STORM WATER BEST MANAGEMENT PRACTICES THAT MAXIMIZE AQUIFER RECHARGE

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ABSTRACT

This article reviews and provides evaluation guidelines for six major storm water best management practices including bioretention areas, grassed swales/filter strips, infiltration trenches, porous pavement, rain barrels and wet detention ponds. A detailed table allows for quick and easy design comparisons, including a separate table which allows for site specific cost comparisons. A logic diagram is provided as a basic tool for screening the most feasible management practice.

KEYWORDS

storm water, best management practices, runoff, pollutant removal, infiltration, biological uptake, ground water recharge, low-impact development

INTRODUCTION

Groundwater recharge is of growing concern worldwide. With dwindling fresh water supplies and increasing demand, high quality clean groundwater replenishment is required to maintain a healthy water supply. Drinking water supplies, industrial uses, commercial uses and other fresh water needs are supplied by groundwater. Globally, a majority of the world's municipal water supplies are from groundwater (Shah et al., 2000). In the past, under natural conditions, aquifers were able to reach equilibrium even with periods of uneven discharge and recharge. Unfortunately, use of groundwater wells adds a new discharge factor, throwing off this equilibrium (Sophocleous, 2002). Shah et al., 2000, noted that even if the annual global supply of groundwater exceeds annual use, the proportion of population to the recharge areas is skewed so that areas with large populations cannot support water usage. This disproportion results in decreased aquifer levels in these areas. A sustainable water cycle requires recharge of these depleted resources, equal to withdraw.

Current storm water management practices deliver water to sewers, streams, rivers, lakes and other bodies of water, reducing the quantity available for aquifer recharge. With these typical practices, aquifer recharge from storm water plays a much smaller part in the water cycle than is possible. One of the most significant factors reducing aquifer recharge rates is an increase in impervious surfaces, which occurs in almost all development and in current storm water management designs. Impervious surfaces lead to greater channelization of storm water increasing water flow and reducing infiltration (Holman-Dodds et al., 2003). Holman-Dodds et al., 2003, states in general that there is an increase in infiltration and reduced runoff for low-impact designs as compared to conventionally developed land. Infiltration of storm water can increase aquifer levels, therefore improving the overall capacity of the groundwater system. Storm water best management must be implemented to achieve the increase in groundwater infiltration rates necessary to produce the desired recharge effects while improving (or at least maintaining) groundwater quality.

Storm water management using low impact development can also reduce flooding events and their magnitude. Storm water management practices can direct water to desired locations using natural processes, avoiding build-up of water in undesirable locations. Flood control is an important factor in selection of BMP's in locations where it may be necessary to minimize the damage and destruction of natural floods.

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According to Shah et al., 2000, if even a portion of runoff could infiltrate due to a reduction in velocity, underground storage quantities could be greatly enlarged. Storm water infiltration best management practices that are designed to maximize the infiltrating water quantity and its quality are crucial to protect groundwater resources. By design, they increase infiltration by increasing porosity, recharge rates and area available for recharge, thereby reducing the impact of impervious surfaces and current storm water management practices. The methods outlined below are designed to reduce pollutants in the water and increase the rate of recharge into the aquifer.

Included is a brief review of options available for storm water management, their practical applications and screening tools for applicable selection. The information provided is intended to present available practices in a quantitative form for simple direct comparison to refine the selection process in order to focus only on those storm water best site-specific management applications.

STORM WATER BEST MANAGEMENT PRACTICES

In this review, storm water best management practices use natural processes to improve water quality and increase infiltration quantity. The designs have less impact to the natural terrain than traditional methods, use biological system components and make use of the soil and vegetation to treat and infiltrate storm water. Low-impact development (LID) is also a term used to categorize multiple hydrology specific management designs combined to reduce pollutant loadings and increase infiltration (USEPA, 2007). LID's are typically located near runoff sources and attempt to maintain the natural conditions of the area prior to development. Below are brief descriptions of practices, applicability and maintenance, with more specific design details located in the comparison table.

Bioretention

Bioretention areas, also known as rain gardens, are intensive, decorative storm water treatment channels. They are constructed by excavating the required volume, backfilling with sand and soil, planting with a variety of vegetation and mulching. The design promotes sheet flow which reduces runoff velocities and increases dispersion throughout the channel, trapping pollutants within the vegetation and soil. A reduction in outflow volume reduces load concentrations and serves as an integral overall pollutant reduction mechanism in bioretention areas (Hunt et al., 2006). Vegetation and soil remove pollution through biological and physical/chemical processes (United States Environmental Protection Agency, 1999a). Methods through which pollutants are removed include adsorption, volatilization, ion exchange, decomposition and filtration (Michigan Department of Environmental Quality, 2001). The ability of a bioretention area to reduce pollutants in the runoff is largely based on the underlying structure and vegetation. Hunt et al., 2006, notes that varying soil and fill media can greatly affect the phosphorus removal efficiency.

Bioretention areas have limitations for their implementation. Establishment of plants and the subsurface structure is necessary to achieve the desired pollutant removal, particularly suspended solids removal (Davis, 2007). They are recommended for smaller sites due to clogging from large flow volumes (United States Environmental Protection Agency, 2002a). However, multiple bioretention sections can be installed for larger sites if care is taken to maintain the required flow volumes (United States Environmental Protection Agency, 1999a). Precisely dividing flow however, can be very difficult and expensive. Areas with great amounts of sediment runoff should not implement bioretention areas due to clogging. Performance efficiency is reduced in cold climates. However, recent work done by Muthanna et al., 2007, suggests that bioretention areas are capable of great pollutant removal from snowmelt. Due to contamination risks, use in areas with high water tables is not recommended (Metropolitan Council of Minnesota, 2003a).

Regular maintenance is required to ensure the effectiveness of the bioretention area. Vegetation must be inspected twice a year to ensure health and proper function. Pruning, weeding and mowing is conducted for aesthetic purposes and to maintain healthy vegetation. Litter, debris and dead or unhealthy vegetation needs to be removed (United States Environmental Protection Agency, 2002a). Erosion may require the replacement of soil and mulch in some areas, as well as replacement due to high contaminant levels. Pollutant removal capacity will become exhausted over time, requiring replacement of the underlying soil foundation to return removal rates to their original values. The soil pH should be evaluated one to two times a year and adjusted for levels appropriate for vegetation (United States Environmental Protection Agency, 1999a). Vegetation needs to be watered regularly until the plants are well established (Metropolitan Council of Minnesota, 2003a).

Grassed Swales/Filter Strips

Grassed swales or filter strips are long narrow grass-lined channels, ditches or median strips designed to filter and treat storm water from impervious surfaces. Alternate names include biofilters, dry swales, grassed channels, grassed filters, grassed filter strips, vegetated filter strips, vegetated swales and wet swales. Grassed swales and filter strips increase filtration and provide a long-term treatment for pollution at low costs (Michigan Department of Transportation, 1998). A reduction in water runoff is achieved through an increase in infiltration due to greater pervious surfaces and a decrease in flow velocities from vegetation. Water quality improvements from pollution removal and the settling of suspended solids results from the greater pervious surface area and decreased runoff rates, increasing the treatment area per volume of storm water (United States Environmental Protection Agency, 1999b). Plant life facilitates the removal of some pollutants through biological processes (Menerey, 1999). Including check dams in the design can improve the swale pollutant reduction performance (Shaw, 2001). Additional benefits include bank stabilization and increased habitat for wildlife. Grassed swales/filter strips can also be used as temporary filters during construction (Metropolitan Council of Minnesota, 2003b).

Grassed swales/filter strips require large amounts of space relative to the impervious area (United States Environmental Protection Agency, 2002c). Treatment area is limited to a few acres, as it is difficult to maintain sheet flow with larger areas. After choosing a design location and the desired shape of the swale, the design specifications can be determined. Pollutant removal rates are directly related to the width, the larger the width the greater the pollutant removal rates (Metropolitan Council of Minnesota, 2003b). Shaw et al., 2001, finds that an increase suspended solids removal is seen with an increase in length (up to 75 meters) and a decrease in slope. Due to the possibility of contamination, areas with high pollution concentrations should not use a grassed swale or filter strip (United States Environmental Protection Agency, 2002c).

Maintaining the vegetation can lead to a long life for the system (United States Environmental Protection Agency, 1999b). Maintenance includes pest control, removal of debris, garbage, invasive species and sediment build-up (United States Environmental Protection Agency, 1999b). Regular inspection and repair of damages to inlets, outlets and dams is required to maintain system function. Grass must be mowed to a height of 3–4 inches (United States Environmental Protection Agency, 2002c). Water for vegetation, particularly during low precipitation months, must be provided. Site inspection for erosion and repair is needed, so that reseeding of bare spots and re-grading can be completed when required (United States Environmental Protection Agency, 1999b).

Infiltration Trench

An infiltration trench, also known as an infiltration galley, is an underground reservoir using porous media to allow infiltration of overland flow (Menerey, 1999). This increases infiltration to groundwater in areas lacking space for other storm water management practices. Overland flow is channeled and drained through stone aggregate and filter fabric designed to filter storm water through porous media at a specific rate (United States Environmental Protection Agency, 1999c). This increases the groundwater recharge while trapping pollutants within the trench. Pollution removal is attributed to filtration of the storm water through the backfill and soil (United States Environmental Protection Agency, 2002d).

This practice is recommended for smaller areas as clogging issues are associated with larger flow volumes (United States Environmental Protection Agency, 2002d). Bypass flow systems should be installed for large storm water events. Due to the speed of infiltration, and the minimal amount of treatment resulting from the gravel, it is not recommended for areas with high pollution concentrations (United States Environmental Protection Agency, 2002d). In order to maintain the life of the system it is important to implement pretreatment to remove suspended solids (Metropolitan Council of Minnesota, 2003c). Pea gravel can be substituted in top foot of trench for increased sediment and pollutant removal.

Trenches require inspection after every rainfall event for the first few months to ensure proper drainage. Observation wells with an above ground cap should be installed for inspections. After the initial few months' semi-annual inspections should continue throughout trench life. Ponding requires immediate attention as it indicates clogged aggregate requiring replacement. Replacement of the trench field will be required after an extended period, as treatment effectiveness will become exhausted with time. The pretreatment unit should be checked for proper functioning at least twice per year (Metropolitan Council of Minnesota, 2003c).

Porous Pavement

Porous pavement, also known as pervious pavement, allows the infiltration of water while still allowing for light traffic (United States Environmental Protection Agency, 1999d). Porous pavement reduces runoff, increases groundwater recharge and decreases pollutant concentrations (Scholz, 2006). Design of porous pavement can maximize runoff reductions with permeable soils, large storage volumes and a reduction in fine sediment build-up on the surface (Bean, 2007). Dreelin et al., 2006, found a 40–45% reduction in runoff from the porous pavement in comparison to the equivalent asphalt paved area due to infiltration, even in low permeability clay soils. The porous material offers minimal filtration (United States Environmental Protection Agency, 1999d). Subsurface soil under the porous pavement may trap and treat pollutants depending on its characteristics and the depth to groundwater. There are a multitude of different porous pavers available for use with variable applications, but the different pavers pose no change to the hydrologic processes (Booth, 1999).

Due to structural design porous pavement is not suitable for heavy traffic areas or locations that must support large loads (United States Environmental Protection Agency, 1999d). A filter fabric is required where aggregate comes in contact with soil to prevent sediment from entering. Porous pavement is also not recommended for areas with high pollution concentrations as there is minimal reduction resulting in possible contamination (United States Environmental Protection Agency, 2002e). Scholz, 2007, suggests the use of an impervious membrane located below the subsurface soil for use in areas with high concentration runoff to transport infiltrated runoff to sewer systems in order for the pervious pavement to provide pretreatment before entrance to the sewer system. Snowfall removal can also pose problems as plow equipment can easily damage the pavement. The application of sand or salt can cause clogging and chemicals can pose contamination problems (United States Environmental Protection Agency, 1999d).

Regular maintenance is required to ensure the porosity of the pavement is maintained (United States Environmental Protection Agency, 1999d). Vacuum sweeping followed by high pressure hosing multiple times per year will maintain the porosity and remove any clogs (United States Environmental Protection Agency, 2002e). Large debris and sediment must be removed monthly. Inspection after large rainstorm events should be done to examine for clogging. Damaged sections of pavement should be replaced, and if using vegetation, such as grass, it should be mowed and bare spots reseeded when necessary (United States Environmental Protection Agency, 2002e).

Rain Barrels

Rain barrels are above or below ground tanks or barrels used to store water runoff from impervious surfaces (United States Environmental Protection Agency, 2002f). Rain barrels may also be considered cisterns, underground collection tanks or subterranean tanks. Rain barrels do not provide increased infiltration alone, but with the addition of proper flow dispersal, rain barrels can provide aquifer recharge (State of Ohio Environmental Protection Agency, 2005). A reduction in water runoff is achieved through channeling flow to a collection tank. Greater infiltration to groundwater occurs when water collected in rain barrels is applied over a pervious area.

The tank sizing should be determined using the area of pervious surface, average rainfall and frequency of dispersion. Gutters and downspouts can be used to divert the flow to the desired location, ensuring a first flow diverter is installed to eliminate runoff with high levels of contaminants collected on the impervious surface (Texas Water Development Board, 2006). Spreading the tank contents at an application quantity great enough to provide infiltration but low enough to prevent runoff will increase infiltration. Infiltration also results from dispensing the flow to an area designed to provide greater infiltration, such as a drainage trench. Water distribution requires suitable area or connection to supplemental systems. Due to direct dispersal and infiltration, this management system can only be used in low pollution concentration areas although soil may act as a filter for those pollutants (United States Environmental Protection Agency, 2002f). Rain barrels have limited volumes, therefore an overflow system should be installed for rainfall greater than the system is capable of handling and when freezing temperatures do not allow for collection and dispersion of precipitation (United States Environmental Protection Agency, 2002f). Pretreatment is required to filter all large debris (State of Ohio Environmental Protection Agency, 2005). Note that rain barrels are very effective as a water conservation practice and are well suited for arid climates to irrigate crops and grass.

Maintenance requires inspection of the tank twice a year for any irregularities and an annual cleaning (United States Environmental Protection Agency, 2002f). Gutters, downspouts, inlets and outlets must be cleaned regularly to maintain flow.

Wet Detention Pond

A wet detention pond, also known as an extended detention pond, pocket pond, retention basin, retention pond, storm water pond, water reuse pond and a wet pool, is a small body of water designed to collect storm water runoff for a designated duration of time, providing pollutant removal and flood control (United States Environmental Protection Agency, 1999e). Pollutant removal also occurs through a variety of processes including sedimentation, biological uptake, adsorption and flocculation (Metropolitan Council of Minnesota, 2003d). Settling and nutrient uptake are accomplished through the extended resting period (United States Environmental Protection Agency, 2002g). To achieve the greatest removal from a variety of pollutants and nutrients wet pond design must maximize contact time with rooted vegetation and organic sediments (Mallin et al., 2002). Reductions in particulate matter are achieved through settling while chemical and biological processes remove dissolved pollutants (Comings, 2000). Infiltration occurs through the bottom of the pond or at the location the water travels to after passing through the detention pond.

Wet Detention ponds are designed for drainage areas greater than 10 acres and require large amounts of land for the treatment location (Metropolitan Council of Minnesota, 2003d). The pond dimensions, including volume and depth, can be determined using the hydraulic residence time (United States Environmental Protection Agency, 1999e). When determining volume, the runoff area must be able to sustain the permanent pool. Larger permanent pool volume to mean storm runoff volume ratios and increased residence time increase pollutant removal (United States Environmental Protection Agency, 2002g). A pretreatment unit for suspended solids removal is recommended to reduce the amount of sedimentation that collects in the permanent pool or sediment forebay (United States Environmental Protection Agency, 2002g). High pollution concentrations can be treated using a wet detention pond if there is sufficient distance to the high water table to protect ground water from contamination (United States Environmental Protection Agency, 2002g). A benefit to this design is that is can be located on site or downstream of the runoff source. However, it can result in warm water outputs, so location should be assessed for possible damage for this side effect. Cold climates may need more detailed planning as biological functions are slowed in lower temperatures and freezing of the detention pond could pose adverse effects. Detention ponds may also require obtaining permits and safety measures, such as a fenced enclosure (United States Environmental Protection Agency, 1999e). Aquatic and wetland vegetation is required for the conditions in a wet detention pond. A vegetated ledge around the edge of the pool will provide a habitat for plant life.

Regular maintenance of a wet detention pond is required. Sediment removal is required every 2–7 years for the permanent pool and forebay to maintain design characteristics (Metropolitan Council of Minnesota, 2003d). Garbage and debris must be cleaned regularly to maintain operation and appearance. Due to the aquatic conditions, mosquito growth must also be controlled (Metropolitan Council of Minnesota, 2003d). Wet detention pond must be monitored for hydrocarbon buildup and erosion, and corrective actions taken when problems arise (United States Environmental Protection Agency, 2002g). Replacing damaged, diseased or nuisance vegetation is required to maintain the pollution removal capacity.

COMPARISON OF BEST MANAGEMENT PRACTICES

Table 1 compares important cost, maintenance and design criteria. USEPA parameters were used when possible to ensure consistency with any environmental laws, restrictions or recommendations. Further, many of the USEPA documents provided a compilation of other research results. Where possible a range of performance values were provided. Many of the publications/bulletins referenced are available online. Websites are provided in the reference section.

SCREENING BEST MANAGEMENT PRACTICES FOR SITE SPECIFIC CONDITIONS

A decision flow chart has been constructed and provided, see figure 1. Simple yes and no questions yield applicable BMP's. Sometimes a single management practice results, other paths will result in multiple alternatives. Decisions and values included in the flow chart have been developed from the resources included in each separate BMP section. Specific design parameters were thoroughly analyzed to determine the yes and no questions and their answers. The decision tree does not include all variables and a comprehensive evaluation of the practices should be made to ensure all factors are addressed. An experienced professional should ultimately evaluate any decision, with the objective to enable a more targeted examination of the applicable practices.

The first step in choosing a storm water management design is to delineate and characterize the drainage area. This will enable the determination of the size requirements for the treatment system, sources and types of pollutants, depth to groundwater and other water bodies.

After selecting applicable systems cost should be analyzed, as it is a major determining factor in any decision process. Table 1 has general cost estimation information; however, the required components of a practice, as listed in Table 2, provides a detailed list of costs associated with conventional or exiting systems, as well as the alternative storm water management practices. Extra spaces are provided for expenses that may arise but are not included on the list.

The costs associated with implementing any of the storm water management practices are largely determined by, but not limited to, the land requirements, fill material, construction requirements and maintenance. Site-specific resources and landscape in the vicinity of the BMP installation is critical to achieve the greatest cost efficiency. Some of the BMP's require large amounts of land, and acquisition of land is costly. This is especially true in urban or suburban areas. Fill material can result in increased capitol and hauling costs. Careful site selection and use of preexisting vegetation and site characteristics can greatly reduce these costs (United States Environmental Protection Agency, 2004a). Large construction costs can result if the landscape, including slope alterations, requires large amounts of construction and variation.

The BMP's can also provide cost recovery in the form of tax rebates and storm water fees. Additional benefits from more pleasing aesthetics and positive publicity are difficult to quantify.

CONCLUSION

Data concerning pollutant removal obtained from these best management practices varies widely from study to study. A broad view was provided, but there is substantial, easily accessible research that is more condition specific with comparable and contradicting results. Choosing a storm water management practice requires further study of design effectiveness on specific pollutant and site characteristics. Due to the wide variation in results, more research is needed to determine the effectiveness and provide standards. Regardless, an experienced professional is critical to avoid mistakes and maximize efficiency.

TABLE 1. Comparison of best management practices.

Design Parameter	Bioretention	Porous Pavement	Infiltration Trench	Wet Detention Ponds	Grassed Swale/Filter Strip	Rain Barrel
Capitol Cost	\$1.25 per square foot \$5.30 per cubic foot (22)	\$2–\$3 per square foot (20)	\$5 per cubic foot (18)	\$0.50–\$1 per square foot (27)	\$0.25–\$0.70 per square foot (16, 17)	\$0.30–\$4.00 per gallon for tank
Construction Costs	$7.30*V^{0.99\ 9}$ (15)	50,000*A (22)	2V–4V (22)	24.5* (Volume in Pond including 10-year storm event)$^{0.705}$ (21)	\$13,000–\$30,000/acre (type of seed or sod) (16)	\$0.30–\$12 per foot for gutters (14)
Maintenance Costs	moderate (5–7% of construction cost) (22)	low (\$200 per acre per year) (25)	high (5–20% of construction costs) (18)	low (3–5% of construction) (21, 27)	low (5–7% of construction costs) \$350 per acre per year (16, 22)	very low–high (based on water use) (14)
Life Span	5–10 years (soil replacement)	15–20 years	5–15 years	20+ years	25 years	20+ years
Total Phosphorus Removal	65–87% (15, 3)	65% (20)	60% (24)	19–48% (21, 2)	30–99% (28, 13, 1)	low/zero
Total Nitrogen Removal	33–68% (15, 5)	80-85% (20)	60% (24)	31% (21)	20–61% (28, 1)	low/zero
Total Suspended Solids Removal	54–90% (23, 3)	64–95% (20, 12)	90% (24)	61–81% (21, 2)	70–94% (28, 13, 1)	low/zero
Bacteria Removal	≥ 90% (23, 5)	n/a	90% (24)	56–86% (21, 6)	none	low/zero
Organics Removal	90% (23)	n/a	90% (24)	n/a	36–61% (1)	low/zero
Metals	43–97% (15, 3)	95–99% (20, 12)	90% (24)	24–93% (21, 4, 2)	50–93% (28, 1)	low/zero
Biochemical Oxygen Demand Removal	n/a	high	70–80% (24)	n/a	Moderate	low/zero
Oil and Grease Removal	moderate-high (2)	n/a	low-moderate (10)	low-moderate (11)	low-moderate (9)	low/zero
Treatment of Highly Contaminated Runoff	yes, if liner is installed (15)	no (20)	no (18)	yes (21)	no (16)	no (19)

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Design Parameter	Bioretention	Porous Pavement	Infiltration Trench	Wet Detention Ponds	Grassed Swale/Filter Strip	Rain Barrel
Land Area Requirements for Management Practice	large (8)	none	small (18)	very large (11, 6)	large (16, 17)	small (19)
Drainage Area Requirement	variable (23)	none	≤ 5 acres (18)	≥ 10 acres (11, 6)	≤ 2–5 acres (16, 17)	design based (14)
Soil Permeability Requirements	variable based on pollutant components (5)	0.5–3 in/hr (20, 25)	≥ 0.52 in/hr (7)	10^{-5}–10^{-6} cm/s (27)	0.5 in/hr or greater (26)	none
Maximum Flow Velocities	1 ft/s for planted ground cover 3 ft/s for mulch (23)	6-month 24-hour rain event (25)	1-year storm event (10)	100-year storm event (27)	5 cubic feet per second (26)	design based (14)
Maximum Slope	20% (23)	5% (25)	15% surface, 0% trench bottom (7, 18)	15% (21)	2–6% (16, 17, 13)	any
Vegetation	diverse assortment (8, 3, 5)	grasses and other groundcover if desired	none	water tolerant, wetland and aquatic	turf grass, wetland and water tolerant	none
Pretreatment Required	none	none	suspended solids (7)	suspended solids (27)	varies based on design	debris screens and first flush diverter (14)
Use with High Water Tables	no (≥ 6 feet to ground water) (23)	no (≥ 4 feet to ground water) (25)	no (≥ 4 feet to ground water) (7)	yes (if not highly polluted runoff) (21)	yes (2–4 feet to ground water) (16)	yes
Use in Cold Climates	reduced efficiency (23)	limitations concerning snow removal methods (25)	limitations (7)	requires excess planning (11)	yes	yes

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FIGURE 1. Storm water BMP decision flow chart.

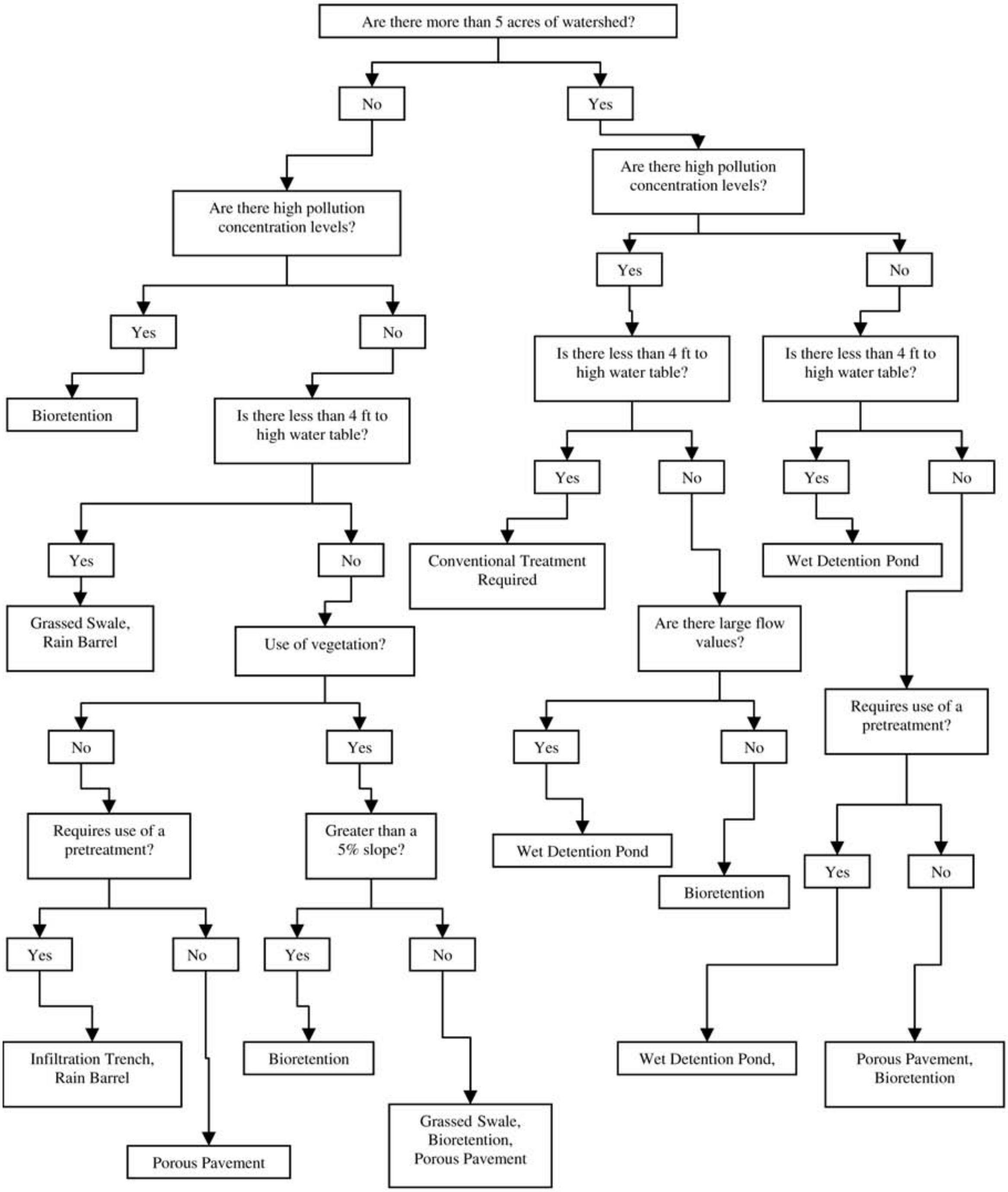

TABLE 2. Cost assessment.

	Existing or Conventional		Storm Water BPM	
	Annual	Life Cycle	Annual	Life Cycle
Preconstruction				
Land Purchase				
Engineering Fees				
Permits and Fees				
Construction				
Clearing				
Fill				
Vegetation				
Seed				
Observation/Inspection System				
Overflow System				
Pipes and Associated Fittings				
Paving Stones				
Sand/Gravel				
Mulch				
Concrete				
Geotextiles				
Vegetation Installation				
Infrastructure Installation				
Tanks				
Screen				
Other Wages				
Other Required Components				
Maintenance				
Mowing				
Fertilizer				
Irrigation Water				
Electricity				
Leaf Removal				
Cleaning				
Vegetation Upkeep				
Pest Control				
Sediment Build-up Removal				
Soil/Aggregate Replacement				
Chemical Tests				
Revegetation				
Inspections				
Maintenance Wages				
Management Wages				
Savings				
Tax Exemptions				
Storm Water Fees				
Water Usage				

This information along with links and supplemental data can be found at the following website: http://www.miamiconservancy.org/Water_Data/StormwaterBMPs/home.asp

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