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National Management Measures to Control Nonpoint Source Pollution from Urban Areas

Management Measure 11: Operation and Maintenance

November 2005

MANAGEMENT MEASURE 11
OPERATION AND MAINTENANCE

11.1 Management Measure

Develop a program for regular inspection and maintenance of urban runoff management practices.

- Develop and implement an operation and maintenance plan for urban runoff management practices. The plan should include scheduled inspections, scheduled maintenance activities, and scheduled evaluations of operation and maintenance practices.
- Inspect, maintain, and repair runoff treatment controls to maintain design treatment capacity.
- Inspect, maintain, and restore riparian buffers.

11.2 Management Measure Description and Selection

11.2.1 Description

The maintenance of storm water controls is essential to ensure that overall program goals are met and that each management practice or set of practices continues to function as designed. Storm water controls need to be periodically inspected and maintained as necessary to fine-tune performance, prevent malfunction, and address any problems that may arise. Although maintenance issues should be a major consideration during the management practice selection process, they are often overlooked and inadequately planned for and budgeted. As a result, many management practices fail to perform as intended.

An operation and maintenance (O&M) plan is one way to systematically ensure that scheduled inspections, maintenance, and practice evaluations occur. Formalizing an operation and maintenance plan also can be helpful in determining and securing the funding necessary to properly operate and maintain runoff management practices.

Program managers should consider incorporating the following elements in their operation and maintenance programs:

- Scheduled inspections (based on climate, precipitation, and runoff management practice);
- Scheduled maintenance activities, such as removal of forebay sediment;
- Use of maintenance checklists to systematize and document the inspection process; and
- Initial and follow-up monitoring of management practices to establish performance baselines and trends to guide maintenance activities.

Maintenance activities may vary by management practice. For example, vegetation management is necessary for some extended detention wet ponds and constructed wetlands to maintain optimal removal efficiency, to avoid the net export of nutrients during winter, and to maintain design flow patterns. Removal of sediment build-up is essential to maintain properly functioning practices. Infiltration devices must be protected and maintained to prevent pore clogging and loss of infiltration capacity.

Preventative maintenance may also be necessary to protect the performance of management practices. Run-on sedimentation from off-site areas may need to be addressed through stabilization measures to prevent unnecessary maintenance expenditures.

The incorporation of maintenance considerations into management practice designs will often reduce subsequent maintenance costs and repairs and help to avoid failures. For example, the removal of material from sediment traps can be facilitated by designs that allow easy access to accumulated sediments without specialized equipment. Safe and convenient access to inlet and outlet structures can reduce maintenance costs and prevent nuisance flooding. Finally, the use of proper construction techniques and phasing can reduce the potential for initial clogging of infiltration devices during the construction process.

Enforcement of inspection and maintenance programs is crucial to their success. A 1992 study in Maryland evaluated 250 storm water practices to determine whether they were being maintained in compliance with the state's Stormwater Management Act. The researchers found that after a few years, approximately one-third of the practices were not functioning as designed, and most required maintenance. Approximately one-half of the facilities were undergoing sedimentation and many had problems with clogging (Lindsey et al., 1992). Implementing the practices described under this management measure can help develop an effective O&M program for continued effectiveness and longevity of runoff management practices.

11.2.2 Management Measure Selection

This management measure was selected because improper operation and maintenance of runoff control practices can result in poor performance and increased discharge of pollutants to downstream waters. Flooding may occur and downstream channel stability could be jeopardized. Poorly maintained runoff systems also may increase risks to public safety and the potential for property damage.

To prevent these potential impacts, effective maintenance programs should include standards for the inspection and maintenance of runoff controls. The entities responsible for maintaining runoff controls must be clearly identified and adequate resources must be provided to conduct the necessary maintenance activities. Because maintenance issues are critical to successful program implementation, they should be planned for at the outset of the runoff management program and conducted continuously for the lifespan of the practice(s).

The following section contains descriptions of specific O&M requirements for various types of management practices.

11.3 Management Practices

11.3.1 Establishing an Operation and Maintenance Program

The following section outlines several practices that will facilitate development of a runoff control O&M program.

11.3.1.1 Establish a runoff control operation and maintenance ordinance

One way for local governments to ensure that maintenance of runoff control facilities is performed is to establish an ordinance that mandates these activities. The O&M language in a runoff control ordinance can specify that runoff management practices must be designed to facilitate easy maintenance and require that regular maintenance activities be performed.

EPA (2000) has provided model ordinance language (at http://www.epa.gov/nps/ordinance) that includes consideration of maintaining runoff control management practices. Ordinance language examples from across the country are provided, including a sample maintenance agreement, a sample easement and right-of-way agreement, an inspection checklist, and a performance bond.

It is important for O&M ordinances to contain language that requires the identification of the specific entity or entities responsible for long-term maintenance and requires regular inspection visits. The ordinance also should provide design guidelines that can help ease the maintenance burden, such as the inclusion of maintenance easements. Note that runoff control ordinance language regarding the maintenance of erosion and sediment control practices differs from that regarding maintenance of postconstruction controls because of the short-term nature of the former.

The City of Alexandria, Virginia has incorporated inspection and maintenance requirements into the Alexandria Zoning Ordinance. The ordinance requires the submission of a long-term inspection and maintenance plan that identifies all maintenance requirements and responsible parties. A standard maintenance and monitoring agreement approved by the city council is required for urban runoff practices in Alexandria and cannot be modified without council approval (Bell, 1997).

11.3.1.2 Make provisions for maintenance in the design and construction of management practices

Because maintenance programs play such an important role in ensuring the proper operation of most structural practices and some source controls, emphasis should be given to maintenance issues when identifying management practices under any runoff management program. Making provisions for maintenance at the design and construction phase involves identifying the urban runoff practices to be used when designing a new facility. Practices should be designed so that maintenance equipment (mowers and vacuum trucks) can easily access the site. Many practices have been designed with inadequate pre-treatment (i.e., without a sediment basin at the inlet), and they have not performed as anticipated. Inlet and outlet structures also tend to clog easily without proper design and maintenance. Adequate size and storage volume based on expected sediment loads from the contributing drainage area should be factored into the design of inlets and pre-treatment structures.

11.3.1.3 Identify mechanisms for program funding

It is important to identify the entity responsible for operating and maintaining structural runoff control practices. The responsible party can be a property owner, homeowners' association, certified contractor, or local government agency. Local governments may assume the responsibility of maintaining privately owned facilities. When private entities do not fulfill their maintenance responsibilities and the facilities fail, the burden of maintaining runoff control and performing downstream restoration may ultimately fall under the local government's responsibility. Public financing for maintenance of both public and private facilities can be generated from general tax revenues, storm water utility fees, inspection or permit fees, or dedicated contributions. Sources of funding should be dedicated to runoff program budgets and or maintenance programs whenever possible. A discussion of these and other financing options for maintenance of runoff control facilities is provided in Chapter 8 of the Watershed Management Institute's *Operation, Maintenance, and Management of Stormwater Management Systems* (1997).

It is important that the funding source for maintenance of runoff control facilities be supported by the public. The Watershed Management Institute (1997) stresses the importance of public education to inform citizens about the locations and functions of runoff control facilities and the importance of regular maintenance. The institute believes that citizens and government officials will be more willing to allocate funds to projects that they know will provide tangible benefits to the community. The institute also recommends that funding programs for maintenance activities have the following attributes:

- Be based on a stable source of consistent funds that will ensure a long-term commitment of personnel, equipment, and materials;
- Be compatible with the local organizational structure to allow use of existing billing, collection, and bookkeeping operations;
- Include provisions for four essential operations: (1) program administration; (2) accounting and budgeting; (3) revenue management; and (4) information management;
- Be based on an equitable, understandable, and defensible fee or rate structure;
- Be continually reviewed and updated to meet the changing maintenance needs of the runoff control program; and
- Be consistent with applicable state laws and regulations.

11.3.1.4 Plan regular inspections

Inspections are essential to maintain the successful operation of the facility. Inspectors should have on hand equipment necessary for taking measurements and making minor repairs, be trained in identifying and remedying problems, and have a set of standard inspection procedures from which to work. An inspection schedule and checklist for each type of management practice should be developed and followed. Inspections and maintenance should be conducted both on a regular schedule and following storms to identify and repair any damage.

11.3.1.5 Schedule maintenance, cleaning, and debris removal to avoid sediment accumulation

Sediment and debris can contain hazardous contaminants and can clog filtration and infiltration practices, reducing their effectiveness over time. In addition to major structural controls, maintenance programs should include measures for cleaning catch basins and drainage channels. Establishment of an effective O&M program should include the creation of maintenance logs and identification of specific maintenance triggers for each class of control (e.g., removing sediment from forebays every year and retention ponds every five years, cleaning catch basins at least annually prior to the rainy season, removing litter from channels twice a year). If maintenance activities are scheduled infrequently, regular inspections should be made to ensure that the control is operating adequately. Additionally, maintenance should be performed following significant storms.

11.3.1.6 Make provisions for monitoring treatment criteria

Regularly monitoring the influent to and effluent from structural management practices will support program goals by facilitating development of a database to track the effectiveness of these practices, which can help guide future decisions about management practice implementation. These data will make it easier to quantify the performance of the practice and determine the behavior of the system as a result of regular maintenance.

11.3.1.7 Implement training and certification programs to provide educational opportunities for management practice operators

Training and certification programs are gaining popularity around the country at both the state and local levels. Municipalities sometimes use contractors to conduct inspections and maintenance because resources are not available to purchase equipment and hire dedicated staff. Good training programs can ensure that inspections and maintenance activities are carried out in a thorough and consistent manner. Also, training programs can be customized to address local concerns and conditions such as high flows, highly erodible soils, or invasive species.

11.3.1.8 Disposal of residuals

Runoff can carry both natural and anthropogenic pollutants and materials to receiving waters. Natural materials, such as leaves and soils, can accumulate in the system and cause localized flooding. Anthropogenic sources, which include oil and grease, heavy metals, deicing materials, and litter, can become adsorbed to leaf litter and sediments (Lenhart and Harbaugh, 2000). The mixed composition of solids that are removed from the storm drain system (termed residuals) can require special handling and treatment, which increases disposal costs (Field and O’Shea, 1994). The characteristics of residuals tend to vary with season and land use. Table 11.1 summarizes the results of a number of studies analyzing residuals in runoff (Field and O’Shea, 1992; Marquette University, 1982; Schueler and Yousef, 1994).

Table 11.1: Properties of urban storm water solids/residuals (adapted from USEPA, 1999).

Properties of Residuals	Wet Ponds[1]	Sediment Basin[2]	Swirl and Helical Bend Solids Separators[3]	In-Line Upsized Storm Conduit[4]	Urban Storm Water Runoff Residuals[5]
Solids					
Volatile Suspended Solids	6%	104–155 mg/l	107,310 mg/l	25,800 mg/l	90 mg/l
Total Suspended Solids	43%	233–793 mg/l	344–1,140 mg/l	161,000 mg/l	415 mg/l
Nutrients					
Phosphorus	583 mg/kg	< 5 mg/l	<5 mg/l	0.3–2,250 mg/l	502–1,270 mg/kg
Total Kjeldahl Nitrogen	2,931 mg/kg	<5 mg/l	<5 mg/l	0.3–2,250 mg/l	1,140–3,370 mg/kg
Heavy Metals					
Zinc	6–3,171 mg/kg				302–352 mg/kg
Lead	11–748 mg/kg				251–294 mg/kg
Chromium	4.8–120 mg/kg				168–458 mg/kg
Nickel	3–52 mg/kg				69–143 mg/kg
Copper	2–173 mg/kg				251–294 mg/kg
Cadmium	No detect–15 mg/kg				
Iron		6.1–2,970 mg/l	6.1–2,970 mg/l	6.1–2,970 mg/l	
Hydrocarbons	2,087-12,892 mg/kg				

[1] Scheuler and Yousef, 1994
[2] Marquette University, 1982 (Racine, Wisconsin)
[3] Marquette University, 1982 (Boston, Massachusetts)
[4] Marquette University, 1982 (Lansing, Michigan)
[5] Field and O'Shea, 1992

A system for managing residuals in runoff should address the proper handling and disposal of both liquid and solid residuals. Ponds, infiltration practices, vegetative controls, and catch basin inserts have different removal mechanisms, and the type of residuals generated from these practices will vary. All residuals should be tested for contamination (unless the management entity has determined that residuals from an individual practice or category of practices pose no hazard), and maintenance employees should be trained in properly identifying and handling contaminated waste according to the requirements of the Resource Conservation and Recovery Act (RCRA) and state and local regulations (USEPA, 1999). Removal mechanisms and requirements for specific practices are described below.

Non-hazardous solids in residuals can be recycled, sent to a landfill, or applied to land. Land application involves spreading the material on designated land at approved application rates. The material should not be applied to cropland, but application to a nonagricultural vegetated area may be appropriate (USEPA, 1999). Disposal of the waste in a landfill may be the most expensive option because of travel costs, testing requirements, and disposal fees (Lenhart and Harbaugh, 2000).

There are a number of low-cost options for recycling. Coarse sand and gravel can be used for road base, and road sand can be recycled for winter maintenance activities. The City of Olympia, Washington uses dried solids from treatment systems by mixing them with cement. The organic portion of residuals can be composted after removing the coarse inorganic materials. These organic residuals can then be combined with yard debris, leaves, straw, or soil. The Washington Department of Transportation mixes solids with mulch and bark for use as topsoil along roadsides (Lenhart and Harbaugh, 2000). In general, urban runoff residuals have very low nutrient content and thus require mixing with high nutrient content organic matter to provide fertilization benefits (Field and O'Shea, 1994).

Additional considerations for the disposal of residuals include air and noise pollution from machinery operation at the disposal site, unpleasant odors, possible ground water or surface water contamination, and public health. To address these issues, local and state agencies should address the following when developing guidelines for disposal of residuals: application rates, treatment requirements, site suitability, and proximity to schools, parks, and residential areas (Field and O'Shea, 1994).

The City of Everett, Washington uses a source separation system that requires operators of vacuum trucks to determine whether contamination of residuals is suspected based on sheen, odor, and color. Residuals suspected of contamination are handled in accordance with state and local regulations. Otherwise, materials are collected and recycled as aggregate material on medians and selected roadsides after being tested for contamination (Lenhart and Harbaugh, 2000).

11.3.2 Source Control Operation and Maintenance

11.3.2.1 Infrastructure

(1) *Street sweeping.* Street cleaning reduces pollutants carried in runoff from street surfaces. The frequency of cleanings should reflect the rate of pollutant buildup and should increase just before the rainy season. An effective program requires that street sweeping be conducted on a regular basis. Sweeper operators require training, and equipment needs to be maintained regularly to ensure that it is functioning as designed. Finally, parking restrictions can be implemented to guarantee adequate cleaning despite on-street parking. Table 11.2 shows O&M costs associated with street sweeping. See Management Measure 7 for more information about types of street sweepers (brush vs. vacuum sweepers and their relative effectiveness, section 7.3.5.1) and roadside trash removal (section 7.3.5.4).

Table 11.2: Street sweeper O&M costs (adapted from CWP, 1998).

Maintenance Considerations		Sweeper Type	
		Mechanical Sweeper	**Vacuum-Assisted Sweeper**
O&M costs (1998 dollars)	Cost ($/curb mile)	30	15
	Weekly sweeping ($)	1,680	946
	Biweekly sweeping ($)	840	473
	Monthly sweeping ($)	388	218
	4 times per year sweeping ($)	129	73
	Twice per year sweeping ($)	65	36
	Annual sweeping ($)	32	18
Expected life (years)		5	8

(2) *Storm drain flushing*. This practice is used to remove deposited materials from storm drain pipes to maintain their flow capacity. The flushing schedule should be designed to prevent excessive buildup based on estimated inputs from the contributing drainage areas, cleaning history, and visual inspections. Flushing is performed either at or upstream from problem areas. There are costs to consider for collecting and disposing of sediments, debris, and flush water, in addition to supplying flush water and treating sediment-laden water if the storm drains are being flushed to a receiving water body.

(3) *Catch basin cleaning*. Cleaning catch basins removes excess pollutants, thereby reducing high pollutant concentrations in a storm's first flush, preventing clogging, and restoring sediment-trapping capacity. Maintenance should target areas with the greatest pollutant loading and those near sensitive water bodies. A maintenance log should be kept to track progress. If there are many catch basins in a community, mechanical cleaners (vacuums or bucket loaders) may be required; otherwise, hand cleaning will suffice. Proper record-keeping, waste disposal, and safety procedures are essential for a successful program.

(4) *Highway, bridge, and road maintenance*. Maintenance of roads and bridges can be a significant source of pollutants. Some methods to prevent materials from contaminating runoff are limiting the use of salts; using suspended tarps, vacuums, or booms to reduce pollutant drift onto waters from scraping and painting; and training road crews in proper waste control and disposal methods. Treatment controls also can be used on-site to reduce the amount of polluted runoff that enters receiving waters. Runoff reduction, conveyance, and treatment practices (e.g., infiltration swales in median strips) can be incorporated into the design of new roadways and bridges to help contain pollutants from traffic as well as from

Sediment Removal from Catch Basins

The Delaware County, New York, Department of Public Works, with the assistance of the Catskill Watershed Corporation, purchased a vacuum truck capable of removing sediment from culverts and catch basins. The truck, which has a 30-foot pipe reach and a 12 cubic yard storage capacity, is available for use by neighboring counties based on need and availability. In the first month of operations, approximately 700 cubic feet of sediment was removed. The sediment s disposed of without posing a threat of contamination to the Cannonsville and Pepacton reservoirs. The County will be sampling sediment in an attempt to quantify the amount of contaminants removed (Delaware County Departments of Planning and Public Works, 2003).

maintenance activities. For more information about runoff management practices for roads, highways, and bridges, see Management Measure 7: Bridges and Highways.

11.3.2.2 Trash in channels and creeks

Clean-up of trash from streams and storm water conveyance infrastructure can reduce pollutant levels in downstream waters. Areas where dumping occurs frequently can be identified and inspected regularly, and "no littering" or "no dumping" signs can be posted to deter future dumping. Steep fines for dumping may also discourage potential transgressors. Associated costs for these practices are the purchase of signs and equipment, paying personnel to conduct inspections and clean-up, and providing landfill space to dispose of recovered items. Cost savings can be achieved through community or volunteer clean-up programs.

11.3.3 Treatment Control Operation and Maintenance

Runoff treatment controls require periodic inspection and maintenance to ensure that sediment, trash, and overgrown vegetation are not impeding their performance. Regular inspections should be performed along with routine maintenance. Nonroutine maintenance may be required to repair structures, control erosion, and remove unwanted vegetation. Table 11.3 and the following practices describe maintenance costs, activities, and schedules for several categories of urban runoff treatment practices.

Table 11.3: Maintenance costs, activities, and schedules for runoff control practices in 1998 dollars (Adapted from CWP, 1998).

Category	Management Practice	Annual Maintenance Cost (% of Construction Cost)	Maintenance Cost for a "Typical" Application	Maintenance Activity	Schedule
Detention ponds or vaults	Dry ponds	~1%	$1,200	– Cleaning and removal of debris after major storms (>2" rainfall) – Harvesting of vegetation when a 50% reduction in the original open water surface area occurs – Repair of embankment and side slopes – Repair of control structure	Annual or as needed
				– Removal of accumulated sediment from forebays or sediment storage areas when 60% of the original volume has been lost	5-year cycle
				– Removal of accumulated sediment from main cells of pond once 50% of the original volume has been lost	20-year cycle

Table 11.3 (continued).

Category	Management Practice	Annual Maintenance Cost (% of Construction Cost)	Maintenance Cost for a "Typical" Application	Maintenance Activity	Schedule
Ponds	Extended detention ponds, wet ponds, multiple pond systems, "pocket" ponds	3%–6%	$3,000–$6,000	– Cleaning and removal of debris after major storm events (>2" rainfall) – Harvesting of vegetation when a 50% reduction in the original open water surface area occurs – Repair of embankment and side slopes – Repair of control structure	Annual or as needed
				– Removal of accumulated sediment from forebays or sediment storage areas when 60% of the original volume has been lost	5-year cycle
				– Removal of accumulated sediment from main cells of pond once 50% of the original volume has been lost	20-year cycle
Wetlands	Shallow wetlands, pond wetlands, "pocket" wetlands	~2%	$3,800	– Cleaning and removal of debris after major storm events (>2" rainfall) – Harvesting of vegetation when a 50% reduction in the original open water surface area occurs – Repair of embankment and side slopes – Repair of control structure	Annual or as needed
				– Removal of accumulated sediment from forebays or sediment storage areas when 60% of the original volume has been lost	5-year cycle
				– Removal of accumulated sediment from main cells of pond once 50% of the original volume has been lost	20-year cycle

Table 11.3 (continued).

Category	Management Practice	Annual Maintenance Cost (% of Construction Cost)	Maintenance Cost for a "Typical" Application	Maintenance Activity	Schedule
Infiltration practices	Infiltration trench	5%–20%	$2,300–$9,000	– Removal of accumulated sediment from forebays or sediment storage areas when 60% of the original volume has been lost	5-year cycle
				– Removal of accumulated sediment from main cells of pond once 50% of the original volume has been lost	20-year cycle
	Infiltration basin	1%–3%	$150–$450	– Cleaning and removal of debris after major storm events; (>2" rainfall) – Mowing and maintenance of upland vegetated areas – Sediment cleanout	Annual or as needed
		5%–10%	$750–$1,500	– Removal of accumulated sediment from forebays or sediment storage areas when 50% of the original volume has been reduced	3- to 5-year cycle
Open channel practices	Dry swales, grassed channels, biofilters	5%–7%	$200–$2,000	– Mowing and litter/debris removal – Stabilization of eroded side slopes and bottom – Nutrient and pesticide use management – Dethatching of swale bottom and removal of thatching – Discing or aeration of swale bottom	Annual or as needed
				– Scraping of swale bottom, and removal of sediment to restore original cross-section and infiltration rate – Seeding or sodding to restore ground cover (use proper erosion and sediment control)	5-year cycle

Table 11.3 (continued).

Category	Management Practice	Annual Maintenance Cost (% of Construction Cost)	Maintenance Cost for a "Typical" Application	Maintenance Activity	Schedule
Filtration practices	Sand filters	11%–13%	$2,200	– Removal of trash and debris from control openings – Repair of leaks from the sedimentation chamber or deterioration of structural components – Removal of the top few inches of sand, and cultivation of the surface, when filter bed is clogged	Annual or as needed
				– Clean-out of accumulated sediment from filter bed chamber once depth exceeds approximately ½ inch, or when the filter layer will no longer draw down within 24 hours – Clean-out of accumulated sediment from sedimentation chamber once depth exceeds 12 inches	3- to 5-year cycle
	Bioretention	5%–7%	$3,000–$4,000	– Repair of erosion areas – Mulching of void areas – Removal and replacement of all dead and diseased vegetation – Watering of plant material	Biannual or as needed
				– Removal of mulch and application of a new layer	Annual
	Filter strips	$320/acre (maintained)	$1,000	– Mowing and litter/debris removal – Nutrient and pesticide use management – Aeration of soil on the filter strip – Repair of eroded or sparse grass areas	Annual or as needed.

11.3.3.3 Ponds and wetlands

Extended dry detention ponds are submerged only during storms and are dry between storms. Depending on the type of vegetative cover used, they may require mowing at least once a month to maintain turf grass cover, or once a year to prevent the establishment of woody vegetation. Sediments should be removed when they are dry and cracked to separate them from vegetation more easily. Pilot or low-flow channels require inspection to prevent undermining of concrete channels and overgrowth of stone channels. Inlets and outlets should be cleared of sediment and debris to prevent clogging.

Wet ponds are susceptible to algae blooms as a result of high nitrogen levels and may need to be cleaned periodically. Sediments that accumulate in the pond inlet or forebay should be removed more frequently than fine sediment, which collects near the pond outlet. Sediment removal requires draining the pond (some water to maintain fish populations should be left), collection of solids, and drying and testing of the residuals before disposal. Pond water should be disposed of in a locally approved manner; it should be tested for pollutants and released to the receiving water, if allowed, or pumped and hauled to a disposal facility. During the period in which the stockpiled materials are drying, erosion controls should be implemented to prevent sediment loss. All structures and surrounding areas should be inspected for leakage, seepage, corrosion, and wear and tear. Inspectors and crews should pay special attention to structural integrity to ensure that ponds operate safely.

Constructed wetlands should be inspected approximately four times per year to determine if they are retaining and discharging storm water at an appropriate rate and whether maintenance is needed. Constructed wetlands require periodic cropping; removal of trash, weeds, invasive species, or woody vegetation; repair of animal burrows in embankments; and clearing of inlets and outlets. Side slopes should be stabilized with vegetative cover to prevent erosion. Wetland plants should be thinned and transplanted as necessary to maintain adequate cover throughout the wetland. In general, semiannual sediment removal is recommended to ensure that treatment capacity is maintained. Mosquitoes may be a problem in some areas, and introducing natural predators such as mosquito fish (*Gambusia*) can be one method of control. Consultation with a wetland scientist is recommended to ensure that the constructed wetland functions as intended.

11.3.3.4 Infiltration practices

Infiltration practices, such as basins, trenches, vegetated swales, and porous pavement, are subject to clogging from sediment, oil, grease, and microbes. Clogging impairs their effectiveness in reducing runoff volume and pollutant loading to downstream waters. When clogging occurs, standing water tends to collect. Seasonal water table fluctuations or ground water mounding can also cause standing water. Facility inspection during dry periods will identify whether standing water is present and provide clues to the possible causes. Inspections should include a site assessment of the contributing drainage area because sediment accumulation in a facility stems from erosion in surrounding areas that can be prevented if the areas are adequately stabilized. The frequency of required maintenance depends on loads from the contributing drainage areas.

If clogging results in pooling, sediment can be removed to restore the facility to its original capacity. If the standing water results from high water table conditions, the facility owner should consider converting the site to a permanent pool facility such as a constructed wetland or detention pond. For systems designed with filter fabric to collect sediments, periodic inspections can identify when and where the mesh should be replaced. In cold climates where street sanding occurs in the winter, the filter fabric in infiltration devices adjacent to roads and parking lots should be replaced prior to spring.

Promotion of a vegetative cover will help to maintain percolation rates, slow runoff velocity, and minimize ground water pollution. To maintain aeration and permeability, nonvegetated basins require tilling or disking and leveling after sediment is removed. Vegetated filters adjacent to infiltration trenches should be cleared of sediments periodically to prevent sediment loading to the trench.

Regular monitoring of infiltration rates after storms will indicate when maintenance is required to maintain the system's treatment design capacity.

11.3.3.5 Filtration practices

Filtration practices include media filters (typically sand) and biofilters. Sand filters contain two phases: a sedimentation chamber and a filtration chamber. The sedimentation chamber can be inspected by measuring to determine if the deposited sediments are becoming deep enough to interfere with the filtration chamber. Different types of sand filters require different levels of maintenance. The Austin sand filter system usually requires maintenance every five to 10 years, depending on the stability of soils in the contributing areas, and can be treated like a dry detention facility. The filter component can be raked of fine sediments or skimmed with a shovel to restore permeability. The Washington and Delaware sand filter sedimentation chambers, which maintain a pool of water, should be vacuumed to remove sediment when inspections identify accumulation greater than 75 percent of capacity. Filtration chambers for these systems may need to be cleaned of fine particles as frequently as twice per year to maintain their efficiency and prevent overflows. A flat-bottomed shovel can be used to remove the sediment-laden filter media and roughen surfaces to improve permeability.

Each system should be inspected for vandalism, leaks, cracks, or damage to concrete at least once per year. These problems should be remedied immediately. Forebays should be pumped or cleaned as necessary. All materials removed from the systems should be tested for contamination and to identify how the material should be disposed of (e.g., as clean fill, in a landfill, or as a hazardous waste).

Biofiltration system vegetation should be mowed periodically to maintain an optimum height (2 to 6 inches) that maximizes infiltration and minimizes runoff velocity. Special effort should be made to promote native species and exclude invasive species, which can grow too vigorously and reduce treatment capacity. Some natural vegetation replacement is desirable, such as wetland plants that colonize a low-lying biofilter. Inspection and maintenance records should reflect these changes.

Biofiltration facilities should be inspected and maintained regularly. Sediment removal is an important and sometimes expensive part of biofilter maintenance. Sediment should be removed when it fills 20 percent of the design depth in any spot or starts to cover vegetation. Efforts should be made to return the system to its original topographic and vegetative condition once the sediment has been removed. Inlets and outlets should be cleared of particles and debris to prevent backups and overflows. Biofiltration systems may also need periodic replacement or amendment of system soils if clogging has occurred.

Maintenance equipment for the tasks described previously, along with purchase and rental costs, is presented in Table 11.4.

Table 11.4: Typical O&M equipment and material costs (WMI, 1997).

Equipment	Purchase	Rent (per day)
Grass Maintenance		
Hand mower	$300–$500	$25–$50
Riding mower	$3,000–$7,000	$75–$150
Tractor mower	$20,000–$30,000	$150–$450
Trimmer/edger	$200–$500	$25–$35
Spreader	$100–$200	$20–$30
Chemical sprayer	$200–$500	$25–$40
Vegetative Cover Maintenance		
Hand saw	$15–$20	$5
Chain saw	$300–$800	$15–$35
Pruning shears	$25–$40	$5
Shrub trimmer	$200–$300	$25–$35
Brush chipper	$2,000–$10,000	$100–$300
Sediment, Debris, and Trash Removal		
Vactor truck	$100,000–$250,000	$700–$1,200
Front-end loader	$60,000–$120,000	$250–$500
Backhoe	$50,000–$100,000	$250–$500
Excavator	>$100,000	$400–$1,000
Grader	>$100,000	$400–$1,000
Transportation		
Van	$18,000–$30,000	$50–$100
Pickup truck	$15,000–$25,000	$50–$100
Dump truck	$40,000–$80,000	$100–$200
Light-duty trailer	$3,000–$6,000	$50–$100
Heavy-duty trailer	$10,000–$20,000	$100–$250
Miscellaneous		
Shovel	$15	$5
Rake	$15	$5
Pick	$20	$5
Wheelbarrow	$100–$250	$15–$25
Portable compressor	$800–$2,000	$50–$150
Portable generator	$750–$2,000	$50–$150
Concrete mixer	$750–$1,500	$50–$100
Welding equipment	$750–$2,000	$50–$100
Materials		
Topsoil	$35–$50/cubic yard	
Fill Soil	$15–$30/cubic yard	
Grass seed	$5–$10/pound	
Soil amenities	$0.10–$0.25/square foot	

Table 11.4 (continued).

Equipment	Purchase	Rent (per day)
Materials (continued)		
Chemicals	$10–$30/gallon	
Mulch	$25–$40/cubic yard	
Dry mortar mix	$5/50-pound bag	
Concrete delivered	$60–$100/cubic yard	
Machine/motor lubricants	$5–$10/gallon	
Paint	$20–$40/gallon	
Paint Remover	$10–$20/gallon	

11.4 Information Resources

The South Carolina Department of Health and Environmental Control (2000) published *A Citizen's Guide to Stormwater Pond Maintenance in South Carolina*, which is available for download in PDF format at http://www.scdhec.net/eqc/admin/html/eqcpubs.html. The booklet is intended as a guide for homeowners' associations and others responsible for the proper maintenance of storm water ponds. Photos and descriptions of nuisance aquatic plant species are presented in the guide to aid in identifying these species and removing them from ponds. Copies of the guide are available from Ward Reynolds at 843-747-4323.

The Stormwater Manager's Resource Center (CWP, no date) has sample O&M checklists available for download from its Web site (http://www.stormwatercenter.net/). When at the site's homepage, click on "Manual Builder" and choose "Construction and Maintenance Checklists" from the pull-down list. There are checklists for the following practices: ponds, infiltration trenches, infiltration basins, bioretention facilities, sand filters, and open channel practices.

11.5 References

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