WorleyParsons

resources & energy

Appendix 1 General Best Management Practices

General Best Management Practices

Best Management Practices (BMPs) can be considered from an ecological watershed context as generally two different types: structural and non-structural (planning).

Planning BMPs: Low-Impact Development Practices

Low Impact Development (LID) practices are effectively Planning BMPs with two key objectives for reducing impervious runoff and achieving target conditions:

- Implement strategies to limit the amount of detrimental land coverage; and
- Preserve significant natural features

Low Impact Development (LID) Implementation Strategies

An Economic Rationale for Integrated Stormwater Management (Centre for Landscape Research, 2005), explains LID principles as falling into 6 main categories; these are summarized below.

Reduce Road Widths

Reducing road widths reduces overall impervious area and infrastructure costs while also providing additional greenspace. Trees could be planted, creating an overarching canopy that shades road and walkways and intercepts rainfall. Reduced road widths also contribute to decreasing motor vehicle speeds and increasing pedestrian and bicycle safety.

Reduce Building Footprints

Rooftops are impervious areas, so by relaxing height restrictions and building taller, more slender buildings, the same floor area can be accomplished with a smaller footprint. Additionally, more natural vegetation can be preserved and more space is available for source controls such as infiltration facilities.

Reduce Parking Standards

Embracing reduced standards of area for residential driveways and car parks, as well as commercial parkades and parking lots, decreases development costs and allows for more affordable housing. This strategy also supplements the creation of compact communities, bringing more amenities within walking distance and increasing the available surface area for public transit routes. Effective strategies are the implementation of effective public transportation demand strategies and increasing the cost of parking.

Limit the Amount of Surface Parking

In addition to reducing parking standards, incorporating necessary parking into existing building footprints (such as multi-level parkades and underground parking facilities) can drastically reduce impervious area and allow for more significant preservation of natural landscape. Parkades may also support green roofs.

Compact Communities

Several benefits of compact communities have already been illustrated, and this strategy supplements all other objectives. By building compact communities, natural areas can be preserved, amenities are within walking or biking distance, the need for transportation is reduced, and average roadway coverage per dwelling unit can be reduced by up to 75%.

Preserving Significant Natural Features

All of the aforementioned strategies contribute to preserving natural features by reducing the need to develop them. However, certain natural features have incredibly beneficial natural functions (which costly infrastructure must be implemented to replicate) including streams and wetlands, absorbent soils, and tree cover. Other features, such as wildlife corridors, cannot be replicated with infrastructure but provide tangible community benefit. These features must be recognized early in site design, and integrated into land use decisions.

Soils and Riparian Vegetation

Leaving soils and vegetation undisturbed minimizes the effect on the natural water balance, maintains the health of aquatic ecosystems, and reduces drainage problems and flood risks by infiltrating surface flows to feed stream baseflows.

Wetlands

Wetlands retain large volumes of water and promote infiltration and groundwater recharge. Wetlands are productive ecosystems, their vegetation contributes to evapotranspiration, and filtration through soils and root systems can remove sediments, nutrients, metals and other contaminants.

Natural Infiltration Areas

Riparian corridors, areas with highly permeable soils and natural depressions where large volumes of water accumulate and infiltrate are pivotal to natural watershed function.

Floodplains

Natural floodplains provide natural flood control by dissipating peak flow energy and allowing space for streams and rivers to expand during high rainfall or snow melt periods. Confining watercourses with dams or dykes prevents this natural energy dissipation and can increase the risk of downstream flooding. Natural flooding areas are also necessary to preserve the natural integrity of riparian forest and wetland ecosystems.

Best Management Practices Examples

The following are brief synopses of source control BMPs from the BMP guide for stormwater (MVS&DD, 1999) and the Stormwater Source Control Guidelines (GVRD, 2005). This list is in no way exhaustive and those BMPs selected are those that are most applicable to Central Saanich's site conditions/constraints and issues.

Pre-treatment BMPs

Pre-treatment BMPs are well established is stormwater management and therefore have been only summarised below. Their main drawback is that they are maintenance intensive and do not perform as designed if not well maintained. Pre-treatment BMPs:

- Coalescing Plate Separator
- Water Quality Inlet
- Manhole Sediment Trap
- Trapped Catch Basin
- Catch Basin Filter

Description

Pre-treatment BMPs are principally used to mitigate high concentrations of contaminants in two categories; oil, grease and sludge, as well as debris, coarse sediments and particulates. In general, these BMPs are underground facilities with 1-3 internal chambers; the chambers and inlets/outlets separated by baffles or other physical barriers to separate and collect the contaminants.

Usage/Benefits

These BMPs are typically installed off-line so as to bypass large storm events. They are applied to frequent runoff events from sites with high concentrations of the aforementioned contaminants, such as the high oil or grease content of impervious runoff from maintenance and repair yards or industrial land uses, or the highly sedimented runoff from gravel parking lots or urban intersections. Pre-treatment facilities are particularly useful to prevent obstruction, increase effectiveness, and reduce O&M costs for other BMPs downstream, such as infiltration or detention facilities, wetlands, ponds, swales, etc.

Drawbacks

Only effective for frequent, smaller storm events, these BMPs must bypass larger events to avoid reintroduction of the screened contaminants. As such, there is no attenuation of peak flows or runoff volume control and groundwater recharge. These facilities are relatively expensive in terms of both capital and O&M costs, and are incredibly maintenance intensive.

Key Factors

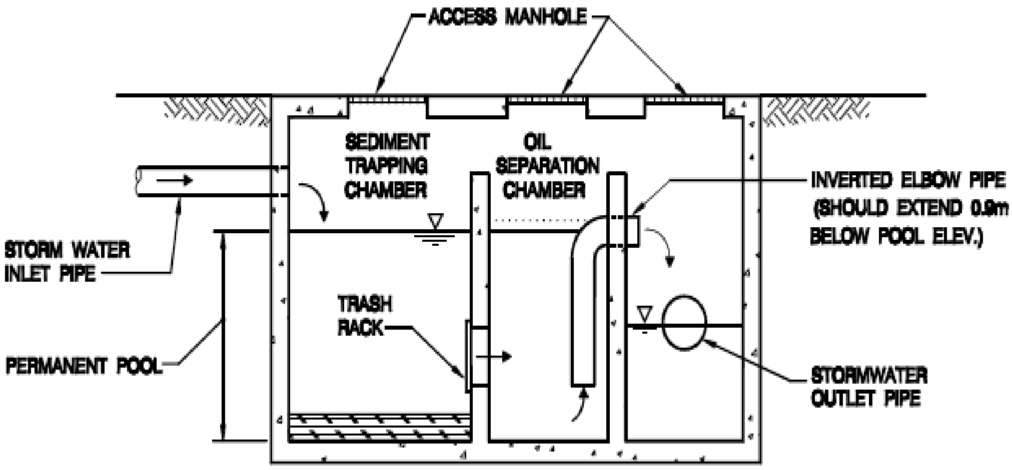
- Stormwater from potential sites must be monitored with water quality objectives and expected benefits quantified in order to select and justify use of pre-treatment BMPs
- Retrofitting to existing infrastructure is more difficult and expensive than installing in new developments

Coalescing Plate Separator

This is the most expensive and special-purpose pre-treatment BMP, and is only cost effective for impervious runoff highly contaminated with non-dissolved and non-emulsified oil or grease. Stormwater is made to flow through a rack of plates on which different particles coalesce and separate; as such coarse sediments and debris can clog the plate rack and should be avoided. Pervious, roof, and otherwise lowly-contaminated runoff should bypass this facility to prevent dilution, and it should be located at least 15m from slopes.

Water Quality Inlet

Also known as an oil/grit separator (see figure below), this 3-chambered facility removes large particulates and coarse sediments, as well as trapping some oil and grease. A permanent pool in the device promotes settling and oil separation, but may result in odour problems, particularly through the dry season, if contaminated with decomposing organic matter. The maximum contributing impervious area is 0.4 ha per facility. This facility should also be placed 15m away from slopes.



Manhole Sediment Trap

Manhole sediment traps are strictly effective in trapping sediment and settleable solids – there is insignificant removal of floating, particulate, colloidal or dissolved contaminants. Although each manhole can support multiple inlets, the maximum contributing impervious area is 1.2 ha per manhole. This facility also utilizes a permanent pool to prevent particulate resuspension, and may therefore be subsequent to odour problems in the dry season.

Trapped Catch Basin

The least expensive pre-treatment BMP, this facility is a variant on the above BMP and has similar contaminant removal characteristics. It is suitable for street-level grated inlets, and a maximum contributing impervious area of 0.4 ha per basin.

Catch Basin Filter

Catch basin filters boost the functionality of other pre-treatment facilities. Design analysis is limited to selecting a filter media (such as fibreglass, activated carbon, absorbent materials, etc.) to remediate a specific contaminant, which is inserted at the inlet of another facility. Low capital costs and space requirements make catch basin filters particularly suited to retrofitting, such as preventing construction site sediment, trash or debris from entering coalescing plates, oil separators, or other BMPs. However, significant maintenance effort is required.

Operations and Maintenance

The accumulation of contaminants separated from the input stream necessitates a detailed and involved maintenance plan to ensure proper function. Regular (monthly or quarterly) monitoring and recording of contaminant levels as well as cleaning and/or removal as necessary will help to prevent the reintroduction of contaminants into the output stream. Season-specific inspections are also required as well as annual vactor truck cleaning.

Cost Implications

Construction costs for these four facilities range from $800 – $22,500, and to estimate total capital costs an additional 35% of construction costs should be added. Additional capital investment of $260,000 - $300,000 in a vactor truck for regular maintenance is required for most of these BMPs. Annual maintenance costs vary and are as high as $15,000.

Constructed Wetlands

Description

Constructed wetlands are a surface facility which functions similar to a wet pond. Once stormwater is introduced, a permanent water pool and wetland vegetation provide contaminant removal. Additional live storage can also be designed for detention, although certain complications may apply.

Two major variations are subsurface flow wetlands; water is permeated horizontally through porous soil or gravel rooted with aquatic vegetation; and free surface flow wetlands, such as shallow marshes, pond/marsh flow systems, extended detention wetlands, etc. Wetland designs are incredibly variable and may include combinations of many features specific to performance objectives and site conditions.

Usage/Benefits

Proper wetland design and function is a careful science incredibly dependant on internal geometry and ecology. If properly designed, wetlands can be tailored to any number of performance objectives. Gravitational settling, soil and root filtration and adsorption, chemical transformations and biological consumption/conversion provides effective mitigation of particulates, suspended solids, heavy metals, dissolved contaminants, and bacteria. Absorbent soils vegetation can detain and infiltrate stormwater to provide peak flow rate and runoff volume control, as well as streambank erosion protection.

In addition, wetlands can provide significant habitat for fish and wildlife as well as adding value to the community through aesthetic and recreational benefits.

Drawbacks

Successful implementation has a significant personnel requirement, as detailed planning, research, monitoring and assessment of environmental conditions are necessary. Once design geometry is established, careful on-site construction supervision is required to ensure it is built properly. The initial vegetation growth phase requires monitoring and maintenance, and effectiveness is delayed until vegetation matures. Even once fully matured, a training program for maintenance personnel may need to be implemented to ensure proper care.

Once developed, constructed wetlands tend to be seen as natural systems and may wish to be conserved in their ‘natural state’ by the public. This may lead to an adverse attitude towards future alteration such as necessary maintenance or functional improvements.

Wetlands also have a large standing water surface area requirement, which makes retrofitting difficult. The typical disadvantages of standing water also apply; including the breeding of bacteria and pest insects such as mosquitoes, occasional odour problems, public safety concerns, and potential for adverse temperature increases downstream.

Key Factors

- Design features are highly variable and all performance aspects are heavily reliant on proper design – design team should include engineer, wetlands specialist, aquatic biologist, landscape architect, groundwater hydrologist, and construction contractor
- Careful evaluation of natural environmental conditions is necessary to properly select and design wetland geometry and vegetation
- Stormwater with concentrated toxic contaminants (such as industrial runoff) may need to be pre-treated to avoid destruction of wetland ecosystems
- Banks and surrounding areas need to be marked and stabilized to allow safe access of maintenance vehicles, equipment and personnel
- Total land requirement is 3% - 5% of total contributing area; minimum contributing drainage area of 4-10 ha
- Requires adequate water supply and water balance considerations on site to prevent dry-up in the summer

Operations and Maintenance

During the first three years after construction, wetlands must be inspected during both growing and non-growing seasons, after each heavy rainfall event as well as periodically throughout the wet season. After this period, annual inspection of structural and hydraulic facilities, as well as routine inspection, cleaning, removal of clogs and floating debris, vegetation maintenance and correction of erosion problems is required. Routine maintenance must be scheduled around sensitive wildlife and vegetation seasons. Sediments must be removed every 5-7 years, and effort must be made to maintain the original contours and elevations.

Cost Implications

The highly variable nature of wetland design and construction can complicate cost estimates, but typical construction costs can be estimated with the formula $34.70 x $(35.31V)^{0.70}$ where V = the storage volume in m^3, and to estimate total capital costs an additional 35% of construction costs should be added. Annual maintenance costs can be approximated at 3% - 6% of construction cost.

Vegetated Swales with Infiltration

Description

Vegetated swales (grassed channels and wet swales) are wide, shallow channels filled with vegetation similar to conventional ditches and provide infiltration capability. They are installed on-line and used to simultaneously convey and treat stormwater, the natural vegetation decreasing stormwater flow velocities and increasing concentration times. Smaller, more frequent events filter through the vegetation and soil while larger events are conveyed through the channel.

Grassed channels are meant to dry out between storm events and vegetated with grasses or turf. Wet swales are vegetated with aquatic or wetland vegetation and maintain standing water; either due to high groundwater table or baseflows or in periodic shallow ponding areas facilitated by installed check dams.

Usage/Benefits

This BMP has many advantages over conventional conveyance systems by combining conveyance and treatment functions in a technically simple, cost-effective method. They are most useful along roadways, beside parking lots, or in other areas without underground conveyance infrastructure, and are suitable for retrofitting to existing developments or in place of existing conveyance systems. By reducing flow velocities and increasing concentration time vegetated swales can contribute to peak flow, flood and erosion control while reducing overall volume with promoted infiltration, groundwater recharge and evapotranspiration. There is also significant contaminant removal (especially in wet swales) via similar mechanisms to wetlands, as well as minor oil and grease removal.

Drawbacks

Even with carefully selected erosion-resistant vegetation, vegetated swales are very susceptible to both erosion and sediment accumulation, and significant remediation efforts must be employed. High concentrations of sediments should be removed upstream, and potentially high-velocity inflows may need to be dissipated using inlet flow spreaders. This erosion sensitivity combined with a number of other factors necessitates a rigorous maintenance program, particularly during the first year while vegetation matures and erosion-resistant root systems form. Flows must be diverted during this period, and temporary alternatives must be utilized. Vegetated swales are not typically suitable for ultra-urban applications.

Key Factors

- Minimum length of 30 m
- Minimum bottom width of 0.6 m

- Only effective for longitudinal slopes of 2% - 6%
- Minimize compaction during construction
- Divert flows until vegetation is established

Operations and Maintenance

Routine (preferably monthly) inspections and maintenance activities are necessary, especially during wet weather and immediately after large storms. Vegetation must be kept in the active growth phase and requires mowing as often as bi-weekly during the growing season. Clippings, fallen leaves, and other obstructions and organic materials must be removed to prevent clogging and nutrient release. Erosion problems or bare soils must be corrected and replanted immediately, and if implemented, inlet flow spreaders must also be maintained.

Cost Implications

Construction costs are dependant on swale dimensions, site geography and soil conditions. However, typical construction costs range from $24 – $74 per linear metre, and to estimate total capital costs an additional 35% of construction costs should be added. Annual maintenance costs can be approximated at 5% - 7% of construction cost.

Biofilters

Description

Biofilters (sometimes known as vegetated filter strips) are in many ways similar to vegetated swales. The main difference is that while swales are used primarily to convey water along a channel, with filter strips the stormwater is intercepted and directed / dispersed to promote even sheet flow over large, planar vegetated surfaces, and the primary benefits are water quality and contaminant removal. The vegetation may range from simple grass and turf to full forests depending on objectives and constraints.

Usage/Benefits

Filter strips are used in many of the same ways as vegetated swales, and are effective when surrounding large impervious areas before runoff becomes significantly concentrated, such as roadways and parking lots. Performance is largely a function of local soils and vegetation, dimensions incoming flow characteristics, and can be designed according to objectives. Contaminant removal mechanisms are similar to wetlands, and are typically more significant than vegetated swales; most effective for small storms in low-density areas. Filter strips also have much more significant infiltration and groundwater recharge potential if properly employed.

This BMP can help to reduce the imperviousness of development sites, preserve the character and integrity of riparian zones and can provide significant wildlife habitats, aesthetic benefits and recreational values; especially if forested.

Drawbacks

The same limitations apply to filter strips as for vegetated swales, as well as significant drawbacks due to the functional dependence on even sheet flow. In addition to requiring a much larger surface area, filter strips are incredibly susceptible to erosion and channelization, especially when forested. As such, areas in which filter strips are employed must be graded to a uniform, even slope, and incoming stormwater should be introduced prior to significant concentration or distributed/dispersed over the width of the filter strip. They are only suitable for low-velocity, low-depth flows, but present significant difficulty bypassing larger flows due to the nature of their application.

Key Factors

- Requires uniform, even slope no greater than 5% grade
- Requires even sheet flow – incoming flows may need to be dispersed
- Channelizing activities must be prevented, adequate signage posted
- Maximum contributing drainage area of 2 ha

Operations and Maintenance

Follow operations and maintenance guidelines for vegetated swales. In addition, specialized maintenance may be required depending on the nature of the vegetation selected. For instance, grasses or turfs may require occasional aeration to maintain permeability, and although forested areas require less frequent routine maintenance, more significant remediation of erosion and channelization may be required. Maintenance may need to be scheduled around sensitive wildlife and/or vegetation seasons as well.

Cost Implications

Capital costs vary with selected vegetation. Typical construction costs for grassed strips are approximately $16 per m^2 surface area for sod and seeding. For forested strips, typical construction costs range from $400 – $2,000 per ha if seedlings are planted, and may require as much as $4,000 – $20,000 per ha for nursery stock planting. To estimate total capital costs an additional 35% of construction costs should be added.

Annual operations and maintenance costs range from $370 – $3,000 per ha depending on degree of allowed natural succession; a typical cost for grassed strips is $1,200 per ha.

Dry/Wet Detention Basins

Description

Stormwater detention facilities serve to collect and store stormwater and release it at a controlled rate through one or more orifices. Dry detention basins (henceforth DDB) are designed to empty completely between storm events, and only detain water when the inflow rate is higher than the designed outflow rate. Conventional DDB have high design outflow rates and are purely to control peak flows, typically only detaining water for a period of a few hours.

A variation is the extended dry detention basin (henceforth EDDB), which is designed with a much lower release rate and hence higher detention period – typically 72 hours. EDDB detain runoff from more frequent storm events, and help to prevent erosion and preserve streambanks by reducing the frequency and duration of erosion-intensive bankfull flow conditions. They can be installed both on-line and off-line depending on design objectives.

Wet basins are designed to maintain a permanent pool of water within the control structure. They can be constructed as a single pond, or as a multi-pond system utilizing different stages and elevations.

Usage/Benefits

Conventional DDB can be designed to control peak flow rates and help to maintain predevelopment rates. EDDB also remove sediments, particulates, and other contaminants via a combination of a sediment-catching forebay and increased gravitational settling promoted by low turbulence and longer detention period.

Wet basins have significantly greater water quality benefits, and infiltration and/or groundwater recharge can be significant in some scenarios. They are multi-purpose facilities, as in addition to stormwater management and contaminant removal, the aquatic and surrounding ecosystems create fish and wildlife habitats, add aesthetic and recreational value, and can even increase property value. They can be sized as small, on-site facilities or service larger regional areas.

Neither variant is usually limited by native soil type, and both may result in some infiltration depending on basin lining material and underlying soil conditions. The use of natural vegetation creates aesthetic benefits and habitats for wildlife.

Drawbacks

DDB are sensitive to repeated large events; if not completely drained before the occurrence of a design event, overflow is bypassed. They also require a large amount of surface area, and are difficult to retrofit to existing developments unless they can be somehow accommodated into existing parks or greenspaces. Such an area can raise certain public concerns; namely safety, due to slope integrity, flow velocities and pool depth, as well as aesthetics as there is a possibility for accumulation of trash or debris or development of boggy areas and associated odours and insects.

To maintain effectiveness the permanent pool for wet basins must be maintained throughout the year, so if adequate baseflow does not exist, soil permeability must be evaluated and appropriate pond liner selected. Woody vegetation must be located no closer than 5m to embankments and structural facilities.

Key Factors

- DDB designed for a large, infrequent event – typically 5 or 10 year storm, while emergency spillways control bypass of larger storms
- Native vegetation must be scoped, planted, and maintained
- EDDB require additional 20% of storage volume for sediment accumulation
- Total required area for DDB is 0.5% - 2% of total contributing area, and is hence difficult to retrofit to existing developments
- Total land consumption including buffers for wet basins is typically 2% - 3% of watershed area; sizing and volume vary with objectives and location
- Wet basins typical minimum contributing area of 4-10 ha; maximum of 25 km^2

Operations and Maintenance

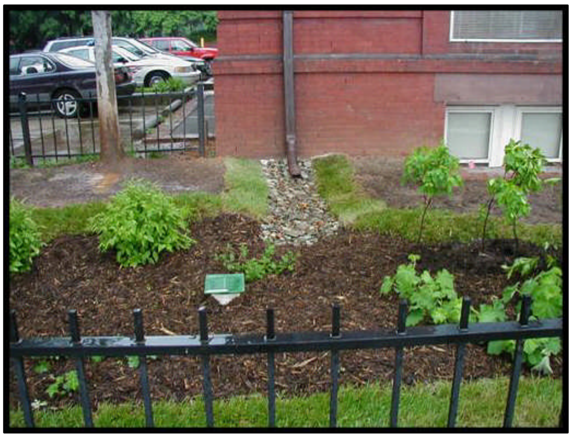
Routine inspection, cleaning, clearing of clogs and floating debris, correction of erosion problems and vegetation maintenance is required in addition to annual inspection of hydraulic and structural facilities. EDDB and wet basins also require sediment removal every 5-15 years, and bank reinforcement and stabilization is required to allow access for maintenance vehicles and equipment.

Cost Implications

Typical construction costs can be estimated with the formula \$11.65 x $(35.31V)^{0.78}$ where V = the storage volume in m^3, and to estimate total capital costs an additional 35% of construction costs should be added. Annual maintenance costs can be app0roximated at 1% of construction cost.

More expensive than extended dry detention basins, wet basins are most cost-effective in larger catchments. Typical construction costs can be estimated with the formula \$28.90 x $(35.31V)^{0.70}$ where V = the storage volume in m^3, and to estimate total capital costs an additional 35% of construction costs should be added. Annual maintenance costs can be approximated at 3% - 6% of construction cost.

Roof Downspout Disconnection



Description

Roof downspout disconnection systems are another method of infiltrating stormwater on a small-scale, site-level basis, receiving impervious runoff from rooftops. Rather than a particular facility, this BMP is in effect a principle – disconnecting rooftop impervious runoff from municipal drainage systems – and methods of implementation vary. Sub-surface methods (including infiltration trenches filled with drain rock, sand filters, dry wells, and perforated infiltration tanks) resemble underground versions of infiltration basins, detaining stormwater in a storage tank until it infiltrates into the ground. Surface dispersion methods (including open-top dispersion trenches, French drains, and other dispersion methods) depend on vegetated areas such as gardens for infiltration.

Usage/Benefits

Relatively small, inexpensive and simple to install, roof downspout disconnection systems are typically applied to residential areas and small office buildings, and can be easily retrofitted to existing developments. Once installed, sub-surface facilities can be landscaped over, and surface facilities lend well to aesthetic landscape integration.

A single roof downspout system may have very little effect, but these systems are incredibly effective when used extensively – such as implementation on each site in a residential development. The cumulative effect can result in large volumes of stormwater infiltration, and many of the same benefits that are detailed for infiltration basins can be obtained.

Rooftop runoff is commonly held as ‘clean’ enough to be infiltrated without treatment, and only screening for leaves and debris is necessary. Properly designed systems require a minimum of maintenance, and can usually be outsourced to residents or property owners. Specific benefits of the various methods are summarized in the table below.

Infiltration System	Minimum Length of Available Land	Minimum Area of Available Land	Minimum Infiltration Capacity	Cost: Material / Labour
Surface Dispersion	Long	Large	High	Low/Low
Infiltration Trench	Medium	Medium	Low	Medium/High
Dispersion Trench	Medium	Medium	Low	Low/Medium
Infiltration Tank	Short	Small	Medium	High/High
Dry Well	Short	Small	Medium	High/High

Drawbacks

Occasionally rooftop runoff can pose significant threat of groundwater contamination, especially in areas with highly permeable soils. Contaminants contributed by excessive bird droppings, decaying organic material such as fallen leaves, asphalt shingles, atmospheric depositions and galvanized metal drainage structures sometimes necessitate pre-treatment. As such, initial evaluations similar to those detailed for infiltration basins are sometimes required.

Although routine maintenance is less frequent, extensive use of downspout systems can involve significant time, effort, and travel when making maintenance rounds if appropriate property owner participation cannot be secured.

Key Factors

- Maintenance and monitoring responsibilities must be established and clearly communicated to residents and property owners
- Avoid compaction of soils and divert runoff during construction
- Install high-flow bypass to prevent residential flooding in large events
- Locate 3 m from any structure and 15 m from any slope steeper than 40%
- Minimum depth to seasonal high water table 0.3 m

Operations and Maintenance

Very little routine maintenance beyond clearing of debris screens is required for the majority of the methods discussed, and if properly executed most of the maintenance and monitoring responsibilities can be outsourced to residents and property owners. Observation wells must be monitored quarterly and after large storms during the first year and annually thereafter.

Cost Implications

Limited cost data exists for individual methods, but a typical construction cost for sub-surface infiltration trenches is $110V where V = the storage volume in m^3, and to estimate total capital costs an additional 35% of construction costs should be added. As indicated in the table above, this figure is representative of the medium to higher range of the cost spectrum.

Infiltration Trenches/Filter Beds

Description

Infiltration trenches, also known as soakaways and are designed to allow infiltration of the water captured / directed to the trench. These BMPs not only provide temporary storage of stormwater, attenuating peak flows but they also allow the water to infiltrate the underlying soils and can achieve varying levels of contaminant removal.

These facilities are large, grass-floored basins designed to store stormwater temporarily and allow it infiltrate directly into the ground. Similar to detention basins, offline infiltration basins store more frequent storm events and bypass larger events via an emergency spillway. Backup underdrains are also installed so as to empty standing water from the basin for maintenance.

Sand and organic filter beds are designed only for contaminant mitigation, not retention. There are several design variations, both above and below ground, but the underlying principle remains the same – stormwater flows into a sedimentation forebay, is then dispersed over the infiltration bed and routed to the underlying drainage system. Two standard surface variants are the Austin filter and the Delaware (or perimeter) filter. Austin filters are basin-like constructions, whereas perimeter filters involve contained sub-surface chambers into which stormwater flows through intake grates. Underground variants are contained facilities which do not intake surface runoff directly, but receive it instead through inlet pipes from other sources. They require much less area but are significantly more expensive.

Usage/Benefits

Provided that facilities are sized and designed to infiltrate all or almost all of the incoming stormwater, they allow for complete control of peak runoff rates, runoff volumes, and water quality. By diverting stormwater into groundwater recharge incoming flows are disconnected from the drainage infrastructure, helping to reduce the size of downstream conveyance, detention and treatment facilities.

Infiltration trenches work well in combination with downspout disconnection (see above). Even though runoff from the roof is generally considered unpolluted, in instances where the water does contain pollution, the infiltration process allows for some level of treatment. Specific performance is dependant on soil and vegetation characteristics as well as design dimensions, and can be modified to suit certain objectives. A stepwise contaminant removal process can be created by layering different types of infiltration media – a typical top layer of crushed limestone will reduce phosphorous and adjust pH.

Filter beds have a relatively small space requirement and are not usually limited by site or climate characteristics. They are suitable for retrofitting and typically employed when the use of other BMPs is precluded by site conditions, and are effective along roadways and around the perimeter of impervious areas such as parking lots. As stormwater percolates through a filter bed, contaminants can be removed through filtration, soil adsorption, biological action, volatilization, ion exchange and plant uptake. Organic filter media can range from specialized mixtures to municipal compost, and have improved contaminant removal performance over sand, particularly soluble nutrients and metals. Mild infiltration may also be promoted.

Drawbacks

Infiltration basins can be prone to sediment clogging and insufficient soil drainage. Pre-treatment to remove at least 80% of the sediment loading is necessary to preclude these clogging failures and maintain soil permeability and drainage characteristics. Even without clogging, emptying time is directly dependant on infiltration rates and is typically much longer than detention basins or wet ponds. Adequate investigation of site soil and groundwater characteristics is necessary to ensure that infiltration basins are dimensioned to receive and infiltrate all incoming flows. Low-permeability soils, particularly clays, are not suitable for infiltration basins.

Although infiltration can provide significant contaminant removal, heavily contaminated inflows, highly permeable soils such as gravel or coarse sands, specific types of contaminants or combinations thereof can lead to groundwater contamination and may necessitate pre-treatment. Careful evaluation of the risk of and sensitivity to groundwater contamination and in some cases monitoring programs are also required.

Sand and organic filters are suitable for contaminant removal only, and do not provide significant flood and erosion control benefits or attenuation of peak flows and runoff volumes. Filter media are particularly susceptible to clogging due to accumulation of sediment, and upstream sediment pre-treatment is integral to proper function; sand and organic filters should not be employed where large sediment loads are expected.

Key Factors

- Pre-treatment for sediments and contaminants often necessary
- Infiltration minimum 450 mm underlying soil containing sufficient organic matter, clay, or silt; minimum 1 m – 1.5 m to impermeable layer or high water table
- Infiltration basin bottom should be as level as possible
- Avoid compaction of soils and divert runoff during construction
- Contributing drainage area of trenches 2 ha – 20 ha
- Locate trenches at least 15 m from slopes greater than 15% grade
- Locate trenches 30 m upslope and 6 m downslope of any building
- Filter bed surface variant area requirement up to 50 m^2 per contributing impervious ha
- Maximum contributing areas for filter beds 12 ha down to 2 ha
- Filters minimum depth of 0.6 m – 1.2 m to high groundwater table for underground

Operations and Maintenance

Inspections of facility once a month and following each major storm are necessary for the first few months after construction, as well as monitoring infiltration rates and groundwater contamination in sensitive areas. Once proper function is observed, infiltration basin ongoing operations and maintenance requirements are reduced similar to dry and wet detention basins, with additional measures to discourage woody growth.

Inspection of structural components of filter beds and routine cleaning should be completed semi-annually and after each major storm event. Routine monitoring of inlet and outlet flow rates must be conducted to check sediment levels and evaluate filter bed permeability; frequency is dependent on the degree of sediment pre-treatment. Surface vegetation maintenance may also be necessary.

Cost Implications

Typical construction costs for infiltration basins range from \$44 – \$71 per m^3 storage volume depending on dimensions of the facility, and to estimate total capital costs an additional 35% of construction costs should be added. Annual maintenance costs can be approximated at 1% - 3% of construction cost.

For filter beds, construction costs vary with size and conditions and there are relatively few case examples of the use of sand and organic filters in our climatic region, so costs are difficult to estimate. Budget construction costs of \$37,500 to \$75,000 per impervious ha contributing area, although costs may decrease if the technology sees more use. To estimate total capital costs an additional 35% of construction costs should be added. Annual maintenance costs can be approximated at 11% - 13% of construction cost.

Absorbent Landscaping

Description

Absorbent landscaping involves the maintenance or addition of absorbent soils, generally topsoil or soils amended with compost, of sufficient depth so that stormwater can be stored within the soil interstitial spaces. The preservation of existing forest cover also assists in maintaining soil absorbency. In a natural undeveloped condition, surface soil is highly permeable due to vegetation root systems, a complex system of organics and decaying matter, and aeration of soils by earthworms and microbes. In historically developed areas, the absorbent topsoil layer and vegetation are stripped away, the site is heavily compacted, and only a small portion of the topsoil is reinstated. The intent of absorbent landscaping is to reinstate or maintain the absorbency of the surface soils to that of the pre-development condition.

Generally, landscaping soils can store between 7% and 18% of their volume as water prior to reaching saturation, attenuating runoff peak flow rates. The stored water may then infiltrate into subsurface soils, aiding in the reduction of runoff volumes. Even in areas where base soils are of low hydraulic conductivity, absorbent landscaping has been found to be effective in eliminating runoff for 50% of the Mean Annual Runoff. In many instances, implementing absorbent landscaping may involve reinstating the pre-development depth of topsoil after development, in other cases it may involve adding topsoil or amending soils with compost.

The absorbency of surface soils can be significantly affected by surface crusting through the accumulation of fine particles, heavy compaction, and raindrop impact. Efforts to maintain landscaping soil absorbency should be implemented, such as planting surface vegetation (enhances evapotranspiration and interception) and adding mulching.

Usage/Benefits

Unlike other BMPs, absorbent landscaping is virtually invisible once in place as it is merely an enhancement to site landscaping. It may lead to more aesthetically pleasing landscaping designs, due to the requirement of surface vegetation. Addtionally, a site may retain more of its natural character by maintaining the existing tree canopy, an integral part of absorbent landscaping.

The benefits of absorbent landscaping increase as rainfall volumes increase since it has been shown that absorbent landscaping virtually eliminates surface runoff. It is best suited for areas with lower levels of impervious coverage since the storage capacity of absorbent soils is dependent on the size of the landscaped area and the area it drains. During extreme rainfall events, absorbent landscaping has been found to attenuate peak runoff rates as well. Due to its storage capacity, absorbent landscaping is also suitable for areas with subsurface soils of low permeability.

Drawbacks

The amount of additional soil required for absorbent landscaping is dependent on the Mean Annual Rainfall and therefore may be significant in very wet areas. Generally, the depth of absorbent soils required is five times the 2 year 24 hour rainfall. Traditional practice on developed sites has been to replace only approximately 50 mm of topsoil after development. In coastal BC, approximately 250 mm to 350 mm of topsoil may be required to retain 50% of the MAR, depending on the surface vegetation planted. The increased cost of the topsoil may make this BMP unattractive to developers.

One of the main drawbacks to this BMP is that its maintenance is likely left in the hands of the property owner. If the landscaping maintenance is altered or neglected, i.e. the plants are removed or not allowed to establish, poor watering, mulching is not reapplied, or the surface is not aerated regularly, the absorbent capabilities of the soil may be compromised.

Key Factors

- Preserve as much existing forest cover as possible
- Maintain 150 mm of absorbent soil for lawn areas and 450 mm for shrub/tree areas
- Plant vegetative cover to prevent surface crusting
- Organic content should be between 8% (for lawns) and 15% (for planting beds)
- Select surface vegetation with herbaceous/thick matt roots and deciduous trees with high leaf density, or evergreens
- Compact landscape subgrade to 80% proctor density, avoid over compaction
- Ensure sources of erosion are contained before absorbent landscaping is applied.

Operations and Maintenance

- maintain absorbency of soils through normal landscape maintenance
- apply organic material such as bark mulch, compost, leaf drop, etc. regularly to promote burrowing insect populations and to maintain permeability
- use sandy topsoil under lawns to avoid compaction problems; regularly aerate locally compacted areas
- dry-season watering is essential, especially while plants are establishing
- maintenance costs/requirements highest in first year due to watering, weeding, replacement of vegetation requirements

Cost Implications

- highly variable; depend on site-specific conditions and choice of vegetation
- typical costs of absorbent landscaping is \$25 - \$70 per m^2

Pervious Pavers

- Porous Pavement
- Grid and Modular Pavers

Description

Pervious paving alternatives allow stormwater to percolate through them and infiltrate into the soil below, reducing total impervious area. Porous pavement is open-graded coarse aggregate asphalt or concrete mixtures overlaying a gravel reservoir bed. Alternatively, poured in place concrete grids, pre-cast grids, or modular pavers can be arranged in a structural matrix, which is interspersed with void spaces, filled with permeable materials such as soils vegetated with turf or grass. These can lie directly on subsoils or can also have underlying fill materials.

Two standard overflow strategies are to simply allow the reservoir to fill and subsequent stormwater to run off as with an impervious surface, or to divert overflow to an underlying drainage system where it is then routed to conveyance systems.

Usage/Benefits

Pervious pavers are another method of directly infiltrating stormwater, and can receive inflows from other areas in addition to receiving direct rainfall, provided there is no significant sediment loading. Benefits are as with other infiltration BMPs, including contaminant removal, control of peak runoff rates and volumes, flooding and erosion protection, and groundwater recharge. Detention can also be provided depending on the capacity of the underlying reservoir, which can attenuate peak runoffs and facilitate more efficient infiltration.

Pervious pavers are practical in low-traffic areas such as parking areas, service and access roads, driveways, storage yards, bike paths and walkways. They can reduce the need for conventional curb and gutter systems, replace existing roadways and be retrofitted to existing developments.

Drawbacks

The same careful initial investigations necessary for infiltration basins also apply with pervious pavers. Stormwater is infiltrated directly and hence contaminant pre-treatment is difficult, so pervious pavers should not be employed in areas at risk to groundwater contamination, such as near gas stations.

Pervious pavers are incredibly sensitive to sediment clogging (particularly porous pavements, which can become sealed in 1-3 years), so incoming runoff from other areas containing sediments should be pre-treated or diverted. Winter sanding is obviously detrimental, and plowing can also cause damage. Capital investment in street cleaning equipment is also necessary to remediate sediments.

Signage must also be posted advertising the capabilities and drawbacks of pervious pavers to prevent damaging activities, including higher traffic volumes or heavy trucks, which can lead to wheel rut deformations.

Key Factors

- Same initial investigation procedures and requirements as infiltration basins
- Protect from sediments: pre-treat runoff from other areas or implement diversionary structures (berms, filter strips, etc.)
- Avoid compaction of subsoil and divert runoff during construction
- Stabilize surrounding areas
- Minimum 1 m – 1.5 m adequately permeable soil to high ground water table
- Post warning signs to prevent damaging activities

Porous Pavement

- More suitable for ultra-urban areas
- Pavement may seal in 1-3 years if sediment inadequately controlled
- May need to ‘aerate’ with 13 mm drill holes at regular intervals
- Maximum 5% slope; locate 30 m upslope, 3 m downslope of buildings
- Locate 30 m from drinking water wells

Grid and Modular Pavers

- Higher capital costs, lower maintenance requirements, easier to renovate
- Maximum 15% slope; locate 30 m upslope, 6 m downslope of buildings
- Locate 30 m from septic fields

Operations and Maintenance

Porous pavement has an estimated effective life of 5-10 years, during which time quarterly cleaning with vacuum street sweepers and high pressure washers is required to prevent sediment clogging. Permeability should be monitored, and if it decreases substantially, 13 mm ‘aeration’ holes may need to be drilled at regular intervals.

Grid and modular pavers have very little maintenance requirements beyond maintenance of vegetation if permitted to grow in void spaces.

Cost Implications

Construction costs can be estimated at \$20 - \$30 per m^2 per porous pavement and while grid and at \$80 - \$115 per m^2 for porous interlocking concrete pavers, poured in place slabs and simpler units should be less expensive. To estimate total capital costs an additional 35% of construction costs should be added.

Design Principles

The following design principles and engineering standards have been adapted from the following publications:

- Center for Watershed Protection (CWP). 1998. Better Site Design: A Handbook for Changing Development Rules in Your Community. Ellicott City, Maryland.
- Center for Watershed Protection (CWP). 2008. Managing Stormwater in Your Community: A Guide for Building an Effective Post-Construction Program. EPA Publication No: 833-R-08-001. Ellicott City, Maryland.

Residential Streets and Parking Lots

a) "Design residential streets for the minimum required pavement width needed to support travel lanes; on-street parking; and emergency, maintenance, and service vehicle access. These widths should be based on actual traffic volume".

   i) Set maximum road widths for low density developments with less than 500 daily trips (ADT) (*i.e*., 18-22 feet).

   ii) Allow the application of alternative street layouts that reduce the length of residential streets while maximizing the number of homes per unit length.

b) "Residential street right-of-way widths should reflect the minimum space required to accommodate the travel-way, the sidewalk, and vegetated open channels".

   i) Set the maximum right-of-way (ROW) width in residential areas (*i.e.,* 45 feet).

   ii) Allow for the placement of utilities and stormdrains under the paved right-of-way (ROW) where feasible.

c) "Minimize the number of residential street cul-de-sacs and incorporate landscaped areas to reduce their impervious cover. The radius of cul-de-sacs should be the minimum required to accommodate emergency and maintenance vehicles".

   i) Set the maximum cul-de-sac radius in new developments (*i.e.,* 35 feet). Consider placing a vegetated depression in the center of the cul-de-sac.

   ii) Consider alternative turnarounds, such as "hammerheads" for short streets in low density areas.

d) "Where density, topography, soils, and slope permit, vegetated open channels should be used in the street right-of-way to convey and treat stormwater runoff".

   i) Promote the directing of stormwater flows into vegetated open channels using curb cuts, building new roads with no curbs, etc. Gently slope sidewalks to drain to a front yard or swale rather than to the street.

   ii) Establish criteria that align the stormwater pollutant treatment capacity of swales (*i.e.*, grassy swale, dry swale, biofilters, etc) and other BMP's to various types of infrastructure (*i.e.,* road side ditch, parking lots, roof-run off).

e) "Existing parking ratios should be reviewed for conformance taking into account local experience to see if lower ratios are warranted and feasible".

i) Set maximum parking ratios for residential areas (*i.e.,* 2.0 spaces per home), professional office buildings (*i.e*., 3.0 spaces per 1000ft2 of gross floor area), and shopping centers (*i.e*., 4.5 spaces per 1000ft2 of gross floor area).

ii) Promote shared parking by developing models of shared parking agreements.

iii) Develop incentives to encourage structured and shared parking to make it more economically viable.

iv) Revise parking codes to reduce parking requirements where mass transit is available or enforceable shared parking arrangements are made.

f) "Reduce the overall imperviousness associated with parking lots by providing compact car spaces, minimizing stall dimensions and incorporating efficient parking lanes".

i) Set standard parking stall sizes (*i.e*., maximum 9 foot width and an 18 foot length).

ii) Develop incentives for developers to build underground parking lots rather than surface parking.

iii) For spillover parking areas, utilize pervious parking materials such as grasspave.

iv) Reduce the amount of required parking areas by developing shared parking arrangements for currently under utilized areas (*i.e.,* church parking lots).

g) "Wherever possible, provide stormwater treatment for parking lot runoff using bioretention areas, filter strips, and/or other practices that can be integrated into landscaped areas".

i) Set criteria requiring that a minimum percentage of a parking area is vegetated.

ii) Allow for the use of bioretention facilities, curb cuts, french drains, and other BMP stormwater practices to capture parking lot run-off in vegetated areas.

Lot Development

h) "Advocate open space design development by incorporating smaller lot sizes to minimize total impervious area, reduce construction costs, conserve natural areas, provide community recreational space and promote watershed protection".

i) Utilize flexible site design criteria (*i.e*., setbacks, road widths, lot sizes) to promote open space or cluster developments that maximize open space and reduce total impervious area of the site.

ii) Relax side, rear and front yard setbacks to minimize driveway lengths and allow narrower frontages to reduce total road length and lot imperviousness. Set maximum driveway widths (*i.e*., 9 feet for one lane; 18 feet for a shared driveway).

iii) Locate sidewalks on only one side of the street and provide common walkways such as trails through common areas whilst linking pedestrian areas. Set maximum sidewalk and trail widths (*i.e*., 4ft).

iv) Promote alternative driveway surfaces (*i.e*., pervious pavement, grasspave, gravelpave, etc) and shared driveways that connect two or more homes together.

i) “Clearly specify how community open space will be managed and designate a sustainable legal entity responsible for managing both natural and recreational open space”.

   i) Develop enforceable requirements that enable associations (*i.e*., land trusts, conservation easements) to effectively manage open space.

   ii) Require that a minimum percentage of open space be managed in a natural condition.

   iii) Develop standards that require open space areas to be consolidated into larger units (*i.e.,* purchasing property that either contain or back onto streams).

   iv) Define allowable and unallowable uses for open space in residential areas.

j) “Direct rooftop runoff to pervious areas such as yards, open channels, or vegetated areas and avoid routing rooftop runoff to the roadway and the stormwater conveyance system”.

   i) Develop educational programs and incentives for rainwater recapture (*i.e.,* rainbarrels) and onsite stormwater reduction (*i.e.,* green roofs, rain gardens, small bioretention areas, stormwater planters, dry wells, french drains, etc).

   ii) In areas where there is adequate drainage, allow for the disconnection of downspouts enabling water to drain into the soil.

Conservation of Natural Areas

k) “Create a variable width, naturally vegetated buffer system along all perennial streams that also encompasses critical environmental features such as the 100-year floodplain, steep slopes and freshwater wetlands”.

   i) Establish a protocol or system so that the function of naturally vegetated buffer systems along streams is maintained and improved (*i.e*., invasive species removal, replanting programs, etc).

   ii) Promote conservation of stream buffers, forests, meadows, and other areas of environmental value.

   iii) New stormwater outfalls should not discharge unmanaged stormwater into jurisdictional wetlands, sole-source aquifers, or sensitive areas.

   iv) Partner with local schools and develop educational programs on stream health and function that tie into local school curriculum.

l) “Clearing and grading of forests and native vegetation at a site should be limited to the minimum amount needed to build lots, allow access, and provide fire protection”.

   i) Require limits to disturbance be shown on construction plans as a part of the development permit application.

   ii) Develop criteria that require developers to preserve a portion of the developable land as greenspace.

   iii) Conserve trees and other vegetation at each site by planting additional vegetation, clustering tree areas, and promoting the use of native plants.

m) “Develop incentives and enable development flexibility in the form of density compensation, density bonusing, transfer development rights, buffer averaging, property tax reduction, off-site mitigation, and stormwater credits”.