THE CITY OF CALGARY

LOW IMPACT DEVELOPMENT GUIDELINES

MODULE 2 – BIORETENTION AND BIOSWALES

FINAL REPORT MAY 2016

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1. Bioretention and Bioswale Overview

Bioretention areas and bioswales are stormwater management practices that treat stormwater, reduce the volume of storm runoff flowing to receiving waters, and provide some peak flow attenuation by providing storage, encouraging percolation into the subsoils and evaporation. The treatment process happens when water passes through vegetation and soil, with sediments, nutrients, metals and other contaminants captured, broken down or retained. These processes (i.e., treatment, volume reduction and flow attenuation) mimic processes provided by the natural landscape in the water cycle. Bioretention areas and bioswales are very similar and have essentially the same components and functions, but they have a couple of key differences.

One of the key functions that differentiate bioswales from bioretention areas is that bioswales incorporate conveyance of stormwater from a point of origin to a destination point. For example, runoff from a section of paved road or parking lot can be transported to a downstream portion of the drainage system via a bioswale.

Another distinct difference is that bioretention areas include ponding capacity to increase the volume of water that can be infiltrated for a given catchment size. Bioswales may also have some allowance for ponding, but it is generally significantly less than for bioretention areas due to the slope of the swale and need for conveyance. Ponding may be incorporated in bioswales using terraces or weirs where there is a significant slope; this will be discussed in more detail in Section 2.4.4.

There are seven key elements to a functional bioretention area or bioswale (see Figures 1-1 and 1-2):

- Growing media layer;
- Filter layer separating the soil from the rock reservoir below;
- Rock reservoir (also called rock trench) of clean crushed drain rock or manufactured underground stormwater storage units;
- Underdrain pipe (also called a sub-drain) consisting of a perforated pipe connected to the storm sewer system;
- Storm sewer system inlet that drains excess water to the storm sewer system;
- Emergency overland escape route; and
- Vegetation on the surface that protects and rejuvenates the growing media, provides phytoremediation, habitat, biodiversity, and aesthetic enhancement.

Bioswales and bioretention areas are intended absorb runoff and store it in the soil as well as return it back to the atmosphere via evapotranspiration. They can also discharge either via percolation (deep infiltration) into the subsoils and/or as underdrain flow to the storm sewer system. They provide volume reduction through infiltration of smaller storm events so that lower runoff volumes are discharged to the receiving water body. A lined bioswale or bioretention area, if lining is required, will still provide some reduction in peak flow rate, but less of a reduction in total volume discharged to the storm sewer system.

Bioretention and bioswales can be used in a wide variety of climates, landscapes, geology, and development scenarios. For the City of Calgary, consideration of low subsoil percolation rates, high-intensity storms, long periods of drought, and cold climate conditions have been incorporated into this design guidance.

1.1 Bioretention

The surface of a bioretention area is typically depressed, with the storm sewer system inlet raised above the bioretention (surface) invert to allow ponding of water in the bioretention area. This maximizes the volume of water that a bioretention area can treat, by storing runoff from short-duration, high intensity rainfall events and allowing it to infiltrate into the soil over a longer period of time. Ideally, a bioretention area has minimal overflow and can absorb, infiltrate and treat a significant fraction of the precipitation for an average year in the Calgary climate.

Photo 1-1: Bioretention area, Carburn Park, Calgary, AB

Bioretention areas can be integrated into the street boulevard to take up minimal space and are generally decorative in contrast to concrete traffic islands or traffic-calming. They can also be incorporated in the landscaping of a site and make attractive landscape features.

Bioretention areas can be a variety of scales and can be used for runoff from any surface, from a busy highway to a small roof.

1.2 Bioswale

The bioswale category of stormwater facilities also includes infiltration swales, or simply swales, which may have slightly different definitions, but all function according to the same principles, as elaborated on in this module.

The bioswale is kept to a maximum slope of 2% to promote infiltration into the growing media. Weirs or "steps" can be used to terrace a steeper slope to allow use of a bioswale (see Figure 1-2). Flatter longitudinal slopes are preferred since this offers more opportunity for the water flowing through it to infiltrate and evaporate.

Bioswales are open channel drainage ways that can be used as an alternative to the conventional curb and gutter and underground storm sewer system along roadways and parking areas. Bioswales incorporate similar design features as bioretention areas; however, as mentioned above, they are designed as part of a conveyance system with a design for slope and depth of flow. Bioswales are used to treat and capture runoff from impervious surfaces as well as to convey excess runoff during major storm events and can also act as an emergency escape path.

Photo 1-2: Bioswale, Currie Barracks, Calgary, AB

The principal differences between a bioswale and a bioretention area are that the bioswale has:

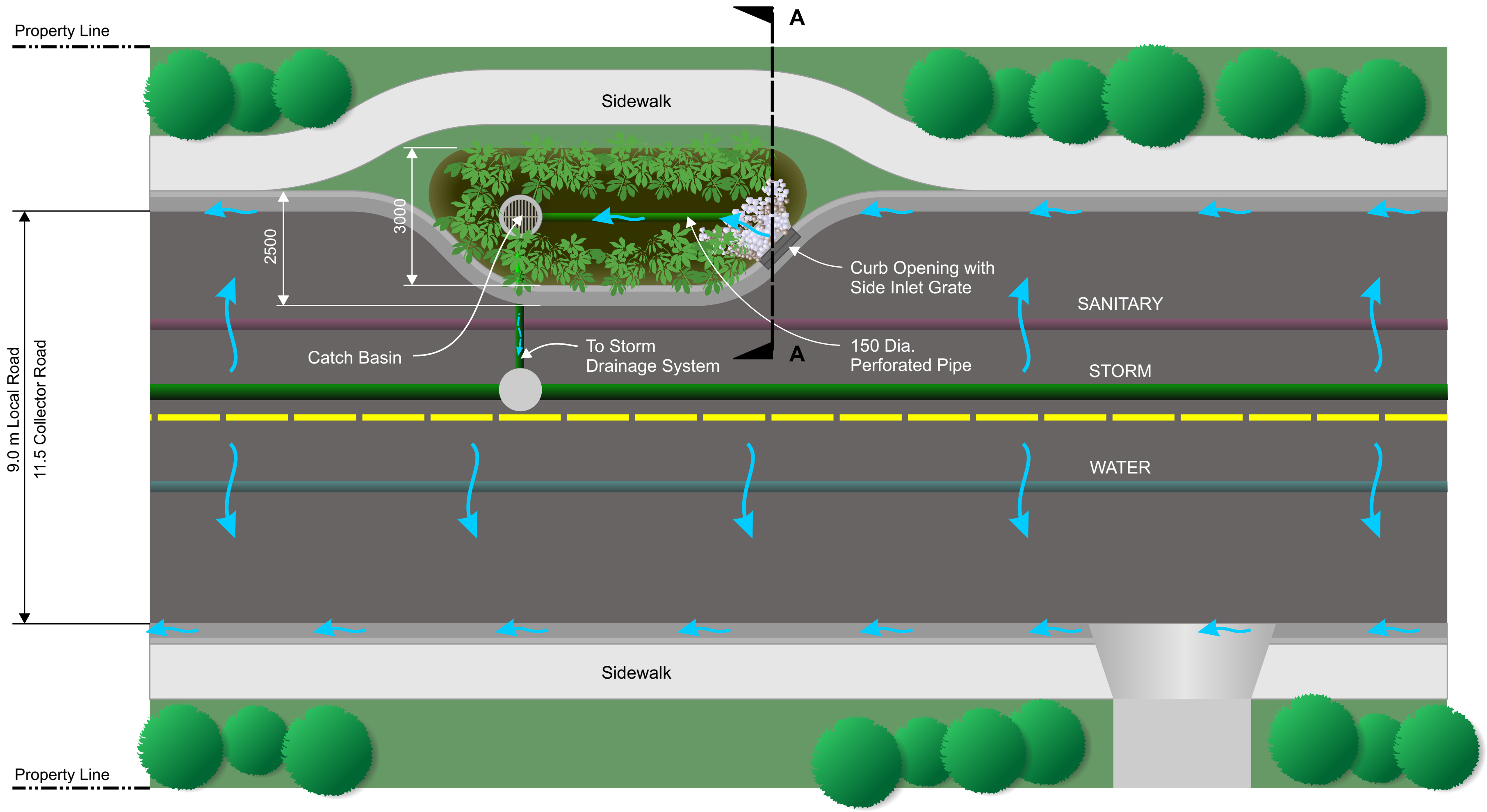
- A linear shape, and
- A sloped invert profile to convey flow in the channel.

Bioswales can be a range of scales and can be used for runoff from any surface, but are typically associated with linear features such as roads or rows of parking. Bioswales can be integrated into the street boulevard to take up minimal space and are greener and more decorative in contrast to standard curb-and-gutter road and parking verges. Bioswales can also be a feature in the landscape and provide green space in the developed environment.

1.3 Additional Information Elsewhere

In addition to the design and construction guidance in this Module, there are other sources of information that are additional to but related to the information provided here. Information that may be found elsewhere includes:

- Utility design in proximity to bioretention and bioswales: bioretention and bioswales are not considered to be inherently affected by proximity to buried utilities or roads, so no guidance on setbacks or limitations to bioretention or bioswales are included here. The design of utilities in proximity to these facilities may be impacted by the separation from or design of the bioretention areas or bioswales. The design of utilities and their site considerations and interactions with other facilities are dealt with in separate guidance for utilities design and construction.
- Subsurface conditions testing, investigations and assumptions: all assessments and considerations of subsoil considerations relative to bioretention, bioswales, and other vegetative absorptive LID practices, are provided in Module 1 of this LID technical guidance.
- Stormwater Drainage System Design: the design of the stormwater drainage system itself is not discussed in this guidance document. Refer to The City of Calgary's *Stormwater Management and Design Manual* (2011).
- Modelling guidance: while it is recognized that modelling goes hand-in-hand with the design of bioretention and bioswales, particularly with regard to incorporating these facilities into a site and achieving runoff targets for the whole site, a comprehensive guide to modelling these facilities is beyond the scope of this design guidance. Refer to documentation for specific software packages for guidance on using that software to model LID practices.
- Safety considerations and recommended practices in conjunction with bioretention facilities and bioswales will be developed separately by The City of Calgary. There are not universal safety requirements in conjunction with these LID facilities, and items such as separation from playing areas, barriers near walkways and bicycle paths, maximum ponding depth allowed without a barrier, etc., will be developed in accordance with local practices and levels of community comfort with these facilities.



Plan
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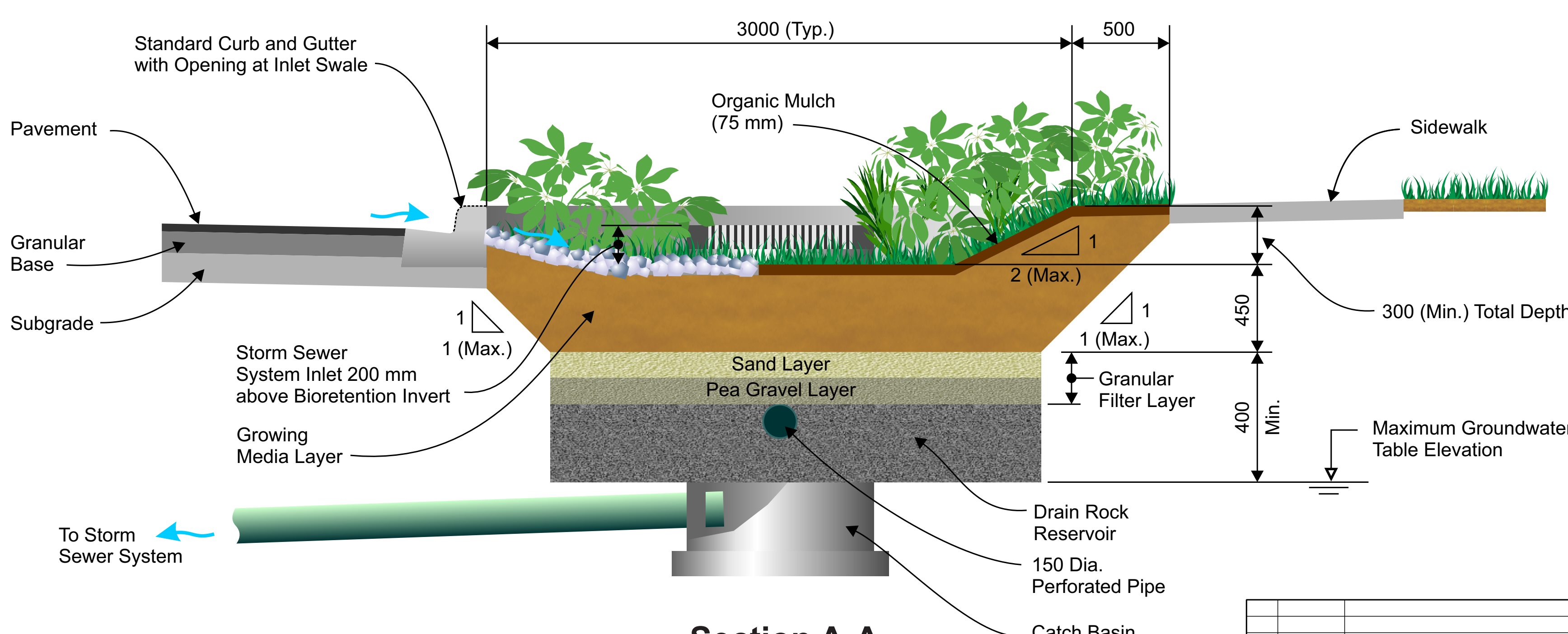

Section A-A
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DIMENSIONS ARE MILLIMETRES UNLESS OTHERWISE NOTED

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JL	2016-05	LM
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THE CITY OF CALGARY WATER RESOURCES

Typical Bioretention Area

Sheet

Figure 1-1

File Number

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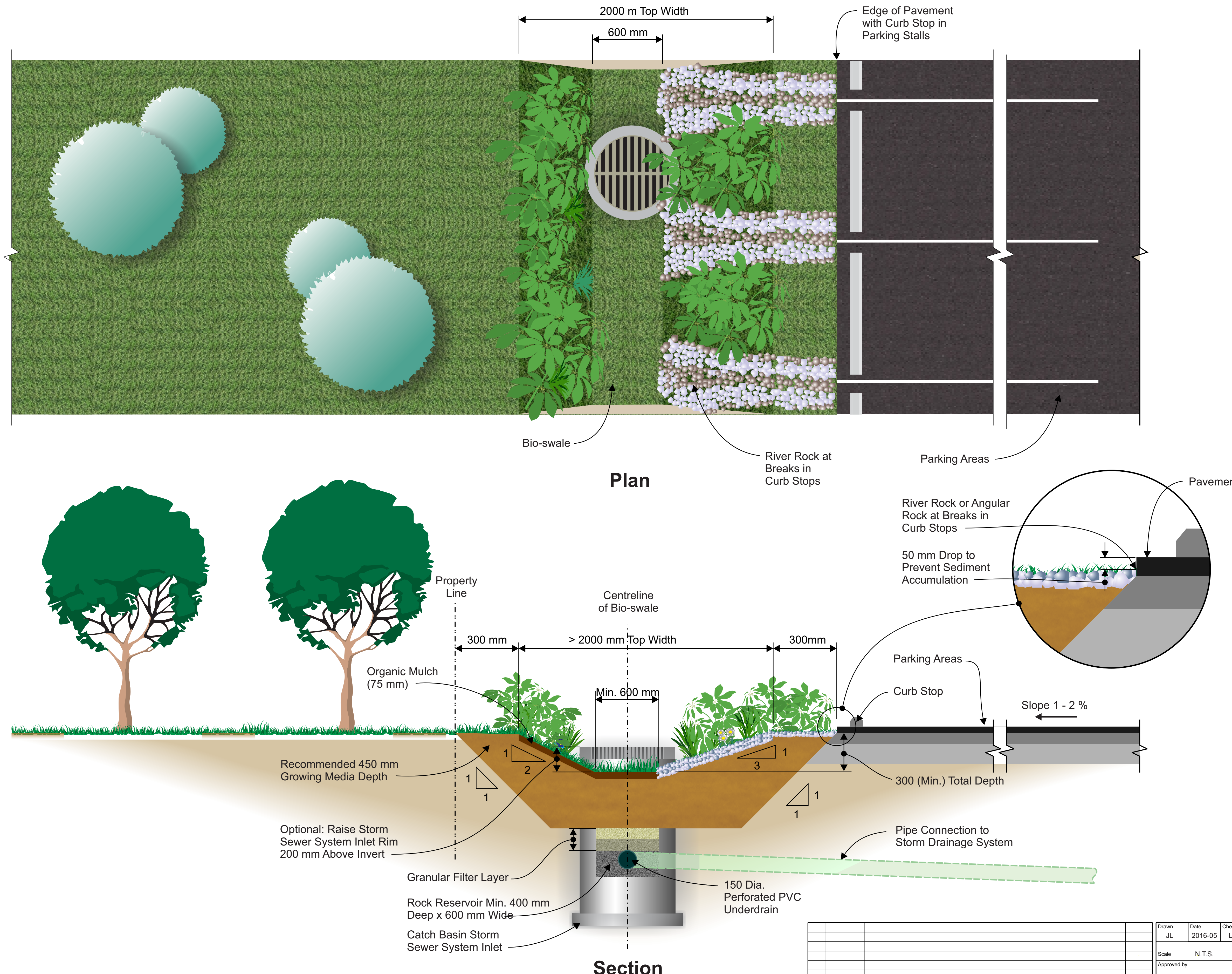

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Typical Bio-swale

Sheet: Figure 1-2

File Number

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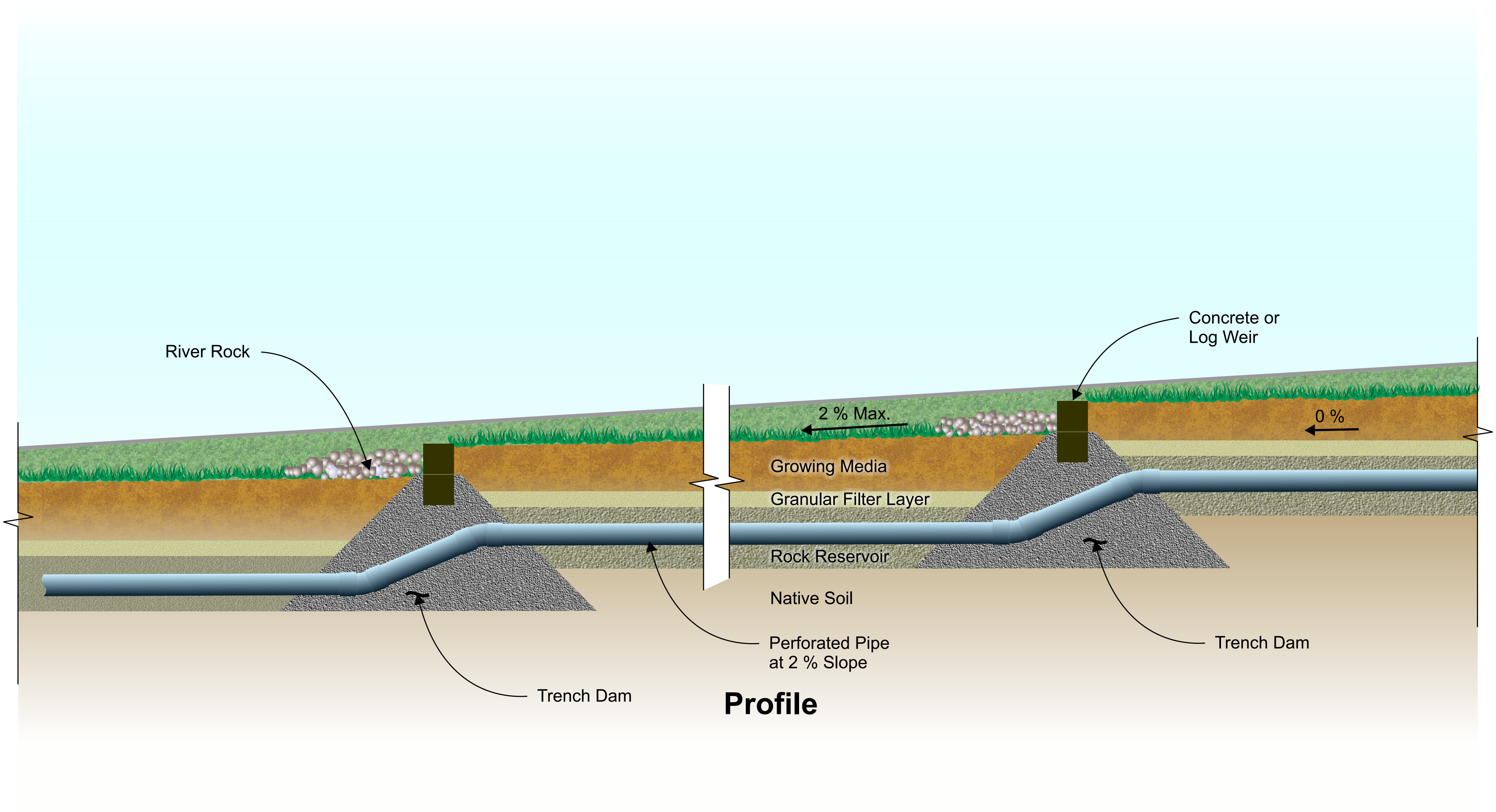

Profile

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Alternate Profile along Bio-Swale - for Slopes > 2 %

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Figure 1-3

File Number

ISC: Unrestricted

2. Design Guidance

This guidance is intended to provide specific selection and sizing guidance for design of bioretention areas and bioswales in the City of Calgary. A bioretention area or bioswale may or may not be providing all of the required water quality treatment, flow attenuation and/or volume reduction to meet the targets for the site and therefore could be part of a larger stormwater system that could include oil/grit separators, other stormwater storage features, outlet controls, or stormwater re-use strategies.

The size and location of a bioretention area or bioswale is likely to be restricted by terrain, layout and density of the site. This guidance provides a basic design and standard variations, but may not provide options for every case. Complex designs, and interactions with other SCPs and stormwater facilities, including facilities in series, may require more intensive design work and the services of an engineer familiar with bioretention design. The general design process for bioretention areas and bioswales is given in a flow chart in Figure 2-1.

2.1 Design Assessment Checklists

For the *Bioretention Area Design Assessment Checklist* and *Bioswale Design Assessment Checklist* see Appendix A, which provides a concise review of the key design elements that should be calculated and checked during design of bioretention areas and bioswales respectively. The checklist should be completed as part of the Stormwater Management Report and/or DSSP submission for each bioretention area / bioswale.

2.2 Bioretention and Bioswale Sizing

A bioretention area or bioswale should be sized based on the impervious area contributing to the facility. The sizing for a bioretention area or bioswale is completed in several steps, according to the stormwater objectives for the facility:

1. Watershed Treatment Objective;
2. Volume Reduction Target;
3. Vegetation Health (Sediment Loading Constraint); and
4. The bioretention or bioswale sizing is illustrated in a flowchart in Figure 2-2. The flowchart provides a visual guide that steps through each of the sizing and design elements described in the following sub-sections.

Note that while the sizing approach and discussion for a bioretention area or bioswale is geared toward a simple case for clarity and understanding, the sizing approach can also be generally applied to a site as a whole. The simple case used is to size a single bioretention area or bioswale for a single impervious catchment area, such as a parking area or a section of road. The simple case does not explicitly consider a larger whole site, with multiple small impervious areas and multiple SCPs. For all of the discussion items below, the simple case is discussed to provide understanding of the design concept and specifics of the supporting calculations.

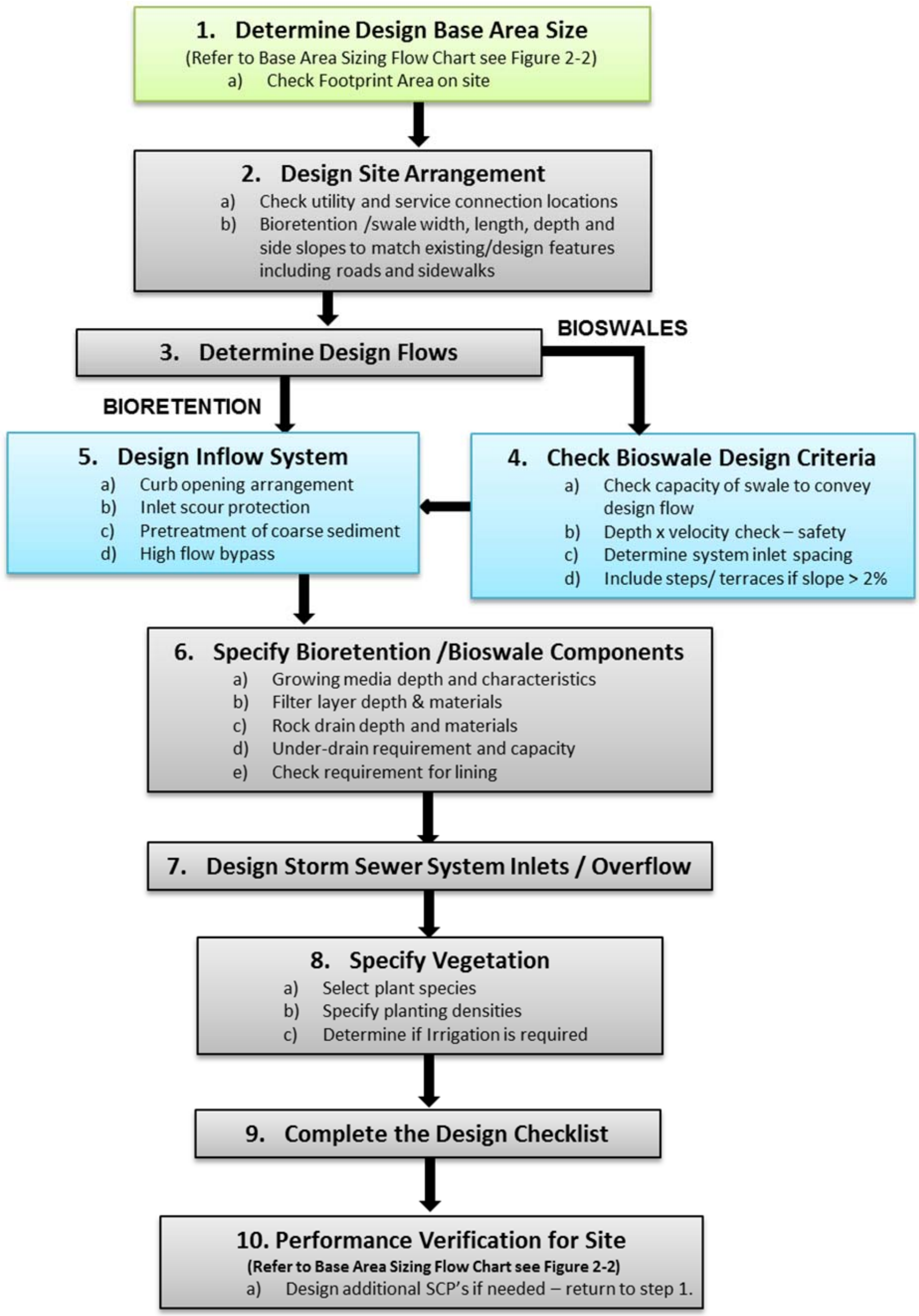

Figure 2-1: Bioretention and Bioswale Design Flow Chart

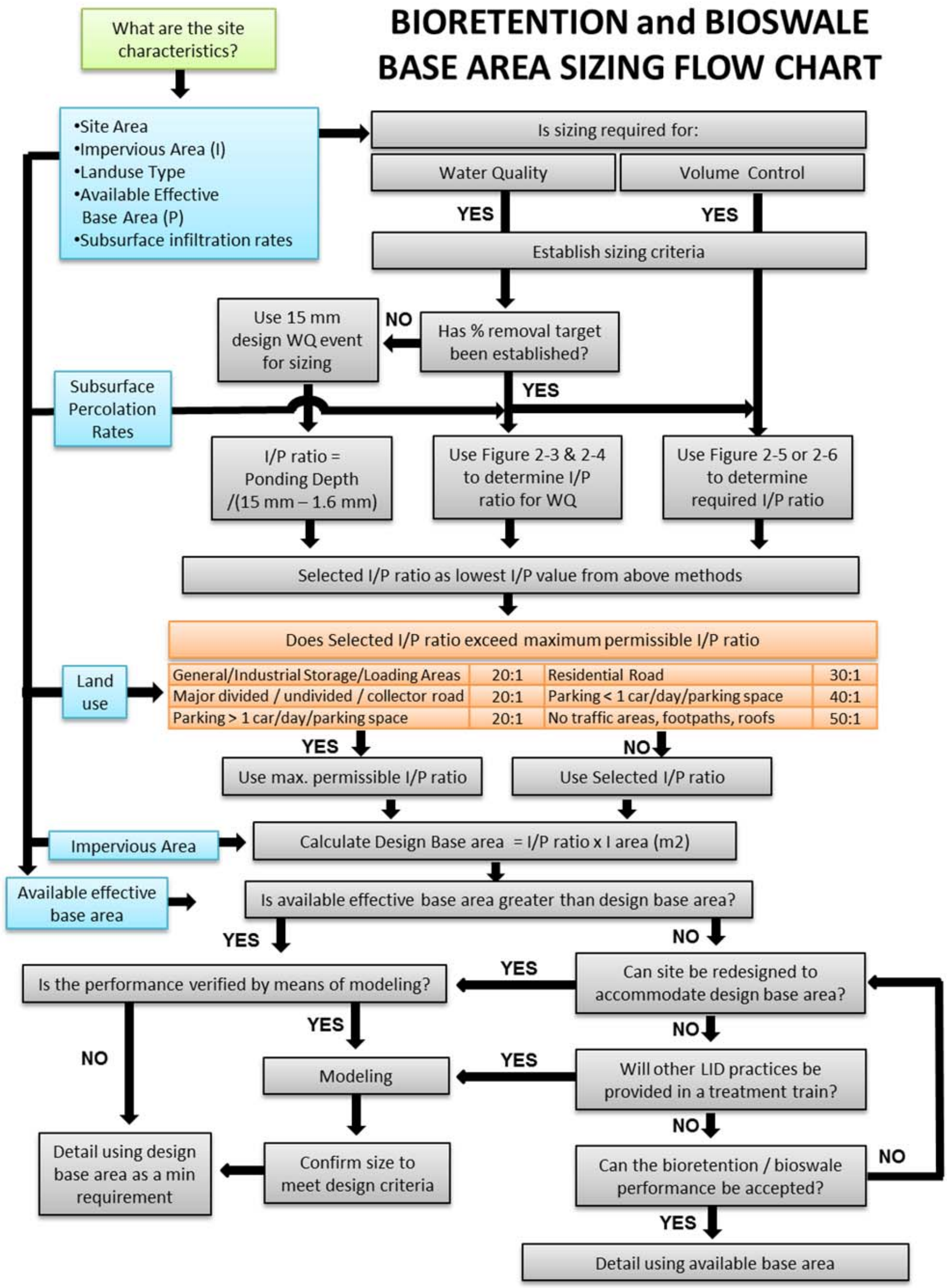

Figure 2-2: Bioretention Sizing Flow Chart

2.2.1 Site Characteristics

Each site is different, and the site layout and design should be reviewed for key information at the start of the design and sizing process. The key areas for design of bioretention and bioswales are the impervious surfaces, including roads, parking areas, and roofs. These impervious areas will drain to the bioretention areas or bioswales so that runoff is treated and infiltrated into the ground. Each site should be reviewed for the following elements:

- Total site (catchment) area draining to the SCP;
- Total impervious area draining to the SCP (designated as "I");
- Land use type for impervious area (e.g., road type, or parking type);
- Available footprint area for bioretention or bioswale (i.e., base area plus side slope area, see Section 2.4.2.);
- Available effective base area (designated as "P" for the effective pervious area of the facility), which excludes the areas of the side slopes; and
- Subsoil percolation rate.

If runoff from the site requires surface conveyance to downstream infrastructure or discharge points as part of the SCP, the site will likely require a bioswale rather than a bioretention area. If not, a bioretention area is preferred, as it provides better performance for both the removal of sediment from the runoff and the higher percentage of runoff that is infiltrated. It is also possible that both bioswale and bioretention areas are needed on a site, and the use of one does not preclude use of the other. Also, a hybrid bioswale with ponding can be designed that functions similarly to a series of bioretention areas with flow conveyance above the ponding elevation.

The design of a SCP will often need to be fitted into the available site (pervious) area. Depending on the land use and development type, the available area on site may, or may not, be sufficient to provide the full benefits of water quality treatment and volume capture that are desired. The sizing process that follows will assess whether the proposed site design provides adequate space for SCPs to meet the desired runoff design targets.

If targets are not met on-site, the difference may be made up further downstream by "regional" facilities that accept flow from multiple lots/sites. However, the designer should always bear in mind that it is easier to treat and infiltrate flows in smaller facilities closer to the source (i.e., impervious surface) than in larger facilities downstream that would have to treat much larger and/or more variable flows. Where possible, the site should be designed to accommodate sufficient area of SCPs to treat the on-site sources of runoff.

2.2.2 Select I/P Ratio for Water Quality Treatment

Treatment of runoff is required for all surfaces that contribute significant pollutant loadings including roads, parking areas, and any surface receiving vehicle traffic. Other impervious surfaces such as roofs are believed to generate runoff that is relatively "clean", containing mainly atmospheric deposition. For roof water only, this step is therefore currently not required.

For runoff from vehicle-accessible surfaces, the design goal is to provide treatment for the Water Quality Design Event (i.e., 15 mm of rainfall in one hour)[1]. When designing a bioretention area, this is easily accommodated by the ponding volume. A standard ponding depth is 200 mm, measured from the invert of the bioretention area to the level of the storm sewer system overflow inlet. To calculate the I/P ratio required to capture the volume of the Water Quality Design Event:

$$I/P = H_{ponding} / (R_{WQ} - R_{ABS})$$

Where:

I/P = Ratio of Impervious catchment area to Pervious base area (m^2/m^2)

$H_{ponding}$ = Ponding depth (200 mm, standard, or actual ponding depth, mm)

R_{WQ} = Water Quality Design Event rainfall depth (15 mm)

R_{ABS} = Allowable rainfall initial abstraction value for the impervious surfaces (1.6 mm), as per the 2011 City of Calgary Stormwater Management & Design Manual.

With a standard 200 mm ponding depth, the maximum I/P ratio allowed for treatment of the water quality event is 15:1.

Other ponding depths are allowed, with a limit of a 500 mm ponding depth near a street. However, increasing the ponding depth requires a larger footprint for the facility due to the side slopes. That area may be more beneficial as infiltration base area for the facility rather than using it for the side slopes to accommodate the greater ponding depth. As the ponded depth must be able to drain in 24 hours or less, using following equation:

$$T\ in\ hour = \frac{H_{ponding}(mm)}{Infiltration\ rate\ (mm/hr)}$$

336 mm is the maximum ponding depth based on the bioretention soil specifications (and factor of safety for the infiltration rate of the growing media as per Section 2.2.7) in this guidance. A more practical upper limit of ponding depth would be simply 300 mm. If ponding depths greater than 336 mm are desired as part of the drainage system design for a site, an additional method to drain down the bioretention area shall be provided, as either a storm sewer inlet or an overflow weir so that the overall 24 hour draindown conditions will still be met.

The ponding depths calculated above do not account for any storage volume above the side slopes of the facility. The ponding depth, calculated by this method, is therefore the same whether the bioretention area has shallow (i.e., 4:1 (H:V) or shallower) or vertical (planter-style bioretention) side slopes.

If the ponding volume outside of the base area (i.e., above the side slopes) is needed to store the runoff from the Water Quality Design Event, the calculation shown below may be used instead. This requires calculation of the total ponded storage volume, which would change depending on the facility's geometry.

[1] City of Calgary Stormwater Management and Design Manual, 2011, Section 3.2.4.4.

In general, if the base area and the area at the design ponding water level can be determined using CAD or GIS, then the trapezoidal volume can be calculated as:

$$V_{storage} = (A_{base} + A_{ponding})/2 \times H_{ponding}$$

Where:

$V_{storage}$ = Volume of storage in the ponded area (m^3)

A_{base} = Base Area of the facility (m^2)

$A_{ponding}$ = Area at the elevation of the top of ponding in the facility (m^2)

$H_{ponding}$ = Depth of ponding (m)

This approach is not applicable for bioswale design unless ponding is incorporated into the bioswale design. In general, the ponding volume in a bioswale would be less than for bioretention areas and the capture of the runoff from the Water Quality Design Event by ponding in a bioswale would be applicable only where very low I/P ratios are used. The resulting I/P ratio depends on the volume of ponding provided. The calculation for sizing a bioretention area or bioswale with ponding is:

$$I/P = (V_{storage} \times 1000)/(A_{base} \times (R_{WQ} - R_{ABS}))$$

Where:

I/P = Ratio of Impervious catchment area to Pervious base area (m^2/m^2)

$V_{storage}$ = Total available storage volume in the ponding zone of the bioswale (m^3)

A_{base} = Base Area of the bioswale (m^2)

R_{WQ} = Water Quality Design Event rainfall depth (15 mm)

R_{ABS} = Allowable rainfall initial abstraction value for the impervious surfaces (1.6 mm), as per the 2011 *City of Calgary Stormwater Management & Design Manual*.

This is the simple approach for the design of bioretention areas and bioswales for water quality treatment. Another approach is to look at the removal of sediment through continuous simulation. The current City of Calgary stormwater treatment objective is to provide a minimum of 85-percent removal of Total Suspended Solids (TSS) for particles 50 µm and larger[2]. Previous studies have indicated that, in general, this level of particulate removal can be accomplished by filtering runoff through the soil of a bioretention area or bioswale. Therefore, this level of treatment would be achieved for runoff where at least 85% of annual runoff is filtered through the growing media of a bioretention area or bioswale. 85-percent treatment can be estimated using the charts shown in Figure 2-3, and Figure 2-4 below[3].

This treatment level can be more accurately determined by continuous simulation modelling of a given site, including all on-site LID practices and stormwater control infrastructure using a software package that can simulate water quality parameters including sediment.

[2] City of Calgary Stormwater Management and Design Manual, 2011.
[3] The current modelling results include both rain and snowmelt as precipitation.

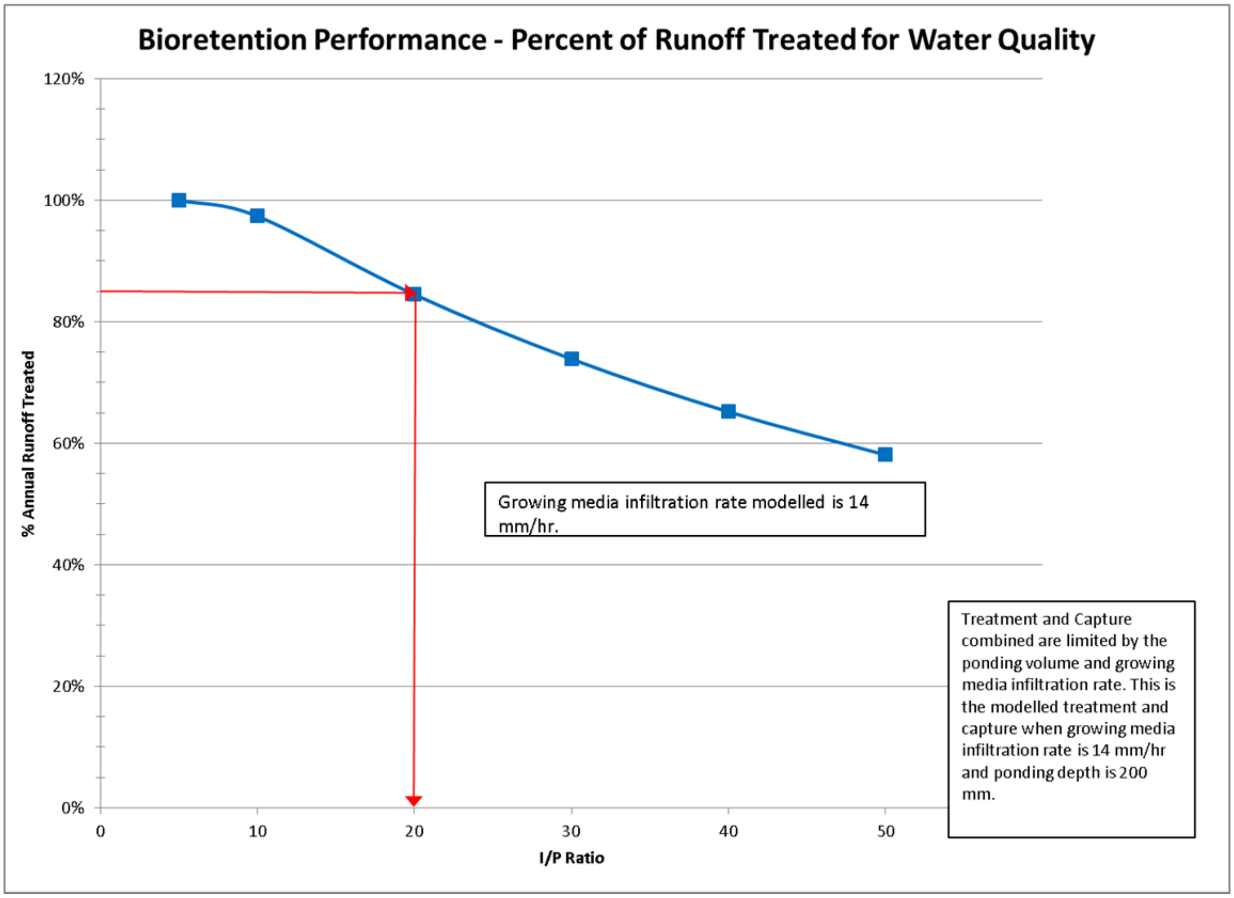

Figure 2-3: Bioretention Performance Showing Percentage of Annual Runoff Captured and Treated For Water Quality Design and Sizing Purposes

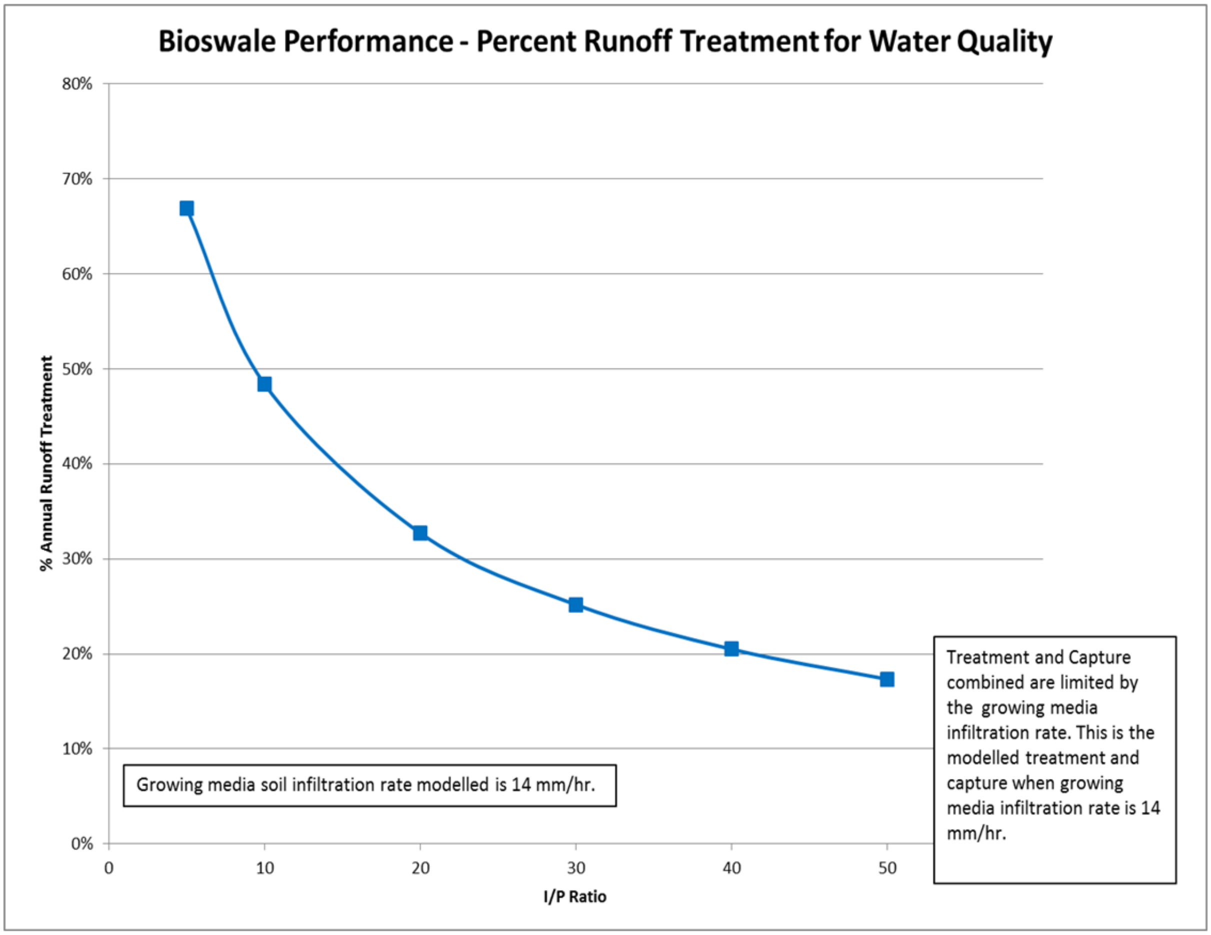

Figure 2-4: Bioswale Performance Showing Percentage of Annual Runoff Captured and Treated For Water Quality Design and Sizing Purposes

Note that the current modelling for bioswales, and results shown, do not provide adequate treatment of average annual runoff for water quality treatment purposes as the 85-percent capture level is not met with any modeled I/P ratio. To improve the treatment efficiency, weirs can be placed to induce ponding over the swale surface.

2.2.3 Runoff Volume Reduction

Once the I/P ratio has been determined to achieve (if required) the water quality treatment desired, the depth of the rock reservoir can be selected and, if possible, the I/P ratio adjusted to maximize runoff volume reduction. The City of Calgary has set runoff volume targets for the major watersheds (receiving water bodies) in the City. The runoff volume targets are based on the runoff that should be discharged from a site to the receiving water body. The runoff targets take the form of average annual runoff volume in mm that should be discharged to the receiving water body.

In order to assess the runoff reduction achieved by a bioretention or bioswale facility, the facility, and other LID practices on a site, should be modelled using a continuous simulation of multiple years of rainfall. Because an in-depth discussion of the supporting continuous simulation calculations is not within the scope of this module a simplified approach was developed that allows bioretention areas or bioswales to be sized in a consistent manner and/or allows the expected performance of bioretention areas or bioswales to be assessed. It may not be possible to achieve the runoff volume reduction targets on individual sites. This guidance document provides a method of assessing the performance of a facility for volume reduction so that those results may be used for the design of other practices to make up the difference, if required.

A bioretention area facility's predicted runoff reduction performance is shown in the graph in Figure 2-5. The graph shows the results from modeling scenarios that have been run to perform continuous simulation of a bioretention design based on rainfall data from the City of Calgary's Ogden Gauge and Calgary International Airport (YYC) precipitation data to create a combined precipitation (rainfall and snowmelt) data set with a 6-minute time-step for the years 1998 through 2005. The parameters used in the modelling include a standard growing media depth of 450 mm and a standard ponding allowance of 200 mm (as shown in Figure 1-1 and Figure 1-2) with varying I/P ratios and depths of the rock reservoir. The growing media is assumed to be one of the standard growing media specifications from this guidance document. The I/P ratio for the bioretention base area is shown along the bottom (X-axis) of the chart. The resulting average annual runoff from the site for the bioretention design is shown along the left (Y-axis) of the chart.

A similar chart for a bioswale design is shown in Figure 2-6, where the assumed growing media depth is 300 mm and no ponding is assumed.

The design chart is used by first identifying the subsoil percolation rate (in mm/hr). There is an upper and lower bounding curve for each subsoil percolation rate, showing the performance using the minimum thickness of the rock reservoir layer and the maximum thickness of the rock reservoir layer. Values between the two curves may be interpolated.

The design I/P ratio for volume control is selected from the design chart based on the runoff target for the site. The watershed runoff target is a depth (mm) of average annual runoff volume for the City of Calgary that is allowed to discharge to receiving water bodies, such as Nose Creek. Ideally, bioretention areas or bioswales on-site would provide capture of the runoff volume from impervious surfaces such that the total runoff from the site meets that target. There may be specific average annual runoff volume targets for individual developments as well as for watersheds.

If the site does not have sufficient available area to accommodate a facility with the selected I/P ratio, then the site layout should be re-worked, if possible, to increase the area available for a bioretention or bioswale facility. If the site cannot be reconfigured to accommodate the design target I/P ratio, then the available base area should be used to calculate an actual I/P ratio and determine the performance of the site from the design chart.

If no volume reduction is required, then the bioretention area or bioswale is sized according to the I/P ratios determined for water quality treatment and the default bioretention or bioswale design (as shown in Figure 1-1 and Figure 1-2 respectively) should be used.

In general, volume reduction improves with better soils, i.e., where the subsoils have higher percolation rates. However, once the subsoil percolation rate exceeds the infiltration rate of the growing media, the volume reduction is limited by the growing media infiltration rate and little additional volume reduction occurs if the subsoil percolation rate increases beyond that point.

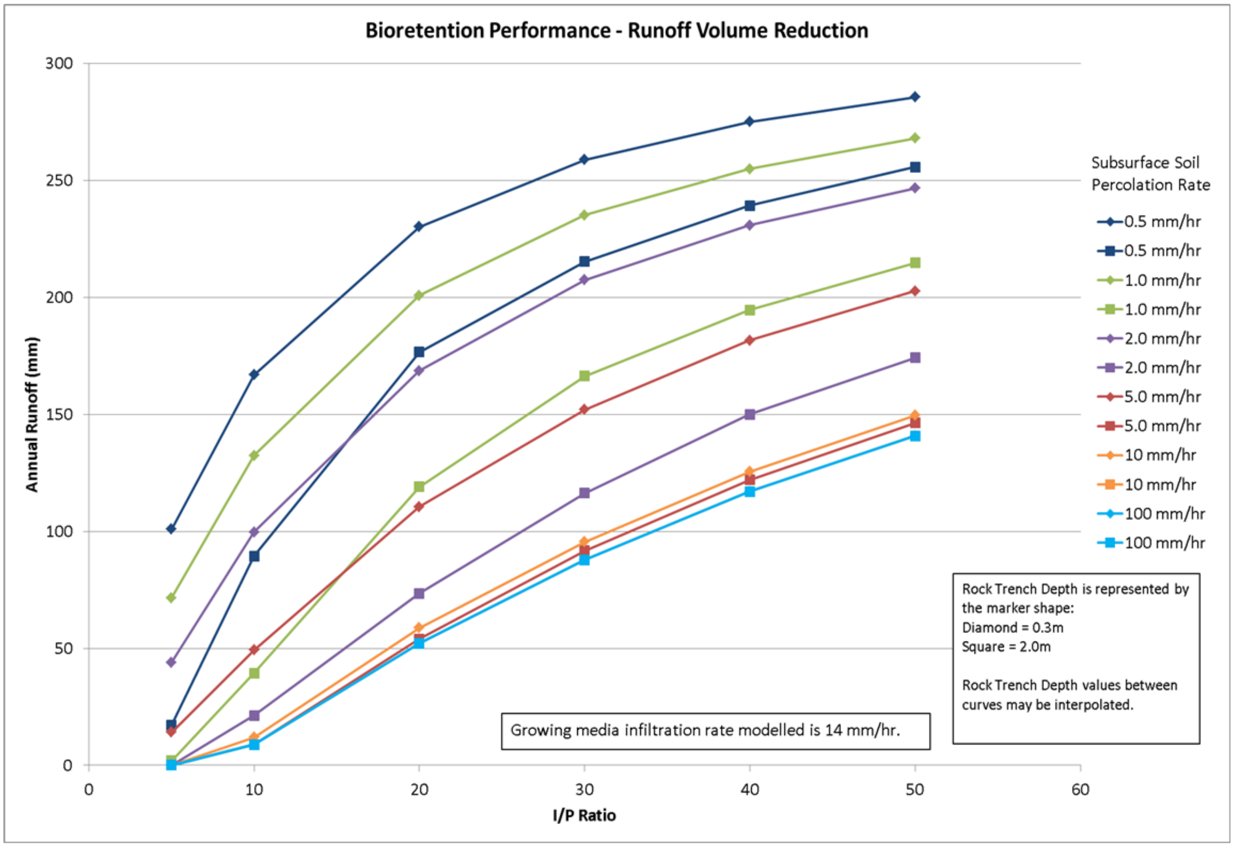

Figure 2-5: Performance of Bioretention for Runoff Volume Reduction

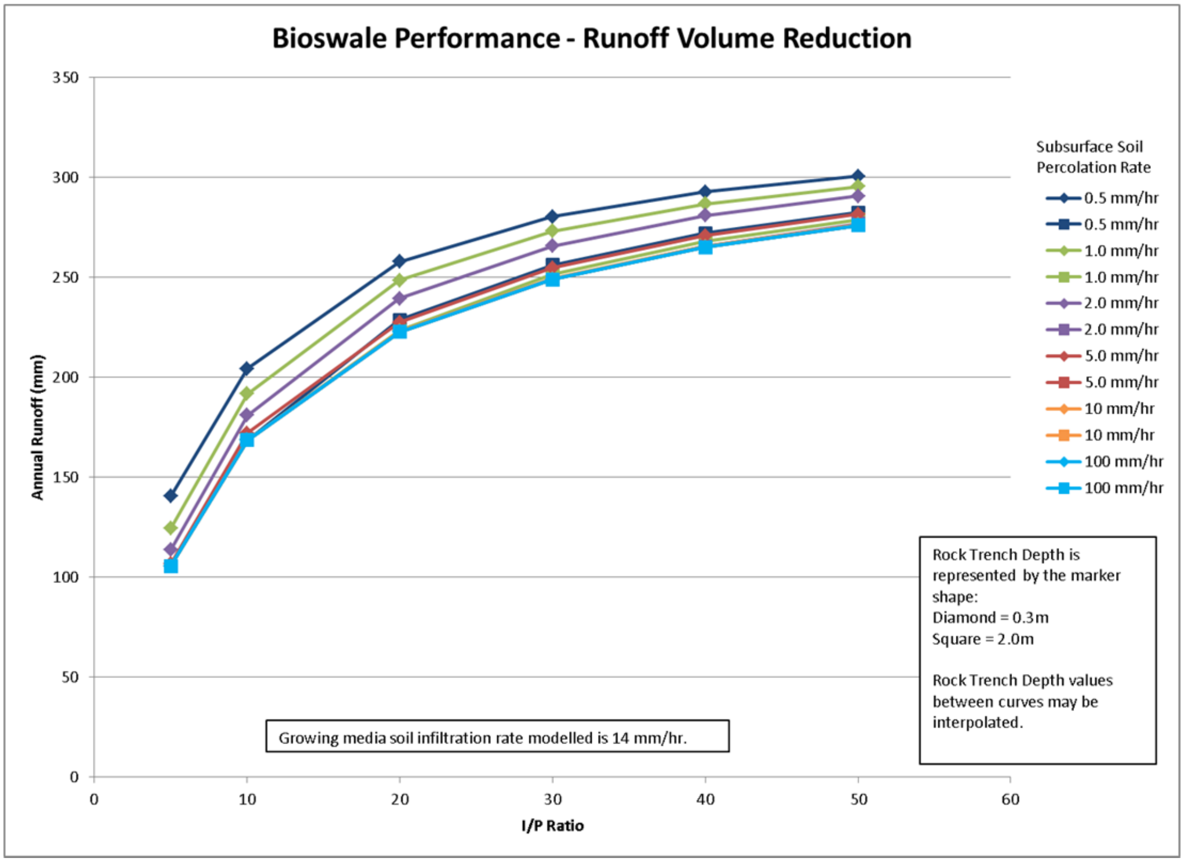

Figure 2-6: Performance of Bioswale for Runoff Volume Reduction

2.2.4 Maximum Permissible I/P Ratio

Once a bioretention area or bioswale has been sized to provide performance for water quality treatment and runoff volume reduction, a final check of the sizing should be done to be sure that the design will function over the long term. The I/P ratio of a bioretention area or bioswale must be limited according to the type of surface that is contributing runoff and pollutants to it. If a bioretention area or bioswale is sized to meet the water quality and/or runoff volume targets, then it will likely be within acceptable limits of the I/P ratio. If, for any reason, a bioretention area or bioswale is not or is not required to be sized for either water quality treatment or runoff volume reduction, it must still be within the limits of the maximum permissible I/P ratio. The design for a bioretention area or bioswale should not exceed the maximum permissible I/P ratio for any reason.

The maximum permissible I/P ratio is an empirical value that has been developed through historical performance of bioretention areas and bioswales[4] and represents a maximum ratio that will allow the vegetation to survive and flourish rather than be overwhelmed by the sediment loading from the catchment. This is not related to treatment or removal rates of sediment, but is for long-term survival of the facility. Maximum permissible I/P ratios are shown in Table 2-1. The values in the table are for fully stabilized catchments and do not consider sediment loadings during the construction phase in the contributing catchment area.

Table 2-1: Maximum Permissible I/P Ratios for Bioretention or Bioswale by Surface Type

Surface Type	Maximum I/P Ratio
General/Industrial Storage/Loading Areas	20:1
Arterials and Major Roads	20:1
Collector Roads	20:1
Parking >1 car/day/parking space	20:1
Residential Road	30:1
Parking <1 car/day/parking space	40:1
Low traffic areas, no parking (e.g. paved laneways)	50:1
Single Family Residential, Lot and Roof	50:1

2.2.5 Surface Clogging

Surface infiltration is an important parameter when considering the performance of a bioretention area or bioswale from a water quality and peak flow control perspective. For any bioretention area or bioswale that incorporates ponding, the ponded volume of water must be able to drain within 24 hours. This should be based on the long-term assumed infiltration rate of the growing media. For the soil specifications in this guidance document, the in-situ installed infiltration rate of the growing media should be at least 40 mm/hr with an optimum rate of 70 mm/hr for water quality treatment performance. The infiltration rate is expected to decrease over time, and a factor of safety is therefore used to account for surface clogging of the soil. The factor of safety to be used for design purposes has been provided in Section 2.2.7 for a range of conditions. **A factor of safety is used in the design sizing and performance guidance in this document, such that the long-term infiltration rate of the growing media is assumed to be 14 mm/hr.** This long-term infiltration rate provides the maximum ponding value, noted in Section 2.2.3, of 336 mm. The factor of safety for the infiltration rate should be used universally until long-term performance of the engineered bioretention growing media has been evaluated.

[4] The basis for these ratios has been developed over approximately 20 years by KWL in observing performance of bioretention areas and bioswales. These were primarily located in the lower mainland of BC, but a field review and assessment of installed bioretention areas in the City of Calgary was also done as part of the work for the development of this guidance. The I/P ratios from the observed Calgary facilities were also considered in development of this table. In addition, modelling performed for the 2007 "Stormwater Quality Upgrades for the WH Canal Catchment Level 1 Study" was also incorporated, which included modelling of estimated sanding loads for roads in the City of Calgary.

For the two growing media specifications provided in this document:

- Growing Media A, minimum initial hydraulic conductivity 70 mm/hr – Factor of Safety ≤ 5
- Growing Media B, minimum initial hydraulic conductivity 40 mm/hr – Factor of Safety ≤ 3

2.2.6 Sediment Accumulation

To manage the sediment accumulation over the long-term in a bioretention area or bioswale, either the ponding depth for the bioretention area should also include an allowance for sediment accumulation over the lifetime of the SCP, or a pre-treatment approach should be used to enable periodic removal of the accumulated sediments. This is important particularly for bioretention facilities that receive drainage from roads and high volume parking areas, as they are likely to generate larger volumes of sediment.

Sediment accumulation rates are not well known, but based on City of Calgary winter road sanding practices, it is estimated that the sediment generation from roads ranges from 700 kg/ha/yr. to 2000 kg/ha/yr. If this is translated to a volume based on sand, the higher end volume of sediment from roads is approximately 1.25 m^3/ha/yr. This value should be used to estimate the volume of sediment that will accumulate in a bioretention area or bioswale over the expected 50 year lifetime of the facility, or over the maintenance period for a pre-treatment approach. The resulting sediment accumulation volume should be added to the ponding depth of the facility to ensure that the accumulation of sediment is not undermining the design of the facility over its lifetime by reducing the water quality treatment volume provided by the ponding depth.

2.2.7 Safety Factors to Represent Surface Clogging

The potential for clogging of the growing media surface is greatly influenced by the level of sediment entering the bioretention area of bioswale. The main factors that influence the sediment load is the surface type, the I/P ratio and the presence of a pre-treatment device. Table 2-2 provides the recommended factors of safety to should be used when analyzing and designing bioretention areas and bioswales,

Table 2-2: Pre-treatment Factor of Safety

Surface Type	I/P Ratio	Infiltration Factor of Safety	
		With Pre-treatment	No Pre-treatment
Roads and Parking	< 10:1	2	4
Roads and Parking	> 10:1	3	5
Roof and Non Trafficable Paving	< 50:1	2	3

2.2.8 Pre-Treatment System Design

Pre-Treatment Considerations

Pre-treatment involves using devices and physical settling mechanisms to remove larger sediment particles prior to the stormwater runoff entering a bioretention area or bioswale. Pre-treatment is helpful to improve the performance and extend the functional life of bioretention areas or bioswales while reducing the overall maintenance requirements.

Because bioretention areas and bioswales rely on infiltration to maintain their performance and vegetation health, pre-treatment is recommended for all sites that generate significant sediment loadings, including paved and gravel roads, laneways, and parking lots. It is mandatory for bioretention areas and bioswales where a reduced safety factor of 3 is needed to be applied, allowing for an initial infiltration rate of 40 mm/hr, see Section 2.2.5.

Although there are many effective approaches for pre-treatment, this guidance provides the sizing approach and design considerations for (1) a sedimentation sump and (2) a grassed swale or buffer strip. A sedimentation sump includes a modified catch basin arrangement or a custom-built structure.

Sedimentation Sump

Sedimentation sumps are structures that can remove a significant portion of the coarser sediment particles if appropriately sized and configured. They have the highest performance during low to medium flow regimes. However, the removal efficiency of these sumps decreases as the flow rate increases due to shorter residence times and the potential for resuspension of the accumulated sediments. Figure 2-7 shows the schematic of a sedimentation sump. They are ideally suited where space is limited as they usually have a smaller footprint than other pre-treatment approaches. They are also easy to maintain using existing City of Calgary maintenance equipment.

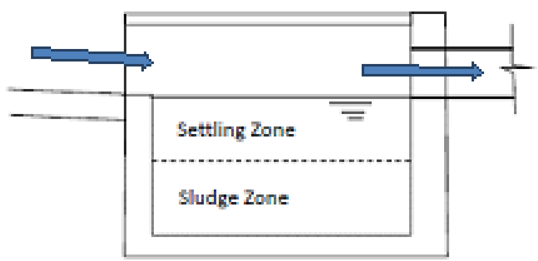

Figure 2-7: Typical Sedimentation Sump

Standard type catchbasins could be modified to incorporate a sedimentation sump to provide the desired level of pre-treatment. Figure 2-8 shows the schematic of a modified catch basin acting as a pre-treatment device. These catchbasin sumps will typically not be connected to the storm sewer system and therefore are expected to remain filled with water.

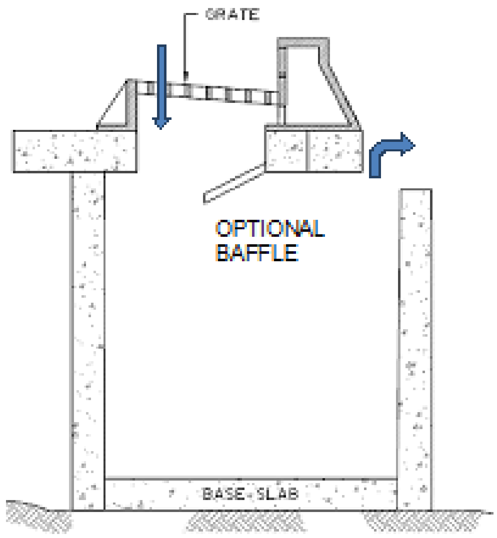

Figure 2-8: Modified Pre-treatment Catch Basin Type 'C' Assembly

Sedimentation Sump Design Considerations

Surface Area

The TSS removal efficiency of a sedimentation sump can be established by the ratio of the size of the tributary impervious catchment and the surface area of the pre-treatment device. The average annual sediment load reduction was estimated for ideal settling conditions using 50 years of hourly precipitation data. The TSS loading rate, particle size distribution curve and settling velocities given in the *City of Calgary Stormwater Management Design Manual* (2011) were used as part of the analysis. Based on the equation below, the ratio of the size of the tributary impervious catchment area and the sump surface is calculated as follows:

$$Area\ Ratio = \frac{Imp.Catchment\ Area}{Surface\ Area\ of\ Sedimentation\ Sump}$$

Curves illustrating the TSS reduction for particle sizes greater than 50 µm as a function of the ratio of the catchment impervious area to sump catchbasin surface area are plotted in Figure 2-9 for ideal settling conditions and for a 65% efficiency regime. As expected, the TSS removal efficiency decreases as the area ratio increases.

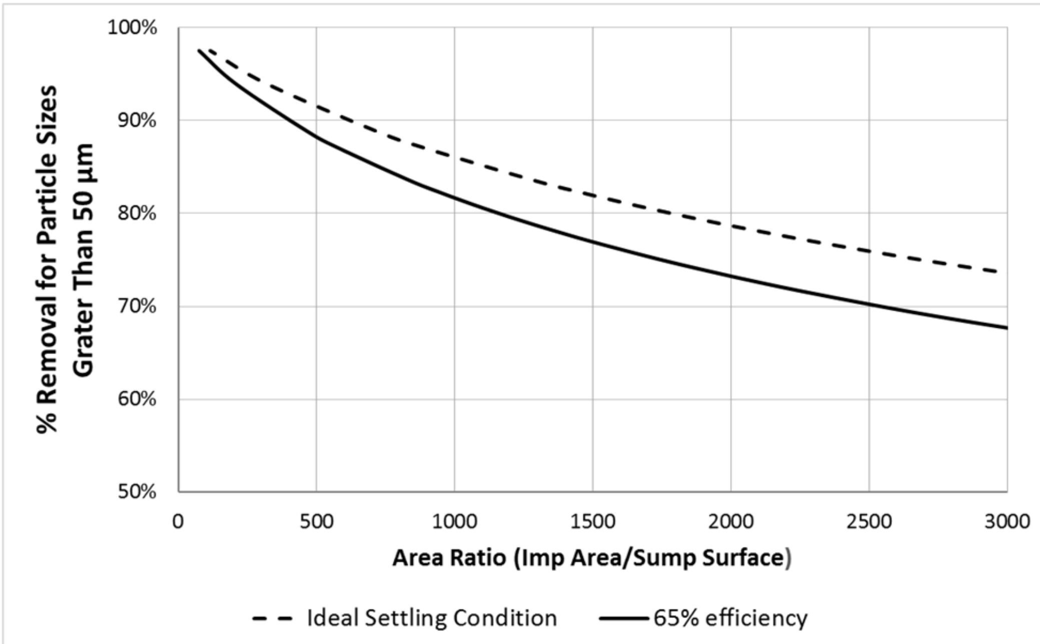

Figure 2-9: Correlations between TSS Removal Efficiency and Area Ratio

Non-Ideal Settling Considerations

Non-ideal settling conditions can be expected to occur in most pre-treatment structures, resulting in reduced TSS removal. Deviations from the ideal conditions are caused by many factors that can be grouped into three categories: short-circuiting, turbulence, and resuspension.

- Short-Circuiting

  When stormwater enters a sump catch basins, it may not be distributed evenly due to a temperature or TSS concentration difference, as well as due to the configuration of the inflow structure. Under these flow conditions, the actual horizontal velocity will be larger than the theoretical idealized average velocity causing short-circuiting that results in shorter settling times and leads to less efficient TSS removal.

- Turbulence

  The incoming water is often turbulent, particularly when concentrated inflows occur. Turbulence continues into the sump for some distance. Turbulence may prevent settleable solids from reaching the bottom of the structure as well as result in re-suspension of accumulated solids, reducing the overall removal efficiency.

- Re-Suspension

  Resuspension of previously settled sediments during larger events reduces the overall removal efficiency. Resuspension is likely to occur in the inlet and outlet area where turbulence is created at the bottom of the structure near the sludge zone. Resuspension in the outlet area will have greater negative impacts.

Empirical factors are commonly used to account for the inefficiencies because estimating the negative impacts caused by non-ideal conditions is impractical for stormwater pre-treatment devices due to the unsteady flow conditions. The inefficiencies due to these deviations from ideal conditions are accounted for by applying an inefficiency factor, represented by the 65% efficiency curve in Figure 2-9.

Various devices can be used to mitigate the negative impacts of the above non-ideal settling conditions and improve the hydraulic conditions to achieve ideal settling conditions. Diffusion baffles could be used near the inlet area to achieve an even distribution of the flow, thus reducing short-circuiting and re-suspension conditions.

Sump Depth

A minimum sump depth of 300 mm is required for the settling zone of Figure 2-9. The installation of a permeable baffle near the inlet area may help to reduce turbulence and achieve even influent distribution. However, in order to minimize resuspension, the distance between the sediment sludge zone and the lowest elevation of any baffle should be at least 300 mm.

Regular removal of the accumulated sediments is essential to avoid sediment wash-out during higher flows. Figure 2-10 shows the average annual sediment accumulation depth for different area ratios and (average) TSS loading rates. The TSS loading rate should include the bedload contribution.

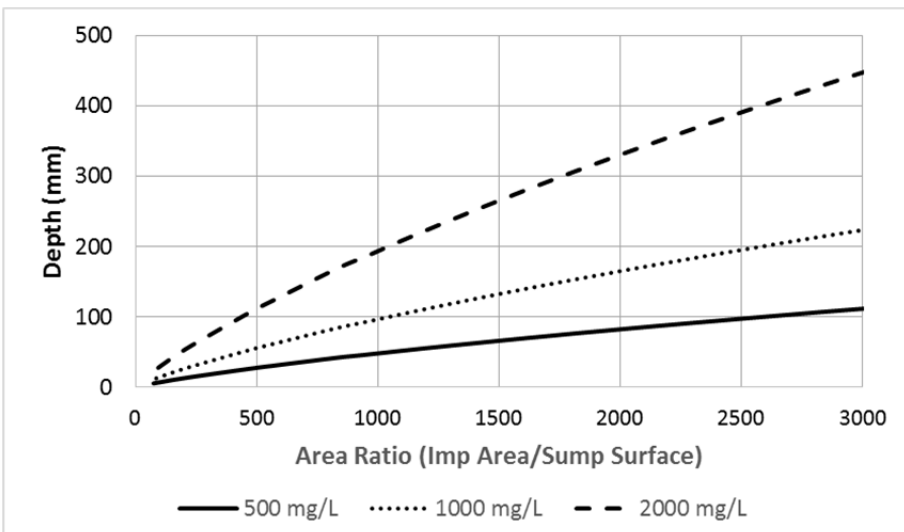

Figure 2-10: Annual TSS Accumulation Depth as a Function of the Area Ratio

The thickness of the accumulated sediment layer was estimated based on the particle size distribution curve presented in the *City of Calgary Stormwater Management Design Manual* (2011). Using the sediment accumulation depth obtained from Figure 2-10, the minimum depth of a sedimentation sump shall therefore be:

$Depth\ (mm) = 300 + Annual\ Sediments\ Accumulation\ Depth$ (mm)

Grassed Swales

Grassed swales can operate as a very effective pre-treatment measure. However, the sizing of grassed pre-treatment swales is governed by limiting the sediment build-up over time to maintain grass health.

Sizing

Significant sediment deposition will inhibit grass growth and therefore decreases the effective grass height, adversely impacting the performance of grassed pre-treatment swales. Hence, the sediment deposition rate is the governing design factor for sizing of grassed pre-treatment swales or buffer strips. Using a maximum permissible sediment accumulation rate of 10 mm/yr., Figure 2-11 displays the corresponding area ratio as a function of the influent TSS concentration. The influent TSS concentrations displayed in Figure 2-11 range from 200 to 2000 mg/L which cover most design conditions. The area ratio decreases when the TSS concentration increases, indicating that a larger surface area is needed for the swale when the TSS concentration in the surface runoff increases. Using the area ratio obtained from this graph, the surface area of the grassed pre-treatment swale can be calculated using Equation:

$$Surface\ area = \frac{Imp.\,Catchment\ Area}{Area\ Ratio}$$

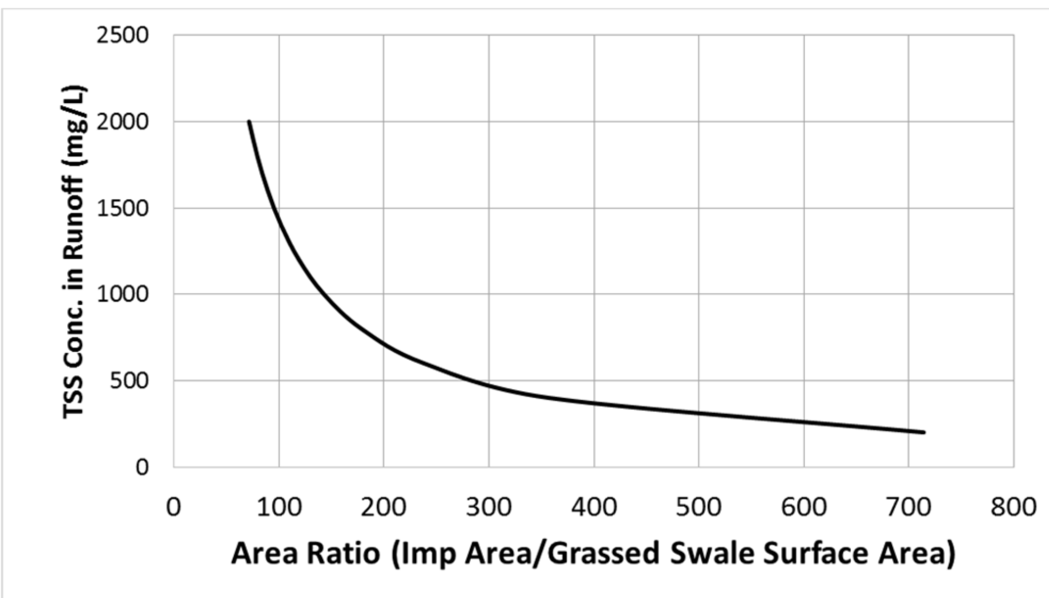

Figure 2-11: TSS deposition in Grassed Pre-Treatment Swales for Different TSS Concentration

In order to achieve effective TSS removal, uniform sheet flow conditions are essential in the grassed pre-treatment swale. Table 2-3 provides the key design criteria. In general, a shallow and wide swale is preferred, but there is a practical maximum width at which the flow cannot be evenly distributed across the cross-section of a grassed pre-treatment swale. The maximum slope and velocity should be adhered to avoid channelized flow conditions and resulting scour.

Table 2-3: Grassed Pre-Treatment Swale Design Criteria

Design Parameter	Design Criteria
Swale Geometry	Trapezoidal
Minimum bottom width	Minimum 0.5 m or width of curb cut, whichever is greater
Maximum bottom width	3 m
Minimum slope in flow direction	0.5%
Maximum slope in flow direction	2%
Maximum flow velocity (WQ design event)	0.3 m/s
Maximum flow velocity (1:100 year event)	1.0 m/s
Minimum Height of Grass	100 mm to 150 mm
Maximum depth of flow during WQ event, based on Manning's roughness equal to 0.15	25 mm below top of grass

2.2.9 Subsoil Percolation Considerations

Ideally, the saturated hydraulic conductivity of the subsoils should be tested at approximately the depth at which exfiltration from the bioretention area or bioswale into the subsoils will occur. This is considered to be the percolation rate of the subsurface (native) soil. For detailed guidance on subsoil percolation rates, testing methods, and assumptions, refer to *Module 1: Geotechnical and Hydrogeological Considerations for Low Impact Development.*

2.3 Estimating Design Flows

2.3.1 Minor and Major System Design Flow Estimation

Minor and major system design flow estimates are typically used in stormwater design practice for the dimensioning of inlet and outlet provisions and the establishment of their characteristics.

Typically, a bioretention area or bioswale is designed to accommodate or handle the flows generated by minor day-to-day storm events. The minor system design flow rate is typically the ***design flow rate*** to be used for the design of the inlet(s) to the SCP, as well as the storm sewer system inlet (SCP outlet), which should be provided for every bioretention area or bioswale (with exceptions noted in Section 2.9). This assumes that the major system design flow is routed to bypass the SCP and is handled separately by the designated emergency overland escape route.

It may not be the case that every bioretention area or bioswale can be located and designed such that the major system design flow bypasses the SCP. When the major system design flow rate must flow through the SCP, then the major system flow rate becomes the ***design flow rate*** for the SCP, and must be used for the checks and calculations discussed below. Where the design flow rate is referenced, that flow rate will be either the minor system design flow or the major system design flow, whichever is required for the bioretention area or bioswale being designed.

Minor and major system design flows must be estimated according to methods approved by the City of Calgary for the size and type of site being developed or retrofitted. The minor system design flow for the City of Calgary corresponds to a 5-year return period event. The major system design flow corresponds to a 100-year return period event, but the prescribed calculation methods vary.

The calculation of the resulting minor event flow rate can be based on one of three methods. The preferred method of calculation for the minor event is the use of a unit area release rate (UARR) or a modified unit area release rate (MUARR) which varies depending on the site characteristics (i.e., the slope, density, and storage availability) and the infrastructure downstream of the site. The expected range of unit area release rates is between 70 and 120 L/s/ha, though a lower rate may used, if justified. No unit area release rate below 45 L/s/ha will be accepted by the City. Refer to the *Stormwater Management and Design Manual* (2011) for details on the calculation methods acceptable in Calgary.

For small catchment areas, the Rational Method is acceptable for estimating the peak design flow rates. The Rational Method relies on a runoff coefficient, C, for determining the amount of runoff generated from a site, see also Section 3.2.4.4 of the 2011 *Stormwater Management & Design Manual*.

For larger, more complex areas and areas where additional stormwater design is required, hydrologic and hydraulic modeling may be required to determine the minor system design flow rate from a site. Refer to the 2011 *Stormwater Management and Design Manual* for guidance. If modelling is used for the determination of the minor event flow rate, the bioretention areas and bioswales shall be included both for flow routing and peak flow determination though their impact on the magnitude of the minor design flow rate is expected to be relatively small. Guidance on how to model LID practices is beyond the scope of this guidance document, but stormwater professionals with modelling experience should be able to use the design guidance in this document to develop input information for bioretention areas and LID practices.

As stated above, the major system design flow rate corresponds to a 1:100 year event. This should be estimated for a site based on design storm modelling of the 1:100 year event in accordance with the 2011 *Stormwater Management and Design Manual*. The major design flow is used to evaluate whether the resulting flow can be safely accommodated within the proposed development.

2.3.2 Maximum Growing Media Infiltration Rate

The maximum growing media infiltration rate represents the design flow rate for the underdrain system. The capacity of the underdrain must be greater than the maximum growing media infiltration rate to ensure the growing media drains freely.

The maximum growing media infiltration rate can be estimated by applying Darcy's equation:

$$Q_{\max} = k \times L \times W_{pond} \times \frac{h_{\max} + d}{d} \times 3.6 \times 10^{-3}$$

where:

$Q_{\max}$ is the maximum flow rate (L/s)

k is the saturated hydraulic conductivity of the growing media (mm/hr)

W_{pond} is the average width of the ponded cross-section above the invert of the bioretention area (m), see Figure 2-12.

L is the length of the bioretention zone (m)

$h_{\max}$ is the depth of the ponding above the growing media (m)

d is the thickness of the growing media layer (m).

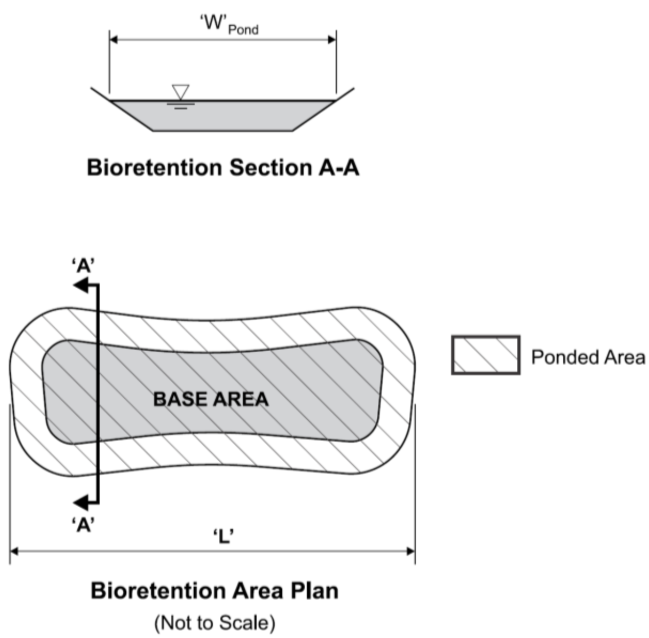

Figure 2-12: Average Width of the Ponded Cross-Section

The saturated hydraulic conductivity of the growing media should be the minimum design post-installation saturated hydraulic conductivity, in accordance with the growing media specifications of Section 3.5. The hydraulic conductivity is expected to decrease over time, but the initial (higher) value should be used here to size the underdrain.

2.4 Grading and Footprint

2.4.1 Side Slopes

The I/P ratio used to size the bioretention area or bioswale provides a base area only for the facility as this is the primary functional area of the facility for infiltration. The overall footprint of the bioretention area or bioswale will include the side slopes needed to connect the bottom surface of the bioretention area or bioswale with the ground surface, curb, sidewalk, etc. that surrounds the bioretention area or bioswale.

Photo 2-1: Bioswale grading in process at Walden Development, Calgary, AB

The sides slopes for a bioretention area or bioswale should typically be no steeper than a maximum of 2:1.(H:V) Side slopes of 3:1 or 4:1 (H:V) are preferred for ease of maintenance, and are recommended in particular for bioswales to reduce the risk of erosion from stormwater flows. Slopes shallower than 4:1 (H:V) may be used if they suit the site design.

The steeper the side slopes of the bioretention area or bioswale, the smaller the overall footprint will be. However, steeper slopes have an impact on the vegetation that may be used as well as the maintenance for the facility. For example, a side slope of 2:1 (H:V) cannot be easily mowed, so the slope must be planted with this maintenance limitation in mind. For ease of mechanized mowing, a 4:1 (H:V) side slope is preferred.

Bioswales are commonly planted with grasses or sedges in the bottom, which may require mowing for maintenance or other purposes. Where mechanized mowing is desired, there must be at least one access point per section of bioswale with a 4:1 (H:V) slope, so that the mechanized mowing equipment can access the swale bottom. However, mowing is not necessarily preferred in that mowing reduces the rooting depth of cool-season grasses, which, in turn, reduces their resistance to the tractive forces exerted by the flow moving through the bioswale. (Note that the resistance to erosion of grasses in Table 2-3 , Section 2.2.8, is given for unmowed conditions.) In addition, smaller or cut-back plants have reduced performance with respect to phytoremediation, evapotranspiration, and nutrient cycling.

For small, isolated bioretention areas, such as parking bump-outs and traffic islands, maintenance is likely to be performed manually so a steeper 2:1 (H:V) side slope may be acceptable. Tight urban footprints may also be attained by using all the available area as the base area for the bioretention facility, and surrounding the area with a vertical curb or decorative wall to create a bioretention “planter” area or flow-through bioswale “planter” area. Safety considerations may require a setback (minimum 0.3 m) from the sidewalk or barriers, for example a kneewall or low fence, to prevent pedestrians, bicycles, or vehicles from accidentally entering a “planter” area that is recessed below grade. Careful attention must be given to the vegetation and planting choices for a planter as mechanized mowing will not be possible. The vegetation must be tolerant to flow during runoff events and be able to be maintained manually only.

2.4.2 Footprint

The calculation of the bioretention area or bioswale footprint will translate the depth of ponding (200 mm default for bioretention areas and the desired depth of flow for bioswales) plus the freeboard allowance (150 mm default) to an additional length and width beyond the base area. For a bioretention area, based on the defaults and no steeper than 2:1 (H:V) slope, the side slopes require at least 1.4 m additional length and width in addition to the base area. Shallower side slopes will add a larger margin to the base area and require a larger footprint.

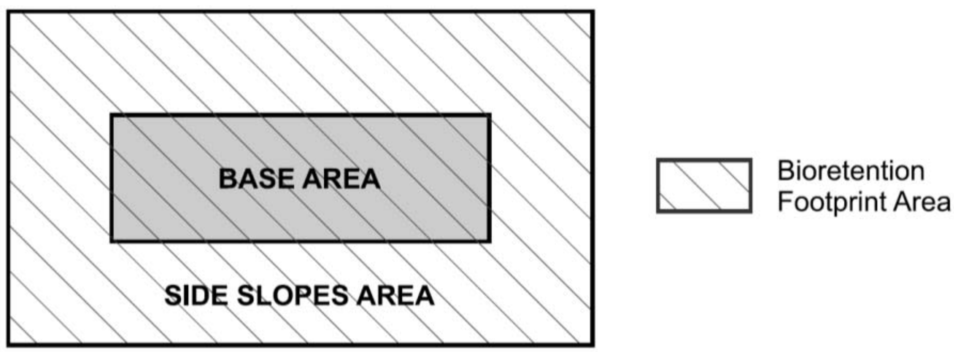

Figure 2-13: Illustration of Base Area and Footprint

2.4.3 Bioretention and Bioswale Base Area and Slope

The bioretention or bioswale base area was determined in Section 2.2. The grading objectives are different in order for the base area to be fully functional as a function of whether a bioswale or a bioretention area is being designed. A bioretention area must be graded to be essentially flat or slightly "dished" to slope toward the centre. The slope of the base area should be no more than 1%. A bioswale must have a longitudinal slope flatter than 2%.

The design of bioretention areas in sloped terrain where no flat area is readily available may be challenging. It is recommended to design the bioretention area with a flat base based on the design ponding depth, and extend the side slopes to meet the surrounding ground surface. This will result in a larger footprint for a bioretention area in steeper terrain due to the extension of the side slopes. Or, the bioretention area may need to be terraced, with flat terraces, and connected by terrace "steps" of up to 0.3 m in height, and rock splash pads (refer to scour protection in Section 2.5.3. for more information) at the base of the terrace steps. Ponding must be included in each terrace, with concrete weirs for overflow to the next lower level. This configuration is illustrated in Figure 2-14.

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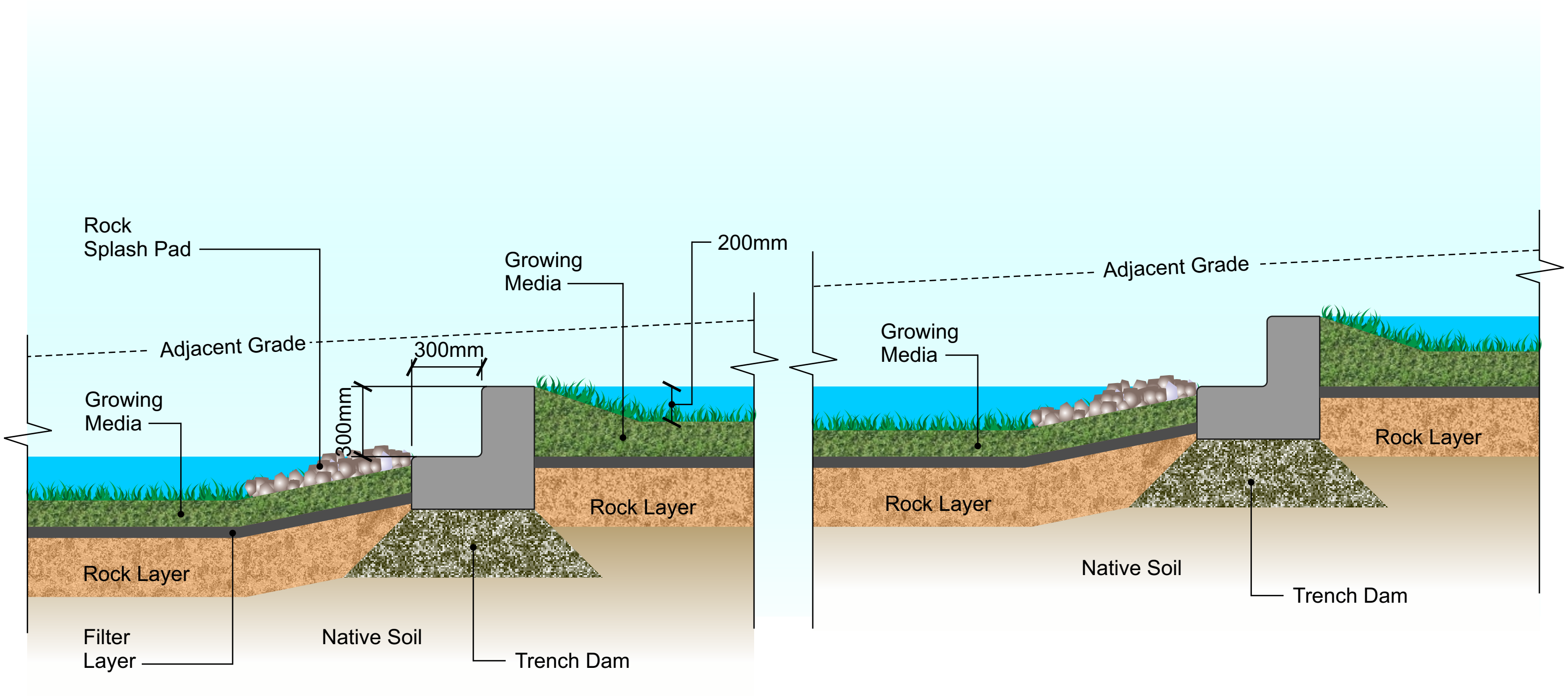

Profile

DIMENSIONS ARE MILLIMETRES
UNLESS OTHERWISE NOTED

METRIC

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JL	2016-04	LM
Scale	N.T.S.	
Approved by		
for City Engineer		

THE CITY OF CALGARY
WATER RESOURCES

Bioretention Area with Terraces

Sheet
Figure 2-14
File Number

ISC: Unrestricted

For inclusion of bioswales in sloped terrain where the longitudinal slopes are steeper than 2%, it is recommended to design the bioswale with terrace “steps” or weirs, including rock splash pads at the bases of the terraces, similar to described above for bioretention areas. The terraces are to provide elevation drops of up to 0.3 m between the swale sections, but with a maximum 2% slope, as shown in Figure 1-3 in Section 1 of this report. If desired, the terrace edges can be raised above the swale invert to function as weirs and provide some level of ponding above the swale bottom, effectively creating a series of bioretention areas within the swale, similar to Figure 2-14. The maximum ponding depth along a swale should be 300 mm. Weir restrictions, crossings (see Section 2.4.5) and ponding must be taken into account as hydraulically blocked flow when calculating the conveyance depth for the cross-section.

2.4.4 Bioswale Width and Depth

The required width of a bioswale is generally determined by the configuration of the site area, and/or may be based on the I/P ratio selected for the bioswale. When the swale is designed to run parallel to the edge of an impervious surface, such as a road or parking area, the base width of the swale will be the width of the pavement that slopes towards the bioswale divided by the I/P ratio. The base width of a bioswale shall vary between a minimum value of 600 mm and a maximum value of 2400 mm; the maximum width is intended to reduce the likelihood of frequent flows forming a channel in the swale bottom[5].

The depth of the swale shall be established by the magnitude of the design flow. The swale must generally be able to carry the minor system design flow for the contributing catchment area at a minimum, but may need to accommodate an additional allowance for the safe conveyance of the major system design flow unless flow controls are being implemented in the tributary catchment. This will be determined by the stormwater management planning for the overall development site. If there is no flow control for the major system design flow, the bioswale shall be sized to carry the entire 1:100 year major system design flow rate.

The depth of flow can be determined by the use of Manning’s equation and the typical trapezoidal cross-section of the swale. The Manning roughness coefficient (n) varies with the depth of flow over a vegetated surface, as shown in Table 2-4, on the next page. In general, for flow depths less than 10% of the vegetation height, the roughness value is higher, and for flow depths greater than 50% of the vegetation height the roughness value is an order of magnitude lower. When the flow depth is between 10% to 50% of the vegetation height, the flow is in transition and has a wide range of possible values spanning between the low and high values. A 150 mm minimum freeboard allowance is recommended above the design flow depth of the swale. Therefore, the depth of the bioswale should be at least [150 mm + calculated depth of flow].

The values in Table 2-4 are for grassed swales specifically, but would be applicable to similar vegetation such as sedges, reeds or other plants expected to cover the bottom of a bioswale. For a mulched swale planted with shrub-type plants, the flow velocities must be very low to prevent the mobilization of the mulch and growing media, see also Section 2.6. The roughness values for this case should be on the higher side due to the low flow depth, around 0.1 – 0.2.

[5] Minnesota Pollution Control Agency. Minnesota Stormwater Manual, http://stormwater.pca.state.mn.us/index.php/Design_criteria_for_filtration.

Table 2-4: Manning's n Variation for Grassed Swales*

Depth of Flow	Manning's n Range
Flow depth less than 10% vegetation height *this is called "low flow regime" relative to the roughness of the vegetation	0.15 to 0.4
Transition from flow through grass to flow over grass *this is called "intermediate flow regime" relative to the roughness of the vegetation	0.04 to 0.4
Flow depth over 50% of vegetation height *this is called "high flow regime" relative to the roughness of the vegetation	0.03 to 0.04
*Based on Barling and Moore (1993)	

2.4.5 Crossings

Where a road or driveway crosses a bioswale, the bioswale becomes discontinuous. The crossings must be hydraulically designed to allow the design flow rate to pass from one section of the bioswale to the next one so that the resulting level (hydraulic grade line) of the flow will still allow an 150 mm freeboard allowance. Each section of the bioswale should remain functional as a swale. As the roughness (i.e., Manning's n value) of a pipe is usually lower than the roughness of the swale, a culvert crossing pipe can be smaller than the width of the swale bottom; however, appropriate inlet and outlet losses shall be incorporated as part of the hydraulic design. For a better hydraulic performance, it is recommended that culverts have flared and beveled inlets and outlets with grates that conform to the side (end) slope of the swale, with an opening width less than or equal to the width of the swale bottom. See also Section 3.3.8 of the 2011 *City of Calgary Stormwater Management & Design Manual*.

Crossings of bioretention areas are less common than crossings for bioswales, but may occur connecting multiple cells on either side of pathways, walkways, driveways, etc. As a bioretention area typically does not have a sloped invert, a pipe crossing must be designed to allow flow up to the design flow rate to pass through the culvert without causing backwater conditions (i.e., an increase in water level above the design ponding elevation for the design flow rate) on the inflow side. The culvert pipe itself could have a longitudinal slope, but this may not be possible for all scenarios depending on the site terrain. Culvert crossings may be used to connect sections of bioretention area on steeper terrain, creating bioretention "pools" between the crossings and utilizing the crossings for grade drops between the bioretention areas. Similar to bioswales, culvert crossings between bioretention areas should have flared and beveled inlets and outlets with grates to minimize clogging of the pipes.

A separate issue is the presence of utility crossings of bioretention areas and bioswales. As noted in Section 1.3, the design of utility crossings is addressed elsewhere. In general, utility crossings of bioretention areas and bioswales should be installed in sleeves and trench dams or clay plugs should be used to prevent the infiltrated water from the bioretention areas or bioswales flowing away through the backfill material of the utility trench.

2.5 Groundwater Considerations

In order for a bioretention area or bioswale to function correctly, the bottom of the entire SCP must be above the groundwater table. The seasonally high groundwater elevation, see Section 3.3.6.8 of the 2011 *City of Calgary Stormwater Management & Design Manual*, will likely coincide with the wet season; the groundwater table should be at least 0.60 m below the base of the rock reservoir of the facility[6]. This is not a universal number and a site hydrogeology assessment may recommend a different value, but this is a standard separation value used for infiltration facility design. For more information about the groundwater table elevation and how to determine it, refer to *Module 1: Geotechnical and Hydrogeological Considerations for Low Impact Development*. If the seasonally high groundwater table is above the elevation of the base of the rock reservoir, bioretention may not be a suitable option for runoff disposal through infiltration. Bioretention may still be used for treatment of runoff flows, but the groundwater table would reduce or prevent infiltration from the facility and may contribute groundwater to the underdrain flow and to the storm sewer system. A lined bioretention facility may be an option to provide treatment with no infiltration; refer to Section 2.7.2 for the details of the liner required.

Other groundwater considerations may also be relevant for bioretention design. More complete guidance relative to groundwater and associated geotechnical considerations for LID design may be found in *Module 1: Geotechnical and Hydrogeological Considerations for Low Impact Development*. Possible concerns include:

- Setbacks from building foundations and property boundaries – this is dependent on the terrain and the soils, but a setback of 3 to 5 metres is generally recommended;
- Proximity to septic fields – a hydrogeologist should be consulted, but generally a setback of at least 10 metres is recommended for infiltration down gradient of septic fields;
- Setback from water supply wells – stormwater infiltration should be restricted to 15 to 30 metres from any water supply wells;
- Recent or compacted fill – recently placed (unconsolidated) fill materials may experience adverse effects from infiltration (such as buoyancy, shrinkage or compaction, displacement, piping, etc.), and stormwater infiltration should not be installed in recent fill;
- Contaminated sites – infiltration practices should not be used on sites containing known contaminated soils. These may include former industrial sites, gas stations, wrecking yards, industrial sites, marinas, recycling facilities, among others. Further discussion of the relevance and consideration of stormwater quality "hot spots" and contaminated soils may be found in *Module 1: Geotechnical and Hydrogeological Considerations for Low Impact Development*.
- Assessment of groundwater mounding – potential groundwater effects from infiltration practices.

[6] Metro Vancouver (2012). Stormwater Source Control Design Guidelines and City of Calgary (2007) Source Control Practices Handbook.

2.5.1 Angle of Inflow

The orientation of the inlet relative to the direction of the flow must be considered. The design of bioretention areas and bioswales shall include a review of the grading and slopes that will direct flow into the bioretention area inlet. For example, in the common situation where flow runs parallel to a curb cut opening (refer to photo below) the flow needs to change direction to enter the inlet similar to a side weir arrangement. The road slope and crossfall influence the capacity of a curb cut opening. Using the standard weir flow equation provided in Section 2.5.2. to size the curb cut in this situation usually results in between 30 to 50% of the design flow being captured. If the opening width is inadequate, a significant portion of the approach flow can unintentionally bypass the bioretention area, with flow ending up entering and overloading a downstream facility it was not intended for. Additional grading or additional inflow points could be necessary to direct the catchment runoff to the bioretention area or bioswale.

The site design may make use of this idea to direct only a portion of the design flow to a bioretention area or bioswale, with the remainder of the flow being directed to SCPs downstream that are designed to account for additional flow from upstream areas.

Curbs cuts that are depressed below the roadway edge (no more than 50 mm) can be used to improve the inflow capacity. Deflector vanes can be built into the concrete gutter where the longitudinal road slope is greater than 2% to improve flow capture in these situations.

2.5.2 Curb Opening Width At Entry

A bioretention area or bioswale inlet may have a variety of configurations, from a single curb cut opening or a pipe discharge to a flat panel (reversed) curb along the length of the facility. For a flat panel (reversed) curb, the inflow should be sheet flow only with no opening width to check.

For one or more curb cut openings, the width of the opening should be checked that it has adequate capacity. The opening width shall be sufficient for the design flow rate to be free-draining into the facility.

Flow Perpendicular to the Curb

A broad-crested weir equation may be used to calculate the flow capacity of the curb opening(s) for trap lows and where the curb cut is orientated perpendicular to the direction of the approach flow. The opening width required can be determined by solving for the weir length L (m) on the next page:

Photo 2-2: Curb cut leading to bioretention area, Walden Development, Calgary, AB

$$L = Q \div \left(C \times H^{3/2}\right)$$

Where:

Q is the design flow rate (m^3/s)

C is the weir coefficient (common value = 1.7)

H is the calculated flow depth in the gutter/road (m)

There is no maximum design entry width. A minimum opening width is recommended to be used to reduce the likelihood of the opening becoming frequently clogged by leaves or trash. The recommended minimum opening width is 0.75 m.

Flow Parallel to the Curb

When the flow is along a roadway, flowing primarily parallel to the curb, a side-inlet weir calculation should be used. The length of the curb-opening inlet required for the total interception of the gutter flow on a pavement section with a uniform cross slope is expressed by:

$$L_t = KQ^{0.42}S_L^{0.3}\left(\frac{1}{nS_x}\right)^{0.6}$$

Where:

L_t = Length of the curb opening required to intercept 100% of the flow (m)

K = 0.817

S_L = Longitudinal slope of the gutter (m/m)

Q = Flowrate (m^3/s)

n = Coefficient of roughness in Manning's Equation

S_x = Transverse Slope (m/m)

The efficiency of curb-opening inlets shorter than the length required for total interception is determined using the following:

$$E = 1 - \left(1 - \frac{L}{L_t}\right)^{1.8}$$

Where:

E = Interception efficiency of the inlet

L = Opening length of the curb, m

L_t = Length of the curb opening required to intercept 100% of the flow

The inlet interception capacity, which is the magnitude of the flow rate intercepted by an inlet whose efficiency for capturing the design flow has been determined in accordance with the equation above, is found by:

$$Q_i = EQ$$

Where:

Q_i = Interception capacity

E = Interception efficiency of the inlet

Q = Flowrate, m^3/s

The inlet interception capacity provides the flowrate expected to enter a given inlet of design length $L < L_t$. Multiple inlets may be designed to each intercept a portion of the design flow such that the inlets combined provide enough capacity for the full design flow for the bioretention area or bioswale.

2.5.3 Inlet Scour Protection

For any design where a bioretention area or bioswale has a point inflow such as a pipe outlet or curb cut, scour protection should be provided at the inlet to dissipate flows, reduce energy, and spread the flow to the width of the facility. Cobble-sized rock (i.e., 100-150 mm diameter) is commonly used for this purpose, placed to slow and disperse the flow as it enters the facility. This may be a clean crushed rock material, which may be less prone to movement under high flow conditions, but a decorative, rounded "river rock" is generally preferred for aesthetics.

Guidance for the design of scour protection may be found in the "Erosion and Sediment Control Manual – 2011" by Alberta Transportation (http://www.transportation.alberta.ca/4626.htm). To assess whether or what scour protection material is required, refer to Table 2-5, which lists the permissible velocities for bare soil and various surface cover materials including grasses and small to large rock. Rock should be sized according to this table, i.e., the design flow rate should be used for the selection of the required rock size for scour protection. For flows resulting in velocities greater than 3.0 m/s, riprap sizing should be done in accordance with section F.17.2 of Appendix F of the Erosion and Sediment Control Manual - 2011 by Alberta Transportation.

Other scour protection options other than grasses and rock are available. Turf reinforcement mats (TRMs) can be used where appropriate, but they must be carefully selected, installed and maintained to be capable of supporting the vegetation through the long-term. Erosion control matting (ECM) may also be used in conjunction with the vegetation on the surface; however, ECM has a relatively short lifespan and should be considered a temporary measure to reduce the risk of scour while vegetation is becoming established. Any such products must be used in accordance with the manufacturer's recommendations and specifications for the design and installation.

Table 2-5: Maximum Permissible Shear Stress Values and Velocities for Various Materials[7]

Materials	Test Time (hr)	Performance Properties	
		Maximum Permissible Shear Stress (N/m²)	Maximum Permissible Velocity (m/s)
Bare soil[a] (see Figure F.12) (*Table F.3d)			
Noncohesive (Dia. = 0.1 – 25 mm)	NDG	1.5 – 20	0.46 – 0.76*
Cohesive (P.I. = 4 – 50) (see Figure F.11) (Table F.3d)	NDG	0.5 – 38	0.52 – 1.13* 1.8 (hard pan)
Gravel riprap[a] (*Table F.3(d))			
D_{50} = 25 mm (thickness t = $2D_{50}$)	NDG	15.8	0.76 – 1.13*
D_{50} = 50 mm (thickness t = $2D_{50}$)	NDG	31.6	1.13 – 1.22*
Rock riprap[a] (** Table F.3(e))			
D_{50} = 150 mm (thickness t = $1.5D_{50}$)	NDG	95.8	2.2 **
D_{50} = 300 mm (thickness t = $2D_{50}$)	NDG	191.5	3.0 **
Gabion Mattress (*** Table F.3(f))			$V_{critical}$ – V_{limit}
thickness = 0.25 m; D_{50} = 120 mm	NDG	200	4.5 – 6.1 ***
thickness = 0.30 m; D_{50} = 150 mm	NDG	230	5.0 – 6.4 ***
thickness = 0.50 m; D_{50} = 190 mm	NDG	250	6.4 – 8.0 ***
Grass (established)[a] (Table F.3g)	NDG	16.8 – 177.2	0.8 – 2.4
Vegetative			
Class A Retardance	NDG	177.2	
Class B Retardance	NDG	100.6	
Class C Retardance	NDG	47.9	
Class D Retardance	NDG	28.7	
Class E Retardance	NDG	16.8	
Fiberglass roving[a] (SOP)			
Single	NDG	28.7	NDG
Double	NDG	40.7	NDG
Straw (loose) covered with net[a]	NDG	69.4	NDG
EROSION CONTROL MAT (ECM)			
Coconut material[c]	0.5	143	3.0 – 4.6
Wood excelsior material[a]	NDG	74.2	NDG
Jute net[a]	NDG	21.5	NDG
Straw blanket with sewn net[c]	0.5	95.7 – 105	1.8 – 3.0
Straw/coconut blanket[c]	0.5	120	3.0
TURF REINFORCEMENT MAT (TRM)			
Bare ground conditions[a,b]	0.5	239 – 287	5.5 – 8.2
	50	95.6	2.4
Vegetation established[b]	0.5	100 – 380	5.5
growth period ≥ 36 mos. & growth density dependent	50	100 – 239	3.0
COMPOSITE TURF REINFORCEMENT MAT (C-TRM)			
Bare ground conditions[b]	0.5	239	3.7
	50	95.6	2.1
Vegetation established[b]	0.5	382	6.1
	50	239	4.3

[a] From Chen and Cotton (1988)

[b] From IECA (1991, 1992, 1995)

[c] As reported by manufacturer

[7] Alberta Ministry of Transportation. Erosion and Sediment Control Manual – 2011. Appendix F Table F.3(c).

There can be a wide variety of inlet configurations and scour protection may take other forms. For an inlet underneath a sidewalk with a grated top, the inlet to the bioretention area or bioswale may be a contoured concrete apron that spreads the flow and is easy to clean. See Photo 2-3.

Photo 2-3: Curb cut leading to bioretention area through sidewalk with a grated top, Marlowe Place, Calgary, AB

2.5.4 Sediment Accumulation at Inlet

Where the inlet to a bioretention area is a flat contributing surface such as a parking area or a flat panel (reversed) curb, resulting in sheet flow conditions, there should be a short drop of 50 mm from the paved surface to the top of a 0.30 m wide strip consisting of .a layer of crushed or rounded rock (25 mm diameter or larger) along the pavement/bioretention edge to provide a surface where the coarse sediment can drop out without the tendency to form a sediment "dam", see Figure 2-15. The rock provides erosion protection and energy dissipation for the slope edge. Care should still be taken to be sure the surface of the rock is 50 mm below, not at or above, the surface of the pavement.

This 0.30 m strip is to allow for any accumulation of coarse sediment that drops out when the flow enters the facility and the velocity slows. While grass has been shown to be particularly effective at catching sediment at the inlet, it will form a "dam" of sediment at the pavement edge if the vegetation is flush with the paved surface. Therefore, a crushed rock strip or rounded rock strip is preferred.

In the case of a curb cut or other point inflow, scour protection is required (see Section 2.5.3.).

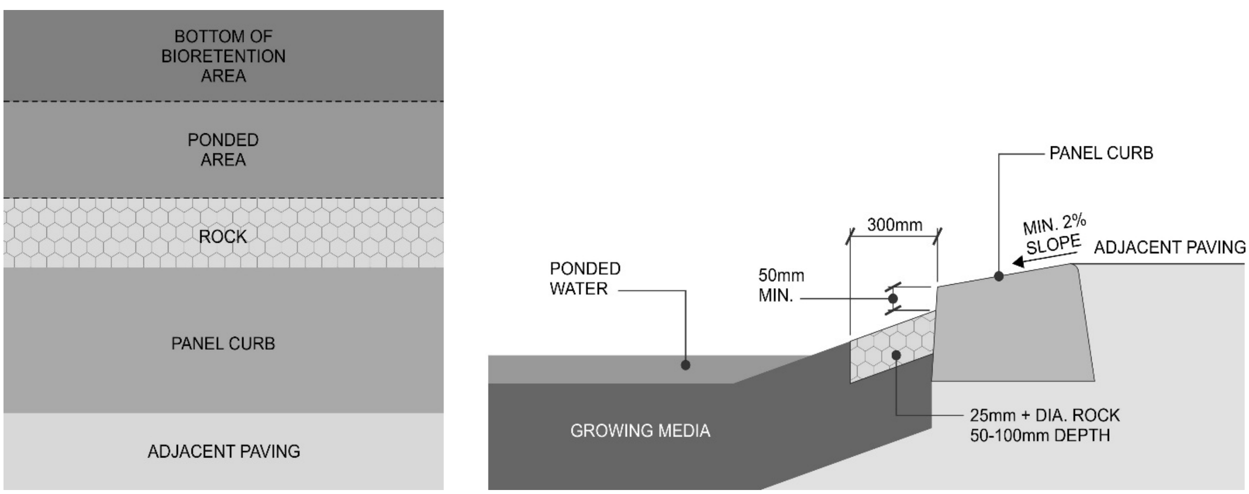


Figure 2-15: 50 mm Drop at Curb Edge

2.6 Mulch Movement and Scour Velocity

The flow of water across the bioretention area or bioswale should be checked for the potential for movement of mulch and scouring of the underlying growing media. A check should be done for the design flow event. If modelling has been done to determine the design flow rate, the model results may also be used to determine the critical velocities within a bioretention area or bioswale. Or, the full design flow can be assumed to be flowing through the width of the facility at the design flow depth (in the case of a bioswale) or ponding depth (in the case of a bioretention area). The velocity is estimated as the flow divided by the cross-sectional area of flow (i.e., depth x width) and should be below 0.5 m/s for the design flow rate.

The mulch layer in a bioretention area or bioswale may move around somewhat during the design flow event, but the above check velocity is low enough that the mulch layer should not be fully mobilized or removed.

Note that the velocity at the inlet is expected to be higher than the velocity through the bioretention area or bioswale, so the velocity should be checked at more than one point for the risk of growing media scour.

2.7 Underdrain System Design

The underdrain system is a method of ensuring that water that has filtered through the growing media layer has a means of discharge even when the rock reservoir is full and the infiltration rate into the bioretention area exceeds the percolation rate into the surrounding soil. This allows infiltration into the bioretention area, and volume reduction from runoff flows, while protecting the vegetation from drowning due to long term saturation of the growing media and drawing-down the ponded volume to provide storage capacity for the next storm event.

Manning's equation shall be used to calculate the flow rate in the perforated underdrain pipe. The perforated pipe should be sized to be able to carry the maximum infiltration rate as calculated in Section 2.3.2. 150 mm diameter pipe is standard, but a 100 mm or 200 mm pipe is sometimes used. Refer to the underdrain system specification in Section 3.2.1. If the flow exceeds the capacity of a single pipe, pipes may be laid in parallel under a large bioretention area.

2.7.1 Perforations Inflow Check

Standard perforated PVC pipe is recommended for the bioretention underdrain. The standard pipe has two rows of perforations, 10 to 15 mm diameter and approximately 120 mm apart, with 120° (2/3 radian) between the rows. This pipe will have an inflow rate of about 2.1 L/s per metre length of pipe, allowing for a theoretical 50% blockage of the perforations[8].

[8] Based on manufacturer's information for a standard 150 mm perforated PVC pipe (from IPEX, 2014).

The inflow rate can be checked using the following formula:

$$Q_{perforations} = \frac{C \times A\sqrt{(2gh)}}{B}$$

Where:

C = orifice coefficient = 0.61

A = total area of the orifice (m^2)

g = Acceleration of gravity (9.81 m/s^2)

h = maximum depth of water above the pipe (m)

B = Blockage factor. (2 is recommended)

This inflow rate for the length of the underdrain pipe shall be checked vs. the maximum growing media infiltration rate for the bioretention area. If the bioretention area is relatively wide, the maximum growing media infiltration rate may exceed the inflow capacity of the underdrain pipe. Two underdrains placed in parallel and connected at the downstream end may then be required.

The sizing of the underdrain pipe does not account for ICDs in the downstream catchbasins as the design level of service for the infiltration system in a bioretention area or bioswale is generally much lower than that of an ICD.

2.7.2 Design When Infiltration Is Undesirable

In general, the goal for bioretention and bioswale systems is two-fold, i.e., (1) to treat runoff for pollutants and (2) to infiltrate runoff to reduce runoff flow volumes. However, there are cases where percolation of water into the subsoils is not desirable and the bioretention area or bioswale must be designed to provide treatment and minimal retention but cannot provide significant runoff volume reduction through percolation into the subsoils.

If the percolation capacity of the surrounding native soil is relatively low, the rate of percolation will be slow relative to the discharge through the rock reservoir and the underdrain. If percolation into the subsoils is not desired and should be minimized, the underdrain pipe should be located at the bottom of the rock reservoir, or even be slightly depressed relative to the bottom of the rock layer. Then the rock no longer acts as a reservoir for percolation but as a conduit for water to the underdrain. The rock reservoir and underdrain are required even when the bioretention area or bioswale is not designed to provide percolation of water into the subsoils. There should be a difference of one to two orders of magnitude between the saturated hydraulic conductivities of the growing media layer and the native soils for the bioretention to function in this manner.

The differential between infiltration and percolation rates will not discourage seepage out of the bioretention area or bioswale where utility trenches run along or frequently cross the bioretention area or bioswale. The gravel backfill used for utility trenches will easily act as a conduit for water from the reservoir area unless there is a barrier (trench dam or clay plug) placed to prevent this. Refer to City of Calgary *Standard Specifications for Waterworks Construction* (2012), Page 43 and Sheet 56, for information pertaining to the design of this barrier.

If absolutely no infiltration is allowed, the bioretention area must be lined to contain all water within the system. The liner may be a flexible, waterproof membrane, such as a PVC or HDPE sheet, or may be a concrete casing. Concrete is not common, but is reportedly used on occasion in urban areas where a "flow-through" planter installation is desired for water quality treatment but not for percolation of runoff. PVC or HDPE membranes should be heavy-duty material, such as 20 mil PVC or 40 mil HDPE.

2.8 Interaction with Trap Lows

Trap lows are typically formed to provide active storage within the road ROW or commercial/ industrial lots to release the 1:100 year event flow through the minor storm sewer system. An inlet control device (ICD), is usually located on the catchbasin lead to limit the maximum rate of flow into the storm sewer, in order to prevent unwanted surcharging of the downstream system. Bioretention areas are also commonly located within trap lows resulting in a number of challenges and considerations for the design of these areas.

In numerous new subdivision and retrofit examples the underdrain is connected into either the catch basin or beehive storm sewer inlet structure, usually upstream of the ICD. For minor storm events when the storm sewer inlet is not engaged the ICD should have adequate capacity to cater for the underdrain flow with no major backup within the rock drain layer. However, once the inlet structure is engaged the ICD will begin backing up the flow creating a number of potential concerns.

The main concern is the potential for untreated stormwater to flow back into the underdrain system. This may result in the finer TSS being deposited within the rock drain resulting in reduced percolation over time. In some cases, the underdrain could become clogged, potentially attracting plant roots, and/or reducing the capacity of the rock layer. The risk of this occurring will depend on the bioretention I:P ratio and the characteristics of the catchment that is being managed. Of lesser concern is the influence that backup from the ICD has on the bioretention performance, particularly the plants and media. Options to avoid these potential risks involve connecting the underdrain downstream of the ICD or placing a backflow preventer or screen at the outlet of the underdrain.

Another concern is that when water is ponded in a trap low and adjacent bioretention area or bioswale, the ponded water disguises the varying grades of road and SCP inverts. There is a need for visual cues to indicate the edge of the roadway and/or edge of an adjacent recessed bioretention area or bioswale surface. Including visual cues such as taller plantings (shrubs or trees), post and cable fencing, or other method of indicating an edge that will show above the ponded water surface will reduce the risk of vehicles inadvertently entering the deeper bioretention area or bioswale. The total depth of inundation at the bioretention area itself shall not exceed 0.5 m on those occasions.

2.9 Emergency Overland Escape Route and Storm Sewer System Inlet

The design of a bioretention area or bioswale must include appropriate design considerations to handle the design flows just as any other stormwater facility. In order to handle these flows, each SCP must have a storm sewer system inlet and there must be a designed emergency overland escape route.

2.9.1 Storm Sewer System Inlet Design

The bioretention area or bioswale must have a storm sewer system inlet that allows ponding up to the desired ponding depth but then overflows directly to the storm sewer system. The storm sewer system inlet must be designed with an inlet and pipe capacity to carry the minor design flow rate, similar to typical catchbasin inlet design practice. The storm sewer system inlet may be a Grated Top Manhole, or a Side-Inlet Catch-Basin Type 'C', as specified in the 2012 City of Calgary *Construction Specifications for Sewers*. A Type 'C' inlet may be used in smaller bump-out roadside bioretention areas or in smaller bioswales, but a Grated Top Manhole will be more common for both types of practices.

For a bioretention area, the storm sewer system inlet may be located near the inlet to the bioretention facility to reduce flow-through for flows above the facility's infiltration capacity. However, this could in some cases promote settling of sediment near the bioretention inlet for more frequent flows. In this case, an area planned for sediment removal (such as a concrete apron or a pre-treatment method) could be included in the area between the inlet and the storm sewer system inlet. Otherwise, it is preferable to locate the storm sewer system inlet at the opposite end of the facility in order to spread settled material more evenly through the facility and reduce maintenance. Or, in the case where there are two inlets to a bioretention area, the storm sewer system inlet could be located along the road curb as a standard catchbasin inlet provided the flow is first directed into the bioretention area then into the catchbasin. This approach is believed to provide a better performance during the winter months when there is a risk of the inlets being plugged with snow and ice.

Where the interception of the minor system design flows is desirable, the storm sewer system inlet elevation (and therefore the design ponding depth, for bioretention) should be 100 mm below the invert of the street Lip of Gutter. This allows the storm sewer system inlet to function at the minor system design flow level without any backwater effects onto the street. The 100 mm difference between the storm sewer system inlet elevation and the invert of the street Lip of Gutter may be allowed as head in calculating the capacity of the grated inlet for the minor system design flow rate.

For a bioswale, conveyance is part of the design of the facility, so the storm sewer system inlet would always be located at the downstream end of the bioswale. As a bioswale may not include ponding, the storm sewer inlet elevation may be at the invert of the bioswale at the downstream end.

The sizing of the Grated Top Manhole or Type 'C' catchbasin should be in accordance with Section 3.3.4. of the *Stormwater Management and Design Manual* (2011). For bioswales, a larger storm sewer system inlet than is required is acceptable; however, ICDs may be required to prevent major system design flows from overloading the storm sewer system. Storm sewer system inlets should be protected by standard grates (spacing of bars to be 100 mm or less) to prevent trash and debris from lodging in the pipes.

2.9.2 Emergency Overland Escape Route

Bioretention areas must also be designed in conjunction with a planned route for high flows to take all flows greater than the minor system design flow rate up to the major system design flow rate. Requirements for this emergency overland escape route are described in the *2011 Stormwater Management and Design Manual*. It is preferred for the long-term performance of bioretention areas and bioswales that the emergency overland escape route from sites does not flow through but rather bypasses the bioretention area or bioswale.

While bypass of the major system design flow is preferred, if required by the topography and layout of the site, the emergency overland escape route may flow through a bioretention area or bioswale. If this is the case, the bioretention area or bioswale must be designed to handle the major system flow, as discussed in Section 2.3.1. The major system design flow shall spill from the bioretention area or bioswale to a road or walkway or other conveyance system in accordance with the *2011 Stormwater Management and Design Manual* requirements.

3. Design Specifications

3.1 Introduction

The specifications include the various engineered layers such as the rock reservoir, underdrain system, the granular filter layer, and growing media; along with the vegetation and surface cover components. The design specifications reflect the availability of local materials and City of Calgary maintenance requirements.

3.2 Rock Reservoir Specification

The underdrain shall be surrounded by drain rock as shown in Figure 3-1 and Figure 3-2. The drain rock shall be double-washed, graded, durable rock (generally, this is angular crushed rock from a quarry or stone processor, but rounded rock may be used as well) conforming to the following gradations:

Table 3-1: Drain Rock Gradation

Sieve Designation	Percent Passing
25.0 mm	100
19.0 mm	0 - 100
9.5 mm	0 - 5
4.75 mm	0 - 1

Although larger rock may be more expensive, it may be used, if available, so long as the maximum particle size is less than one third of the smallest dimension (usually thickness) that makes up the rock reservoir. The gradation provided in Table 3-1 is a minimum rock gradation and no smaller rock shall be used for the reservoir. If larger rock is used for the rock reservoir, the ratio of diameters must be considered between the drain rock material and the coarse layer of the granular filter material. Similar to the filter layers, the D_{15} (rock) ≤ 5 x D_{85} (pea gravel part of granular filter material).

The rock must be transported and handled so that it remains clean, with a minimum or dirt or fines, throughout the installation.

The depth of the drain rock in the rock reservoir shall be a minimum of 400 mm; the rock shall fill the width of the trench. If the bioretention area or bioswale is not designed for percolation into the subsoils, the minimum depth of rock is 100 mm above the underdrain pipe; therefore, a minimum depth of 200 mm of drain rock is required, even in a lined bioretention area or bioswale.

The drain rock shall be covered with a Granular Filter Layer, as per Section 3.3, that fully covers the top surface of the rock leaving no drain rock that is not covered with the full thickness of both components of the Granular Filter Layer. The drain rock may also be wrapped along the sides of the trench with the filter fabric, as per Section 3.4, to prevent migration of fines into the rock and prevent clogging of the rock voids. If the rock reservoir is large and the terrain flat such that migration of fines into the rock is expected to be minimal, the filter fabric is not required.

Open Chamber Reservoir Option

As an alternative to a rock reservoir, an open chamber reservoir may be used as part of a bioretention area. Open chamber systems use proprietary structures, typically resembling milk crates, to provide a much larger void space in the reservoir volume. Open chamber systems typically provide 95% void space, as opposed to 35% void space for drain rock, and are relatively quick to install. However, the proprietary crate structures may be more expensive for a facility than rock, even though a larger volume of rock is required to provide an equivalent void space.

3.2.1 Underdrain Specification

The underdrain specification is also found in the City of Calgary Sewer Construction Specifications in Section 403.15.00.

All bioretention areas shall have underdrains below the growing media to drain excess water to the storm sewer system. The underdrains are required unless specifically waived upon request and substantiated by a qualified geotechnical professional engineer that the subsoil conditions provide sufficient percolation capacity (e.g., having an in-situ saturated hydraulic conductivity in excess of 25 mm/hr).

The underdrains shall be a minimum of 100 mm diameter perforated PVC pipe. The pipe shall conform to Section 402.01.01.04 of the latest edition of the City of Calgary Sewer Specifications. 150 mm diameter perforated PVC pipe is recommended for most installations.

The underdrain pipe shall be installed along the length of the rock-filled trench below the bioretention area growing media. The underdrain pipe shall run the full length of the bioretention area.

The pipe shall be installed with “holes down” and “printing up”.

The maximum run of connected underdrain pipes between connections draining to the storm sewer system shall be the lesser of:

- The maximum length using Section 2.3.2 to achieve full flow capacity in the pipe; OR
- One city block length; OR
- 130 m.

The pipes shall preferably be laid in straight sections between connections/observation ports, but may curve to the maximum permitted radius as per the manufacturers’ recommendations.

The connections to the storm sewer system shall be able to accommodate a sewer inspection camera and shall be:

- Straight connections to pipe at least 200 mm diameter; AND
- Shall have only “sweep” bends between the underdrain and a manhole; OR
- Connections to manholes.

The connections to the storm sewer system must conform to the City of Calgary Sewer Specifications.

The pipe shall be laid on a minimum 0.1 percent slope to have positive drainage toward the storm sewer system connection. A slope of 1 to 2 percent is preferred if the storm sewer system invert depth can accommodate it.

The terminal end of the pipe shall be closed with an observation port.

The underdrain pipe shall be laid in a trench filled and/or backfilled with drain rock and:

- The pipe shall be laid at the top of the rock reservoir, immediately below the filter fabric or granular filter, if the bioretention area is designed to percolate water into the subsoils to achieve volume reduction of stormwater runoff; OR
- The pipe shall be laid on the bottom of the rock reservoir if the bioretention area is not designed for infiltration (i.e., it may be lined or limited by the subsoil percolation capacity). This is to prevent residual water from freezing in the rock reservoir in cases where a liner is provided.

The bioretention areas and bioswales must be maintained in a clean condition to permit infiltration and water storage. No deleterious materials of any kind are allowed to enter the gravel/rock or the underdrain pipe. Extreme care must be taken during construction to prevent any water, mud or other material from entering the bioretention or bioswale construction area. See the Construction Considerations in Section 4.3 for additional information.

Observation Port

Observation ports shall be provided for each underdrain, and shall be one of the following:

1) Solid wall PVC riser pipe with a diameter equal to the underdrain pipe and with a long radius bend connection to the under-drain pipe to permit passage of a video camera. The riser pipe shall terminate a minimum of 150 mm above the ground surface to prevent entry of water or debris when open, and shall be fitted with a water-tight removable cap. If installed outside the area where ponding of water will occur, the riser may be installed flush with the grade. The pipe shall conform to Section 402.01.01.04 of the latest edition of the City of Calgary Sewer Specifications.
2) A catch basin protected to prevent entry of debris and sediment and conforming to Sections 402.01.06 and 402.07.01 of the latest edition of the City of Calgary Sewer Specifications.
3) A manhole protected to prevent entry of debris and sediment and conforming to Sections 402.01.05 and 402 06 01 of the latest edition of the City of Calgary Sewer Specifications.

The observation ports shall be tested with standard video camera equipment following installation to verify that the video equipment can satisfactorily traverse the length of the underdrain pipe.

3.3 Granular Filter Layer Specifications

A granular filter layer must be used to maintain separation of the growing media and the rock reservoir.

The granular filter layer consists of two layers, one of sand immediately below the growing media and one of pea gravel immediately below the sand layer, as shown in Figures 3-1 and 3-2.

The sand for the granular filter layer shall be a clean, washed, poorly graded sand with a maximum particle size of 3 mm and an average size of no less than 1 mm. The pea gravel for the granular filter layer shall be 7 mm or 10 mm diameter clean, washed uniform material. Both materials must contain less than 2-percent fines (i.e., material 80 microns or less) by dry weight.

Table 3-2: Granular Filter Material Specification

Layer (in order, top to bottom)	Material Requirements
Sand	Clean, washed Poorly graded Maximum particle size: 3 mm Average size ≥ 0.5 mm Fines ≤ 2% by weight
Pea Gravel	Clean, washed Uniform gradation 90% Passing the 14 mm screen Average size 7 – 10 mm dia. Fines ≤ 2% by weight

The materials for the Granular Filter must be transported and handled with care and kept clean and separate prior to and during the installation.

The Granular Filter Layer shall be 200 mm thick and composed of:

- 100 mm of pea gravel over the drain rock reservoir AND
- 100 mm of clean sand over the layer of pea gravel and below the growing media.

To ensure that filter materials are effective at preventing migration of finer materials into and through the larger materials the following requirement must be met for the filter layer materials:

D_{15} (gravel) ≤ 5 x D_{85} (sand)

and

D_{15} (sand) ≤ 5 x D_{85} (growing media)

For example: D_{15} (gravel) = 5 mm ≤ 5 x D_{85} (sand) = 5 x 2 mm = OK

3.4 Optional Geotextile Filter Fabric

A geotextile filter fabric may be used to separate the rock reservoir from the native subsoils along the sides of the rock reservoir. This is not required at all times, but can be used to help keep the rock in the reservoir clean and free of fines during construction. When used, the filter fabric shall be a non-woven geotextile fabric with minimum specified properties as follows:

- Apparent Opening 0.212 mm
- Tensile Strength 400 N
- Puncture Strength 240 N
- Trapezoidal Tear Strength 175 N
- Water Flow Rate 6000 L/m/m^2

Or, equivalent as approved by a qualified professional engineer, and subject to approval by Water Resources. It shall be delivered, stored, and installed in accordance with the manufacturer's instructions.

The Filter Fabric shall surround the sides of the drain rock in the trench.

The ends of the filter fabric shall be overlapped a minimum of 500 mm.

3.5 Growing Media Specification

The growing media shall be imported material conforming to a performance-based specification outlined in this section unless, and subject to approval by Water Resources, a registered Professional Agrologist oversees and approves the amendments and processes to build a suitable amended soil from on-site native materials. Care must be taken with growing media during its transport and handling to ensure it remains properly mixed and free from soils that are not part of the growing media mix and free contaminants including weeds and pathogens.

The growing media must be tested in a laboratory setting to verify compliance with the specifications including the minimum saturated hydraulic conductivity. The saturated hydraulic conductivity shall also be tested in-situ for the installed growing media using the testing procedure as per Module 1-Geotechnical and Hydrogeological Considerations.

The excavated side slopes in the native soil below the growing media shall generally be the same as the side slopes of the bioretention area in order to maintain an even thickness of the growing media layer. The excavated side slopes may be as steep as 1:1 (H:V), if required.

The properties of the growing media are outlined in Table 3-3. Most bioretention areas and bioswales would be expected to utilize growing media with a minimum hydraulic conductivity of:

- 70 mm/hr, in the case of <u>no pre-treatment</u> of the inflows to the SCP; or
- 40 mm/hr, in the case <u>with pre-treatment</u> of the inflows to the SCP.

An average of the lab sample tests for each batch may be used to meet the minimum hydraulic conductivity and other required properties as shown in Table 3-3 prior to supply of the growing media to the site. Tolerances for the target values are shown in the table. Key requirements for the supply of growing media include:

- Processed and mixed growing media shall be a homogeneous mixture, created through a mechanized process.
- The drainage of the growing media shall meet the following testing requirements for the required minimum saturated hydraulic conductivity:
    - A laboratory measure of the saturated hydraulic conductivity of the growing media shall be performed for every 500 m^3 of media mixed, or for a minimum of one test per batch mixed, using ASTM F1815 for laboratory testing of hydraulic conductivity. Samples used must be representative of the fully mixed batch of material and may not be adjusted using any material not taken from the mixed batch.
    - A field measure of the mixed and placed growing media shall be tested in-situ, once per bioretention area or bioswale facility, or once for every 1000 m^2 for very large areas. The testing procedure shall conform to *Module 1-Geotechnical and Hydrogeological Considerations*.

Table 3-3: Properties of Growing Media for Bioretention Areas and Bioswales

Property	Requirement: High Infiltration Media	Requirement: Moderate Infiltration Media	Notes
Minimum Saturated Hydraulic Conductivity	70 mm/hr	40 mm/hr	Hydraulic Conductivity must be above minimum shown on average per batch of media mixed.
Coarse Gravel: Larger than 19 mm Smaller than 40 mm	0-1%	0-1%	Gravel component is a maximum limit with a tolerance of 1% above values shown.
All Gravel: Larger than 2 mm Smaller than 40 mm	0-5%	0-5%	
Note: Percent Gravel is calculated as Percent of Dry Weight of Total Growing Media. All other Requirements are Calculated as Percent of Dry Weight of Growing Media Excluding Gravel.			
Sand: Larger than 0.05 mm Smaller than 2 mm	75-80%	40-80%	Particle ranges for clay, silt and sand have a tolerance of 2% outside of requirements shown.
Silt: Larger than 0.002 mm Smaller than 0.05 mm	10-15%	10-25%	
Clay: Smaller than .002 mm	3-10%	0-20%	
Clay and Silt Combined	Maximum 15%	Maximum 35%	
Organic Content	5-10% Tolerance for Organic content is +/- 1%	15-20% Tolerance for Organic content is +/- 1%	The organic content is recommended to be composted vegetable matter. Biosolids products may not be used as they may contain high metals contents and hydrophilic compounds that impede drainage.
Acidity (pH)(in water)[(3)]	5.5-7.3 Tolerance for Acidity is +/- 0.2 pH	5.5-7.5 Tolerance for Acidity is +/- 0.2 pH	The acidity of Calgary soils is known to generally be lower (i.e., higher pH value) than neutral. The pH values recommended for the growing media are independent of the native soil conditions because the growing media is

Property	Requirement: High Infiltration Media	Requirement: Moderate Infiltration Media	Notes
			expected to be an imported landscape soil prepared specifically for bioretention. The pH value of the growing media should be adjusted to within the specified range to promote the health and growth of vegetation in bioretention areas and bioswales. The pH range shown is a range designed for optimum plant growth; a higher pH value may be permitted, but will be expected to have less than optimum plant productivity.
Salinity (EC - ds/m)	0-3	0-2	The saturation extract conductivity shall not exceed 3.0 milliohms/cm at 25 degrees Celsius
Boron (ppm)	Maximum 1.0	Maximum 1.0	There is no tolerance above the maximum value.
Nitrogen (% by weight)	0.2% to 0.6%	0.2% to 0.6%	A minimum of 50% of nitrogen shall be in slow release form. Tolerance for N is +/- 0.05% outside of the range.
SAR (sodium adsorption ratio)	Target 0-4, Maximum 8	Target 0-4, Maximum 8	As calculated by analysis of the saturation extract. There is no tolerance above the maximum value.
Available Phosphorus (ppm)	Target 20 to 25	Target 20 to 25	If the tested Phosphorus level exceeds 30 ppm then the growing media must be amended with 5% iron filings by volume.
Available Potassium (ppm)	50 to 1000	50 to 1000	There is no tolerance outside of the range.
Carbon to Nitrogen Ratio	Maximum 40:1	Maximum 40:1	There is no tolerance above the maximum value.
Max Compaction	Normal Compaction	Normal Compaction	Normal compaction assumes 85% Proctor density; Tested density must be within 3% of target compaction.

Note that highly plastic clays may not be used as part of the growing media, including the clay fraction of the material.

Irrigation may be required to support plant growth through the summer growing season, depending on the growing media and the plants selected for the SCP. The decision of whether irrigation is required is up to the landscape architect or designer.

3.6 Mulch Layer

Wood Mulch

Typically, bioretention areas and some bioswales are planted with vegetation that does not quickly form a continuous cover for the growing media. Usually, these are facilities that are dominated by shrubs and/or trees. In these facilities, an organic mulch or alternative groundcover must be added as an initial placeholder for the eventual establishment of a permanent leaf-litter layer. A mulch layer is required to protect the soil surface. A wood mulch mimics leaf litter by discouraging weeds, retaining moisture, buffering temperature, providing a natural slow-release fertilizer, and providing habitat for beneficial insects. In bioretention areas and bioswales, an organic mulch also reduces the potential for surface crusting, aids in sediment filtration, sequesters metals, breaks down hydrocarbons, and reduces the potential for wind erosion.

Where velocities do not exceed 0.5 m/s, and where slopes are not steeper than 3:1 (H:V) (see Section 2.6), a double-shredded (ground), long-strand, wood and/or bark mulch shall be placed to a depth of 100 to 125 mm. The mulch must be kept 50 mm away from trunks and stems of all plants to prevent rotting. The mulch should be placed within a short time period after planting in order to reduce the potential for weed establishment. Particular care should be taken to ensure the full depth of the mulch is placed around the perimeter of the facility in order to discourage weeds. Mechanically applied mulch is preferred, as it will tend to adhere to the growing media better than hand-placed mulch.

Mulch may or may not be aged, as some nitrogen drawdown of the underlying growing media may be desirable. Any wood type is acceptable, except those that are chemically treated or salvaged from construction lumber, building demolition, or shipping waste. The material should have no more than 5% (by volume) of soil, sawdust, peat moss, or needles. No mulch from diseased or infested plant materials is allowed.

Alternatives to Wood Mulch

If a groundcover, nurse crop, or grass from seed is used for all or part of the vegetation, a biodegradable mulch with a tackifier (i.e., hydromulch) is recommended to be installed at the time of construction until the grass or groundcover is established so that it will fulfill the role of protection of the growing media.

Additional Considerations

Additional considerations for mulching in bioretention areas and bioswales include:

For scour protection for concentrated flows, see Section 2.5.3 on inlet protection for further information. For additional information on side slopes, see Section 2.4.1.

3.7 Vegetation Specifications

Vegetation is an important component of a bioretention system. The plants uptake water and release it into the atmosphere through evapotranspiration, thereby reducing runoff volume. They uptake pollutants and nutrients, thereby improving water quality. Plant roots enhance the infiltration capacity of the growing media, structurally stabilize the growing media mass, and are essential to facilitating remediation processes in the growing media.

The plants used in bioretention areas and bioswales need to tolerate drought conditions, inundation, and the contaminants found in runoff.

3.7.1 Vegetation Strategy

The strategy for successful planting includes the following measures:

- Use a variety of species rather than a monoculture. Where appropriate, provide both a groundcover and understory layer, and, where possible, a canopy layer.
- Use some species that will self-seed, expand, or form a thicket, so that desirable species can compete with weeds for bare patches and can move around to desirable conditions. Plan to manage the area and not the individual plant.
- Avoid straight lines of single plant species. This both camouflages individual plants that might perform poorly and prevents the formation of preferential flow channels.
- Choose native species wherever possible. Natives tend to be more resilient to stresses.
- Consider a cover (nurse) crop rather than a woody mulch. Cover crops stabilize the growing media, compete with weeds, and increase nutrient uptake and evapotranspiration while permanent plantings are getting established.
- Appendix B provides lists of suitable plants and their characteristics.

3.7.2 Vegetation Form

Plants may be supplied as seed, plugs, whips, bare root, container, or caliper stock.

For trees and shrubs, in order to reduce transplant shock, and in order to retain the integrity of the performance characteristics of the growing media, bare root stock or smaller container-grown stock in an appropriate bioretention/bioswale growing media is preferred. In accordance with *The City of Calgary Parks Development Guidelines and Standard Specifications: Landscape Construction 2013*, “bare root stock to not exceed 40 mm (1.5") caliper. Root Ball diameter will be 300 mm (12") for every 25 mm (1") caliper.”

3.7.3 Snow Storage Concern

Snow storage within bioretention areas and bioswales is not desirable. The growing media is subject to compaction, salt and sanding residues bypass pre-treatment areas, woody plants break or die, and shorter plants are severely delayed in their growth and reproduction cycle. Nevertheless, snow storage may occur. If this is anticipated, the following design measures may alleviate impacts:

- Avoid woody plants;
- Choose herbaceous plants that bloom earlier in the year;
- If woody plants are necessary, choose flexible species (e.g., willow); and
- Choose salt and sediment tolerant plants.

3.7.4 Planting Density and Coverage

Mulch is not a permanent cover. Establishing a vegetation cover so that weeds and erosion potential will be reduced, design evapotranspiration rates will be met, and natural leaf litter quickly takes over will all contribute to a successful low-maintenance installation.

Forbs and graminoids supplied as plugs or small containers should provide 100% surface coverage within 3 years of planting. This can typically be achieved with a 300 mm on-centre planting density. Seeded surfaces must provide 90% coverage within the first year. See Appendix B for further installation guidance.

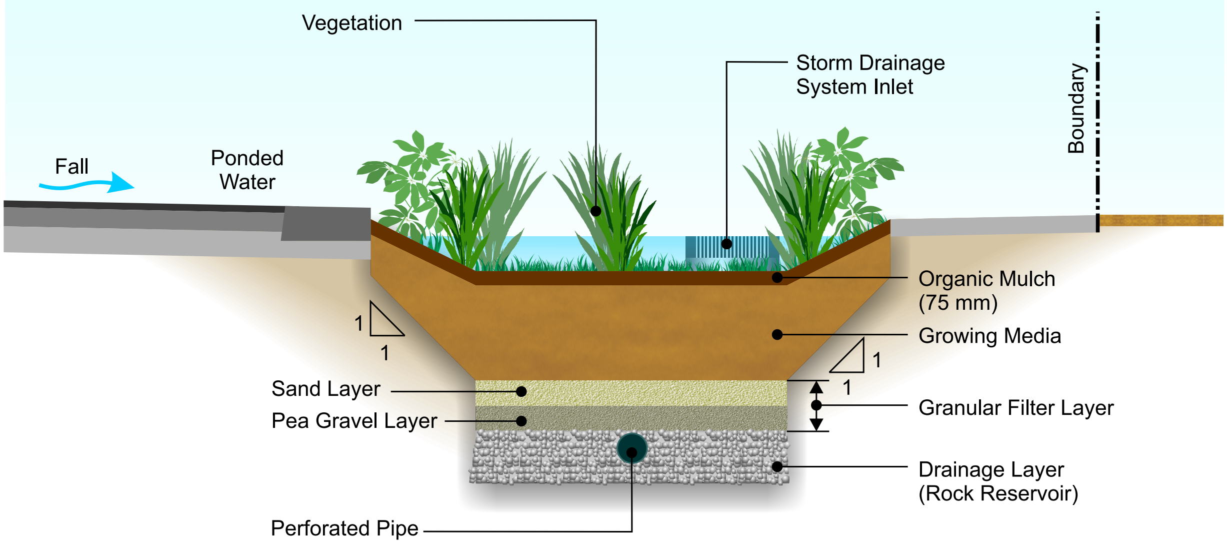
Shrubs should be planted at a density so that no bare ground is visible between plants when viewed from above after 5 years. If a more open spacing of shrubs is desired, a permanent groundcover must be incorporated.

Trees require a groundcover and/or shrub layer to extend at maturity to within 150 mm of the anticipated mature trunk flare.

Seeding rates depend on species. An example seed blend is as shown in the following table:

Table 3-4: Example Seed Blend for Bioretention Area or Bioswale

Common Name	Botanical Name	% viable seeds/m^2
Tufted Hairgrass	*Deschampsia caespitosa*	15
Fowl Manna Grass	*Glyceria striata*	15
Slender Wheatgrass	*Elymus trachycaulus*	15
Western Porcupine Grass	*Hesperostipa curtiseta*	10
Green Needlegrass	*Nassella viridula*	10
Northern Wheatgrass	*Elymus lanceolatus*	20
Aspen Fleabane	*Erigeron speciosus*	5
Lilac Beardtongue	*Penstemon gracilis*	5
Canadian Milkvetch	*Astragalus canadensis*	5
Note: Blend to be mechanically applied at a rate of 27.3 kg/ha		



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DIMENSIONS ARE MILLIMETRES UNLESS OTHERWISE NOTED

METRIC

No.	Date	Revision	App'd

Drawn	Date	Checked
JL	2016-05	LM

Scale N.T.S.

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THE CITY OF CALGARY WATER RESOURCES

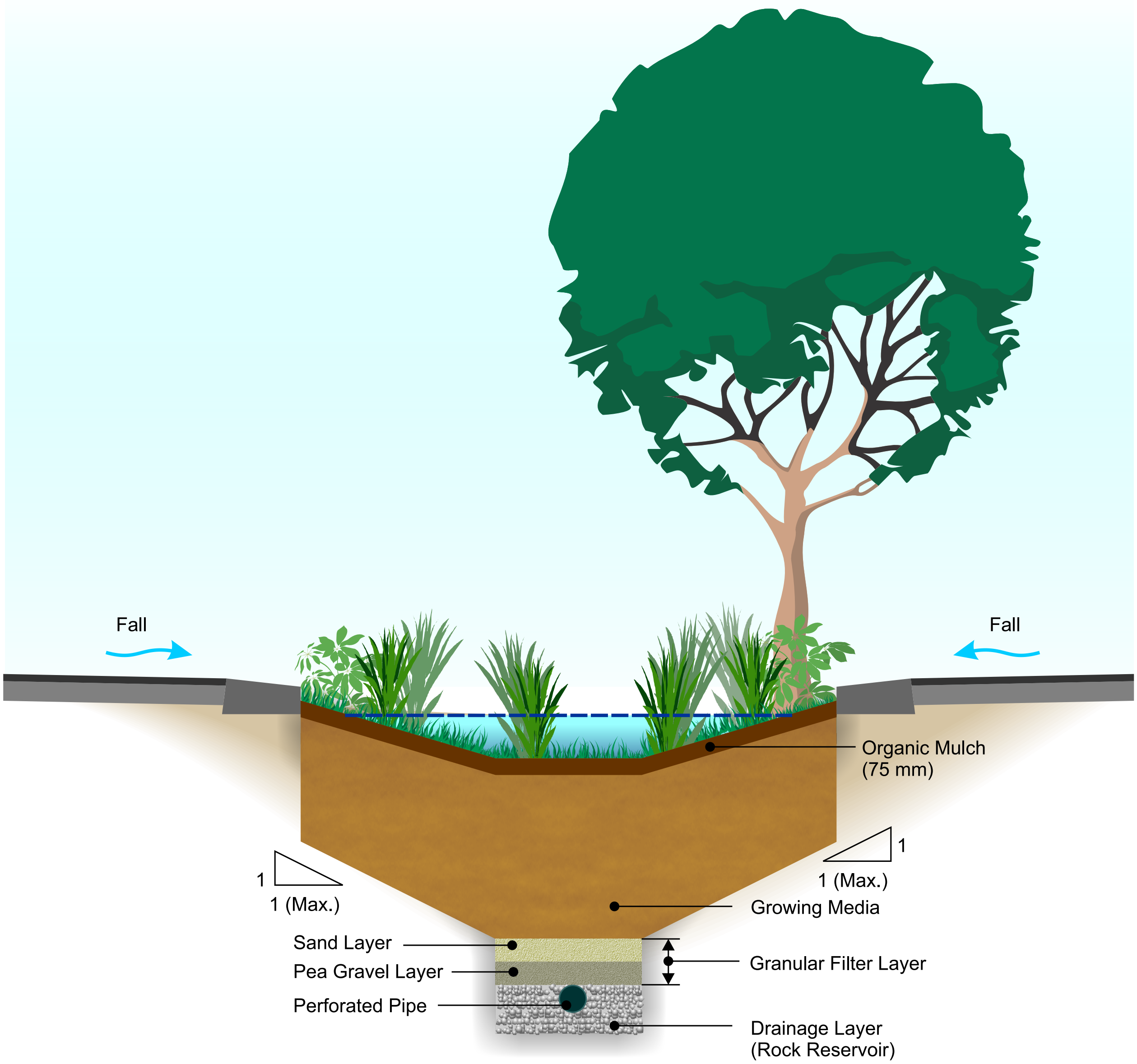
Bioretention with Granular Filter Layers

Sheet

Figure 3-1

File Number

ISC: Unrestricted



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No.	Date	Revision	App'd

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THE CITY OF CALGARY
WATER RESOURCES

Bio-Swale with Granular Filter

Sheet
Figure 3-2

File Number

ISC: Unrestricted

4. Construction Considerations

The construction process is critical to creating a functional bioretention and bioswale installation. Poor construction methods are frequently to blame when LID facilities fail. Good construction practices for bioretention or bioswale installation are not difficult or unusual, but contractors and inspectors must have an awareness of the parts and functions of the bioretention area or bioswale and how they interact with the rest of the site during the construction process.

4.1 Construction Sequencing and Standard Component Installation Methods

4.1.1 General Construction Planning and Sequencing

The planning and sequencing of the construction of bioretention areas and bioswales are key to the success of the completed installations. Some of the planning is related to seasonal freezing concerns, and some related to ongoing construction operations in the surrounding areas. Considerations include:

- If possible, delaying construction of all bioretention areas and bioswales until after all sediment-producing construction in the drainage area is complete (i.e., buildings have been constructed and landscaped areas have been stabilized) can prevent degradation and contamination of completed or partially completed bioretention areas.
- Bioretention areas and bioswales may be used as sediment basins for construction if partially installed components are properly protected and/or the site is fully remediated prior to completion of the bioretention area (as per details in Section 4.3 below). If bioretention areas or bioswales are used in this manner, they must be inspected or re-inspected to ensure that the underlying layers are clean subsequent to removal of the protective layers and remediation.
- Traffic and deliveries should be routed around bioretention area and bioswale locations to prevent damage, compaction of the subsoils and deposition of fines in the bioretention areas / bioswales.
- The bioretention area or bioswale must be staked and marked to keep all construction traffic, equipment, and material stockpiles out of the proposed bioretention area or bioswale.
- The growing media and filter layer media should not be delivered to the installation site until the bioretention or bioswale facility location has been excavated or graded to the design elevations and geotextile fabrics and underdrain systems are in place. The planting materials should not be delivered until after the growing media layer has had time to settle (see Section 4.1.7) and is trimmed to the proper grade elevation.
- Sequence work such that all earth-moving and soil impacting activities occur prior to freeze-up, if possible. Work may be done when the soil is dry and fully frozen, but not when conditions are thawing and/or the soil may become wet.
- Stabilize all exposed soil surfaces with vegetation (sod), mulch (non-floating organic mulches or hydromulch, not stone) or synthetic (polysheet or tarp) cover before the ground surface freezes.

- Seed (if using) during the growing season of May 1st to September 30th to ensure germination and adequate growth before cold conditions set in. If appropriate for the seed mix specified for a given project and at the discretion of the landscape designer, late fall seeding may be done for spring germination the following year.

4.1.2 Construction Stages

Bioretention areas and bioswales can be developed in two stages of construction:

- Stage 1 includes the supply and installation of the drain rock reservoir, perforated underdrain and filter layer; and
- Stage 2 includes the supply and installation of the growing media, plants and mulches as applicable to the design.

In some cases, there will be practical advantages in separating the timing of Stages 1 and 2. For example:

- For Stage 1, which involves excavation activities, the avoidance of glazing on the excavation of the bioretention or bioswale floor and sides in clay soils will be easier when soil conditions are drier. In a typical Calgary year, the dry construction season is August through October, and this is the ideal window in which to schedule Stage 1 construction activities. Other excavation and grading (e.g., for roads and embankments) will also be preferable in this dry season, so it would often be practical to install Stage 1 of the bioretention area in coordination with road or grading construction.
- For Stage 2, which involves the planting, there will be a need to handle the growing media in near-optimum moisture conditions. The stockpiled material should never become saturated. The other consideration is watering for establishment of seed, sod or plantings. If the proposed site is not planned to have automatic irrigation, preference should be given to a spring planting window so that plantings may take advantage of spring/early summer rainfall. In urban situations, supplementary watering of the plantings will dramatically increase survival, even if that watering is by temporary surface hose and sprinkler or by watering trucks with sprayers.
- Delaying the completion of Stage 2 provides practical advantages related to adjacent building or site construction in a typical subdivision. If Stage 2 (i.e., growing media and landscape completion) is completed too early in the construction sequencing of the total development, there is often extensive damage and surface compaction caused by the activities of the building trades crossing the bioretention or bioswale site (or boulevard) to get access to construction sites. In addition, there will be high demands on appropriate erosion and sediment control provisions so that the growing media does not become clogged with sediment. See Section 4.3 for details for protection of a partially completed bioretention area or bioswale. Regardless of whether the SCP is partly or fully constructed, it must be protected from sediment and damage during the remainder of the construction period for the site.

4.1.3 Excavation and Subgrade Preparation

Calgary has a preponderance of clay and silt soils, with local areas of lighter sand and gravel deposits. Glazing or compaction during excavation and grading is a concern in all soils, but more likely to occur in wet clay soils. To avoid or manage glazing during excavation and subgrade preparation:

- The excavation should not be allowed during wet or saturated conditions. Schedule bioretention excavation in seasons when site soils are relatively dry (i.e., < the midway point between the field capacity and the wilting point for clays) so as to minimize damage to the soils. The excavation may be done in fully frozen soil conditions, if desired, but the edges and surfaces may be rougher due to frozen soil breaking apart in chunks.
- Use equipment and excavation techniques (see next bullet) that will minimize glazing of the trench bottoms or sides. However, working in drier weather / drier soil conditions is the most effective technique.
- The bioretention area or bioswale should be excavated using a backhoe excavator. The equipment must avoid running over the bioretention area to minimize compaction of the underlying sub-surface soils. No heavy equipment with narrow tracks, narrow tires, or large lugged, high-pressure tires should be allowed on the bottom of the bioretention facility. If machinery must operate in the bioretention cell for excavation, light weight, low ground-contact pressure (LGP) equipment should be used, while the base should be ripped at completion to re-fracture the soil to a minimum of 300 mm. The sidewalls of the trench shall be roughened where sheared and sealed by heavy equipment. LGP equipment should have a ground pressure of 5 psi or less. Rather than operate in the bioretention area or bioswale, it would be preferable for an excavator to be used to work in the SCP footprint by reaching into the excavation from outside the footprint area.
- Inspect excavations for glazing prior to backfilling. Where glazing has occurred, remove the soil glazing to create a textured surface where soil pores are open and visible. Removal of glazing may require air drying of the excavation, followed by over-excavation (i.e., removal of the glazed surface) or scarification to daylight soils with open pores.
- The grading tolerance for the subgrade shall be +/- 50 mm from the design elevations. All elevations for the completed bioretention area or bioswale shall be within +/- 50 mm of the design with the exception of the growing media surface.

4.1.4 Drain Rock and Geotextile Installation

The open excavation can have soil pores plugged by machine or foot compaction, sedimentation due to runoff from unstabilized soils outside of the excavation, or to a certain extent, from impact of heavy rainfall or irrigation directly onto unstabilized soil surfaces within the excavation. To avoid this plugging of soil pores, and drain rock, the installation requires the following considerations:

- Protect the subgrade excavation from compaction, sedimentation, or concentrated rainfall / irrigation or surface flows until covered by subsequent construction stages.
- Prevent natural or fill soils from intermixing with the gravel/drain rock. All contaminated stone aggregate must be removed and replaced. The gravel/drain rock should be double-washed.

- Immediately after subgrade approval, install the drain rock layer and filter layer. If a geotextile is used to separate the rock reservoir from the native subsoils along the sides of the rock reservoir, install the geotextile to the sides. Care should be taken to ensure that geotextiles are not clogged, punctured or torn during construction. If they are damaged they must be repaired or replaced.
- The geotextiles shall overlap by at least 0.50 m at seams to prevent short-circuiting or intrusion of fines. Openings in the geotextile, for example around underdrain pipes, shall be sealed.
- The gravel/drain rock shall be installed in lifts of 300 mm or less and lightly worked or compacted to settle the rock and eliminate voids between the geotextile fabric (if used) and the surrounding soils, and then immediately install the filter layers above it.
- If the bioretention area is to be intentionally used as a sediment trap once the drain rock is installed, it must be protected with a layer of sturdy polysheet material (i.e., 8 mil thickness, minimum) as well as a 100 mm thick sacrificial layer of sand or soil. As noted in Section 4.1.1., any bioretention area or bioswale used as a temporary sediment trap must be inspected or re-inspected subsequent to removal of the protective layers and remediation of any impacted areas or materials.
- Details (including above recommendations) for installation of the drain rock, granular filter layer, and geotextile (if using) shall be included on the construction drawings.

4.1.5 Underdrain Installation

The underdrain is to be constructed and installed at the same time as the construction of the rock reservoir. As underdrains are part of the storm sewer system, they must be installed and inspected as such in accordance with the requirements of the City of Calgary's Sewer Specifications. Specific construction considerations include:

- The underdrain pipes must be bedded in drain rock and fully supported along their length (i.e., no section may be 'hanging' above the drain rock).
- The underdrains must be installed at the design slopes and elevations in order to properly connect to the storm sewer system infrastructure.
- Care should be taken that the underdrain pipes are not cracked or damaged prior to or during installation. The underdrains shall be covered with rock and a granular filter layer in accordance with the design. The underdrains should not be left exposed to weather or receive any runoff sediment. Any damaged pipes must be replaced and pipes and associated drain rock exposed to mud or sediment must be cleaned and flushed or replaced.
- All inspection ports and storm sewer system connections shall be constructed in accordance with the City of Calgary's requirements in the Construction Specifications for Sewers.

Video Examination

Completed underdrain pipe installations shall be examined by means of a video camera introduced through the observation ports. The observation ports must be completed and in their final configuration. Any difficulty or inability to video the entire extent of pipe installation shall be corrected prior to acceptance of the installation.

Any evidence of damage to the pipe observed by video shall be exposed and physically checked and repaired.

Any evidence of debris, sediment or other deleterious material in the pipe may indicate unacceptable material has been introduced into the bioretention area or bioswale. When directed to do so, the areas where this material is observed shall be exposed and physically examined. Removal and replacement of contaminated gravel/rock may be required and shall be done to the satisfaction of the City of Calgary.

4.1.6 Granular Filter Layer Installation

A granular filter layer must be installed over the drain rock reservoir. The granular filter layer consists of two layers, one of pea gravel above the drain rock and one of washed sand above the pea gravel. The installation of the granular filter requires consideration of the following:

- Each layer must be installed to completely cover the material below to the required thickness. If there is any variation in thickness, it must be above the minimum thickness and not below.
- The granular filter materials may be placed by hand or by backhoe, but will generally require hand work to create even thickness layers. Some mixing can and should occur at the boundaries between the layers so that the change between material porosities is not too abrupt. However, this mixing may occur only at the boundaries, and the material must remain in layers and not be "mixed in" to other materials.
- If the bioretention area or bioswale is being constructed in stages and the area is to be left open, the granular filter layer must be protected from sediment contamination by a layer of sturdy polysheet material (i.e., 8 mil thickness, minimum) covered by a 100 mm thick (minimum) sacrificial layer of sand or soil.
- Prior to the installation of the growing media, the sand surface should be scarified to leave a rough open surface.

4.1.7 Growing Media Supply and Installation

As noted in Chapter 3, bioretention areas and bioswales rely on the use of growing media that must meet minimum standards for material content and performance. All growing media must be tested prior to use in bioretention areas or bioswales. In addition to the growing media performance specification, the nutrient content of the growing media shall be capable of supporting plant growth from the time it is installed, in accordance with the requirements in Section 3.5. A laboratory measure of the saturated hydraulic conductivity of the growing media shall be performed for every 500 m^3 of media mixed, or for a minimum of one test per batch mixed, using ASTM F1815 for laboratory testing of hydraulic conductivity. Samples used must be representative of the fully mixed batch of material and may not be adjusted using any material not taken from the mixed batch.

Considerations required for growing media installation practices for bioretention areas and bioswales areas include:

- The growing media shall be handled within +/- 3% of optimum moisture content (as tested by a soils laboratory as part of the testing to determine the Standard Proctor Density for compaction) and placed meeting the specifications and to meet the minimum field measure for saturated hydraulic conductivity. Material failing this measure shall be removed and replaced at the contractor's expense. The growing media shall not be handled or placed when excessively wet (i.e., should be moist but not 'wet') or frozen.

- Processed and mixed growing media shall be a homogeneous mixture, created through a mechanized process.
- All growing media delivered to the site and not installed at the time of delivery shall be placed on a clean tarp, clean asphalt, or clean concrete pad, and shall be tarped to be protected from rain, debris and weed or invasive plant contamination. The growing media shall not be stockpiled over pervious pavement or in a location where it will be subject to flow and can erode.
- The growing media shall only be placed over subgrades prepared to the specified standard. Any sedimentation of the Stage 1 construction shall be completely removed growing media installation; this includes removal of subsoils contaminated with sediment, removal and replacement of rock or filter layers contaminated with sediment, as well as removal of accumulated sediments.
- The growing media shall be placed and spread with appropriate equipment and in a manner that does not adversely affect its structure.
- The growing media should be placed in 200 mm (8 inches) to 300 mm (12 inches) lifts, and should be slightly compacted until the desired depth is reached. The placed growing media shall be allowed to settle or may be compacted by light rolling or tracking with LGP equipment. Compaction shall not be more than necessary to meet this requirement. The final compaction is expected to be 85% Procter density for the growing media, or as required in Appendix A.
- The depth of the growing media required is the compacted depth to final grade, i.e., not the depth of loose fill. Growing media should be overfilled and compacted above the design depth to accommodate further consolidation of media over time prior to FAC. The final depth of the growing media will be checked at closeout of the FAC checklist.
- Over time, settlement and compaction of the soil mixture will occur naturally. Depending on the composition of the growing media, up to 20% natural consolidation may occur. The growing media must be overfilled above the proposed surface grade to accommodate natural settling to proper grade. To speed settling, each lift, once placed and compacted, can be sprayed with water until just saturated. Any surface crusting shall be removed by raking or cultivating the top 25 mm of growing media surface (mechanized or hand). It is recommended that the post-installation compacted depth of the growing media should be 10% above the design growing media depth to accommodate additional consolidation that is likely to occur prior to FAC. This can be 10% above the 50 mm +/- tolerance allowed for the completed surfaces of the bioretention area or bioswale.
- A field measure of the mixed and placed growing media shall be tested in-situ, once per bioretention area or bioswale facility, or once for every 1000 m^2 for very large areas. The testing procedure shall conform to Module 1-Geotechnical and Hydrogeological Considerations.

4.1.8 Planting of Trees, Shrubs and Ground Covers

Planting of trees, shrubs and ground covers should follow the existing City of Calgary Parks *Design Guidelines and Standard Specifications*. Additional planting considerations for bioretention areas and bioswales include:

- Planting species for bioretention and bioswale areas shall follow the guidance in this document (Appendix B).
- Any surface crusting shall be removed by cultivation or raking after planting is in place.
- All plant materials shall normal, well-developed branches and vigorous root systems, and be free from physical defects, plants diseases and insect pests. Large tree roots must be trimmed flush with the sidewalls in order to prevent puncturing or tearing during subsequent installation procedures.
- All plants shall be tagged for identification when delivered.
- Substitutions must be approved by the designer in order to ensure that the performance criteria the original selection was chosen to fulfill are met by the substituted plant material. Substitutions shall be recorded on as-builts of the landscape drawings to facilitate subsequent CCC and FAC inspections and future operation and maintenance activities.
- Mulch shall be provided and installed immediately after trees and shrubs are planted.
- Vegetation shall be watered as necessary until established. Full establishment may take more than one growing season, depending on the plants used.
- If a plant survival rate of 90% is not achieved after the first growing season, a reinforcement planting is required.

4.1.9 Seed or Sod Installation

Sod and seeding should follow the existing City of Calgary *Parks Design Guidelines and Standard Specifications*. Additional sod and seeding considerations include:

- Any surface crusting shall be removed by cultivation or raking immediately before sodding or seeding.
- **The standard 'flush with adjacent surfaces' clause (5f) does not recognize the requirement for a 'drop' at drainage inlets to sod or seeded areas. Seed and sod shall not be installed flush with pavement or flat-paneled curbs but must have a drop of 50 mm to allow for sediment build-up, see Section 2.5.4.**
- Adjacent non-native invasive species shall be identified and measures such as providing a soil breach shall be taken to eliminate the threat of these species invading the bioretention area or bioswale.
- In general, mature plantings are recommended over seed because fluctuating water levels following seeding (i.e., prior to germination) can cause seeds to be transported. Seed is also difficult to establish through mulch if a mix of seed and plantings are used (i.e., for seed only, hydromulch is used).

- Seed may be used for bioretention areas and bioswale installations and may be the only choice if specific mixes of native grasses are desired that are not commonly grown as sod. Seed shall be applied and raked in to the growing media surface at the coverage density specified by the landscape architect.
- Installed seed must be protected from rain and runoff by use of a hydromulch (biodegradable tackifier only shall be used) or stitched straw erosion control matting applied in accordance with the manufacturer's instructions for use with seed.
- Sod is effective and recommended over seeding for use in bioswales and bioretention areas, but native species and other mixes desired for use in bioswales and bioretention areas may be available as seed only. Kentucky bluegrass is not recommended for any bioswales or bioretention areas, but may be used as a protective sacrificial landscaping layer during construction.
- All sod installations will require maintenance watering during the first growing season.
- The Calgary Parks' *Design Guidelines and Standard Specifications* shall be followed for seed mix, seeding rate and seeding method, with the exception that seed mixes shall only include the species listed in Appendix B.
- If a minimum coverage of 90% is not achieved after the first growing season, a reinforcement planting is required.

4.1.10 Mulching

Mulching shall be in accordance with Section 3.6. As mulch is used to protect the surface of the growing media, mulch should be installed as soon as possible after growing media installation and planting.

4.1.11 Watering and Irrigation

The lighter soils and highly drained conditions in bioretention areas may create drier conditions than in typical Calgary landscaping where heavier clay loams may be in use. This is particularly true for the higher infiltration rate growing media type of the two performance standards for growing media (see Section 3.5). Automatic irrigation may be considered for both media types of growing media. The plants in the 'moist' category on the plant lists, on normal Calgary soils, are drought tolerant and do not need supplemental watering after establishment. However, given that both growing media mixes are lighter than typical Calgary soils, plant performance is less certain. The landscape architect or planting designer will be responsible for determining when automatic irrigation should be part of a bioretention area or bioswale design.

If irrigation is used, the irrigation system shall be designed and installed by a certified irrigation designer and contractor.

4.2 Compaction Prevention and Slope Stabilization Methods

4.2.1 Subsurface Compaction

It is critical to prevent compaction of the subsoils in and around bioretention areas and bioswales during construction. The setback for equipment use should be at least 2 metres, if possible. Compaction of the subsoils will reduce the percolation capacity into the subsoils and impair the function of the bioretention area or bioswale. No compaction equipment should be used in the region of the bioretention area or bioswale, and other heavy equipment should be routed around locations of bioretention areas and bioswales. As noted above, when required, LGP equipment should be used over and near bioretention areas and bioswales for excavation and grading.

Installation in dry weather and with dry soil conditions is critical to prevent accidental smearing and compaction of the subsoils. Work must be scheduled during dry weather periods and work shall not proceed if soil conditions are wet. Even exposure of soil to heavy (high intensity) rainfall can cause compaction, and crusting, of the soil surface.

Heavy equipment may be used for stripping a site provided the area of the bioretention area / bioswale installation is remediated prior to installation of the bioretention area or bioswale. In these areas and where compaction has occurred, the soils in and around the area should be ripped, tilled or scarified to a minimum of 300 mm depth. If machinery must operate over or in the bioretention cell for excavation purposes, light weight, low ground-contact pressure (LGP) equipment should be used, while the base are should still be ripped at completion to re-fracture the soil to a minimum of 300 mm.

4.2.2 Compaction of Rock and Growing Media

Drain rock for the rock reservoir, pea gravel, and sand require only light compaction in the bioretention area or bioswale. Materials may be worked into the sides of the bioretention area or bioswale by hand or backhoe (LGP equipment only) and tamped with a backhoe bucket, but no heavy equipment or compaction equipment shall be used. The growing media shall be compacted to 85% Standard Proctor density and within +/- 3% of optimum moisture content (see Table 3-3). Compaction of the growing media shall be attained by tamping with a backhoe bucket or traversing with LGP equipment.

4.2.3 Bioretention Side Slopes

The side slopes of bioretention areas or bioswales shall not be left exposed in an open excavation for long periods of time without some form of stabilization. The excavation of the bioretention or bioswale trench shall be done shortly before the drain rock, underdrain and filter layers will be installed. If construction is performed in two stages and only part of the side slopes are exposed, the exposed portion must be protected both to prevent glazing and compaction of the surface and to prevent erosion of the subsoils into the partially constructed bioretention area or bioswale.

The side slopes of the bioretention area or bioswale shall be protected while exposed and shall not be trafficked on by workers or equipment. Covering with sturdy polysheet material (8 mil thickness, minimum) is a simple method to protect the side slopes during construction. Sod or erosion control matting may also be used. Seeding, mulch and tackifier are not recommended as they will migrate into and contaminate the excavation, requiring removal and remediation prior to further construction.

4.3 Erosion and Sediment Control Requirements

The City of Calgary has extensive existing guidance for erosion and sediment control during and after construction. All City requirements apply on sites where bioretention areas or bioswales are being constructed. Refer to the City of Calgary's Guidelines for Erosion and Sediment Control and Stormwater Management and Design Manual for requirements and details. The discussion here is considered supplemental to these documents.

Erosion and sediment control often calls for a system of controls, including management of stormwater run-on and run-off, timely stabilization of exposed soils and stockpiles and a range of other practices. Sites that incorporate bioretention areas or bioswales for stormwater control require closer attention to detail because the drainage areas are reduced and massive grading to one low point is discouraged. As a result, grading and sediment control practices should be applied on a lot-by-lot basis to minimize the opportunity for soil transport.

It is key to understand that fine particles such as clays and silts that run off a construction site can be harmful to the function of a bioretention area or bioswale. Fine particulate matter will contaminate, clog and prematurely seal the surface pores of the soil that are needed for a bioretention area or bioswale to absorb and filter runoff over its lifespan. This applies to the subsurface area of the excavation for bioretention, as well as all of the media components, including rock, pea gravel, sand, growing media, and geotextile fabric. Fine sediment will settle in and clog underdrains, inlets, and other pipe facilities. Therefore, the completed bioretention area or bioswale must not contain any surfaces or materials that have been contaminated with construction site runoff. There are two basic approaches to succeed at this, and they may be used separately, or in combination for 2-stage protection:

1. Ensure that the bioretention area / bioswale is protected from construction site runoff by grading and routing flow around the site, and protecting the area with barriers to runoff and fine sediments. Depending on the site this can be difficult to achieve due to the fact that bioretention areas / bioswales should be located at points where drainage will be directed after construction is complete. If the bioretention area / bioswale is small, it may be covered with a sturdy polysheet material and a minimum 100 mm thick layer of soil, sand, or gravel for weight. If this protection approach fails, perhaps due to unseasonal weather or unforeseen circumstances, then the bioretention area / bioswale must be remediated prior to completion. Remediation would consist of:
   - Removal of concentrations or accumulations of fine clay and silt sediments, and
   - Tilling of the subsoils to minimum depth of 300 mm prior to rough grading in order to open the soil structure for drainage.

2. Allow that contaminated runoff will impact the site during construction and plan to include a "sacrificial" soil or sand layer that will be contaminated with construction runoff and sediment, and removed prior to final completion of the bioretention area or bioswale. This layer should be at least 100 mm thick for growing media and at least 50 mm thick for sand. Sod may be used as long as it is very clear (with barriers and signs) that the area is off-limits to all foot and vehicle traffic. If any components are installed as part of Stage 1 construction (i.e., rock reservoir, underdrain, geotextile or granular filter layer), they MUST be protected with a sturdy polysheet material (8 mil minimum thickness) underlying the sacrificial soil layer. The sacrificial sand or soil material should be placed so that it can be removed without damage to the underlying polysheet and without contaminating the materials below. If the polysheet is likely to remain in place for a period of 2 years or more, a layer of geotextile fabric may be used to supplement the polysheet for strength.

These two approaches cover the basic erosion and sediment control needs for bioretention areas. Specific considerations for interim sediment control (during construction), in addition to those in the City of Calgary Guidelines for Erosion and Sediment Control, include:

- While not currently required, all erosion and sediment control plans should include education of site management and contractors for awareness of issues, how erosion and sediment control will work, and specific site management tasks that improve or impact runoff on the site. This step can significantly increase the success of erosion and sediment control measures.
- Hazard or protection fences are useful to keep traffic and equipment away from a bioretention area / bioswale.
- Erosion and sediment control should involve planning for both minor and major storms. Most erosion and sediment control best management practices (BMPs) handle minor storms well, but may be overwhelmed by larger storms. Site planning should include flow routing, management of run-on and run-off, protection/stabilization of exposed soils and stockpiles, and sediment control planning for larger storms when the erosion and sediment control BMPs may not be functional so that it is understood what will happen to construction site sediments during larger events. This can be as simple as reviewing the location of sediment ponds, soils stockpiles, flow routes and such so that if, for example, a sediment pond is overwhelmed during a major event, the overflow is not directed at a soil stockpile which then flows to an open bioretention area / bioswale excavation.
- Sediment control devices shall be inspected at the end of each workday. All sediment controls should be in good condition and all sediment traps shall have capacity for additional sediment loading. Any deficiencies should be repaired **immediately**.
- **Any drain rock, pea gravel, sand, growing media, or geotextile fabric contaminated by sediment must be removed and replaced**.
- If the bioretention subgrade is contaminated by sediment the sediment as well as the contaminated subgrade materials must be removed, while the subgrade surfaces, bottom and sides, must be scarified to a minimum 50 mm depth. This shall be performed immediately prior to completion of the bioretention area / bioswale construction.
- Any underdrains, inlets, or other structures that have received construction runoff sediments prior to installation must be cleaned and flushed prior to completion of the bioretention construction. Flushing water shall be collected and/or directed to the site sediment handling facility such as sediment ponds or tanks, away from the bioretention area / bioswale. If any installed structures have accumulated construction sediments prior to completion of the bioretention area or bioswale, the surrounding drain rock and other materials must also be checked for sediment contamination. As above, all contaminated materials must be removed and replaced.

The final erosion and sediment control will be provided by good establishment of the permanent landscaping surfaces and vegetation. The final construction and planting of the bioretention area / bioswale should preferably be subsequent to or coincident with landscaping and establishment of permanent cover on the surrounding areas of the site.

All areas of the site should have permanent landscaping and other surfaces in place prior to construction of the final lift of asphalt and removal of sediment and runoff barriers to the bioretention area / bioswale. At this point, when the bioretention area / bioswale is completed and receiving runoff from its full design catchment area, the catchment should have all permanent vegetation and surface covers in place as the City will take ownership only of facilities that are in first-rate condition and expected to provide the full life expectancy.

The infiltration rate of the growing media at the time of full build-out (i.e., completely landscaped) of the area tributary to a bioretention area / bioswale shall be at least 50% of the original design infiltration rate of the growing media.

5. Inspection Considerations

5.1 Construction Inspection Procedures

Regular construction inspections for bioretention areas and bioswales are mandatory and should be integrated with the existing inspection processes as in the City of Calgary Consulting Engineer's Field Services Guidelines (6th Ed. 2012). Inspections of bioretention areas and bioswales will be a joint effort by Water Resources, for the civil components, and Parks, for the landscaping components. Any irrigation design, construction, inspection, maintenance, and operation will follow the existing guidelines and specifications and are not included in this document specific to bioretention. The following inspections will make up the items in the inspection checklist presented in Section 5.2:

- Ensure the bioretention area or bioswale is protected from disturbance, compaction, and sedimentation;
- Ensure the subgrade is not too wet, is not glazed, and scarified;
- Ensure the filter layers or filter cloth are installed appropriately and the drain rock is free of contamination;
- Ensure the pipe, structures, and bedding are installed per the specifications;
- Complete laboratory testing of the growing media to confirm that it meets the specifications as described in Section 3.5;
- Review plant material prior to planting;
- Ensure the growing media depth (may be checked using a length of re-bar marked with the required depth) and placement meet the design; and
- Ensure the surface mulch is installed per the specifications.

5.2 Inspection Checklist

The following construction inspection checklist is specific to bioretention areas and bioswales and applies to both installations to be assumed by the City of Calgary and installations on private land. It mimics the layout of existing City of Calgary checklists and includes civil work items (Water Resources) and landscape items (Parks). This list is intended to be used in conjunction with the existing inspection schedule and checklists. Please see the City of Calgary Consulting Engineer's Field Services Guidelines (6th Ed. 2012) and Parks General Guidelines section VII for more details on the inspection schedule and construction completion certificate (CCC) process related to infrastructure that will ultimately assumed by the City of Calgary. All items on the checklist are essential prior to CCC and the inspections are required to take place when the site is free from snow and/or frost.

Community		Subdivision	Report #
			Plan Block Lot
Description	Phase	Developer	Development Agreement #
Legal/Municipal Address			

Consultant	Contact Person	Phone
Contractor	Contact Person	Phone
		Date YYYY MM DD

	Works Inspected*	Approved		Date YY/MM/DD	Parks or WR Rep.	Dev. Rep.	Def. Cor.	Comments &
		Yes	No					
A	Item #1: Site Preparation and Setout							
	Conforms to Construction Sequencing Plan							
	Traffic control measures implemented							
	Locations and dimensions of bioretention areas conform to design plans							
	Site protected from existing flows							
B	Item #2: Materials meet specifications							
	Drain Rock							
	Filter Layers							
	Growing Media							
	Mulch material							
	Scour protection							
	Storm Sewer System Inlet							
C	Item #3: Excavation meets design							
	Bed of SCP has correct shape							
	Side slopes as per drawings							
	Subsoil type - consistent with design							
	Subsoils appear to have reasonable water content for working (i.e., not too wet, not too dry)							
	Glazed surfaces are not present or have been removed							
	If subgrade compacted, surface has been ripped to 300 mm minimum depth							
D	Item #4: Structures meet design							
	Provision of liner, if specified							

	Perforated pipe installed as designed							
	Curb Inlet installed to design details							
	Storm drain system inlet installed as designed							
	Pipe joints and connections appropriately							
	Overflow installed as designed							
	Culverts installed as designed for bioswales							
	Video inspection satisfactory							
E	Item #5: Bioretention Layer Installation meets design							
	Rock reservoir installed as designed							
	Correct placement of filter fabric, if specified							
	Filter media layers installed correctly							
	Growing media depth, levels and compaction							
F	Item #6: Bioretention Surface Treatments meet design							
	50 mm drop from flat curb grade to mulch or rock surface							
	Inlet erosion protection installed							
	Proper placement of plant materials (type, size, quantity, spacing)							
	Correct depth and placement of mulch							
G	Item #5:Final Inspection (1 year post construction)							
	Levels of inlets and outlets are acceptable							
	Traffic control in place							
	Sizes and dimensions of all elements are acceptable							
	Side slopes are acceptable							
	Vegetation as designed							
	Settling of soil is acceptable							
	Inlet erosion protection is functional							
	Maintenance access provided							
*NOTE: Some of the above inspection items may be part of the same inspection, but the grouping of items for inspection will be up to the inspector(s) and may depend on the progress of construction.								
	General Comments & Prior to F.A.C. Conditions							

			Print Name	Signature
☐	No Deficiencies Noted	Developers Representative		
	Report Distribution			
☐	Developers Representative	Parks and Water Resources Inspector		
		Inspection Date		
☐	Design & Development File	Application Expiry Date		

5.3 CCC / FAC Requirements

CCC and FAC requirements for bioretention areas and bioswales are to be completed in conjunction with the CCC and FAC processes outlined in the City of Calgary Consulting Engineer's Field Services Guidelines (6th Ed. 2012) and Parks Landscape Construction Development Guidelines and Standard Specifications. Similar requirements should be applied for installations on private land. The CCC requirements are covered by the construction inspections and checklist (above). The FAC requirements are as follows:

Community		Subdivision	Report # Plan Block Lot
Description	Phase	Developer	Development Agreement #
Legal/Municipal Address			
Consultant		Contact Person	Phone
Contractor		Contact Person	Phone
			Date YYYY MM DD | | | |

	Works Inspected	Approved Yes	Approved No	Date YY/MM/DD	Parks or WR Rep.	Dev. Rep.	Def. Cor.	Comments &
1	Growing Media:							
	Field infiltration test of growing media as per Section 3.5 Must have > 50% design infiltration rate, on average. Test every 400 m2 or each bioretention area or bioswale.							
	There must be no erosion, rilling, or channelization on surface							

	There must be no ponding in unexpected areas, uneven settling, or visible surface clogging of growing media							
2	Vegetation Health:							
	No presence of weeds or dead plants							
	Minimum survival after the first growing season: 90% coverage for seed or sod installation; 90% survival for shrub and ground cover plantings; and 100% survival for trees.							
3	General:							
	Inspect the drainage pipes and structures to ensure they are connected, clean and undamaged							
	Confirm the 50 mm downdrop from the final grade curb to mulch or rock surface (if inlet is sheet flow from impervious surface)							
	Check for any damage or vandalism							
	Ensure all debris and accumulated sediment is removed							
	NOTE: Any noted deficiencies must be repaired and full functionality restored prior to FAC approval by Water Resources and Parks							

			Print Name	Signature
☐	No Deficiencies Noted	Developers Representative		
	Report Distribution	Water Resources Inspector		
☐	Developers Representative	Parks Inspector		
		Inspection Date		
☐	Design & Development File	Application Expiry Date		

Any items not meeting the FAC requirements must be repaired or restored to the required condition prior to the City inspectors signing the FAC. Only facilities that are in good working condition and likely to function for the intended lifespan will be accepted.

The CCC can be applied for by the developer after the final construction inspection. The FAC can be applied for not less than three months prior to the maintenance period expiry date. CCC and FAC maintenance obligations shall be as stipulated in the Development Agreement and/or the conditions of approval of the Stormwater Management Report describing the performance of the bioretention areas and bioswales and/or the conditions of the approval of the Construction Drawings, if any, during which time the developer, at no expense to the City, will maintain the bioretention areas and bioswales over a continuous period.

If a minimum survival and coverage of vegetation is not achieved after the first growing season, a reinforcement planting is required. The minimum survival and coverage after the first growing season required is:

- 90% coverage for seed or sod installation;
- 90% survival for shrub and ground cover plantings; and
- 100% survival for trees.

6. Maintenance Requirements

Maintenance of bioretention areas and bioswales may include regular weeding, pruning, irrigation, or mowing. As well, re-grading may be necessary to reshape the bioretention area or bioswale as sediments collect and form pools. Further detailed maintenance tasks are listed in the procedures and checklists that follow.

6.1 Operation and Maintenance Procedures

The main tasks of maintenance and operations are to:

- ensure storm water is flowing to and through the bioretention areas;
- prevent or remove channelization, rilling, and erosion of the soils;
- prevent failure of permanent scour protection (e.g., due to short-circuiting of flow);
- prevent failure of weirs;
- clean out culverts;
- maintain vegetation by removing weeds and replacing dead plants;
- remove accumulated sediment and debris;
- remove clogged growing media and replace with new material;
- test the infiltration capacity if there is a visible problem or once every five years; and
- inspect the drainage pipes and flush if required.

The most intensive period of maintenance for bioretention areas and bioswales is the first two years during plant establishment. During this period regular watering, weed removal, and replanting may be required. As well, large loads of sediment could affect plant growth, particularly in areas with construction activity. After the vegetation is well established the maintenance checklist should be used for 3 inspections per year; one in the spring, one in the mid-summer, and one in the fall.

Debris, if not removed, can be unsightly and block inlets or outlets; therefore, debris should be removed between inspections whenever it is observed on-site. Lastly, inspections are recommended following large storm events to ensure the overall performance of the bioretention areas as well as to check for scouring.

Maintenance for Pre-Treatment Swales

Grassed pre-treatment swale maintenance involves removal of trash, debris, and accumulated sediments. Even though the flow rates are expected to be significantly smaller during the winter season, the removal efficiency of grassed pre-treatment swales may potentially be reduced during the winter months if preferential flow paths through the snow occur and the grass may be flattened by snow and ice. To minimize the potential of this occurring, the height of the grass shall be at least 100 mm as per Table 2-3.

6.2 Operation and Maintenance Tasks

The operation and maintenance tasks required for bioretention areas and bioswales are shown in Table 6-1. These tasks should be reviewed on a recurring schedule with frequency as shown in the table and maintenance performed at that frequency or as required. All bioretention areas and bioswales should be reviewed for maintenance needs on an annual basis, though not all maintenance tasks will be required annually. Any time maintenance items are found to be deficient; the deficiencies should be remedied as soon as possible, whether or not the items are on the maintenance schedule at that time.

Table 6-1: Maintenance Tasks for Bioretention and Bioswales

Component	Routine Maintenance Task	Frequency[1]		Completed (Date)
		Minimum[2]	High[3]	
Contributing Impervious/ Pervious Area	• Remove trash, natural debris, and clippings	BA	Q	
	• Remove accumulated sediment • Re-plant or seed bare soil areas	A	BA	
Inlets and Outlets	• Remove trash, natural debris and clippings	BA & MS	Q & MS	
	• Remove accumulated sediment • Remove woody vegetation at inflow points	A	BA	
Pre-treatment	• Remove trash, natural debris, clippings	BA	Q	
	• Remove accumulated sediment	A	BA	
	• Re-grade and re-plant eroded areas when ≥ 30 cm in length	AN	AN	
Perimeter	• Replace dead/diseased plants to maintain a minimum of 90% vegetation cover [4]	AN	AN	
	• Add mulch to maintain 5 to 10 cm depth on non- vegetated areas	Every 2 years	Every 2 years	
	• Re-grade and re-plant eroded areas when ≥ 30 cm in length	AN	AN	
Growing Media Area	• Remove trash • Re-distribute mulch or stone cover to maintain 5 to 10 cm depth on non-vegetated areas	BA	Q	
	• Remove accumulated sediment when ≥ 5 cm depth • Re-grade and restore cover over any animal burrows, sunken areas when ≥ 10 cm in depth and erosion rills when ≥ 30 cm in length	AN	AN	

Component	Routine Maintenance Task	Frequency[1]		Completed (Date)
		Minimum[2]	High[3]	
	• Add mulch or stone cover to maintain 5 to 10 cm depth on non-vegetated areas	Every 2 years	Every 2 years	
Vegetation	• Watering during first two months after replanting	BW	BW	
	• Watering for the remainder of the first two (2) growing seasons (i.e. May to September) after replanting or until vegetation is established	W	W	
	• Watering for the remainder of the SCP lifespan	PD	PD	
	• Mow grasses to maintain height between 10 and 15 cm	M	BM	
	• Remove undesirable vegetation (e.g. tree seedlings, invasives/weeds)	BA	Q	
	• Replace dead/diseased plants to maintain a minimum of 90% vegetation cover	A	BA	
	• Prune shrubs and trees • Cut back spent plants • Thin out overcrowded plants	A	A	
Sub-drain & Monitoring Well	• Flush out accumulated sediment with hose or pressure washer	AN	AN	

Notes:

1. A = Annually; AN = As needed, based on Routine Operation inspections; BA = Bi-annually or twice per year, ideally in the spring and late fall/early winter; BM = Bi-monthly; BW = Bi-weekly or twice per week; M = Monthly; MS = After a major storm event (i.e. 5 year return period storm event or greater); PD = After a prolonged dry weather period (e.g. 21 days with less than 5 mm of rainfall); Q = Quarterly or four times per year, ideally in the spring, summer, early fall and late fall/early winter.
2. These frequencies are recommended as the minimum necessary to ensure the BMP functions adequately over its expected lifespan.
3. BMPs located in prominent locations or those receiving flow from large or high traffic drainage areas (vehicles or pedestrians) may warrant a higher frequency of routine maintenance tasks involving removal of trash/debris/sediment and mowing/weeding/trimming of vegetation.

If an item has on-going recurring maintenance issues that are significantly more frequent and not in line with the guidance in Table 6-1, this should trigger a review of the installation and consideration of whether some aspect of the SCP should be remediated and re-worked to improve its function and longevity.

7. Performance Monitoring Considerations

7.1 Monitoring Protocol

The objective of post-construction monitoring is to measure the performance of the bioretention areas and bioswales. Post-construction monitoring can consist of rainfall, groundwater levels, infiltration rates, and flows downstream of the bioretention areas and bioswales. More detailed monitoring could be conducted including measuring inflow and outflow, water quality, growing media moisture and health and percolation rates. These data can be compared with the design targets.

7.2 Visual Checks

Key hydrologic and hydraulic operation characteristics define the detention time of bioretention areas and bioswales. Monitoring of the following operations of the bioretention areas can provide important insights on their performance:

- Performance of pre-treatment devices;
- Flow pattern to identify short-circuiting or non-uniform distribution of inflow;
- Duration of inundation to assess the operating detention time and to highlight potential clogging of the growing media or the outlet;
- Turbidity of inflow and outflow which acts as a good surrogate for suspended solids, total phosphorus, and heavy metals in urban stormwater; and
- Vegetation health and growth rates.

7.3 Detailed Monitoring Considerations

More detailed monitoring approaches require the following site features for successful implementation:

- Recently installed bioretention SCP constructed in strict accordance with current guidance, preferably with extensive construction documentation that ensures little or no soil over compaction;
- Data on planting plan, soil composition testing, and full range of expected flows for proper monitoring planning and knowledge of a site baseline;
- Drainage basin representative of typical installations, preferably without excessive sediment loading unless pre-treatment device is installed;
- Single piped or channelized inlet for water balance and influent water quality;
- System installed with underdrain, preferably raised off bottom of drainage layer to encourage infiltration;
- Typical flow (up to design storm) at inlet and underdrain should be open channel to allow accurate water balance measurements with a flume. Two flumes maybe required at the inlet to capture the full flow range. Full pipe flow conditions can also be effectively monitored via alternative approaches;
- Small head drop at inflow and outflow for installation of primary flow measurement devices;

- Specific overflow point to allow overflow monitoring, if implemented;
- Large vault with good access for water balance and water quality monitoring of effluent underdrain;
- Space to allow for adequate site security for monitoring equipment; and
- Site supplied power for continuous monitoring devices to avoid installation of stand-alone power supply.

While minor site retrofits can be considered for some sites, major site retrofits should generally be avoided in favor of designing new bioretention that incorporate specific monitoring features.

Table 7-1: Bioretention/Bioswale Monitoring Considerations

Monitoring Parameter	Recommended Approach	Alternate Approaches & Comments
Flow/Water Balance	Continuous inflow/outflow monitoring using flumes and water level sensors.	Runoff modeling for inflow, alternate flow monitoring methods
Water Quality	Composite inflow/outflow sampling and laboratory analysis for TSS and nutrients	Discrete inflow/outflow sampling and analysis
Growing Media Infiltration	Biannual double ring or MPD infiltrometer testing	Estimations using water ponding and flow data
Media Moisture & Ponding	Continuous surface and subsurface water level and soil moisture monitoring	None recommended
Vegetation & Soil Quality	Periodic vegetation monitoring and soil sampling with laboratory analysis	None recommended

8. Bioretention Worked Example

Bioretention Design Example for Maximum I/P Ratio

Scenario Description

A bioretention area is proposed to capture a portion of the runoff from a parking lot. See Figure 8-1 that follows this section.

The following parameters are known:

1. The parking lot services more than 1 car per day per space;
2. The lot is 740 m^2 impervious and 60 m^2 pervious;
3. The available effective base area (assuming 2:1 sideslopes and 0.2 m ponding depth + 0.1 m freeboard allowance = 0.3 m total depth) is 33.8 m^2; and
4. The native subsoil percolation rate is 2 mm/hr.

Sizing

1. Sizing is required for both water quality and volume control.
2. The annual runoff target for the site is 90 mm, corresponding to the upper limit of the 10 – 20% imperviousness target as per the 2010 Municipal Development Plan.
3. A water quality criterion of 85% TSS removal for particles 50 microns and over is assumed.

Design steps follow the Design Flow Chart demonstrated in Section 2, Figure 2-1.

Step 1: Establish Sizing Criteria

Water Quality

- Since this is a simple site, design the site to capture the runoff generated by the Water Quality Design Event: 15 mm of rainfall in one hour (see Section 3.2.4.4. of the 2011 Stormwater Management & Design Manual).

Volume Reduction

- The average annual runoff volume target for the site is 90 mm.

Step 2: Calculate the I/P Ratio

Water Quality

As discussed in Section 2.2.2., for the standard 200 mm ponding depth and the 15 mm Water Quality Design Event design storm, the I/P ratio required to capture the volume of the rainfall is calculated as follow:

$$I/P = H_{ponding} / (R_{WQ} - R_{ABS})$$

where,

$H_{ponding}$ = Ponding depth (200 mm)

R_{WQ} = 15 mm (Water Quality Design Event depth)

R_{ABS} = 1.6 mm (allowable rainfall initial abstraction value for the impervious surfaces as per the 2011 City of Calgary Stormwater Management & Design Manual.)

I/P = 200 mm/ (15 mm -1.6 mm) = 15:1

Volume Reduction

Following the guidance in Section 2.2.3, use the bioretention runoff volume reduction performance chart in Section 2, Figure 2-3, to determine the I/P ratio to achieve a 90 mm average annual runoff volume.

For a subsurface infiltration rate of 2 mm/hr:

- A rock trench depth of 2.0 m will achieve the runoff of target at an I/P ratio of 24:1.
- A rock trench depth of 0.3 m will achieve the runoff target at an I/P ratio of 9:1.

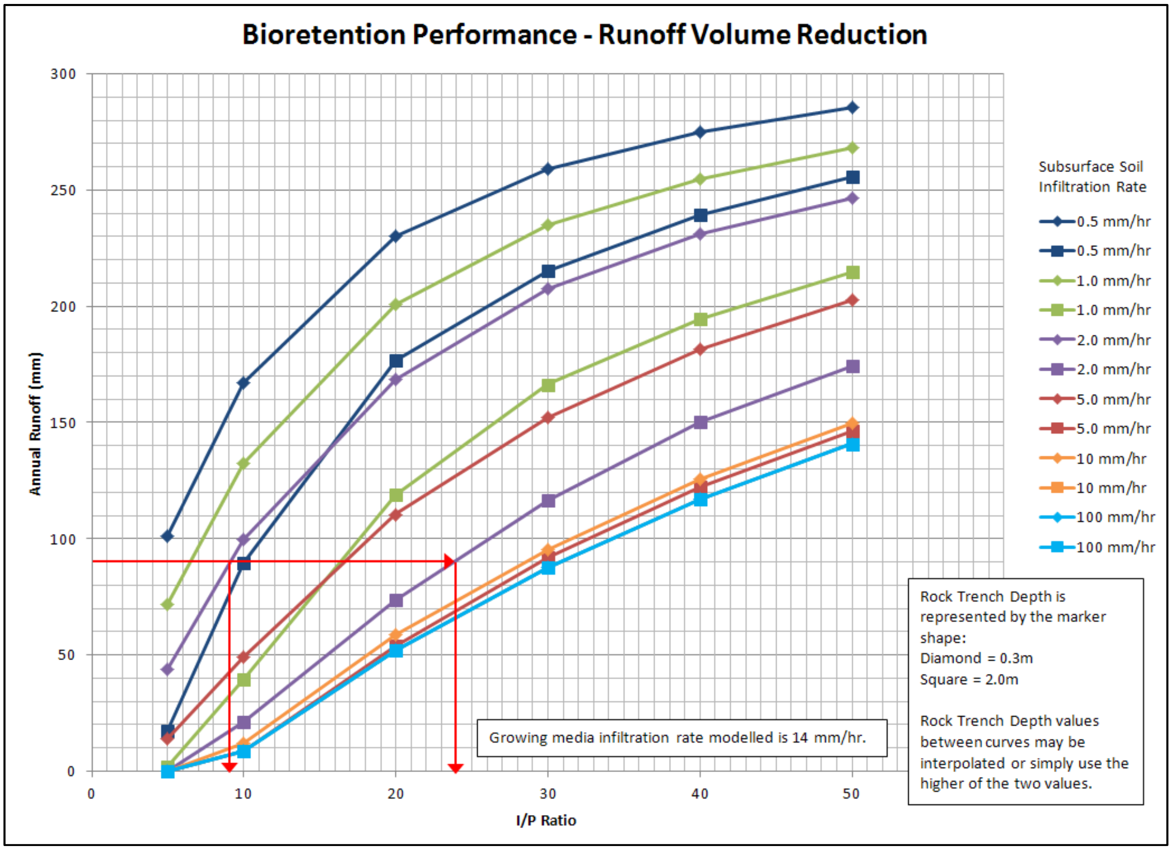


Figure 8-1: Performance of Bioretention for Runoff Volume Reduction

Step 3: Select I/P Ratio

The lowest I/P ratio for the above methods will govern the design:

- For a rock trench depth of 0.3 m, the lowest I/P ratio is 9:1. The runoff volume reduction criteria govern the sizing.
- For a rock trench depth of 2.0 m, the I/P ratio of 24:1 is greater than the required I/P ratio for the Water Quality Event, therefore an I/P ratio of 15:1 will govern the sizing.

To minimize the area of the bioretention facility, a design I/P ratio of 15:1 is selected. At this I/P ratio, a rock trench depth of 1.0 m is required to achieve the runoff target. Note that the rock trench depth is interpolated from Section 2, Figure 2-3 to determine the depth required to achieve the volume reduction target. The calculation for interpolation is:

(15-9) / (24-9) * (2.0-0.3) + 0.3 = 0.98, which is rounded to 1.0 m

Step 4: Ensure the I/P Ratio Does Not Exceed Maximum Permissible I/P Ratio

For a parking lot that services more than 1 car per day per space, the maximum permissible I/P ratio is 20:1. The selected I/P ratio does not exceed the maximum.

Refer to Table 2-1 or Figure 2-2 above for the maximum allowable I/P ratios.

Step 5: Calculate Design Base Area

Calculate the design base area (A_D) as per the equation in Figure 2-2:

$$A_D = \frac{760\ m^2}{15} = 51\ m^2$$

Step 6: Compare Available Effective Base Area to Design Base Area

The available effective base area (34 m^2) is smaller than the design base area (51 m^2). The following options are available:

- Redesign the site to accommodate a larger effective base area; or
- Use other LID practices in a treatment train.

In this case, it is assumed that the site can be redesigned to accommodate an effective base area of 51 m^2.

Step 7: Detail Using Design Base Area as a Minimum Requirement

With a subsurface infiltration rate of 2 mm/hr and a rock trench depth of 1.0 m, a bioretention facility with an effective base area of 51 m^2 is sized to capture the Water Quality Design Event (15 mm of rainfall in 1 hr) and to release a maximum average annual runoff volume of 90 mm.

See Figure 8-2 at the end of this section for a cross-section of the final design.

Hydraulic Components

Inflow: The pavement runoff sheet flows into the bioretention area. A short drop of about 50 mm from the paved surface to the vegetated surface is required to prevent sediment accumulation from creating a dam-like obstruction along the perimeter of the parking lot. Large gravel (> 25 mm) should be placed in a strip along the pavement edge to reduce erosion potential, as described in Section 2.6.5.

Storm Sewer System Inlet: A surface inlet in the bioretention area, consisting of a typical City of Calgary catchbasin with beehive cover, decants water that cannot infiltrate into the growing media once the ponding reaches a depth of 200 mm.

The surface inlet is connected to the storm sewer system and is equipped with an ICD, the size of which corresponds to the acceptable minor system design flow rate of 59 L/s from this site, calculated using the UARR method and a UARR of 80/L/s/ha. The bioretention area must also be equipped with a planned overland emergency escape route for higher flows to accommodate all flows greater than the minor system design flow up to the major system design flow of 240 L/s from this site, calculated using the Rational Method. Flows are calculated in accordance with the City of Calgary *Stormwater Management and Design Manual (2011).*

Subdrain: A perforated pipe located in the top of the rock layer decants excess water into the storm sewer system when the rock trench is full of water.

Standard perforated PVC pipe is to be used for the bioretention underdrain. The standard pipe has two rows of perforations, 15 mm diameter and approximately 120 mm apart, with 120° (2/3 radian) between the rows [[1]]. The inflow rate can be checked using the following formula as in Section 2.8.1:

$$Q_{perforations} = \frac{C \times A\sqrt{(2gh)}}{B}$$

Where:

C = orifice coefficient = 0.61

A = total area of the orifice (m^2)

g = Acceleration of gravity (9.81 m/s^2)

h = maximum depth of water above the pipe (m)

B = Blockage factor. (2 is recommended)

A= π x diameter of perforations^2/4 * number of perforations (2 x Length of pipe / 0.12 m / perforations)

A= 3.141*15 mm/1000 mm/m/4*(2 x 20 m / 0.12 m / perforations)

A= 0.059 m^2 of perforations

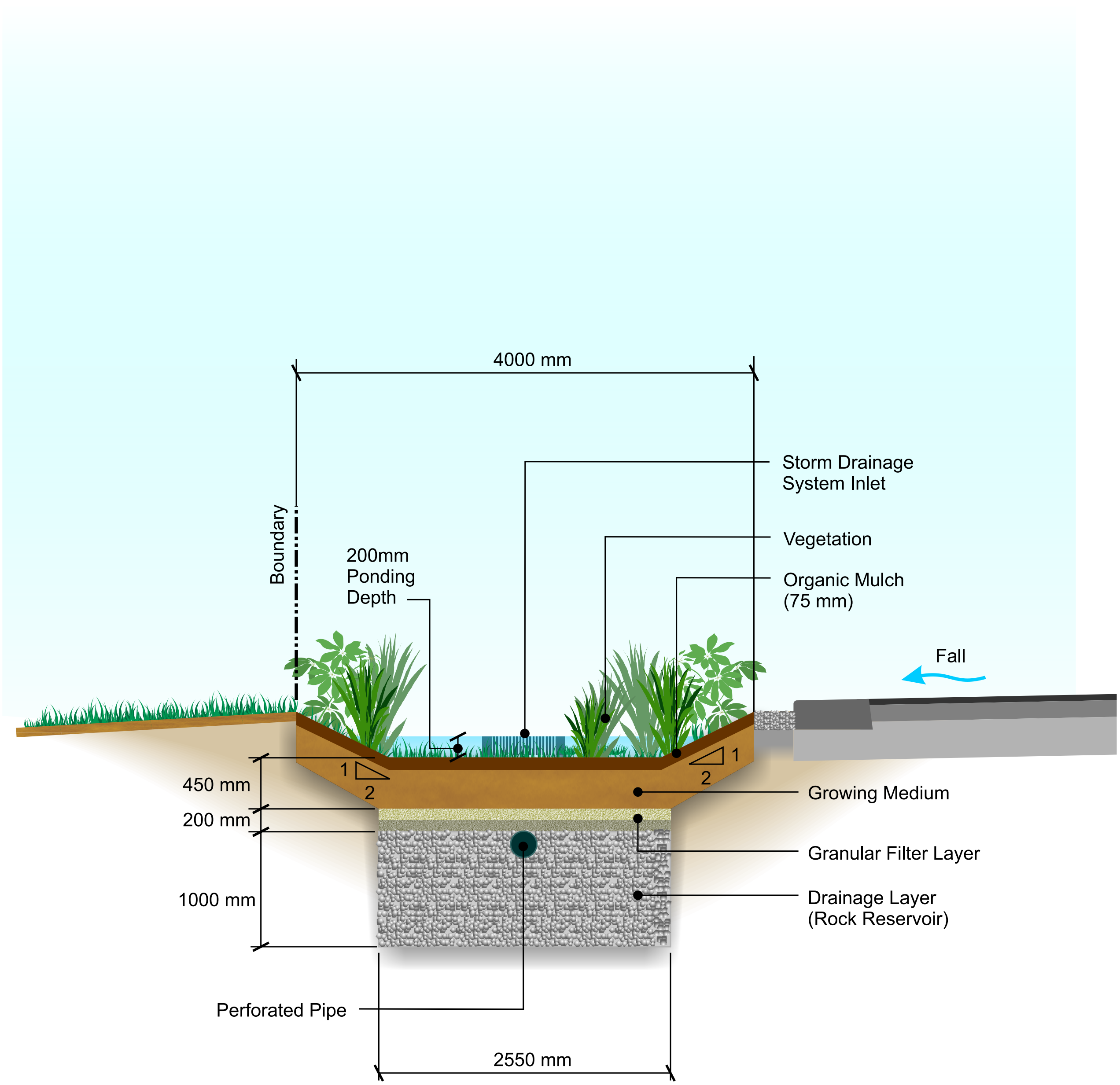
h = 200 mm ponding depth + 450 mm amended soil + 200 mm filter layer

h = 850 mm or 0.85 m

Q_perforations= (0.61x0.059√ 2x9.81*0.85)/2
Q_perforations=0.073 m^3/s or 73 L/s

Maximum Flow Rate = Maximum infiltration rate xbase area
Maximum Flow Rate = 70 mm/r/1000 mm/m x 2.55 m base area*20 m length
Maximum Flow Rate =3.57 m^3/hr /3600 s/hr*1000 L/m^3
Maximum Flow Rate = 1 L/s< 73 L/s -- OK!

[1] Based on manufacturer's information for a standard 150 mm perforated PVC pipe (from IPEX, 2014).



DIMENSIONS ARE MILLIMETRES
UNLESS OTHERWISE NOTED

METRIC

No.	Date	Revision	App'd

Drawn	Date	Checked
JL	2016-04	LM
Scale	N.T.S.	
Approved by		
for City Engineer		

THE CITY OF CALGARY
WATER RESOURCES

Bioretention Section Parking Lot

Sheet
Figure 8-2

File Number

2400-018\501-Drawings\b-Figures\2400018_Fig8-2_Bioretention.cdr

9. Glossary of Terms

Amended Soil – A soil that has an amendment such as sand or compost added to increase the infiltration capacity and/or water retention capabilities.

Bioretention – A stormwater filtration and infiltration practice. The practice consists of a shallow excavated surface depression containing a prepared growing media mix, mulch, planted with specially selected vegetation and underlain by a rock reservoir. The system is engineered to temporarily store runoff in the depression, gradually filtering it through the mulch, engineered growing media mix, and root zone. Bioretention areas remove pollutants from runoff through filtration in the growing media and uptake by plant roots; they can help to reduce runoff volume through evapotranspiration and infiltration.

Bioswale – A shallow landscaped channel with growing media and a reservoir beneath, which captures stormwater runoff and allows it to soak into the growing media and subsurface ground below. Similar to bioretention, but provides conveyance of water across a site similar to a vegetated swale.

Compaction – The process in which a stress (force) applied to a soil causes densification as air is displaced from the void spaces between the soil grains. Compaction is often achieved with a roller or vibrating rammer.

Conveyance – A way to transport water from one point to another; conveyance methods include pipes, ditches, and channels.

Drawdown Time – the period from the maximum water level to when a bioretention area or ponding area in a bioswale does not display any standing water anymore.

Filtration – the technique of removing pollutants from runoff as it infiltrates through the growing media and filter layer.

Fines – soil materials with less than a 0.050 mm diameter particle size.

Forb – flowering herbaceous plant

Forebay – a pre-treatment basin at the inlet of a practice that allows settling out of sediments and associated contaminants suspended in urban runoff.

Freeboard – The vertical distance between the design (1:100 year) water surface elevation and the top edge of the bioretention area or bioswale.

Friable – A word used to describe soil that is easily crumbled or broken apart.

Geotextile - a filter fabric that is installed to separate dissimilar soils to prevent fine-textured soil from entering a coarse granular bed, or to prevent coarse granular from being compressed into underlying finer-textured soils.

Glazing of soil – Process by which rainfall or water or surface traffic make the surface of soil smooth and less pervious, so that the infiltration of water through the surface is reduced.

Graminoid – grasses, sedges and rushes collectively; grass-like plant

Granular Filter Layer – sand, gravel, or crushed stone of various size gradations (i.e., diameter), used in construction; void forming material used as filter material, bedding and runoff storage reservoirs and underdrains in stormwater infiltration practices.

Growing Media – the engineered soil bed component of a bioretention area or bioswale, typically composed of sand, loam and compost, which provides a growing medium for vegetation, while maintaining a high rate of infiltration over the lifespan of the practice. It retains contaminants through filtration and adsorption to soil particles.

Hardscape – The impervious areas of a site that are not roof including driveways or parking areas, walkways, patios, or any other ground-level impervious surfaces that shed water; contrasts to 'landscape' areas of the lot that are covered with soil and vegetation.

Herbaceous – a plant that does not have persistent woody stems; includes annuals, perennials and biennials.

Homogeneous Mixture - A mixture which has uniform composition and properties throughout.

Hydraulic Conductivity or Saturated Hydraulic Conductivity – A property of saturated soil that represents the rate of water moving through it; often equated to or used as a measure of the infiltration rate.

Impervious – A surface that does not allow water to pass though; includes surfaces such as roofs and driveways.

Infiltration – The downward entry of water into the growing media surface. Infiltration is often expressed as a rate (millimetres per hour), which is determined though an infiltration test.

Inlet – A way for entering; an opening or pipe to allow water into a bioretention area or bioswale.

Invert – The lowest point on the inside of a pipe, or the bottom elevation of a bioretention area or bioswale.

Iron Enhanced Growing Media – Involves adding iron to a bioretention growing media mix to provide enhanced phosphorus retention. The iron binds several dissolved constituents, including phosphate, in stormwater and may also reduce the leaching of phosphorus contained within the growing media.

Loam – A rich soil consisting of sand and clay and decaying organic matter.

Low Impact Development (LID) – a stormwater management strategy that seeks to mitigate the impacts of increased urban runoff and stormwater pollution by using natural features and processes to restore the pre-development hydrologic regime.

Mulch – a protective layer placed on top of soil to mimic the functions of natural leaf litter.

Nurse Crop – an annual or short-lived plant that is added as a placeholder while other plants are establishing.

Offline – refers to a system that, when full, is bypassed by stormwater. Offline systems use flow splitters or bypass channels that only allow the design volume to enter the facility. This may be achieved with a pipe, weir, or curb opening sized for the target flow, but in conjunction, contain a bypass channel so that higher flows do not pass over the surface of the filter bed.

Outlet – A place or opening though which something is let out; an opening or pipe to allow water to leave a bioretention area or bioswale.

Overland Flow – Overland flow or major system flow is another term for surface flow. With a stormwater drainage system, often it is concentrated flow in excess of the capacity of the storm sewer system or minor system.

Percolation – Loss of water from a drainage system as a result of exfiltration or absorption into the surrounding subgrade (e.g., the exfiltration of water from a bioretention area into the native subsoils).

Perforated Pipe – Pipe with holes or slots in the pipe. See also "Underdrain".

Permeability – The ease with which water penetrates or passes through a layer of soil or porous medium; can also be referred to as perviousness and is related to the size and continuity of the void spaces in soils.

Pollution Hot Spot – areas where certain land uses or activities have the potential to generate highly contaminated runoff (e.g., vehicle fuelling, service or demolition areas, outdoor storage and handling areas for hazardous materials and some heavy industry sites).

Pollutant Load – the total mass of a pollutant entering a waterbody over a defined time period.

Ponding / Ponded Water – area of temporary shallow standing water (not flowing as in a channel or stream) that drains away through an outlet or into the ground over a few hours or days.

Porosity – Similar to void ratio, this is the portion of a volume of material such as soil or rock representing empty spaces between particles; usually expressed as a percentage of the total volume.

Pre-treatment – initial capturing and removal of unwanted contaminants, such as debris, sediment, leaves and pollutants, from stormwater before reaching a best management practice; Examples include, settling forebays, sedimentation sumps, vegetated swales and filter strips.

Rock Reservoir – an underlying aggregate material bed that temporarily stores stormwater before percolating it into the native subsoils or being conveyed away by an underdrain pipe.

Scarified Subgrade – Subgrade of which the surface has been loosened or broken up.

Scarify – To scarify is to loosen, break or roughen the surface of soil. Can be done with a rototiller (small areas) or a cultivator (large areas).

Sedimentation – Settling-out or deposition of particulate matter suspended in runoff.

Sheet Flow –shallow flow over plane surfaces that can be directed evenly to bioretention or bioswales from adjacent paved or grassed surfaces.

Source Control Practice (SCP) – A practice or facility that handles precipitation where it falls or treats runoff near the impervious area source where it is generated to achieve one or more of the following: improve water quality, reduce flow rate, and reduce volume of runoff. Bioretention areas and bioswales are two types of SCPs.

Subgrade – The underlying ground beneath any constructed feature; often called native soil as it is material that was in place before excavation or construction started. Typically, this is the bottom of an excavation for construction and is the underlying base for the construction which goes on top.

Subsoil – The native subsurface soil that lies below the topsoil and/or disturbed layer of surface soil.

Trapezoidal – A four sided shape that has two sides that are parallel and two sides that are not parallel. In stormwater a trapezoidal channel has a base that is narrower than the parallel top.

Underdrain – PVC pipes with holes drilled though one or two sides, installed either on the top of the rock trench within bioretention areas or bioswales, which are used to collect and remove excess water that has infiltrated through the growing media.

Vegetated Filter Strip – are gently sloping, densely vegetated areas that treat runoff as sheet flow from adjacent impervious areas. They function by slowing the runoff velocity and filtering out suspended sediment and associated pollutants, and by providing some infiltration into the underlying soils. Also known as buffer strips and grassed filter strips.

Vegetated Swale – A vegetated swale is a broad, shallow channel with a dense stand of vegetation covering the side slopes and bottom.

Void Ratio – Similar to porosity, this is the ratio of the volume of the void (or ‘empty’) spaces (including space occupied by both air and water/liquid) in the material to the volume of the solid particles; typical range is between 0.3 and 0.9.

Water Quality Volume – the amount of stormwater runoff required to be treated by a source control practice to reduce the pollutant load to an acceptable level. The default water quality volume is the volume of the Water Quality Design Event as defined in the *City of Calgary Stormwater Management & Design Manual (2011)* in Section 3.2.4.4.

Water Quality Design Event – A design storm event as defined in the *City of Calgary Stormwater Management & Design Manual (2011)* in Section 3.2.4.4.

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Revision History

Revision #	Date	Status	Revision	Author
B	May 2016	Final	Incorporated changes from client.	LM
A	April 2016	Draft	Issued for Client Review	LM

OQM | Organizational Quality Management Program

MPE Engineering Ltd. APEGA Permit # PO3680

Kerr Wood Leidal Associates Ltd. APEGA Permit # PO7929

Appendix A

Bioretention/Bioswale Design Checklist

The City of Calgary
Development Approvals, Water Resources

Checklist for STORMWATER SOURCE CONTROL PRACTICES
BIORETENTION AREAS AND BIOSWALES

Project:

Developer:

YES NO N/A

☐ ☐ ☐ 1. For each bioretention area or bioswale, provide a table summarizing

- Location
- Size of bioretention area or bioswale (i.e., surface area of media) plus pre-treatment system, if any;
- Size and type of hard areas, if any, draining into bioretention area or bioswale;
- Corresponding I / P ratio for bioretention area or bioswale;
- Size and type of total area draining into bioretention area or bioswale;
- Design saturated hydraulic conductivity of media;
- Design percolation rate of the subsoils,
- Design safety factor for long-term performance
- Permissible and actual discharge rate into subdrain / storm sewer system for 1:100 year event and type of flow control, if any;
- Target and anticipated water quality enhancement provided (with supporting information);
- Thickness and composition of media, including type of vegetation and proposed mulch system;
- Median annual runoff volume conveyed to subdrain / storm sewer system and/or median annual spillover volume.

☐ ☐ ☐ 2. Supporting hydrologic / hydraulic computations of the operation of the bioretention area or bioswale, including annual runoff volumes, peak inflow and spillover flows, and annual spillover volumes, are provided. The values for the saturated hydraulic conductivity of the media, and the infiltration rate into the subsoils, if any and supported by field tests, and assumed evapotranspiration rates are provided as well.

☐ ☐ ☐ 3. Confirmation that the entire runoff volume generated by the 1 hour, water quality design event is treated by the bioretention area without surface overflow, if no secondary treatment (in e.g. a storm pond) is provided.

☐ ☐ ☐ 4. For each bioretention area or bioswale, plan view and cross-section details included on construction drawings c/w:

- ☐ Flat bottom with (OR 2% maximum slope for bioswale) minimum 600 mm width
- ☐ Maximum 2:1 (H:V) side slopes (flatter preferred), Maximum 3:1 (H:V) where mowing equipment requires access
- ☐ Inlet to have adequate hydraulic capacity to ensure runoff enters bioretention area or bioswale prior to entering adjacent (overflow) catchbasins or bypassing to the storm sewer system inlet;
- ☐ Maximum ponding depth in the bioretention area or bioswale of 300 mm for 1 hour, water quality event;
- ☐ Maximum ponding depth in the traplow that contains bioretention area of 500 mm for 24 hour, 1:100 year "major" storm event,;
- ☐ Bioretention or bioswale growing media and filter system
  - ☐ Mulch layer
    - ☐ 75 mm layer of mulch.
  - ☐ Growing Media layer
    - ☐ 0.40 to 0.60 m deep,
    - ☐ Growing media composition
  - ☐ Granular filter layers
    - ☐ 0.1m depth of 1-3mm diameter clean washed poorly graded sand overlaid by
    - ☐ 0.1m depth of 7 - 10mm average diameter clean washed pea gravel
  - ☐ Drain rock
    - ☐ 25 mm (minimum diameter) double washed drain rock layer (maximum 800mm).
  - ☐ Subdrain
    - ☐ PVC perforated pipe, 100 mm minimum diameter
    - ☐ Observation port.
    - ☐ Subdrains directly connected to a structure should be non-perforated for a distance of at least 1.5 m from the structure interface to avoid possible piping problems,
- ☐ Geotextile fabric on sides of the basin
- ☐ Impermeable liner if soils are expansive or if concerned for groundwater contamination.
- ☐ Subgrade below rock drain layer must be tilled to a minimum depth of 200 mm.
- ☐ Details of emergency surface overflow are provided
- ☐ Details of erosion protection at inflow locations and provisions to spread out incoming flows are provided.
- ☐ Details of pre-treatment to settle out large sediments in runoff from hard areas are provided.

☐ ☐ ☐ 5. If percolation into the subsoils is depended on to drain the bioretention area or bioswale, provide a geotechnical report, signed by a professional geotechnical engineer, including:

- ☐ Results of a soil borings or test pit results, as per Module 1:Geotechnical and hydrogeology Considerations for Low Impact Development with a minimum depth of 1.5 m below bottom of the bioretention area,
- ☐ In-situ Percolation capacity of the subsoils (i.e., representative of the compaction conditions underneath the bioretention area following construction)
- ☐ Confirmation that the maximum ground water level is at least 600 mm below the bottom of the bioretention area if water is to be infiltrated.
- ☐ Bedrock depth,
- ☐ Soil profile,
- ☐ Appropriate geotextiles and liners.
- ☐ Confirmation that the infiltrating runoff will have no detrimental impact on adjacent or downstream buildings, roadways, infrastructure or landscape.
- ☐ Confirmation that the infiltrating runoff will have no detrimental impact on adjacent or downstream aquifers or groundwater supplies.

☐ ☐ ☐ 6. Weir and drop structure (to be used for longitudinal site slopes of over 4%)

- ☐ Height from 150 mm to 300 mm,
- ☐ Spacing no closer than 15 m,
- ☐ Energy dissipation and erosion protection provided below drops,
- ☐ Keyed in for at least 100 mm

☐ ☐ ☐ 7. All driveway or street crossings are equipped with culverts with adequate scour protection

- ☐ with minimum 2% slope, and
- ☐ minimum 450 mm diameter.

☐ ☐ ☐ 8. Maximum 1% slope of bioretention area and maximum 4% slope in a bioswale.

☐ ☐ ☐ 9. Subdrain slope to be a minimum of 0.1%.

☐ ☐ ☐ 10. Emptying time shall not exceed 24 hr based on the depth of ponding below the storm sewer inlet. Ponding onto roadways, parking lots, etc. and onto private property should be equivalent to traplow operation without the benefit of bioretention areas for a 24 hour, 1:100 year “major” storm event (i.e., 30 minutes).

☐ ☐ ☐ 11. Bioretention areas or bioswales should not be located above deep or shallow utility trenches.

☐ ☐ ☐ 12. Bioretention areas or bioswales to be located at a minimum distance from building foundations or property boundaries as recommended by the geotechnical engineer.

☐ ☐ ☐ 13. Where concentrated flows enter a bioretention area or bioswales, appropriate erosion protection is provided to accommodate the peak flow rate and spread out the flow over the bioretention area, without erosion.

☐ ☐ ☐ 14. Where bioretention areas or bioswales are used to accommodate runoff from paved surfaces, pre-treatment of the runoff is provided to settle out large sediments.

☐ ☐ ☐ 15. The growing media have low P-index of less than 20mg/kg to minimize phosphorus leachate from the media, otherwise .provide 3% iron

☐ ☐ ☐ 16. The vegetation has been selected by a landscape designer with bioretention area or bioswales specialization and is supplied by a grower using locally grown and locally sourced stock..

☐ ☐ ☐ 17. An Operations and Maintenance Manual is provided.

☐ ☐ ☐ 18. If provided within private property as part of the stormwater management system, the future property owner(s) are required to sign an affidavit stating that they will be responsible for Operations and Maintenance of the bioretention area and will submit an annual report, signed off by a professional engineer, confirming that the permeable pavement structure still operates within its original design parameters

☐ ☐ ☐ 19. The Erosion and Sediment Control Plan provides provisions to ensure that the drain rock and/or growing media will not be contaminated, at any stage, during the construction process.

Comments:

I, the undersigned, have reviewed the Bioretention Area Checklist

Signature of Report Author	Name (Please Print)	Date

Appendix B

Planting Tables and Vegetation Selection

Plant	Botanical Name	Common Name	Native	Moisture		Tolerance			Cautionary Notes	Sourcing	Other Notes
Type			Y/N	Moist	Wet	Salt	Velocity	Sediment			
T	***Amelanchier alnifolia***	**Saskatoon**	**Y**	**x**		**N**	**Y**		**May sucker, which may or may not be desirable.**	**Available**	**Specify clumping or tree form**
T	***Betula occidentalis***	**Water Birch**	**Y**	**x**		**N**	**Y**		**May sucker, which may or may not be desirable.**	**Available**	**Specify clumping or tree form**
T	*Betula papyrifera*	Paper birch	Y	x		Y/N			bronze birch borer	Available	Specify clumping or tree form
T	*Betula platyphylla 'Fargo'*	Dakota Pinnacle Birch	N	x						Available	Columnar
T	*Malus spp.*	Flowering Crabapple	N	x					Choose fireblight-resistant varieties. Choose non-fruit producing varieties.	Available	
T	*Populus balsamifera 'Paskapoo'*	Paskapoo Poplar	Y	x		Y	Y		May have weak branch attachment.	Available	More upright and drought tolerant than the species
T	***Populus tremuloides***	**Trembling Aspen**	**Y**	**x**		**N**			**May sucker, which may or may not be desirable.**	**Available**	**Specify clumping or tree form**
T	*Populus tremula 'Erecta'*	Swedish Trembling Aspen	N	x						Available	Columnar
T	*Prunus maackii*	Amur Cherry	N	x					susceptible to black knot	Available	Small varieties, e.g., 'Jeffspur'
T	*Prunus pensylvanica*	Pincherry	Y	x					suckers, which may or may not be desirable; susceptible to black knot	Available	
T	*Prunus virginiana*	Chokecherry	Y	x		N			may sucker; susceptible to black knot	Available	
T	*Prunus virginiana 'Schubert'*	Schubert Chokecherry	N	x					invasive in natural areas	Available	
T	*Pyrus ussuriensis*	Ussurian Pear	N	x					may have weak branch attachment	Available	Fruit may be messy
T	***Quercus macrocarpa***	**Bur Oak**	**Y**	**x**		**Y**			**Acorns may be messy**	**Available**	**Taprooted. Long lived but about 5 years to establish.**
S	*Alnus crispa / viridis*	Thinleaf Alder	Y	x		N			Readily browsed	Available	Fixes nitrogen
S	*Artemisia cana/ tridentata*	Silver Sagebrush/Big Sagebrush	Y	x		Y					good for erosion control
S	*Atriplex spp.*	Saltbush/Saltsage	Y	x		Y					good for erosion control
S	*Betula pumila/ glandulosa*	Bog / Dwarf Birch	Y	x		N				Available	
S	***Cornus sericea (formerly stolonifera)***	**Red-osier dogwood**	**Y**	**x**		Y	Y	Y	Only the species is recommended	Available	Can be propagated from live stakes (e.g., bioengineering application). Good for metals, oil and grease uptake; good erosion control
S	*Lonicera caerulea var. edulis/ var. Emphyllocalyx*	Sweetberry / Haskap Honeysuckle	Y / N	x						Available	
S	*Lonicera involucrata*	Bracted Honeysuckle	Y	x		Y				Available	
S	*Eleagnus commutata*	Wolf Willow	Y	x		Y	Y	Y	Aggressive spread will occur. Rangey.	Available	
S	***Potentilla fruticosa***	**Potentilla**	**Y**	**x**		**Y**			**Only the species is recommended**	**Available**	
S	***Ribes aureum***	**Golden Currant**	**Y**	**x**		**Y**				**Available**	
S	*Ribes lacustre*	Black Swamp Currant	Y	x							
S	***Ribes oxyacanthoides***	**Gooseberry**	**Y**	**x**		**N**			**Thorny**	**Available**	**Good erosion control**
S	***Rosa acicularis***	**Prickly Wild Rose**	**Y**	**x**		**Y**	**Y**	**Y**	**Thorny. Aggressive spread can occur. Rangey.**	**Available**	
S	*Rosa glauca*	Red Leaf Rose	N	x						Available	
S	***Rosa woodsii***	**Common Wild Rose**	**Y**	**x**		**Y**	**Y**	**Y**	**Throny but less so than *acicularis***	**Available**	
S	***Salix bebbiana***	**Bebb's Willow**	**Y**	**x**		N			stakes need to be harvested and planted during completely dormant period (Nov - Mar)	Available	Can use live stakes. Prefers drier positions.
S	*Salix brachycarpa*	Fox Willow	Y	x					Blue Fox' is not recommended		
S	*Salix candida*	Hoary Willow	Y	x							
S	*Salix discolor*	Pussy Willow	Y	x		N	Y	Y		Available	
S	*Salix drummondiana*	Drummond's Willow	Y	x							
S	*Salix exigua*	Coyote/Sandbar Willow	Y	x	x	N	Y	Y	Rangey. Aggressive spread will occur.	Available	Very effective propagation from live stakes. Highest tolerance for storage and non-ideal cutting times after breaking dormancy.
S	*Salix glauca*	Grey Leaf Willow	Y	x		Y					Good erosion control
S	*Salix integra 'Albomaculata', 'Hikuro Nishiki'*	Tri-colour, Dappled Willow	N	x						Available	long-term performance unknown
S	*Salix lucida*	Shining Willow	Y	x		Y	Y	Y			Best propagated from hardwood cuttings. Less tolerant with timing and storage than Sandbar Willow. Good erosion control.

Plant Type	Botanical Name	Common Name	Native Y/N	Moisture Moist	Wet	Tolerance Salt	Velocity	Sediment	Cautionary Notes	Sourcing	Other Notes
S	***Salix lutea***	**Yellow Twig Willow**	**Y**	**x**		**Y**	**Y**	**Y**	**More salt tolerant than other willows.**	**Available**	**Very effective propagation from hardwood cuttings but less tolerant on timing.**
S	*Salix pedicellaris*	Bog Willow	Y	x						Available	
S	*Salix petiolaris*	Slender Willow	Y	x						Available	
S	*Salix purpurea 'Gracilis' 'Nana'*	Arctic Willow	N	x						Available	
S	*Salix rigida 'American McKay'*	American McKay Willow	N	x						Available	
S	*Sambucus canadensis 'Aurea'*	Golden Elder	N	x					Suckers	Available	
S	*Sambucus pubens / racemosa*	Red-berried Elder	Y	x		N				Available	good erosion control
S	*Sarcobatus vermiculatus*	Greasewood	Y	x		Y					
S	*Spiraea spp*	Hardy x varieties Spirea	N	x		Y				Available	Resistant to browsing
S	***Symphoricarpos albus***	**Snowberry**	**Y**	**x**		**N**			**Forms a thicket**	**Available**	**Resistant to browsing; good erosion control**
S	*Symphoricarpos occidentalis*	Buckbrush	Y	x		Y			Forms a thicket	Available	Resistant to browsing; good erosion control
S	*Virburnum lentago*	Nannyberry	N	x					May sucker	Available	

Plant Type	Botanical Name	Common Name	Native	Moisture		Tolerance			Cautionary Notes	Sourcing	Other Notes
			Y/N	Moist	Wet	Salt	Velocity	Sediment			
G	*Agropyron trachyculum*	Awned Wheatgrass	Y	x	x	N					
G	*Agrostis scabra*	Rough Hair Grass	Y	x	x	N		N		Available	bunchgrass, tolerates metals
G	*Arrhenatherum bulbosum 'Variegatum'*	Bulbous Oat Grass	N	x		Y	Y	Y		Available	
G	*Beckmania syzigachne*	Slough Grass	Y	x	x	Y	Y	Y			
G	*Bouteloua gracilis*	Blue Grama Grass	Y	x						Available	good for slopes; tolerates drier areas
G	*Bromus ciliatus*	Fringed Brome	Y	x		N		N		Available	
G	***Calamagrostis x acutifolia***	**Feather Reed Grass**	**N**	**x**						**Available**	**tolerates drier positions; 'Karl Foerster' and 'Overdam' recommended**
G	***Calamagrostis canadensis***	**Bluejoint Reed Grass**	**Y**	**x**	**x**	**N**		**Y**	**can form monocultures**	**Available**	
G	*Calamagrostis inexpania*	Northern Reed Grass	Y	x	x	Y					
G	*Carex aquatilis*	Water Sedge	Y		x	N	Y	Y		Available	
G	*Carex atherodes*	Awned sedge	Y	x	x	Y		Y	can form monocultures	Available	
G	*Carex bebbii*	Bebb's sedge	Y	x	x	N		Y		Available	
G	*Carex comosa*	Bottlebrush Sedge	Y	x	x					Available	
G	*Carex grayii*	Bur Sedge	N	x	x					available	also tolerates drier positions
G	*Carex lanuginosa*	Woolly sedge	Y		x					available	
G	*Carex microptera*	Thick-spike sedge	Y	x	x	N		Y			
G	*Carex pellita*	Woolly sedge	Y	x	x	N		Y			
G	*Carex praegacilis*	Graceful sedge	Y	x		Y		Y			
G	*Carex praticola*	Meadow sedge	Y	x		N		Y			
G	*Carex raymondii*	Raymond's sedge	Y	x		N		Y			
G	*Carex sartwellii*	Sartwell's sedge	Y	x	x	Y					
G	*Carex scirpoidea*	Rush-like sedge	Y	x		N					
G	*Carex sprengelii*	Sprengel's (Long-beaked) Sedge	Y	x	x	N	Y	N		Available	also tolerates drier positions
G	*Carex stipata*	Beaked Sedge	Y	x	x					Available	
G	*Carex utriculata*	Bottle Sedge	Y		x	N	Y	Y	can form monocultures	Available	
G	***Deschampsia caespitosa***	**Tufted Hair Grass**	**Y**	**x**	**x**	**N**	**Y**	**Y**		**Available**	
G	*Eleocharis acicularis*	Needle spike-rush	Y	x	x	Y		Y			
G	*Eleocharis palustris*	Creeping spike-rush	Y	x	x	Y	Y	Y		Available	
G	*Elymus canadensis*	Canada Wild Rye	Y	x		N		Y			
G	*Equisetum spp.*	Horsetail	Y	x	x	N				available	
G	*Festuca rubra*	Red Fescue	N	x		N		N		available	
G	*Glyceria grandis*	Tall Manna Grass	Y	x	x	Y	Y	Y		available	
G	*Glyceria striata*	Fowl Mannagrass	Y	x	x	N	Y	Y		available	
G	*Hierochloe odorata*	Sweetgrass	Y	x	x	N				available	
G	*Hordeum jubatum*	Foxtail Barley	Y	x	x	Y					
G	*Juncus alpinoarticulatus*	Alpine Rush	Y	x	x	N	Y				
G	*Juncus balticus*	Wire Rush	Y		x	Y	Y	Y		Available	
G	*Juncus longistylis*	Long-styled Rush	Y	x	x	N	Y	Y			
G	*Juncus nodosus*	Knotted Rush	Y	x	x	N	Y	Y		Available	
G	*Juncus tenuis*	Slender Rush	Y	x	x	N	Y	Y			
G	*Juncus torreyi*	Torrey's Rush	Y	x	x	N	Y				
G	*Muhlenbergia richardsonii*	Mat Muhly	Y	x		Y		N			also tolerates drier positions
G	*Molinia spp.*	Moor Grass	N	x	x						excellent for low to mid-slope
G	*Nassella viridula*	Green Needle Grass	Y	x		N	Y	N		Available	also tolerates drier positions
G	*Panicum virgatum 'Heavy Metal'*	Heavy Metal Switch Grass	N	x		Y				Available	also tolerates drier positions, several varieties available-check for hardiness

Plant Type	Botanical Name	Common Name	Native	Moisture		Tolerance			Cautionary Notes	Sourcing	Other Notes
			Y/N	Moist	Wet	Salt	Velocity	Sediment			
G	***Poa palustris***	**Fowl Blue Grass**	**Y**	**x**	**x**	**Y**	**Y**	**Y**		**Available**	
G	*Poa secunda (juncifolia)*	Alkali Bluegrass	Y	x		Y				Available	
G	*Puccinnellia nuttalliana*	Nuttall's Salt-meadow Grass	Y	x	x	Y	Y	Y		Available	
G	*Pennisetum alopecuroides*	Fountain Grass	Y/N	x		Y	Y	Y		Available	Several cultivars, drier positions
G	*Schizachyrium scoparium*	Little Bluestem	Y	x		N	Y	Y		Available	bunchgrass, several cultivars, prefers drier positions
G	*Scirpus atrovirens*	Green Bulrush	N		x	Y		Y		Available	
G	*Scirpus cyperinus*	Woolgrass	N		x	Y		Y		Available	
G	*Schoenoplectus microcarpus*	Small-fruited Bulrush	Y	x	x	N	Y	Y		Available	
G	*Scirpus pungens*	Three-square Rush	Y		x	Y	Y	Y		Available	
G	*Scolochloa festucacea*	Spangletop	Y	x	x	Y		Y			
G	*Spartina gracilis*	Alkali Cord Grass	Y	x		Y		Y		Available	also tolerates drier positions
G	*Stipa richardsonii*	Richardson's Needlegrass	Y	x							bunchgrass

Plant Type	Botanical Name	Common Name	Native	Moisture		Tolerance			Cautionary Notes	Sourcing	Other Notes
			Y/N	Moist	Wet	Salt	Velocity	Sediment			
F	*Achillea millefolium*	Yarrow	Y	x		Y		Y	Aggressive; self-seeds and spreads	Available	also tolerates drier positions
F	*Agastache foeniculum*	Giant Hyssop	Y	x		Y				Available	also tolerates drier positions
F	*Anemone canadensis*	Canada Anemone	Y	x						Available	also tolerates drier positions
F	*Anemone cylindrica*	Long-fruited Anemone	Y	x		N		N		Available	also tolerates drier positions
F	***Arnica chamissonis***	**Leafy Arnica**	**Y**	**x**		**Y**		**Y**		**Available**	**also tolerates drier positions**
F	***Arnica fulgens***	**Shining Arnica**	**Y**	**x**		**Y**		**Y**		**Available**	**also tolerates drier positions**
F	*Aruncus dioicus*	Giant Goatsbeard	N	x						Available	
F	***Asclepias speciosa***	**Showy Milkweek**	**Y**	**x**						**Available**	
F	*Aster puniceus*	Red-stemmed Aster	Y	x		Y		Y			
F	*Astragalus canadensis*	Canada Milkvetch	Y	x		N		Y		Available	
F	*Bidens cernua*	Nodding Beggarticks	Y	x	x	Y		Y		Available	
F	*Centaurea montana*	Perennial Bachelor Buttons	N	x						Available	also tolerates drier positions
F	*Dalea purpurea*	Purple Prairie Clover	Y	x		N		N		Available	Fixes nitrogen
F	*Echinacea purpurea*	Purple Coneflower	N	x	x	Y		Y	Needs regular watering to establish	Available	
F	*Eupatorium purpureum maculatum 'atropurpureum'*	Spotted Joe Pye	N	x		Y		Y	Needs regular watering to establish	Available	
F	*Gaura coccinnea*	Scarlet Gaura/Butterfly Weed	Y	x		Y		Y			
F	*Geranium macrorrhizum*	Bigroot Geranium	N	x						Available	Spreads to form a clump
F	*Geranium richardsonii*	Richardson's Geranium	Y	x				Y		Available	Self seeds, spreads to form a clump
F	*Geranium viscosissimum*	Sticky Purple Geranium	Y	x				Y		Available	Self seeds, spreads to form a clump
F	*Geum aleppicum/Geum macrophyllum/Geum rivale*	Yellow / Purple / Water Avens	Y	x	x	N					
F	*Geum triflorum*	Prairie Smoke	Y	x		Y				Available	Self seeds
F	*Glaux maritima*	Sea-milkwort	Y	x	x	Y					
F	*Glycyrrhiza lepidota*	Wild Licorice	Y	x		Y			has burrs		
F	*Grindelia squarrosa*	Curly-cup Gumweed	Y	x	x	Y			sticky		Taproot
F	*Helenium autumnale*	Sneezeweed	Y	x					Needs regular watering to establish	Available	
F	*Helianthus annuus*	Annual Sunflower	Y	x						Available	Self seeds
F	*Helianthus maximiliani*	Maximilian Sunflower	Y	x	x	Y			Can be mildly invasive		Do not plant next to pristine natural areas
F	***Hemerocallis spp***	**Daylily spp**	**N**	**x**		**Y**			**Centre will die out as patch expands**	**Easily available**	**Many varieties**
F	*Iris missouriensis*	Missouri Iris	Y	x		Y			Centre will die out as patch expands	Easily available	COSEWIC status
F	*Iris siberica*	Siberian Iris	N	x					Centre will die out as patch expands	Easily available	Many varieties
F	*Iris versicolor*	Northern Blue flag Iris	Y	x					Centre will die out as patch expands		
F	***Liatris ligulistylis***	**Meadow Blazingstar**	**Y**	**x**		**Y**					
F	*Linum lewisii* , cultivars (e.g., Blue Sapphire)	Blue Flax	Y/N	x		Y			Native: self-seeding annual; cultivars: perennial, mild spread	Available	Good cover for weed control/suppression
F	*Lysimachia ciliata*	Fringed Loosestrife	Y/N	x					Spreads	Available	Firecracker' has red leaves
F	*Lysimachia clethroides*	Gooseneck Loosestrife	N	x					May not be drought tolerant	Available	
F	*Lysimachia punctata*	Yellow Loosestrife	N	x					May not be drought tolerant	Available	
F	*Oxytropis splendens*	Showy Locoweed	Y	x		N				Available	
F	*Petasites spp.*	Coltsfoot	Y		x	Y			May not be drought tolerant		
F	*Pedicularis groenlandica*	Elephant's Head	Y	x	x	N					
F	*Penstemon procerus*	Slender Blue Beard-tongue	Y	x		Y				Available	
F	*Physostegia virginiana*	Obedient Plant	N	x						Easily available	
F	*Polygonum amphibium/Polygonum coccineum*	Water / Marsh Smartweed	Y	x	x	Y					
F	*Polygonum lapathifolium*	Pale/Green Smartweed	Y	x	x	Y					
F	*Ranunculus cymbalaria*	Alkali Buttercup	Y	x	x	Y					

Plant Type	Botanical Name	Common Name	Native	Moisture		Tolerance			Cautionary Notes	Sourcing	Other Notes
			Y/N	Moist	Wet	Salt	Velocity	Sediment			
F	*Ranunculus macounii*	Macoun's Buttercup	Y	x	x	N					
F	*Rudbeckia hirta*	Black-eyed Susan	N	x	x	Y	Y		Can be mildly invasive	Available	
F	***Solidago canadensis***	**Canada Goldenrod**	**Y**	**x**	**x**	**Y**	**Y**	**Y**	**Self seeds + aggressive spread**	**Available**	**Common on disturbed shorelines**
F	*Solidago missouriensis*	Missouri Goldenrod	Y	x	x	Y	Y	Y		Available	
F	***Solidago rigida***	**Stiff Goldenrod**	**Y**	**x**		**Y**	**N**	**N**		**Available**	
F	***Solidago gigantea***	**Giant Goldenrod**	**Y**		**x**	**Y**		**Y**			
F	*Stachys palustris*	Marsh Hedge-Nettle	Y	x		N	N	N			
F	*Thermopsis rhombifolia*	Golden Bean	Y	x		Y	Y	Y	Moderate aggressive spread	Available	
F	*Verbena hastata*	Blue Vervain	N	x							
F	*Zizia aptera*	Heart-leaved Alexander	Y	x		N	N	N		Available	

APPENDIX B

PLANT SELECTION FOR BIORETENTION AREAS AND BIOSWALES

The advent of bioretention areas and bioswales opens up a world of possibility for landscape designers. The novel moisture regime, soil conditions, and source water quality characteristics of these facilities present both opportunities and challenges for their establishment, long-term performance, maintenance, and social acceptance. In our semi-arid, cold, Chinook climate, there are additional challenges in the form of salt and sediment loadings, winter freeze-thaw events, and long periods of drought.

At the same time, the additional moisture, along with an uncompacted soil volume, can lead to plants attaining larger sizes more quickly, and provide an opportunity to include plants that might not be selected in a purely dryland setting. With the right plant selection, designers have the opportunity to achieve not only aesthetic and stormwater performance objectives, but habitat and biodiversity objectives as well.

This plant list represents approximately five years of collaborative dialog and observation in the Calgary area. The Module consultants engaged with Industry and ALIDP partners, having provided invaluable insight and feedback along the way.

INTERPRETING THE LIST

Organization

The plant lists are subdivided into woody plants (trees and shrubs), graminoids (grasses, sedges and rushes), and forbs (herbaceous flowering plants). Plants in bold have been reported to be successfully used in Calgary. It is not an indication of preferred status.

Components

The plant lists include the common and botanical name; whether the plant is native or not; moisture tolerance/preference; tolerance for salt, sediment and velocity; notes of characteristics; and availability.

Native classification. Indication of native status means native in Alberta, not necessarily native in Calgary. In this context the usefulness of including this classifier is to suggest where the plant may be sourced, to indicate something about adaptation to local conditions, and to assist with narrowing down if the plant is indeed native to Calgary, if that information is relevant (for example when working adjacent to pristine natural areas).

Moisture. This plant list only includes plants suitable for the zone of inundation. Any suitable plant may be selected above the zone of inundation. ’Moist’ classification denotes a bioretention/ bioswale zone of inundation condition, i.e., where you expect to have standing water up to 24 hours. A ‘wet’ classification denotes a tolerance or preference for wetter conditions than true bioretention. It is recognized that achieving a perfectly homogeneous moisture condition on the bottom is subject to field conditions, and small areas that are wetter or drier than the true bioretention condition may exist. Including a certain percentage of plants that thrive in such circumstances will increase the likelihood of vegetation success. Plants that tolerate both the true bioretention condition and somewhat drier conditions are indicated in the notes, but not exhaustively.

Tolerances. An effort has been made to include, where known, salt, sediment, and velocity tolerance characteristics. Velocity tolerance, where noted, has largely been inferred from riparian area observations. All graminoids have some velocity tolerance. ‘Sediment’ tolerance may refer to either riparian area observations, or early observations of bioretention in the Calgary area. Because the composition of sediment in stormwater is different from sediments in riparian areas, the sediment-tolerance notation is of varying certainty. Early observations seem to indicate that vegetation immediately adjacent to concentrated inlet flows, where sediment settles out on the bottom of the facility, are the most challenged locations to establish vegetation. It is not known whether this is because of the sediment itself or something in the sediment.

Cautionary notes. Disease or infestation susceptibility, notes on aggressiveness, and other characteristics that may limit suitability are included here.

Sourcing. At this time, this is a partially developed listing of whether plants are in the marketplace or merely theoretically suitable. Consult with growers as early as possible to avoid disappointment. As the market matures, we expect to see greater availability. Consult the Alberta Native Plant Council’s listing for additional detail on native plant suppliers. The City of Calgary Parks also has its own sources which may be able to be used.

Other notes. Additional characteristics are noted here. This is a partially developed listing.