the roadway.
   b. Watering of perennial vegetation when needed.
   c. Maintain the integrity and viability of the raingarden, including all planted perennial vegetation in the raingarden in a manner that does not compromise the effectiveness of the design. All established vegetation should be checked for survival and replaced as quickly as possible.
5. The Middle St. Croix Watershed Management Organization (MSCWMO) will provide periodic inspection to ensure the raingarden is being properly maintained. If an issue is observed, the MSCWMO will assist the landowner in addressing the problem.

By signing this agreement the landowner agrees to the statements above.

Landowner    Address    Date

MSCWMO Representative    Date

**Middle St. Croix Watershed Management Organization Member Communities**
Afton, Bayport, Baytown, Lakeland, Lakeland Shores, Lake St. Croix Beach, Oak Park Heights, St. Mary's Point, Stillwater, & West Lakeland

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