Summary of Best Management Practices for Residential Stormwater Management - Review of performance and costs

This report summarizes the best management practices for stormwater management on residential properties and includes a description of each practice, its most appropriate applications, and estimated costs. It covers the following practices:

- Rain barrels
- Downspout redirection
- Rain gardens/Bioswales
- Soakaway pits/Infiltration galleries
- Permeable paving

Rain barrels

Rain barrels collect rain water from roofs and other impermeable surfaces, providing short-term storage so the rainwater can be used for non-potable purposes later. The short-term storage attenuates run-off volumes and peak flows related to storm events (Jeon et al., 2017) Modelling has shown that rain barrels can reduce stormwater volumes up to 19% if half of all roofs drain to a rain barrel (Ahiablame & Shakya, 2016). Combined with other stormwater management techniques, rain barrels are an important part of maximizing run-off reduction (Ahiablame & Shakya, 2016; Jeon et al., 2017; Yang et al., 2020). Rain barrels can also satisfy irrigation demand, especially in drier parts of North America (Litofsky & Jennings, 2014).

For rain barrels to be effective, they must be emptied between rain events in order to provide storage volume and thus run-off volume reduction. Promoting the use of the collected rain water for irrigation of lawns and gardens can promote the emptying of barrels and help maintain storage volumes (Litofsky & Jennings, 2014) however in climates like Ottawa’s irrigation needs are lowest when the highest storage volumes are required such as spring. If a rain barrel is continuously full, outputs from the barrel will equal inputs from rainwater sources (roofs etc.) and the stormwater benefits realized will only be related to the positioning of the overflow outlet and not from the barrel itself (Abi

Aad et al., 2010). Thus, promoting proper use of rain barrels is as important to stormwater management as their overall promotion. Municipalities in Ontario have seen success in promoting rain barrels but their impacts on stormwater conditions have been limited by the way they are used (not emptied) (N. Gollan, personal communication, June 18th, 2020).

Rain barrels must also be maintained to keep them from being clogged with debris. Barrels can also provide breeding habitat for pests such as mosquitoes if they are not fitted with a screen over the top. In the winter, rain barrels can be damaged by freezing water and must be 'winterized' by emptying the barrels and turning them upside down or storing them inside.

Costs

Rain barrels are readily accessible at home renovation centers in Ontario. Many municipalities make them available for purchase at reduced rates or for free at municipal depots. They range from $80-200 at home renovation centers, and from $10 to full price at municipal depots. Organizations such as rainbarrel.ca organize community-led fundraisers to sell rain barrels. The consumer price of a rain barrel through rainbarrel.ca is $65 and the fundraising organization gets to keep $10 from each rain barrel sale.

Downspout redirection

Downspout redirection refers to any actions that result in roof downspouts draining away from a house and onto permeable surfaces as opposed to impermeable surfaces such as driveways or patios (Newburn & Alberini, 2016).

Downspouts are designed to take rain from impermeable surfaces such as roofs and move it away from housing foundations and other problematic situations. However, many downspouts move water away from housing foundations by draining onto impermeable surfaces such as driveways. This is effectively the same as draining directly to the storm sewer. Many municipalities have introduced disconnection programs, both mandatory (Toronto, Windsor) and voluntary (Peel Region), to address this problem.

Downspout redirection on its own can eliminate the connection between impervious areas and the municipal sewer system resulting in a slower entry of the water to the system. When redirected to other practices such as soakaway pits and rain gardens, a downspout disconnection can result in the infiltration of a majority of the rainwater from an impermeable surface and prevent it from entering the sewer system at all. This results in the recharge of groundwater resources and the protection of streams and rivers from rushing waters and the erosive forces that come along with them.

Redirection projects can vary widely in their complexity. Some are as simple as turning a downspout to drain to a lawn or adding an extender over an infrequently used path. Others involved cutting concrete or driveway materials, or regrading surfaces to avoid draining to impermeable surfaces.

Costs:

A Sustainable Neighbourhood Action Plan program in the Kidd Creek area near Lake Simcoe delivered a targeted program in a small geographic area that redirected 24 downspouts(Newburn & Alberini, 2016). Costs varied between $100 (‘easy fix’) and $1400 which involved cutting a driveway and installing a French drain. The project characterized the redirections completed into 5 categories:

Table 1. Costs of different types of downspout redirections.

Project type	**Cost**	**Work description**
Install a Flexible downspout extension and re-route over land to lawn	$100	• Install flexible downspout extender pipe to second downspout (usually on the other side of the garage) and direct outlet towards infiltration strip between driveways
Install a lawn infiltration trench	$375	• Dig a trench and lay pipe with cleanout riser to specifications (see next section 6.1.2) • Insert downspout into a PVC pipe with overflow and leaf cap • Add topsoil and grass seed and rake to pre-existing grade of lawn
Under walkway to lawn	$950	• Lift and stack existing paving stones

infiltration trench		• Dig a trench and lay pipe with cleanout riser to specifications - insert downspout into a PVC pipe with overflow and leaf cap • Replace and secure existing paving stones • Add topsoil and grass seed and rake to pre-existing grade of lawn
Through walkway to lawn infiltration trench	$1,200	• Cut through poured concrete slab and install grated sidewalk trench • Dig a trench at end of slab and lay pipe with cleanout riser to specifications • Insert downspout into a PVC pipe with overflow and leaf cap - finish area with cold patch asphalt • Add topsoil and grass seed and rake to pre-existing grade of lawn
Through driveway to lawn infiltration trench	$1,400	• Cut through concrete driveway and install grated driveway trench • Lift and stack existing paving stones at walkway • Dig a trench and lay pipe with cleanout riser • Insert downspout into a PVC pipe with overflow and leaf cap • Finish area with cold patch asphalt and fill edge of trench drain with polymeric sand • Add topsoil and grass seed and rake to pre-existing grade of lawn

Even at the high end of the cost spectrum for complex fixes, downspout redirections present a good value proposition for how much impermeable area is taken ‘offline’ and how much run-off can be prevented from entering the storm system per dollar invested. The Kidd Creek redirection project estimated run-off reduction costs between $32-120/m^2. This is comparable to rain gardens.

Rain gardens

Rain gardens are a type of bioretention that use native vegetation, sand and soil in a shallow depression to collect rainwater and infiltrate it into the ground. Rain gardens provide efficient recharge of ground water in urban environments. Rain gardens that represent about 10-20% of the impervious area drained are most efficient and increasing depth increases water detention time (Newburn & Alberini, 2016).

Rain gardens are very effective at reducing stormwater volumes and combined sewer overflow events. Modelling has shown that 85% of CSO volume can be reduced if rain gardens are installed at a rate of 20/ha, however, this would require almost every house to have one which is not realistic (van Seters et al., 2013). The number of required rain gardens is influenced by overall landscape imperviousness. Rain gardens can also remove pollutants from storm run-off including lead, copper, zinc, and total suspended solids. Rates of removal vary but they are generally above 60% (Brunetti et al., 2016). Other benefits measured from rain gardens include reduction of heat island effects due to conversion of paved area to more-natural ground cover and reduced thermal aquatic impacts.

Rain gardens can process run-off from areas 5-20 times large than the surface of the rain garden itself. This ratio depends on the natural infiltration rate of the native soils. Rain gardens that are oversized are not cost-effective, while rain gardens that are undersized will receive too much silty sediments that can result in clogging. Rain gardens can be constructed with underdrains or without. Those with underdrains can process more water in extreme events, but generally infiltrate a low proportion of entering waters. Water that does enter the under drain is often conveyed to storm sewers. For this reasons, drainless designs are highly preferable when native soils and other limitations allow.

Rain gardens must be planted with vegetation in order to reach their full potential. Plant roots help maintain the infiltration capacity of soils and counteract the clogging effects of sedimentation. Plants should be selected for native hardiness, light tolerance, drought and flood tolerance, and salt tolerance in areas with elevated salt exposure (near roads).

Studies in the Baltimore-Washington area showed that residents were more willing to build a rain garden as rebate incentives increased. While 18% of residents were found to be willing to install a rain garden without incentives, an incentive of $6.72/sqft USD resulted in 50% of residents being willing to install a rain garden (van Seters et al., 2013) where the total cost of installing a rain garden is about $9/sqft.

Costs

The cost of installing a rain garden is largely dependant on labour costs. If a resident installs a garden themselves, the cost can be quite low. Soil amendments such as compost and sand as well as the mulch that goes on top of a rain garden can all be bought in small amounts at a home improvement store. For larger rain gardens, a bulk price may be possible, but delivery costs should be considered. Prices in the Ottawa area are as indicated in Table 2.

Table 2. Prices for materials often used in the creation of a rain garden.

Material	Small quantity price	Bulk price
Sand	$319.60/tonne + HST	$33/tonne + HST (~$100 delivery)
Compost	$154.40/m^3 + HST	$62.78/m^3 +HST (~$100 delivery)
Mulch	$71.25/m^3 + HST	$62.78/m^3 +HST (~$100 delivery)
Native perennials	$4.40 + HST/ 4 plugs	$3.30/ 4 plugs + HST
	$13.20 + HST/ 1 gal pot	$8.25 + HST/ 1 gal pot

A 2013 study of LID technology costs produced an estimated $245.94/m3 (2013 CAD) for a rain garden receiving waters from a 2000 m^3 parking lot (van Seters et al., 2013). Unlike most residential applications, this rain garden had engineered elements such as curbs which increase overall costs, but it was also larger than any residential rain garden, providing construction and material efficiencies.

Soakaway pits

Soakaway pits or ‘French drains’ are a shallow depression filled with porous media (soil and stones) that allows the entry and storage of run-off waters and the eventual infiltration into the ground. Soakaway pits are a common solution for dealing with run-off waters in private property applications. They are essentially a pit filled with a loose porous medium that allows for the efficient conveyance of run-off water through the medium – often clean gravel. Similar to the use of rain gardens, underdrains should be avoided when the goal is to infiltrate run-off into the ground and thereby avoid the storm sewer system. As in most infiltration systems (including rain gardens) contaminated water is not appropriate for soakaway pits. Run-off from roofs, walkways and low traffic driveways is generally acceptable, but not when near well-heads or drinking water sources. Additionally, soakaway pits should not be used within 4m of building foundations.

Soakaway pits are roughly as effective at processing pollutants and sediments as rain gardens, although less research is available on the subject. Studies from the Nepean area of Ottawa show lead, copper, zinc and total suspended solids removal rates of 90% and higher (Brunetti et al., 2016). They are also effective at reducing run-off volumes; averaging 85% reductions in the systems with perforated underdrain pipes (van Seters et al., 2013). Systems without underdrain are likely even more effective at reducing run-off.

Soakaway pits can receive and infiltrate water from areas 5-20 larger than the surface area of the soakaway pit. Because the surface area of the pit itself can be quite small, soakaway pits are particularly appropriate in highly developed urban areas where land is scarce, and it allow residents to maintain turf/lawn coverage.

Costs

Like rain gardens, soakaway pit costs are driven by labour costs with materials being relatively price-stable and inexpensive. Maintenance costs are non-existent or low until performance begins to decline in which case cleaning or retrofitting may be required. There are no published cost estimates for lot-level soakaway pits, but because of the work, materials and contractors who conduct the work, costs are assumed to be similar to rain gardens for applications that manage the same amount of run-off.

Table 3. Material costs associated with soakaway pits.

Material	**Small quantity price**	**Bulk price**

Sand	$319.60/tonne + HST	$33/tonne + HST (~$100 delivery)
Clear gravel	$221/tonne + HST	$23.50/tonne +HST (~$100 delivery)

Permeable pavement

Permeable pavement refers to durable surfaces that allow rainwater to be infiltrated through the surface and into a porous medium and eventually into the ground. Different types of permeable pavements have been developed and are categorized into three main types;

- **Modular Interlocking Concrete Block Pavement** consists of impervious concrete blocks that allow water to infiltrate into a reservoir through inter-block or intra-block voids. These voids may be filled with gravel or soil and grass. Gravel is the most common filler as it is less susceptible to clogging.
- **Porous Asphalt** or **Porous Concrete** consists of standard asphalt or concrete mixes from which the finer aggregates have been removed. Removal of these fine materials results in a pavement with a matrix of pores that allows water to permeate through the surface.
- **Plastic Grid Systems** consist of plastic interlocking units with virtually no impervious surface area. Grid spaces may be planted with grass or left unplanted and filled with gravel. The grids provide structural stability and prevent settling while allowing a large amount of void space for infiltration of stormwater. (Adapted from (Brunetti et al., 2016)

Permeable pavements have the least reliable track record of infiltration performance over time of all the low impact development techniques (van Seters et al., 2013) While permeable pavements systems have been designed to infiltrate copious amounts of run-off, concerns around clogging reduce their appropriateness as a management technique for stormwater control. Recent research is establishing the role of regular maintenance and showing how it can ameliorate some of the concern around clogging, improve long-term functioning and solidify the role of permeable pavements in stormwater management (van Seters et al., 2013). Additionally, novel ‘mixes’ of permeable paving materials show promise for improved performance, including ones with polymer (plastic) binding agents which allow increased flexibility and strength maintenance under freeze-thaw conditions (van Seters et al., 2013).

A two-year study of several permeable paving technologies in the Greater Toronto Area found that the surfaces were effective at managing surface waters through infiltration (van Seters et al., 2013). The study examined three types of paving including two permeable pavers (where gravel filled gaps between the pavers provide infiltration capacity) and a permeable concrete (where fines have been eliminated from the mix resulting in a permeable surface). Infiltration rates rapidly declined over the first two years of use due to clogging. After four years and scheduled vacuum maintenance on all three surface types, the permeable concrete maintained the highest infiltration rate, while the two paver-based systems failed to meet the theoretical infiltration threshold consistent with an intense rainfall. Run-off volumes from the warm-season weather were reduced by 40-52% and virtually all of the first 5mm of rain was retained by the systems. Most pollutant concentrations were reduced by the permeable surfacing when compared to typical asphalt run-off. Additionally, thermal loads were reduced when compare to asphalt.

Permeable pavements are ideal for applications where space for other LID such as rain gardens is limited. Due to the risk of clogging, permeable pavements are more suitable for low traffic areas such as parking lots, pedestrian paths and driveways. Additionally, they must be subjected to regular maintenance in order to provide long term stormwater management performance.

Costs

Permeable pavements vary in their costs based on variations in site requirements as well as the technology used. Common to all paving installations is the base preparation. Different base preparations are required based on soil types and any existing base. The costs of base preparation change independently from the costs of the surfacing technology whether they are impermeable or permeable.

Permeable pavements cost about double what impermeable pavements cost. Due to fixed costs, larger applications of permeable pavement are less expensive per unit area.

For a typical residential driveway (65m^2) the cost can be \$190/m^2 for a high-end proprietary porous asphalt product that mimics a conventional driveway, but large applications (or multiple small applications in a single day) can reduce the price to around \$124/m^2.

Costs for permeable pavers for residential projects are not readily available. (van Seters et al., 2013) produced cost estimates for a large parking lot installation which include 1,000m2 of permeable pavers with an additional 1,000m2 conventional parking lot that contributed run-off to the permeable section. The permeable area cost about double (\$98/m^2) what the conventional pavement cost (\$43/m^2). However, the total cost of the system is dependent on the ratio of permeable to impermeable paving which can be as high as 2:1 for low traffic installations.

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