Low Impact Development: Design Guide for Saskatoon

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November 2016

Preface

This document was developed by the City of Saskatoon to provide guidance to those making plans and decisions about how to develop property. It will interest engineers, developers, property owners, and designers that wish to use low impact development to reduce stormwater runoff generated by infill development, new development, and existing development. It provides a variety of solutions that may be integrated to ensure the safety of the proponent's property and the properties located downstream. This Low Impact Development Design Guide supports needs identified in the *Wetland Design Guidelines* to give support in selecting options to reduce runoff volume, improve runoff water quality, and delay peak runoff flows from entering the stormwater system simultaneously.

The following 13 sections detail the information necessary to select a low impact development beneficial management practise (LID-BMP) to achieve the desired outcomes in the type of environment and development specific to the individual project. Sections 1 through 4 outline the basic concepts, regulatory framework, local conditions, and LID planning process. Section 5 summarizes LID-BMPs suitable for Saskatoon. Sections 6 through 13 provide specific information on each suggested LID-BMP.

LID methods identified as potentially useful on projects in Saskatoon include:

- Bioretention and Raingardens,
- Bioswales,
- Green Roofs,
- Permeable pavements,
- Stormwater box planters,
- Naturalized drainage ways, and
- Rainwater harvesting for reuse.

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1 INTRODUCTION

1.1 Current Stormwater Management

Storm water runoff is any water that flows across the land as a result of rainfall or snow melt. It can travel into and through ditches, culverts, catch basins, manholes, pipes, ponds, and outfalls after collecting from streets, sidewalks, lanes, and private properties.

Typically in Saskatoon, storm water is collected via storm drains located at the curbs of roads, then moved via a piping system to large mainline storm sewer pipes. Eventually the storm water flows into the South Saskatchewan River through a variety of discharge points along the river's edge. It may be detained temporarily in storm ponds or tanks, which allow the downstream pipes to be smaller than they would be if no temporary storage was provided.

Figure 1: 72 inch Sewer Pipe in Saskatoon, between 1912 and 1915 (Saskatoon Library, 2016)

This storm water system is a vital part of the City's infrastructure. Saskatoon's storm water infrastructure has a replacement value of over two billion dollars (Saskatoon Water, City of Saskatoon, 2015). Parts of the existing stormwater system date back more than 100 years, and much of the existing system has little remaining capacity for additional upstream development. Before 1989, no major storm system design was required and the infrastructure that was installed is often undersized by current standards. In order to allow further development and infill, it is often required to minimize and/or delay storm water runoff though the use of orifice controls, on-site storage, and/or low-impact development techniques.

Managing storm water protects the health and safety of the public and the environment by avoiding flooding, erosion, and preventing pollutants from reaching the river.

1.2 Low Impact Development

1.2.1 Definition

Low Impact Development (LID) is a term used in Canada and the United States to describe a land planning and engineering design approach to manage stormwater runoff. It emphasizes on-site features and systems that help to lower runoff quantity, lower peak runoff volumes and flow rates, and improve runoff water quality. LID seeks to improve and maintain natural hydrologic processes on site: absorption, infiltration, evaporation, evapotranspiration, filtration through soils, pollutant uptake by select vegetation, and biodegradation of pollutants by soil microbes. (US Environmental Protection Agency, 2016) These natural processes work together to achieve the desired outcomes of the LID design. LID may also include elements of storage and reuse, such as rain barrels or larger cisterns to allow irrigation and other uses from stored runoff water.

1.2.2 Design Considerations

Each LID project will require a site specific design that incorporates local conditions to find the best solutions for the desired outcome. Factors such as soil properties, frost depth, precipitation amounts and types, winter site maintenance (salt, sand or gravel application), desired maintenance effort, etc. can all impact which low impact development beneficial management practices (LID-BMPs) may be suitable for a project. The desired outcome will also drive the types of LID-BMPs to pursue – some methods will primarily reduce peak flows, while others will improve runoff quality. In Saskatoon, consideration of the cold winter conditions is very important to any LID design.

LID supports infill development and redevelopment within the historical storm sewer system boundaries. These runoff management methods can control that amount of new runoff introduced to the existing stormwater sewer system and keep it at allowable volumes and release rates that ensure a safe operation of the system as a whole.

2 STORM DRAINAGE REGULATIONS & GUIDELINES

A variety of regulations and guidelines apply to the design and implementation of LID facilities.

2.1 Federal Regulations

2.1.1 Navigable Waters Protection Act

Section 5(1) of the Navigable Waters Protection Act (2010, Transport Canada) states that:

“No work shall be built in, on, over, under, through, or across any navigable water without the Minister’s prior approval of the work, its site, and the plans for it.”

LID facilities are unlikely to be sited in locations where this act is in effect, as they generally seek to not compromise environment and habitat and would not be effective on the river bank. If a LID-BMP does invoke the Act, it would be treated in the same way as conventional stormwater management facilities.

2.1.2 Federal Fisheries Act

Section 35 of the Federal Fisheries Act (2010, Department of Fisheries and Oceans) states that:

"No person shall carry on any work or undertaking that results in the harmful alteration, disruption, or destruction of fish habitat."

In the event a project takes place in or adjacent to fish habitat, the LID-BMP facility will be treated in the same way as conventional stormwater facilities.

2.2 Provincial Guidelines

Saskatchewan does not currently specifically regulate stormwater quality. The Water Security Agency (WSA) does provide guidance and encourages a diligent approach to stormwater management through the Stormwater Guidelines.

2.2.1 Stormwater Guidelines (Water Security Agency, 2014)

Urbanization can result in a 400% or more increase in stormwater runoff as the land use changes. It also results in lowered water quality of runoff as pollutants on the urban landscape are washed into waterways. Stormwater management practices considered for the control of urban stormwater include source controls, on-site and conveyance system controls, and end-of-pipe controls.

Source controls include measures like pet waste collection, street cleaning, storm drain cleaning, catch basin cleaning, pesticide control, and eliminating non-stormwater discharges.

On-site (lot level) controls include reducing grading on lots to 0.5% at 2 to 4 m away from buildings (but not in areas with clay soils, which includes much of Saskatoon), directing the roof leader to an on-lot ponding area, rooftop storage, on-lot infiltration systems (soak away pits –useable if bottom of pit is at least 1 m above water table), directing sump pump foundation drainage into ponding or infiltration trenches, and oil/grit separators.

Conveyance system controls include pervious pipe systems, pervious catch basins, grassed swales, and vegetated filter strips. Pervious pipes and catch basins are relatively new systems that require more investigation and research before widespread implementation.

End-of-pipe controls are final treatment points before discharging into receiving waters. These include wet ponds, dry ponds, constructed wetlands, infiltration trench, infiltration basin, and sand filters. The guidelines provide design criteria for each of these controls.

The City of Saskatoon currently employs wet ponds, dry ponds, constructed wetlands, grassed swales, vegetated buffer strips, oil/grit separators, soak-away pits and on-lot ponding areas. There have been occasional installations of bioretention cells. Overall, LID-BMPs are not explicitly dealt with in these Stormwater Guidelines but their effects are in line with the expectations and goals of the Water Security Agency.

2.3 Municipal Guidelines, By-laws, and Regulations

2.3.1 Design & Development Manual

Section 6 of the City of Saskatoon's *Design and Development Manual* (2017) addresses the storm water drainage system. Planning and design of LID-BMPs will influence the required Storm Water Drainage

Plan submission at the neighbourhood concept stage. These facilities should be included in the storm water model submitted for review. Information on design storms for major and minor storm water systems is provided in this document. Generally, lots may be sloped at 2-4% for property drainage. Grassed channels, including bioswales and naturalized drainage ways, should have a minimum 1% slope in residential areas and/or clay soils, and may reduce slope to 0.5% in commercial or industrial areas with well drained soils.

2.3.2. Drainage Bylaw

Bylaw No. 8379: The Drainage Bylaw addresses "the drainage of storm water between private properties so as to protect property and abate nuisances." (Council of the City of Saskatoon, 2005) Residential property owners are obligated to ensure their property's compliance with this bylaw. Lots must be graded to the surface markers or elevations provided from the neighbourhood drainage plan. No person may interfere with, restrict, or prevent storm water from flowing through their property as part of a surface drainage system.

2.3.3 Neighbourhood Level Infill Development Strategy

The *Neighbourhood Level Infill Development Strategy* document describes the infill strategy for the area inside of Circle Drive. It includes a preference for various low impact development alternatives. It encourages "porous pavement, and landscaped areas with adequate size and soil conditions, should be used where possible to capture roof drainage and surface runoff within parking areas and adjacent internal pathways and to increase the total amount of absorbed run-off infiltration." (City of Saskatoon, 2013) Rain gardens, rain barrels, and box planters are also encouraged. The addition of infill to the existing stormwater sewer system requires care to minimize new runoff and attenuate peak flows.

2.3.4 Wetland Design Guidelines and Wetland Policy

The *Wetland Design Guidelines* (CH2MHill, 2014) provides a set of guidelines to developers and designers to help with understanding, siting, and designing surface flow constructed wetlands and floating wetland island systems within neighbourhoods. These guidelines outline the required design elements and considerations involved in using wetlands as part of the stormwater runoff system.

The Wetland Policy (Council of the City of Saskatoon, 2013) outlines the policy the City follows when approaching wetlands. The city inventories and classifies existing wetlands. Depending on conditions, a wetland may be preserved or managed.

Figure 2: Hyde Park Wetland, Saskatoon

2.3.5 Zoning Bylaw

The Zoning Bylaw (Council of the City of Saskatoon, 2016) makes several references to requirements for paved parking spots. Collaboration between departments should ensure that references to "paved" include LID alternatives such as permeable pavements. This bylaw also indicates landscaping requirements for different zoning classifications. Vegetated LID facilities may be included in the soft landscaping requirements, fulfilling the need to provide green space as well as handling storm water.

2.4 Stormwater Utility and ERU Calculation

The City Of Saskatoon has a stormwater utility that collects user fees to fund the stormwater system. Generated funds provide vital storm water infrastructure and flood protection services. The unit of measure to assess lots for this utility is the Equivalent Runoff Unit (ERU). Each ERU represents the runoff from a completely impervious 265.3 square meters. A residential property is automatically assessed at 1 ERU. Commercial and industrial properties are assessed at a based on actual conditions on the property, with a minimum rating of 2 ERU. Decreasing the hard surface area from a property will decrease the assessed ERUs and result in lower ongoing stormwater utility bills. ERU reassessment must be requested by the property owner and the newly calculated ERU will be applied to future stormwater utility bills. Periodic inspection may be required to ensure the LID facility remains fully functional.

The following table shows the measured runoff reduction observed for various LID-BMPs. This table was derived from field experiments in the Virginia Piedmont area and is based on the average rainfall event in that location. It provides an idea of the approximate volume reductions from the treatment drainage area that can be achieved through LID-BMP implementation.

Table 1: Runoff reduction for various BMPs

(Joseph Battiata, 2010)

Practice	Runoff Reduction (percent) *
Green Roof	45-60
Rooftop Disconnection	25-50
Raintanks and Cisterns	40
Permeable Pavement	45-75
Grass Channel	10-20
Bioretention	40-80
Dry Swale	40-60
Wet Swale	0
Infiltration	50-90
ED Pond	0-15
Soil Amendments	50-75
Sheetflow to Open Space	50-75
Filtering Practice	0
Constructed Wetland	0
Wet Pond	0

*Range of values is for median (Level 1) and 75th percentile (Level 2) designs.

3 SASKATOON LOCAL CONDITIONS

The implementation of LID-BMP's requires a design that is prepared with local characteristics in mind. The environment – climate, hydrology, soil, and vegetation – will dictate the success or failure of a LID-BMP. This section describes the typical conditions in Saskatoon.

3.1 Physical Conditions

Saskatoon is located in central Saskatchewan along the South Saskatchewan River, at a latitude and longitude of 52.1333° N, 106.6833° W. The average elevation of the city is 486 m (1,594 feet) above sea level.

Saskatoon is in a Prairie ecozone and a Moist Mixed Grassland ecoregion (Saskatchewan's Ecoregions, 2017). This ecoregion has semi-arid moisture conditions and dark brown soil. Small aspen groves are found around water and "prairie potholes" – small unconnected sloughs and ponds – are common. Most of the land around Saskatoon has been cultivated. Natural areas tend to surround water or have poor agricultural soil quality.

Soils found in Saskatoon vary from sandy to heavy clay. A site assessment should be conducted during the planning stage to assess the site soil type and conditions. Much of the areas of new development north-east and east of the existing city have lacustrine soils and perched water tables. This results in low infiltration rates.

3.2 Climate Conditions

General climate data is in the following table.

Table 2: Saskatoon Climate Data

Climate Parameter	Value
Average Annual Mean Temperature[1]	3.9 °C
Average Daily Temperature, January[1]	-13.7 °C
Average Daily Temperature, July[1]	19.6 °C
Average Frost Free Days[1]	135
Typical Frost Depth[2]	1.86 m
Average Annual Snowfall[1]	73.4 cm
Average Annual Precipitation[1]	364.5 mm

[1] (Canadian Climate Normals 1981-2010 Station Data, 2016)

[2] (Ambient Temperatures - Below Ground, 2016)

3.2 Hydrology

3.2.1 Precipitation

Average annual precipitation measured for Saskatoon is 365.4 mm, of which 291 mm is rainfall and 73.4 mm is snowmelt. On average, 87.2 days per year record precipitation over 0.2 mm. The driest month is March, with an average of 12.9 mm of precipitation, and the wettest month is July with an average of 67.1 mm of precipitation. (Canadian Climate Normals 1981 – 2010 Station Data)

3.2.2 Evaporation

The average annual lake evaporation (the water that evaporates from water bodies) is 750 mm in Saskatoon. (Branch, 1978) Annual evaporation is greater than annual precipitation. With lower precipitation in winter, the soil moisture is not always restored to capacity in an average year.

4 LID SITE PLANNING AND DESIGN

4.1 Features of LID Neighbourhood Design

LID can be applied at the initial design of a neighbourhood development or may be applied as a retrofit at a lot level. The largest benefits are seen when LID principles are applied over a large area with integrated design of many LID elements. LID can be balanced with traditional design concerns, such as a variety of population densities, lot sizes, and a mix of dwelling types. Holistic urban design will consider the interdependence of the whole neighbourhood system: ecology, hydrology, biology, economics, and growth. It will work with the predevelopment topography, soil types, and wetlands to minimize construction disturbances and retain as much natural hydrology, existing vegetation, and local stormwater containment and infiltration as possible.

A neighbourhood designed to minimize stormwater runoff and capitalize on natural hydrology of the site will help transform runoff to a resource rather than a problem. The following examples of design improvements can harmonize to minimize negative stormwater impacts:

- arranging streets to minimize street length (and thus, impervious road surface),
- minimizing site grading and preserving existing drainage paths,
- minimizing area of compaction to preserve existing infiltration,
- aiming to reduce vehicular traffic in residential areas while encouraging pedestrian and cyclist connectivity to institutional and commercial areas,
- connecting green spaces,
- reducing impervious surfaces through green roofs, permeable pavements, and parking lot bioretention areas,
- using neighbourhood stormwater storage in natural depressions and wetlands, and
- installing bioswales in central boulevards.

Note that some of these features will result in lower construction costs – less street length and less site grading is a cost savings to the developer and the City, for example. Others will introduce new maintenance costs which must be considered as part of the design and funding plan.

4.2 LID Site Design Process

The design of a low impact development site seeks to work with the natural hydrologic characteristics of the site. The best fit LID features will minimize the negative hydrologic impacts of development by reducing impervious surfaces and seeking to use stormwater runoff on site. LID facilities can help to reduce runoff volume, lower runoff peak flows, and/or improve runoff water quality. In order to design the LID features to be successful over the long term, it is important to involve a multi-disciplinary design team in the early stages.

4.2.1 Site Assessment

In order to know what will improve runoff hydrology, it is important to know the specific properties of the site. Soil properties, topography, existing wetlands, contributing watershed, receiving waters, existing trees, and past construction or alterations are all important factors in LID site design. General principles like minimizing clearing and grading and using drainage as a design element should be present from the beginning of the plan.

Prior to design, a full field investigation should be conducted to collect data on soils (texture, structure, colour, saturation condition, particle distribution, bulk density, nutrient content, cation exchange capacity, pH), geology (soil types, soil layer depths, groundwater elevation, groundwater quality, hydraulic conductivity), vegetation (rare plants survey and protection area delineation), and hydrology (topography, flow paths, data on precipitation, temperature, humidity and wind). This information is critical to planning plant selection, soil amendment, and infiltration rates.

4.2.2 Design and Document Submission

In addition to the regulations identified in Section 2, it is important to discuss LID plans with the Community Services department at the concept plan stage to identify the constraints that may apply to specific areas. There may be restrictions on the size and applications of LID facilities in right-of-ways due to width limitations, and limitations on road width reductions to ensure access to large service vehicles.

The Transportation and Utilities department and Parks Department will review construction drawings at the building permit stage.

The level of detail provided in planning documents for LID implementation should be consistent with the requirements for the storm sewer system in general. These requirements are detailed in the City of Saskatoon New Neighbourhood Design and Development Standards Manual: Section Six Storm Water Drainage System (City of Saskatoon, 2016).

LID intentions should be highlighted in the land use planning documents, transportation maps, and drainage plans.

4.2.3 Delineation of the Development

When planning for LID development, it is necessary to consider how the site fits into the area as a whole. Boundaries of watersheds, soil layers, and aquifers must influence design, as well as legal land boundaries. There may be servicing constraints, existing environmental contamination, or surrounding land uses that influence what is suitable for the site. There may be primary conservation lands that include non-developable river bank or other water adjacent land, wetlands identified as “preserve” in initial surveys, and steep or unstable slopes. Secondary conservation areas include existing tree stands, less intact wetland areas (identified as “manage”), historically or culturally significant sites, or sites with exceptional views of the surrounding land. Primary conservation areas may be designated “Environmental Reserve” (ER). This land may be left in its natural state or developed as a public park with regard given to why the land is environmental reserve.

What remains is the “potential development area”. *The Planning and Development Act 2007* requires 10% of a residential subdivision and 5% of other subdivisions be set aside for municipal reserve (MR). Secondary conservation areas may contribute to MR.

The following considerations will help to preserve natural hydrologic processes and minimize runoff:

- Identify protected areas (riparian habitat, stream buffers, wetlands, etc.), easements, setbacks, existing drainage, topographic features, and natural drainage features. LID works most effectively when integrated into the natural landscape.
- Preserve areas with higher infiltration areas for LID facilities – develop naturally less permeable areas, like clay soils, into required impermeable surfaces
- Set the project limits to follow natural features, topography, and hydrology
- Site bioswales at the bottom of existing slopes
- Keep building footprints small to minimize grading and clearing
- Avoid compaction and preserve natural vegetation where possible
- Site roads along natural topographic ridges to minimise soil disturbance
- If possible, zone to achieve LID design objectives. Smaller front yard setbacks can reduce imperviousness by shortening driveways and increasing lot green space.

4.2.4 Reduction of Impervious Surfaces within the Development

The Servicing Agreement with the City of Saskatoon will dictate the level of flexibility in neighbourhood layout design. Widths of roads, sidewalks, alleys, and driveways must be fixed to allow servicing and emergency vehicle access. The layout of the road network, however, allows an opportunity to minimize the paved area through different configurations.

(Canadian Mortgage and Housing Corporation, 2002)

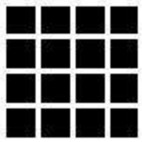
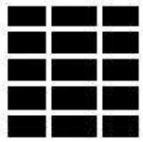
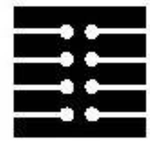
	 Square grid (Miletus, Houston, Portland, etc.)	 Oblong grid (most cities with a grid)	 Oblong grid 2 (some cities or in certain areas)	 Loops (Subdivisions - 1950 to now)	 Culs-de-sac (Radburn - 1932 to now)
Percentage of area for streets	36.0%	35.0%	31.4%	27.4%	23.7%
Percentage of buildable area	64.0%	65.0%	68.6%	72.6%	76.3%

Figure 3: Street Configurations and Pavement Length

As the paved area decreases, the area available for development also increases. Construction costs also decrease as less road is constructed; this is a simple demonstration that LID can result in cost savings rather than cost increases when applied at a systems level.

4.2.5 Development of Preliminary Integrated Site Plan

The preliminary integrated site plan will give context to the development and fine tune the LID strategies. It will ensure that the post-development hydrology is as similar to pre-development as possible. This plan will also provide construction management strategies to protect soils and vegetation to maintain the biologic, ecologic, and hydrologic function of the site.

4.2.6 Hydrology Comparison

Stormwater modelling will help identify the ideal LID methods and will also allow these methods to be supplemented with traditional stormwater management elements to accommodate stormwater for the area as a whole system. This modelling will also provide a quantitative assessment of pre-development flows. Monitoring following development can validate the model and provide feedback on the real-world performance of the LID site.

4.2.7 Construction Management

Construction management is essential to preserve soil infiltration capacity and existing vegetation, such as mature trees. If LID features are pre-planned and sited, the area can be fenced or flagged to prevent compaction. A soil management plan can ensure topsoil is restored appropriately to support vegetation plans. Restricting construction access to clearly defined routes will limit damage. Soil characteristics should be confirmed at planned LID locations to confirm soil characteristics and identify amendment requirements.

In areas with low infiltration rates, underdrains may be required. Soil characteristics can vary greatly across a development site. It is very important to design a solution specific to the installation location.

Sedimentation and erosion will clog many LID features and must be controlled in upstream locations during the construction phase.

Similarly, areas planned for vegetation preservation can be identified and flagged or fenced. Vegetation should be selected to be site and purpose compatible, involving collaboration between landscape architecture, ecology, soil science, and water engineering professionals. A Landscape Maintenance Plan should be prepared to ensure that the vegetation is properly maintained. This should include a Weed Management Plan and estimates of ongoing maintenance costs to be budgeted in the future.

4.2.8 Completion of the LID Site Plan

A LID Site Plan will summarize the findings of all assessments and modelling. The hydrologic modelling should provide justification to the planned LID facility type, location, and impacts to storm water. This site plan will also show conventional stormwater management facilities. It should show erosion and sediment controls and provide the operation and maintenance activities required over the life of the LID facility.

5 LID-BMPS OVERVIEW

5.1 LID Facility Features and Description

LID Beneficial Management Practises seek to mimic the natural hydrologic processes of absorption, infiltration, evaporation, and evapo-transpiration to manage stormwater as close to the source as possible. They also help efficiently convey excess stormwater to the receiving water body.

Through literature review, common LID-BMPs were assessed for suitability to Saskatoon's climate and physical conditions. Seven LID-BMPs were found to be promising and suitable for the local environment: bioretention and rain gardens, bioswales, green roofs, permeable pavements, box planters, naturalized drainage ways, and rainwater harvesting for reuse.

5.1.1 Bioretention / Rain Gardens

Bioretention (also called a rain garden) is directing surface runoff into a shallow landscaped depression that mimics a forested ecosystem to filter and evapotranspirate excess runoff. Bioretention is best suited to serve impervious drainage areas less than 0.8 hectares (2 acres) in size. A bioretention cell uses a filter of layered sand, soil, and organic material to allow runoff into an underdrain system that connects to the main storm sewer. In some situations, the underdrain and sewer connection can be omitted, but this requires permeable soils capable of infiltrating the runoff in a reasonable amount of time. Rain gardens are a small scale bioretention facilities usually installed on an individual residential lot. They can also apply to parks and urban spaces.

A bioretention area will appear like a conventional planting bed, but the bioretention bed uses designed, layered soils and carefully selected vegetation to capture and treat rainwater. It is located at a low point in the landscape to capture runoff naturally.

5.1.2 Bioswale

Bioswales are swaled drainage courses with gently sloped sides filled with plants, compost, and/or riprap. They are designed to be wide and allow runoff time to infiltrate into the underlying soil. A bioswale will improve water quality, attenuate peak flows, and contribute positively to both infiltration and evapotranspiration. In some situations, a bioswale may be used in place of an underground storm sewer pipe. A bioswale differs from a simple grassed swale because the constructed soil layers enhance infiltration and storage beyond what the compacted native soil of a grassed swale can absorb.

5.1.3 Green Roofs

A green roof is an installation of live plants on top of a building. It may be extensive (a thin layer of growing medium covered with a hardy ground cover plant) or intensive (a thicker layer of growing medium and with more park-like landscaping that may include shrubs or trees). Both types of green roof include several layers to ensure that the roof remains structurally safe while providing adequate support to the vegetation for growth. Green roofs reduce runoff from otherwise impervious roof surfaces and improve the water quality of the excess rainfall or snowmelt that leaves the area. They also provide an insulating layer for the building, and help combat heat island effects in the summer.

5.1.4 Permeable Pavement

There are many variations of permeable pavement: porous asphalt, porous concrete, permeable unit pavers, and open grid pavers. Permeable pavements reduce the impermeable area of the development without compromising functionality. These are best suited to low traffic areas such as parking lots or driveways. Proper construction of a permeable pavement surface will consists of four layers: permeable pavement layer, bedding layer of washed stone, reservoir layer of washed uniformly graded aggregate or a matrix of open weave boxes, and a perforated underdrain if required. Proper drainage will ensure that winter does not damage the permeable pavement.

5.1.5 Box Planters

Box planters are basically rain gardens in a container. They use layers of amended soil and carefully selected plants to filter and retain runoff water. A box planter is a more obvious structure (a box) that may be above ground or sunk into the ground. There are three categories of box planters: contained with outlet only by overflow, flow-through planters with an underdrain outlet, and infiltration planters that drain through deep infiltration. Box planters are often constructed from concrete to help contain roots and protect nearby sidewalks and foundations from root damage. They may be designed to receive runoff from downspouts or sidewalks. Box planters provide biofiltration to improve water quality, and retain some runoff in the planter to be evapotranspirated by the plants, as well as delaying peak flow.

5.1.6 Naturalized Drainage Ways

Naturalized drainage ways mimic a small creek and replace a storm sewer main with an overland flow course. They use wetland zones, grade control structures, natural materials, and vegetation to prevent erosion and convey runoff to a receiving water body or downstream pipe. They are visually appealing, provide habitat for wildlife, and enhance recreational areas. They are larger than simple grass swales and more engineered than natural wetlands. They manage flow velocities by design and encourage evaporation and transpiration along the flow path. Naturalized drainage ways may be sited along property lines, utility right-of-ways, or within parks. Infiltration is typically minimal because of saturated soils or connection to the groundwater table.

5.1.7 Rainwater Harvesting for Re-use

Rainwater harvesting is simply collecting rainwater runoff in a container and then re-using it in other applications, such as irrigation or toilet flushing. It may be as simple as a rain barrel used to water a flower bed, or more complex large scale cisterns connected to bus wash facilities. This is most effective in reducing runoff flow volumes in small rainfall events, as once the container is full there is no longer any effect. It also relies on the user emptying the container between rain events.

5.2 Performance of LID-BMPs

LID-BMPs use natural hydrological processes to mitigate the effects of urbanization on surface runoff. They can reduce runoff volumes, lower runoff peaks, and improve water quality.

The first stage of treatment removes particulates by filtering runoff through vegetation and infiltration through mulch and soil. Microbes in the soil will help decompose pollutants like hydrocarbons and excess nutrients. Soils will allow metals and chemicals to attach to soil particles, preventing their release into the river. This initial filtration improves the runoff water quality and captures pollutants on site, where they originate. The following table shows the observed removal efficiencies of LID-BMP facilities for pollutants of interest.

Table 3: Observed Removal Efficiencies (%) in LID-BMP Facilities in the USA and Canada

Pollutant	Bioretention/ Rain Garden	Vegetated Swale[1]	Box Planter/ Green Roof [2]	Permeable Pavement[3]	Naturalized Drainage Way [4]
Annual Runoff Reduction	50-90	40-80	45-60	45-75	
Total Suspended Solids	59-90	65-81	86	85-89	80
Hydrocarbons	87-97	65-90		70-90	
Metals	80-90	20-50		35-90	40-70
Total Phosphorus	5-65	25	59	55-85	20
Total Nitrogen	46-50	15-56	32	35-42	40
Bacteria		Negative	37	40-80	

[1] Grassed swale monitoring

[2] Filtering style

[3] Infiltration style

[4] Wet swale monitoring

(Center for Watershed Protection, 2007a) (Claytor, 1996) (Toronto and Region Conservation, 2010) (Shaffer, 2009) (Nicole David, 2014)

Reductions in runoff volumes will be seen in LID-BMPs that include infiltration or evapotranspiration. Water that moves down into the deep soil or up into plants and atmosphere does not enter the storm sewer system.

Lower runoff peaks result from LID-BMPs that include a storage component. Water will flow into the facility and experience a delay in exiting the facility. This means that the runoff will enter the downstream system offset from the peak in the rest of the system, and the peak flow will be smaller as the release flow is spread over a longer time period.

5.3 LID Benefits and Costs

5.3.1 LID Benefits

The benefits realized from LID-BMPs will be present in proportion to the scale of the project. Some benefits have a direct monetary value, while some are intangible improvements to the area. Cost savings created by LID include lower runoff treatment, lower TSS, air pollutant removal, energy savings, and reduced potable water use.

The benefits of LID include:

- Reduced runoff volumes: LID will increase interception, infiltration, filtration, storage, and detention.

- Reduced flooding: A watershed level plan that uses LID can reduce overall urban runoff volumes and reduce flooding risk.
- Improved water quality: as noted previously, LID facilities can filter, absorb, and biodegrade pollutants as water moves though.
- Increased groundwater recharge: Increasing infiltration directs runoff into the water table rather than into storm sewer pipes.
- Reduced salt application: Permeable pavements ice up less than traditionally paved areas, and so demand less de-icing chemical treatment. This reduces input costs and pollution in runoff.
- Reduced energy use: Increasing vegetated space decreases ambient temperature in the hot summer months. Green roofs reduce roof surface temperatures and decrease cooling costs, as well as adding an insulation layer that decreases heating costs. Rainwater harvesting saves energy by reducing potable water use – this saves the treatment and transport energy required to deliver potable water used for non-potable purposes.
- Reduced water bills: Installations of rainwater harvesting can provide free water to be used in place of metered potable water for irrigation, washing, or toilet flushing.
- Improved air quality: increasing vegetated urban area helps improve air quality.
- Reduce urban heat island: Permeable pavements absorb less heat than traditional pavement, and vegetated areas use evaporative cooling to reduce ambient temperature.
- Improved aesthetics and property values: Many LID facilities are attractive and provide open space to adjacent lots.
- Improved urban habitat: LID can provide valuable urban wildlife habitat and improved habitat connection
- Reduced cost of downstream stormwater infrastructure: LID designs can reduce the amount or size of traditional infrastructure. By eliminating controls such as curb-and-gutter or decreasing the required size of large pipes and ponds, the overall project cost for developing by LID principles can be the same or even lower than traditional development costs.

5.3.2 Life Cycle Costs

One of the top questions when discussing LID is "does it cost more?" This is a complex question, in that the costs and benefits should be considered on a system and lifetime level rather than on the stand-alone construction of a project. It can be helpful to conduct a life-cycle cost assessment over a long time frame (e.g. 50 years) to fairly compare traditional and LID options.

In Toronto, the Sustainable Technologies Evaluation Program (STEP) has worked to provide analytical tools to support LID implementation. In their 2013 report, *Assessment for Life Cycle Costs for Low Impact Development Stormwater Management Practices,* STEP examined a variety of LID approaches over 50 year life cycles. They found that the least expensive LID facilities by upfront costs are infiltration chambers and trenches (not explored in this document as the local soil conditions and water table do not favour these methods), bioretention, and bioswales. Rainwater harvesting offers additional savings by reducing metered potable water use. Permeable pavements are some of the more expensive LID facilities to implement, but function as stormwater storage and treatment as well as a parking surface and replacement for the oil-and-grit separator required by conventional design. Green roofs are the most expensive option, as they require careful design and implementation on a difficult to access location. The primary advantages of a green roof that lead to its construction are not accounted for in the life cycle cost method: aesthetics, biodiversity, and energy savings.

The STEP report compared a conventional asphalt parking lot with oil grit separator to the same area designed with LID practices and found that the life cycle costs were similar. If a value was applied to the storm water treatment benefits, the LID practises were 35-77% less than the conventional design. (Toronto and Region Conservation, 2013)

The findings of STEP reinforce previous calculations by organizations such as the USEPA in 2007, which found that 11 of 12 green infrastructure projects had lower total costs than conventional design due to savings in site grading, stormwater infrastructure, curb and gutter, site paving, and water treatment costs. (United States Environmental Protection Agency, 2007)

LID can lower costs at a system level. Decreasing requirements for detention pond volume and storm sewer main sizes requires a widespread application of LID facilities in series, and an adherence to the operations and maintenance required of those facilities to ensure they continue to function. In addition, the property owner will see a lower stormwater utility bill.

6 LID-BMPS FACILITY DESIGN

This section provides general design advice for LID-BMPs in the Saskatoon area. The design parameters assume that soils have fairly low infiltration rates and that winter snow accumulates and melts in the spring. Cold climate adaptations are an important part of LID-BMP design, and the use of sand, salt, and other de-icers must be considered. Each site has its own specific situation and characteristics, and so each site will require a specific design to ensure success. A pre-design site investigation is required to characterize the local soil and topography conditions.

6.1 Vegetation Selection and Planting

Vegetation provides several functions in LID-BMP facilities, including using water through evapo-transpiration, stabilizing soils through root development, slowing water flow in channels, and improving aesthetics in green urban spaces. The selection and survival of the plants installed is very important to ensure the LID design facility well.

Native vegetation is recommended where appropriate. There are also many ornamental trees, shrubs, bulbs, ornamental grasses ,and perennials that can be suitable and successful in specific LID applications. All plantings – native and other species – will require an establishment watering plan for the first one or two growing seasons. Non-invasive species must be selected.

There are two common scenarios in LID facilities to consider when selecting plants: well-drained soil that is periodically inundated, and poorly-drained soil which is moist to wet for most of the growing season. The soil types and expected water conditions must be considered to select plants that will thrive in each condition.


Figure 4: Yellow Coneflower, rain garden appropriate native plant

Plant selection can provide "visual marketing" to achieve public support for LID projects. It is important to choose plants that will be attractive and avoid negative perceptions of being "weedy" or uninteresting.

Factors that should be considered when selecting vegetation include:

- Plants that will thrive in the specific site conditions (climate, soil, water availability) and that grow well together with minimal life cycle cost
- Base selections on mature plant size to ensure adequate spacing.
- Maintenance requirements (mowing, pruning)
- No irrigation and minimal fertilizer needs after establishment
- Pest resistance
- Tolerance to salt and hydrocarbons from road runoff, depending on facility location
- Pollutant uptake capacity: nitrogen dioxide, sulfer dioxide, and ozone
- Vertical integration of plant canopy: ground cover, grasses, bulbs, perennials, shrubs, and trees
- Trees should be selected with consideration to rooting zone (deep roots are desirable unless foundation damage could be an issue), branching patterns, and mature size
- A written landscape maintenance plan should be provided to the property owner, and the project budget should include extra funds for care during vegetation establishment. A full plan will include directions for pre-planting, planting, post-planting, ongoing care, and weed management.

Landscaping should require minimal care where ever possible: naturalized, no mow, and native species.

6.2 Soil Management and Amendment

6.2.1 Soil Management

In order to maintain soil permeability and infiltration, compaction during construction should be minimized or mitigated. If the LID-BMP site is designed in advance of construction activities beginning, it can be marked and avoided by heavy equipment if possible. If this cannot or did not occur, it is recommended to:

- Loosen subsoil to a depth of at least 150 mm in areas without compaction and 300 mm in areas with compaction
- Remove all subsoil material exceeding 50 mm in diameter
- Cover loose and friable subsoil with 300 mm of topsoil for grass and 450-600 mm of topsoil for shrub beds.

Compacted soil impedes water entering into the ground, as well as slowing plant growth and lowering plant health.

6.2.2. Soil Amendments

Soil amendments such as organic matter, fertilizer, or compost are often required to achieve the optimal soil conditions for vegetation growth and target infiltration rate.

If adding compost, the type, source, and decomposition stage are important. If surface infiltration is being encouraged to groundwater or an underdrain in the LID facility, compost from animal manure is not recommended because of its high nitrogen and phosphorus content. Organic compost must be entirely decomposed with no recognizable components to prevent denitrification, weed growth, bacterial contamination, and nutrient leeching from amended soils.

Amendments may be added to achieve specific hydrologic or pollutant mitigation site targets. Gypsum compost can help to mitigate de-icing salts by providing calcium ions to reduce exchangeable sodium ions. It also adds sulfur and calcium – which help plant growth – without altering pH.

Compost amendments can help increase aeration, percolation, water-holding capacity, and nutrient availability. The amount should be determined to harmonize with the type of topsoil and the subsoil beneath it. The target amended soil for most LID purposes will be a loamy sand or sandy loam with 10-30 ppm of phosphorus, a cation exchange capacity of 10 meq/100g, particle size under 50 mm, pH between 6.0 and 7.5, and a saturated hydraulic conductivity of over 25 mm/hour.

To achieve this, compost should be added at the following ratio to the native soil type:

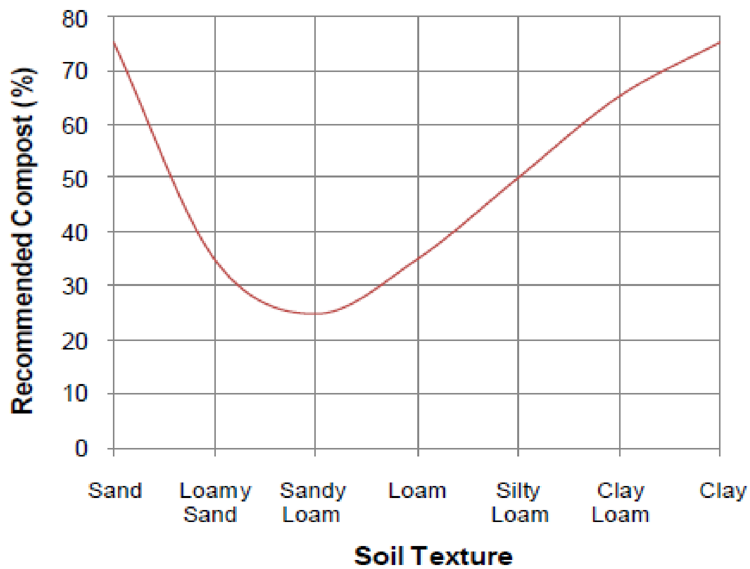


Figure 5: Compost Amendment Ratios for Topsoil and Subsoil Types (Drainage Services, 2014)

A wide range of soil types are present in the Saskatoon area. The amendments required will be very specific to the site and LID facility plan.

6.3 Cold Climate Considerations

The Saskatoon climate presents several design challenges, but does not prevent implementation of LID facilities. Winter must be part of the design from the initial design phase.

Table 4: Design Challenges of Cold Climates (Drainage Services, 2014)

Cold Climate Characteristic	LID Design Challenge
Cold temperature	• Pipe freezing • Reduced biological activity • Reduced settling velocities • Ice-jamming of drainage path and spring runoff accumulation
Deep frost line	• Frost heaving • Reduced soil infiltration • Pipe freezing
Short growing season	• Short time to establish vegetation • Plant selection to fit local climate
Significant Snowfall	• High runoff volumes during snowmelt and rain-on-snow events • High pollutant load in spring melt • Impacts of road salt/ de-icers • Snow management affecting facility storage • Weight of snow piles causing soil compaction

6.3.1 Managing and Designing for Road Salt Applications

Road salt will alter the soil, impairing vegetation growth and decreasing permeability. At high concentrations, soil problems such as swelling, crusting, erosion, and dispersion may be seen. Salts also increase the bio-availability of heavy metals by allowing them to become water soluble in soils. Soil microbes that provide beneficial effects in pollutant breakdown, soil structure, and permeability can also be damaged by high exposure to salts.

Figure 6: Bearberry, salt-tolerant native plant (Dutch Growers, 2016)

Plants may be selected to be more salt tolerant for plantings in areas where salt loading is anticipated.

Salt concentrations are highest in spring snowmelt. The maximum winter loading of chloride into a roadside LID facility planted with salt tolerant grasses is 1000 mg/L. (Drainage Services, 2014) It should be noted that magnesium chloride is as harmful to trees, plants, and soils as other de-icing salts and should be managed carefully to minimize impact on local vegetation.

6.3.2 Managing and Designing for Road Pollution

Traffic on roadways creates pollution. Gasses such as nitrogen dioxide, sulfur dioxide, and ozone can cause health and quality of life issues for residents and wildlife. Hydrocarbons can move from roadways into the surrounding areas and waterways via runoff. Areas receiving water from roadways or parking lots can be expected to contain some hydrocarbons. Plantings in these areas should use plants known to tolerate and remediate hydrocarbons. Preferred species include:

Figure 7: Glycyrrhiza lepidota (American Licorice) (Lavin, 2006)

- Grasses: Agropyron pectiniforme, Bromus inermis, Phleum pratense, and Poa pratensis
- Legumes: Medicago sativa, Melilotus officinalis, and Trifolium repens
- Native forbs: Artemisia frigida and Potentilla pensylvanica
- Native grass: Bromus ciliates
- Native legumes: Glycyrrhiza lepidota and Psoralea esculenta (Robson DB, 2003)

6.3.3 Managing and Designing for Sand and Gravel Applications

LID facilities that have filtration or infiltration components will clog if runoff containing anti-skid material like sand is washed directly into them. Adding a pre-treatment component such as a vegetated buffer strip, settling basin, or fore bay will help remove the sand before the water enters the filtration/ infiltration zone. These pre-treatment zones will require regular maintenance to remove silt and sand. Siting LID facilities away from areas where sand is applied may also be an option.

6.3.4 Recommendations for Saskatoon

6.3.4.1 Design Adaptations

Incorporating cold climate adaptations into local LID-BMP design can provide treatment to spring melt runoff water. Through careful siting and selection of appropriate LID facilities, good results can be seen in in all aspects of LID: improving water quality, decreasing runoff volumes, and lowering peak flows.

The following adaptations will help ensure the expected outcomes from a LID-BMP project:

- **Careful site selection:** Infiltration and filtration facilities should be sited away from zones where high concentrations of pollutants and sediments are unavoidable. If space allows, pre-treatment (forebay) or straining (vegetated buffer strips) will improve longevity and effectiveness for infiltration or filtration facilities.
- **Careful plant selection and placement:** Use more salt and pollutiontolerant plants to buffer less salt and pollution tolerant plants. Choose plants that tolerate the local climate; look at native species first.

- **Adapted application of sand and salt:** If possible, reduce application of sand and salt in the upstream area and be aware that snow storage on top of the facility will introduce grit that may clog the LID facility.
- **Vegetated filter strips:** Along roadways, install vegetated filter strips to help remove sand and gravel from runoff before it gets to the LID facility. Effective filter strip width will depend on the type of roadway and the amount of anti-skid material applied there. It will range from 5 – 35 m.
- **Planned snow storage zones:** Plan for winter and have a designated area to accumulate snow, especially dirty snow with sand, gravel, and pollution in it. Direct meltwater from this area into treatment facilities. **Note:** Bioretention or rain garden facilities located on centre medians or corner beds are in spaces normally used for snow storage. Alternate snow storage needs to be included in the design, as the melt water from roadway snow will harm these planted areas. This runoff is high in salt, sand, gravel, hydrocarbons, and other pollutants.
- **Planned street maintenance**: Street sweeping should occur promptly after snow has melted to remove dust, sand, and gravel from the adjacent streets and boulevards.
- **Directing polluted snow melt away from LID facilities:** Again, if possible locate snow storage so it can melt without damaging pollution sensitive plants and without clogging soil pore space. Use a vegetated swale or direct this melt into the traditional storm sewer system.
- **Size facilities for snow melt volumes:** If flooding will be a safety issue, size the facility by snow melt volume rather than by rain events. Alternately, have an overflow plan to accommodate overflow from large events or snow melt.
- **Enlarge curb cuts:** Ice and snow may block inlets designed for warm climates.
- **Avoid crosswalks and sidewalks:** Site LID facilities away from crosswalks and sidewalks if possible to prevent problem icing during the spring melt.

6.3.3.2 Operations and Maintenance

The long term operation of LID facilities requires avoiding contamination of the snow where possible. Methods to achieve this include:

- Minimizing use of de-icing and anti-skid materials to only what is required
- Improved application technology on sanding trucks (brine wetting, direct roadway application, etc.)
- Avoiding toxic salt additives (eg. Cyanide)
- Store and mix chemicals in a covered area
- Route melt water to appropriate treatment facilities
- Rapid, regular street sweeping immediately after snow has melted from roadway
- Litter control
- Erosion control

Clean snow storage should be above permeable surfaces to allow some runoff filtering. If soil is highly impervious, or if the snow has known high levels of salt, sand, and/or pollutants, it is best stored over asphalt or concrete so that melt water may be directed into a treatment facility. LID systems can be used to filter snow storage melt water if sand is settled out before water enters the filter.

6.4 LID Facility Design Process

After the available site(s) and potential LID facility type(s) have been identified, the facility design begins. There is no “one size fits all” solution to LID facility design; each design will be location specific.

The following factors will shape LID facility design:

- **Available space.** Many facilities require significant open space. Existing hydrologic functional spaces should be maintained or enhanced if possible.
- **Soil properties.** Infiltration and water bearing capacity of the existing soil profile should be identified. If necessary, soil remediation should be planned. Sub-drains should be installed if infiltration rates are low.
- **Slopes.** Gentle to moderate slopes are ideal for small scale LID facilities. Designs can be adapted for steeper slopes, or grading can be adapted to direct runoff appropriately in flat areas.
- **Depth to groundwater table.** The facility base for bioretention, rain gardens, bioswales, and naturalized drainage ways should be at least 0.6 m above the seasonal high water table.
- **Foundations and underground utilities.** These structures do not perform well if saturated; bioretention, rain gardens, and bioswales should be located far enough away to keep water from damaging foundations and utilities.
- **Constructability**. Design of a LID facility should consider equipment restrictions, local knowledge, etc. to ensure it can be built as designed.
- **Operation and maintenance.** The design should account for O&M requirements going forward and provide a clear outline to the owner for ongoing support required.

6.4.1 Facility Selection

After the available space and site properties have been defined, the type of facility should be selected to provide the desired outcome. The main benefits of LID are stormwater volume control, stormwater peak flow control, and improved water quality. The following table summarizes the benefits of each type of LID facility and the land uses where they are most suitable. The table assumes that the soil is clay with low infiltration rates; in areas with soil more favorable to infiltration, there may be more available options.

Table 5: LID Facility Selection

	Management Objective			Land Use								Cold Climate	Area Req
Type	Vol	Peak	Quality	School	Comm	High Density Urban	Indust	Single Family Res	Multi Family Res	Parks	Roads		
Bioretention/ Rain Garden	●	●	●	●	●	◒	○	●	●	●	●	●	◒
Vegetated Swale	◒	◒	●	●	●	○	●	●	●	●	●	●	◒
Green Roof	◒	●	●	●	●	●	●	○	●			◒	●
Porous Pavement	●	●	◒	●	●	●	◒	●	●	●	○	○	●
Box Planters (Inf)	◒	◒	●	◒	●	●	○	●	●	●	○	◒	●
Naturalized Drainage Way	○	◒	◒	◒	◒	○	◒	◒	◒	●	●	●	◒
Rainwater Harvesting	◒	○	○	●	◒	●	◒	●	●	◒	○	○	●

Symbol	Legend	Effectiveness in Meeting Objective	Land Use / Cold Climate Suitability	Land Area
●	**High**	Primary functions of this facility meet this objective.	Well suited for land use / cold climate	Small relative area required.
◒	**Medium**	Partially meets management objective and should be used in series with other facility types.	Possible for land use/ cold climate	Moderate relative area required.
○	**Low**	Facility does not address management objective well and should be combined with other facilities if the objective is important in this location.	Difficult to adapt for this land use / cold climate	Large relative area required.

(Drainage Services, 2014)

6.5 Hydrological Analysis

LID facilities will be part of a storm water system, but are not intended to entirely replace conventional sewer and pond systems. LID works most effectively on small, frequent rain events that are under a 2-year return period. This means that most of the rainfall in a year will pass through the LID system.

When conducting the system hydrological analysis, LID requires more attention to abstraction potentials. Abstraction potential is the runoff retained on the landscape through storage and infiltration. Antecedent soil moisture conditions – how dry the soil was before the rainfall – is also of greater importance when considering small rain events. Continuous simulations are recommended to assess performance of systems designed to accommodate small rain events. Computer models are used at the discretion of the designers; the City of Saskatoon uses XPSWMM and can only review submissions in this format.

Most rainfall events (92% of events measured in the past between 2012 and 2016) are less than a 2 year storm. Treating these small events on-site through low impact development means that most rain events do not contribute pollution or volume to the storm sewer system.

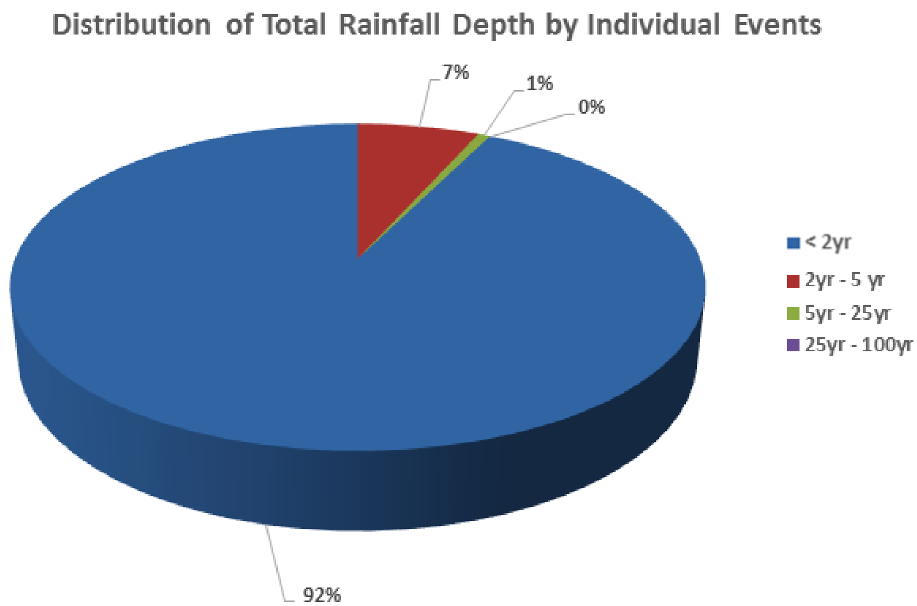


Figure 8: Distribution of rain events over 1 mm, 2012-2016

The “water quality capture volume” represented by a rainfall depth (e.g. the first 25 mm) provides a practical target for LID design. While conventional storm water infrastructure is still required to manage large events, 99% of rainfall events measured in Saskatoon between 1900 and 2016 are under 25 mm. If the first 25 mm of runoff are managed on site, most events will be entirely contained by LID facilities. This keeps pollutants close to their source and provides local treatment.

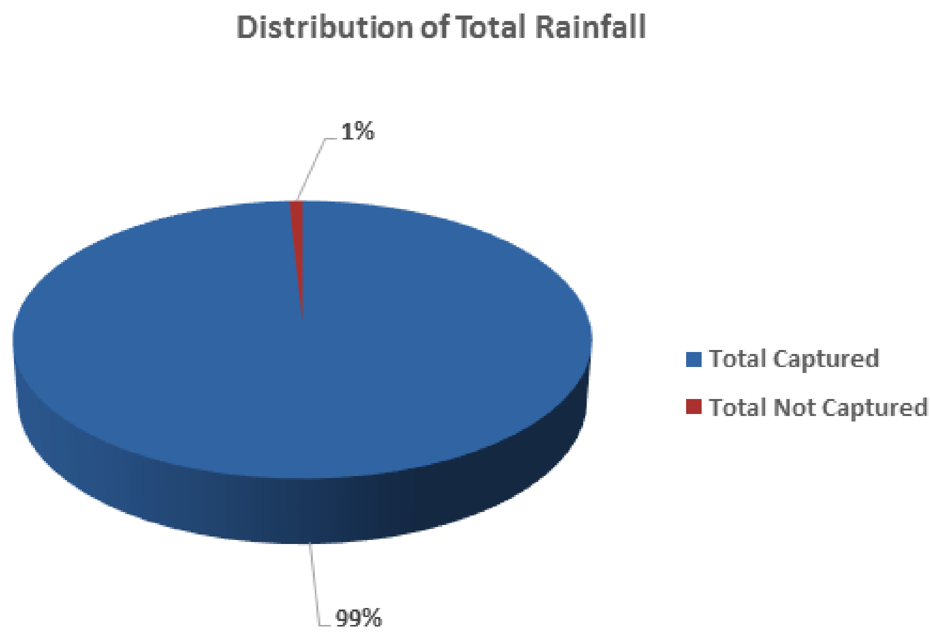


Figure 9: Rainfall events captured by 25 mm LID containment

6.6 Site Monitoring

There are many types of sensors available that can monitor a LID-BMP facility to ensure that it is having the desired effect. Monitoring can consider precipitation, outflow, and water quality. Equipment suppliers will be able to provide advice on the best currently available product to meet the needs of each project. Monitoring is generally not a requirement, but a project owner may choose to add monitoring if a quantification of the effects of LID is of interest.

6.6.1 Precipitation

Precipitation may be estimated from local rain and snow measurements, or a site-specific weather station may be deployed to provide more specific data. The City of Saskatoon operates eight rain gauges across Saskatoon and collects rainfall data that provides a strong picture of rain across the city.

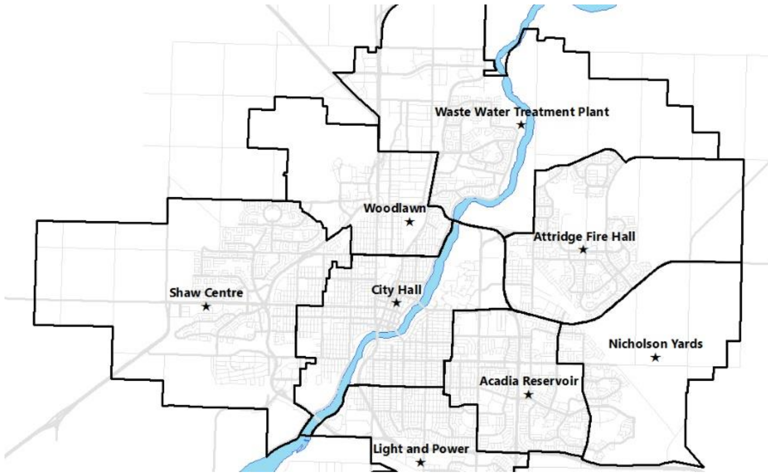


Figure 10: City of Saskatoon Rain Gauges

6.6.2 Flows

Measuring flow into a LID-BMP facility is difficult because it may enter as sheet flow or from numerous directions. Inflow volume can be most effectively estimated from measured precipitation and the catchment area.

Outflows can be measured by using a flow sensor, either permanently or semi-permanently installed. Doppler or ultrasonic sensors are best suited to this application. Outflow should be measured at the outlet pipe from the facility, treatment train, or site. This information will help to provide a real-life comparison to what was modelled prior to construction. If considerable topsoil amendments have been applied throughout the site to increase absorption, the standard modelling methods may over estimate runoff into the facility. All outflow reductions as compared to the conventional development state established in the model should be attributed to the LID improvements.

6.6.3 Water Quality

Water quality monitoring in field applications of LID-BMPs is challenging. Flow inputs are often sheet flow rather than point source, which makes it difficult to sample the quality of water inflow.

Total Suspended Solids (TSS) is a pollutant measurement that is often regulated. Nutrients are also becoming more of an issue as downstream algae and aquatic plant growth impact oxygen levels and fish health downstream. Water quality sensors, or sondes, can measure turbidity, nutrients, and temperature with options to add other parameters. They may be used for point measurements or ongoing logging. Data loggers can be used to record both water quality and quantity measurements. These loggers can be connected via cellular or satellite connection if desired for ease of download.

6.6.4 Optional Parameters

Other parameters that may be of interest and can be measured if desired include:

- Soil moisture

- Water depth in reservoir layers of infiltration facilities
- Pump recorder for irrigation systems
- Water quality autosampler triggered by storm events
- Heated rain gauge to monitor snow water equivalents
- Manual infiltration measurements as spot checks to determine long-term soil capacity

7 BIORETENTION / RAIN GARDENS

7.1 Description

Bioretention may be used in:

- Parking lot islands
- Parking lot edges
- Road medians
- Roundabout landscaping
- Cul-de-sac centres

Bioretention cells and rain gardens use plants and soils to filter stormwater and reduce runoff volumes through infiltration, evapotranspiration, and evaporation. This process mimics the effect of a forest floor on runoff quality and quantity. A depression collects the surface runoff and directs it into layered absorbent soils that are planted with appropriate plants to handle the imposed wet/dry cycle. Bioretention facilities are precisely designed to process a specific volume of stormwater and may include control structures such as under-drains, catch basins, overflow drains, and check dams or weirs. They are most commonly installed on commercial properties or in public right of ways. Rain gardens are smaller and are a more generic solution of layered soils and selected plants, where excess water usually exits by an above-ground overflow. (Drainage Services, 2014)

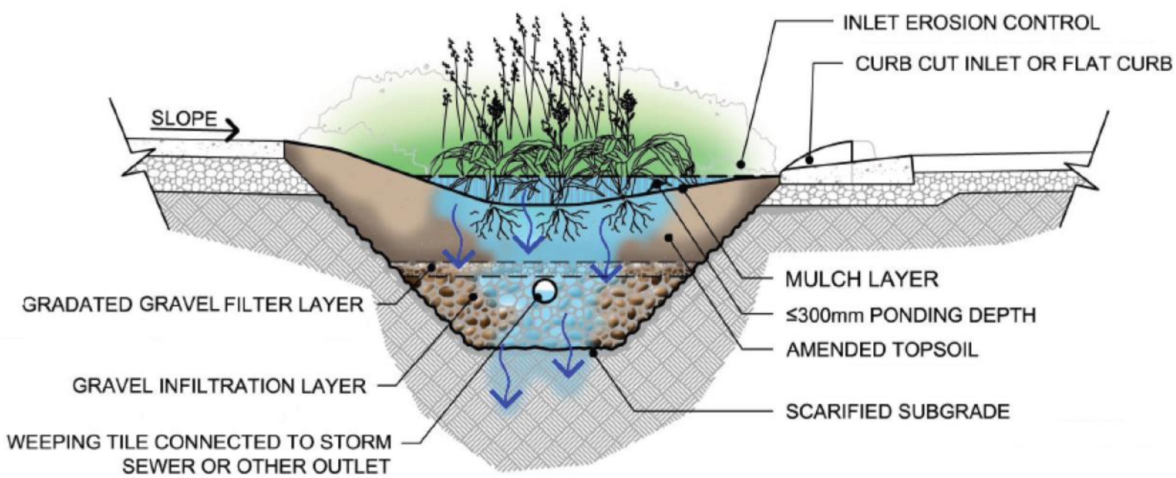


Figure 11: Cross-Section of a Basic Bioretention Area (Drainage Services, 2014)

7.2 Application

Bioretention facilities are located near where runoff occurs. For example, they are constructed near parking lots, in traffic islands, and near building roof leaders. They are suitable for new construction and retrofit projects. Ideal site slope is between 1% and 5%. Bioretention facilities should not be planned in areas that would require removal of mature trees.

Enhanced infiltration may be part of the design if desirable. This requires permeable soils, a seasonally high groundwater table at least 0.6 m below the facility bottom and a low risk of contaminated runoff. Soils other than well drained sands and gravels require an underdrain. (BIORETENTION, n.d.).

Figure 12: Cul-de-sac Rain Garden in Evergreen

7.3 Design Considerations

Bioretention facilities take up approximately 5% of the area served (Stormwater Management Fact Sheet: Bioretention, n.d.), but are generally located in spaces that benefit from landscaping with or without bioretention. They are best for small sites (under 2 hectares), as they tend to clog if used for a larger drainage area. Multiple bioretention facilities may be incorporated into a large project, such as a parking lot.

7.4 Operation and Maintenance

The operation and maintenance of a bioretention facility is similar to any landscaped property feature.

Table 6: Typical Maintenance of Bioretention Systems

Activity	Schedule
• Remulch void areas • Treat diseased plants	As needed
• Water plants daily for two weeks	At project completion
• Inspect soil and repair eroded areas • Remove litter and debris	Monthly
• Remove and replace dead and diseased vegetation	Twice per year
• Add additional mulch • Replace tree stakes and wire	Once per year

(Stormwater Management Fact Sheet: Bioretention, n.d.)

7.5 Limitations

- Cannot treat large areas and will require many small facilities distributed throughout a development to influence overall runoff volume.
- Sediment clogging is a common issue and pre-treatment may be required, especially adjacent to roadways where anti-skid material is used.
- Require 5-20% of the catchment area.
- Use in parking lots will reduce available parking spaces.
- Project-specific design required to ensure timely draining to prevent mosquito issues.
- Construction costs may be high compared to conventional design.
- Regular maintenance required to preserve functionality.

8 BIOSWALES

8.1 Description

Bioswales work well beside roadways or in parks. They are an enhanced open ditch.

Bioswales are engineered drainage paths designed to improve water quality. They have gently sloped sides (less than 6%) and use vegetation to increase retention time and to trap silt and pollutants before they are flushed to the main storm sewer system. This also helps reduce peak flows downstream. Bioswales are an alternative to curb and gutter infrastructure and are often located in parking lots, alongside residential roads, or in parks. Dense vegetation in the bioswale captures particulates, slows flow velocity, and encourages infiltration and evapotranspiration to reduce volumes.

Figure 13: River Landing Bioswale

8.2 Application

Bioswales are particularly well suited to receive roadway runoff because they are linear. They are often constructed in utility right-of-ways or in existing ditches. Improving a ditch from its conventional design into a bioswale will enhance infiltration and pollutant removal. A bioswale can be an aesthetically appealing element of a development that provides additional green space and improves local biodiversity.

8.3 Design Considerations

Bioswale design is an infiltration-dependent practice. An effective design with low maintenance will require considering many parameters: groundwater elevation, area of drainage basin, imperviousness of drainage basin, and size and slope of the swale. Ideal conditions for a bioswale will involve a contributing area of less than 4 hectares and a basin slope of less than 5%. The swale will require an area of approximately 1% of the area served by it. If the design area is larger than 4 hectares, it may be divided and serviced by several bioswales.

Depending on soil conditions, a reservoir layer of larger rocks and a perforated drain pipe may be required at the bottom of the bioswale to transport excess water. Plants in the bioswale may be grasses or other hardy, low maintenance species. A bioswale has three zones requiring appropriate plant selection: highest (xeric), middle (mesic) and lowest (hydric). The bottom of the bioswale needs to tolerate some standing water and fluctuating water levels. The middle zone will be occasionally temporarily submerged. These plants are on the side slopes and will be responsible for preventing erosion. The highest zone should tolerate drier conditions.

The following table outlines the relevant design parameters for a bioswale.

Table 7: Bioswale Design Parameters

Design Parameter	Description and Recommendation
Infiltration Rate	≥13 mm/hr, no underdrain required; underdrain required if infiltration rate is <13 mm/hr and with longitudinal slopes under 1%.
Inlet Design	Grass filter buffer (2m – 30m) upstream of overland entry to swale; filter strips to buffer salt: 3-5m along collectors, 5-35m along arterials.
Design Discharge	Flow contained in swale for 2, 5, 10, 25, and 100 year rain events
Overland Flow Velocity	Use Manning's Equation to account for soil type and vegetation; ensure velocities are non-erosive for 10, 25, and 100 year rain events.
Outlet Release Rate	From underdrain or catch basin lead; must meet targets of matching pre-development flow if such a target has been identified.
Flow Depth	≤0.3 m in a 2 year rain event
Media Layers	Growing media/topsoil: >300mm; Filter layer: (<13mm clean gravel with <0.1% silt) 100mm depth; Infiltration/storage layer: (<40mm clean gravel with <0.1% silt) 450mm depth
Underdrain	Required if site longitudinal slope is <1%, if salt load will be high, or if infiltration rate is under 13 mm/hr; use 200 mm perforated pipe
Overflow Drain	Required to keep ponding depth at designed high water level. This is generally between 150 and 300 mm.
Vegetation	Grass and dense vegetation (100% coverage at establishment – 2-3 years); turf grass recommended on slopes >0.5%. Weed control essential in establishment phase.
Water Surface Elevation in Design Storms	High water level at 2 year and 100 year design rain event does not compromise adjacent structures
Captured Volume	Volume of water retained through ponding or infiltration during the 2 year design rain event; additional volume captured during larger events if applicable
Emptying Time	Duration of ponded water following a 2 year rain event is <24 hours
Surface Area	10-20% of contributing impervious area; determined through continuous modelling; facility to be sized based on snowmelt volumes and salt loadings as required
Geometry	Trapezoidal or triangular
Facility Width (surface)	0.6 – 2.4 m width
Side Slopes	4:1 preferred, max 3:1
Longitudinal Slope	Flat enough to maintain non-erosive velocities in a 10 year rain event – typically 0.5% - 1.0%. Use grade control structures if necessary.
Groundwater Buffer	Bottom of facility at least 1 m above groundwater table
Structural Buffer	Located at least 3 m from building foundations

Other elements may impact the design of a bioswale, such as avoiding mature trees in the design space, anticipating ice issues and sizing ponding capacity to avoid sidewalks, providing curb cuts that direct inflow to the bioswale, salt tolerant plants and/or a filter strip to help shelter the bioswale from de-icing compounds, and compaction to soils from piling snow on the bioswale.

The figures following show the cross section and longitudinal profile of a bioswale.

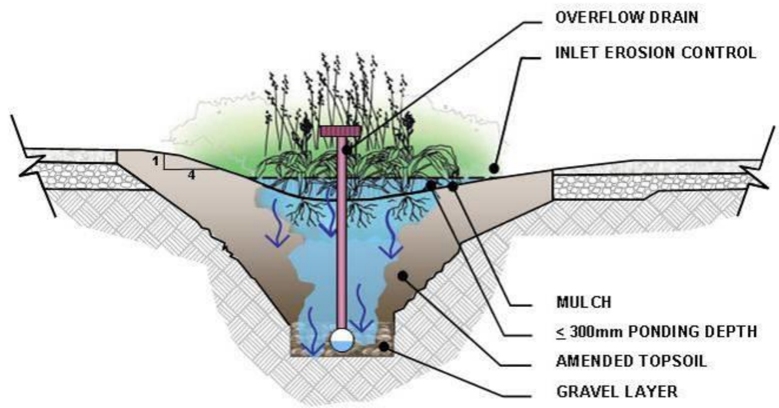


Figure 14: Cross-Section of a Bioswale (Drainage Services, 2014)

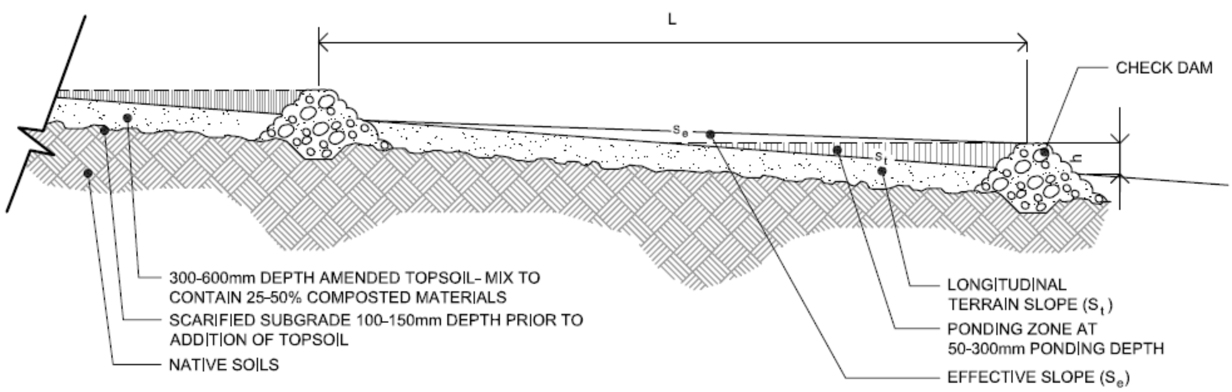


Figure 15: Longitudinal Profile of a Bioswale with Check Dams (Drainage Services, 2014)

Check dams may be used to reduce the effective slope to allow a bioswale to be effective where natural slopes exceed the ideal design slope.

8.4 Operation and Maintenance

Erosion is a concern for bioswales. Deeply rooted plants and a gentle slope will help avoid erosion. Reseeding or replanting may be required in the establishment phase if there are gaps in the vegetation. Bioswales should be inspected at least once a year, after the spring runoff when vegetation has had a chance to begin growth. Inspections should also occur after any event with greater than 25mm of rain. During inspections, dead plants and debris should be removed. The inlet and outlets must be cleaned to ensure water can enter and exit the bioswale as designed. Ponding time should not exceed 24hours. Regrading, tilling, or replanting may be necessary if water is not draining quickly enough.

During the establishment of vegetation, watering will be required to ensure plant survival. Weeding will also be necessary until the desired plants are established. This period of more intensive care will last for at least 2 years. Street sweeping of adjacent streets will help prevent sedimentation and clogging. Hand removal of litter is required seasonally.

8.5 Limitations

- If slopes and vegetation are not properly installed, it will not function correctly to remove sediment and pollutants.
- Cannot treat large areas and will require many small facilities throughout a development to influence overall runoff volume
- Difficult to install along roads with many driveway crossings
- Limited removal of phosphorus and bacteria
- Higher maintenance than curb and gutter
- May be damaged by off-street parking or snow removal operations

9 GREEN ROOFS

9.1 Description

A green roof is a roof of a building partially or completely covered with vegetation and a growing medium. The green roof retains some rainfall and delays runoff peaks. Typical layers of a green roof from outside to inside are: vegetation, growing medium, drainage filter, drainage layer, root barrier, waterproof membrane, cover board, insulation, vapour barrier, and building structure.

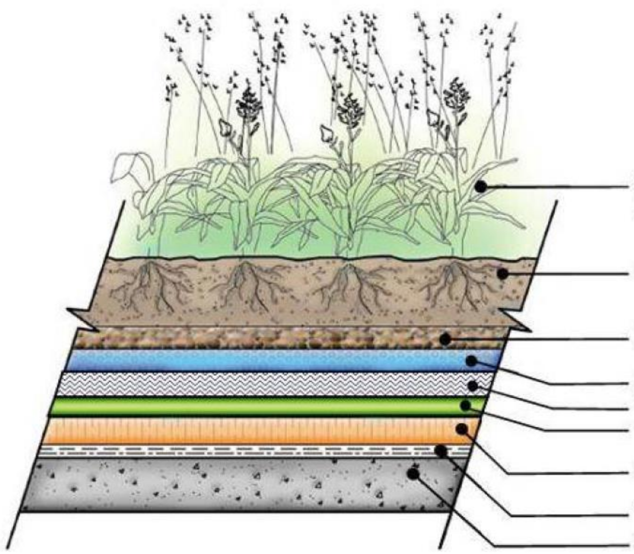


Figure 16: Green Roof Cross Section (Drainage Services, 2014)

Green roofs will retain rainfall based on the depth of the growth medium and roof slope, but can retain 70-90% of the annual rainfall that lands on them (Perry, 2003). They also provide additional insulation effects that can decrease heating and cooling costs. The evapo-transpiration of the plants also helps lower the temperature of the surrounding air. Green roofs also provide urban habitat for birds and insects.

Figure 17: College of Law Addition Green Roof, Saskatoon

Green roofs may be “extensive” – the typical design for storm water purposes – or “intensive”. Intensive green roofs are more garden or park like and will typically allow access to have people enjoy the space or harvest from the plants. Intensive green roofs are heavier and more likely to require irrigation and ongoing plant care. However, they can provide green spaces for the public in areas that are highly urbanized and lack ground space to provide such amenities. Extensive green roofs have the primary purpose of retaining precipitation and providing the benefits of increased vegetated area. They will be accessed infrequently and only for maintenance. Extensive green roofs can improve the cityscape if able to be viewed from above and do provide habitat for urban insects and birds.

The first green roof installation in Saskatoon was on the College of Law Addition at the University of Saskatchewan in 2007. The Health Sciences B Wing also has a green roof. In 2015, Saskatoon’s first extensive residential green roof was installed privately by a residential property owner on the garage of their infill home; they sought to decrease the volume of stormwater runoff generated by their property while enhancing biodiversity and providing viewable green space.

9.2 Application

Green roofs may be designed in the construction of a building or added as a retrofit if the structure can support the additional weight. They provide the most benefit to buildings with large roof areas, and are most effective on flat roofs or those with a pitch of less than 20 degrees. Extensive green roofs will absorb small rainfall events most effectively. In cases of large rainfall events, the green roof will become saturated and the remainder of the rainfall will run off.

Figure 18: Potashcorp Playland Ticket Booth Green Roof, Saskatoon

Benefits of including a green roof include runoff peak attenuation, runoff volume reduction, improved runoff water quality, and improved building insulation.

9.3 Design Considerations

The following elements of design must be considered before installing a green roof:

- Structural capacity of the roof to support the weight of the green roof and snow loads as required by the National Building Code of Canada
- Compliance with the Saskatchewan Building Code
- Meltwater runoff in the spring will mostly run off the roof, as the soil will be frozen and the plants dormant in the early spring. This should be accounted for in the hydrological model.
- Plants should be selected to survive winter temperatures and snow pack on the roof.
- Irrigation may be required during the establishment period of the plants (1 to 2 years). Water for irrigation should be obtained from a cistern collecting excess rooftop runoff.
- Drainage must be provided for overflow events.
- An electronic leak detection system may be added to ensure protection to the roof system.

9.4 Operation and Maintenance

The designer of the green roof should provide a site specific operation and maintenance plan detailing what must occur to ensure the success of the green roof. The green roof will require a minimum of monthly inspections during the first few growth seasons. Maintenance will include caring for the plantings until they are established. Initial care will include irrigation, fertilizer, and weeding. Irrigation can be as simple as roof access with a hose, or may include a spray or drip irrigation system.

After the initial establishment period is over, twice yearly maintenance is generally sufficient. This will include weeding, debris removal, safety inspection, repair of moisture and root barrier membranes, plant replacement of any failed plants, and replacing any clogged or contaminated soil.

9.5 Limitations

- Higher cost compared to conventional roofs (both construction and maintenance)
- Only treats direct rainfall
- Design and construction experience locally may be limited
- Green roof retrofitting is limited to structures that can support the additional weight.
- Routine maintenance is crucial to prevent roof leaks.

10 PERMEABLE PAVEMENTS

10.1 Description

Permeable (or porous) pavements can be used in place of traditional asphalt or concrete to allow the surface to remain absorbent to runoff. There are many types of permeable pavement including modular pavers, structurally reinforced grass and gravel, porous asphalt, and porous concrete. The goal of a permeable pavement is to provide the support required for driving, walking, or parking while not sealing the surface and forcing all runoff into the storm system.

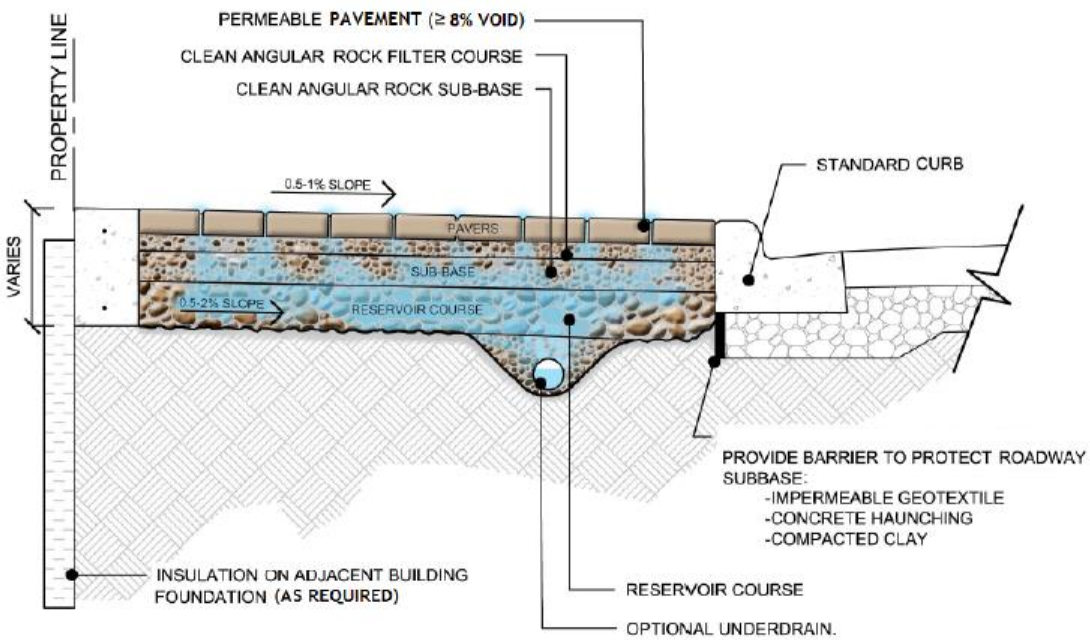


Figure 19: Permeable Pavement Cross Section (Drainage Services, 2014)

Permeable pavers may look very similar to traditional pavers, or may intentionally allow grass to grow in gaps between or within the pavers. Permeable concrete or asphalt will not appear different from conventional systems. The increased pore space in the mix provides a path for water to move into the gravel substrate and then move into the underdrain or underlying soil.

10.2 Application


Figure 20: Permable Pavement Walkway in Calgary (photo courtesy Expocrete)

The first concern raised when discussing permeable pavements in Saskatchewan's climate is often the effect of the freeze-thaw cycle. Permeable pavement has been successfully installed in cold climates. It must be designed, constructed, and maintained with the climate in mind. If this is the case, permeable pavements can be effective and durable in any climate.

Permeable pavements are not suitable for locations with high levels of sedimentation or pollution (such as gas stations or heavy industrial sites). Contaminated sites should be remediated before permeable pavement is installed.

Permeable pavement can be used in parking lots, walking and cycling trails, low traffic roads, driveways, and pedestrian plazas. It is ideal for use in areas without space to implement other LID practices. It is crucial to ensure that the traffic volume, de-icing activities, and operation and maintenance will support the effective functioning of the system. If the permeable spaces become clogged, the permeable pavement will not allow water to infiltrate and will experience damage when frozen.

Permeable pavements should be able to filter and convey the 1 in 2 year storm event. Larger or more intense events will still generate surface runoff from the permeable pavement areas.

10.3 Design Considerations

The structure and depth of the reservoir and drainage levels beneath the permeable pavement are essential to move the water out of the pavement layer. It is crucial to consult with an experienced designer that can provide the necessary expertise to ensure that the permeable pavement functions well through all seasons. In areas where the soil beneath cannot infiltrate adequately, an underdrain may be added to connect to the storm sewer system.

10.4 Operation and Maintenance

The biggest threat to the successful performance of permeable pavements is fine sediments, which will clog the pores and trap water within the pavement structure. A clogged permeable pavement system is no longer permeable and will not allow the planned rate of infiltration, as well as becoming susceptible to frost damage. Manage upstream sediment through effective landscaping and erosion prevention, and street sweeping contributing paved areas to stop sediment from washing into the permeable area.

To care for and prolong the life of permeable pavements, they should be vacuumed annually with a commercial cleaning unit. Inlet structures should also be cleaned at least annually. Simple broom sweeping is not effective at removing the fine sediment that needs to be removed from permeable pavement. Construction staging, soil/mulch storage must not be allowed on the unprotected pavement surface.

Winter plowing may damage a permeable pavement surface. The blade should be kept 10-25 mm above the surface while clearing snow. Rubber spacers on the blade to buffer the flow from the surface may be required. Ice tends to be avoided on permeable pavement because water drains away so quickly. This decreases the need for anti-skid materials, but if they are required, clean gravel (2-5 mm) should be used rather than sand, which will clog the pores.

In case of required pothole repair, areas less than 50 square feet may be patched with porous or standard asphalt without significant loss of permeability. Larger areas should be patched with porous asphalt. Because of the extensive base layer preparation in this system and inherently good drainage, potholes should be rare. Sealants or microsurfacing must never be applied.

Further specific instructions for operation and maintenance should be provided by the designer of the system. Surface infiltration testing should occur every 2 years to confirm the system is operating well. With proper maintenance and care, the permeable pavement system should have a life span of at least 30 years.

10.5 Limitations

- High maintenance requirements compared to other LID-BMP facilities
- High construction costs compared to other stormwater management facilities
- Small treatment area
- Susceptible to clogging if anti-skid material is applied
- Performance reduced if saturated at freeze-up
- Unsuitable in areas with heavy sedimentation or in active construction/excavation areas that are not fully stabilized
- Generally unsuitable for heavy traffic unless designed specifically to handle it

11 STORMWATER BOX PLANTERS

11.1 Description


Figure 21: Filtration Stormwater Box Planter in Philadelphia (Water, 2016)

Stormwater box planters are like a “rain garden in a box”. They are a layered planter system with selected plants designed to take in runoff from surrounding impervious areas. These planters do require some differences in design, placement, and sizing from rain gardens but generally perform by similar mechanisms.

Stormwater box planter designs can be divided into three categories based on how the water exits the planter:

- Overflow: drainage is provided only when the container is overtopped.
- Filtration: drainage is provided by an underdrain at the bottom of the planter.
- Infiltration: drainage is provided into the underlying soil, as the container has no bottom.

Storage is supplied by the porous layers within the planters. Water is transpired into the air by the plants, and evaporated over time. In the filtration design, excess water moves through the planter into the downstream stormwater system, but runoff water quality is improved. In the infiltration system, a bottomless planter allows water to move into the groundwater table. All systems must be designed to drain within 72 hours to prevent mosquito breeding. The choice of which type of planter is most appropriate will be site specific, considering the soil conditions, proximity to building foundations, and drainage area served.

Tree boxes are a large type of stormwater planter. An underground structure is provided to give the tree adequate soil to grow to a healthy mature size; this soil volume also holds stormwater and waters the tree rather than discharging to the storm sewer. Tree boxes may be designed to be filtration or infiltration planters depending on the site. The City of Saskatoon Parks Division provides specifications regarding structural soil cells for deciduous trees in their construction specifications. (City of Saskatoon Community Services Department, 2016)

Often, multiple stormwater box planters are included throughout a site. Each will treat a small area, but together they can have a larger overall impact.

11.2 Application

Stormwater box planters are suited to retrofit projects and highly urbanized areas. They reduce impervious area and improve stormwater runoff quality. The planters may be raised or inset. The size and type of planter will determine the runoff reduction and water quality improvements. Generally, the performance is similar to other bioretention areas.

Planters are designed to drain within 24-36 hours to prevent mosquito breeding. These planters are visually appealing, provide urban green space, and require minimal maintenance.

Soil cells for trees can be included in streetscape design in new developments or retrofitted to enhance existing neighbourhoods undergoing landscape improvements. Providing more soil to urban trees raises tree survival and gives conditions that allow trees to thrive. Trees also provide significant enhancements to air quality.

11.3 Design Considerations

Planters should be sited to minimize exposure to pollutants, de-icing chemicals, and anti-skid sand and gravel. An impermeable membrane should be used between the planter and any adjacent building foundation or roadway structure to prevent damage from increased soil moisture. Overflow water should be directed to avoid sidewalk icing during spring snow melt. Account for the weight of the soil, plants, and runoff when designing the planter structure.

Soil cells may be incorporated to provide a larger volume of soil to support plant or tree growth. These reinforced boxes of soil beneath other structures (sidewalks or roadways) and must be designed to support the weight of traffic above them.

Box planters will act primarily as a water quality improvement tool, although some minor reductions in flow volume will be observed. They work well in series with other facilities to act as a pre-treatment for runoff water.

Figure 22: 3rd Avenue Saskatoon in 2010, Silva Cell installation

The following table shows design considerations for the three categories of box planters:

Table 8: Box Planter Parameters and Guidelines (Drainage Services, 2014)

Design Parameter	Description	Overflow	Filtration	Infiltration
Infiltration Rate	Underdrain required if underlying infiltration rate <50mm/hr. Use 30 mm/hr for design & modeling.			X
Inlet	Erosion control at point source inlet.		X	X
Contributing Area	Overflow: 1 to 1 area ratio; Filtration and Infiltration: <1400 m^2 (for a 100 mm rain in 24 hr)		X	X
Design Discharge	Discharge rates must comply with discharge rate set in Area Master Plan	X	X	X
Planter Material	Stone, concrete, brick, wood (chemically treated wood is unacceptable), clay, plastic	X	X	X
Media Layers	Planting media: 300-450mm amended topsoil Filter layer: 100mm of 16-25mm washed rock, <0.1% silt Drainage layer: 250-300mm of 20-40mm washed rock, <0.1% silt	X	X X X	X X X
Max. Ponding Depth	Overflow: 50mm Filtration and Infiltration: 300mm	X	X	X
Outlet	Min. 150mm weeping tile drain through length of facility to minor system lead		X	X
Emptying Time	Ponding < 12 hour following design events		X	X
Surface Geometry	Overflow: as site allows Filtration: >450mm width Infiltration: >750mm width	X	X	X
Surface Slope	Overflow and Infiltration: flat Filtration: 0.5% surface slope	X	X	X
Infiltration Features	Scarify sub-soils			X
Groundwater Buffer	Base 1m or more above seasonal groundwater level			X
Structural Buffer	Overflow: none Filtration: Impervious barrier within planter, direct overflow appropriately away from structures, damp-proof foundations Infiltration: 10m setback from foundations		X	X
Vegetation	Drought tolerant plants that cover 50% of surface at maturity; irrigation acceptable	X	X	X

11.4 Maintenance Schedule

As with all methods relying on vegetation, more care is required during the first two growing seasons. The facility designer must provide a site specific maintenance schedule and plan.

Figure 23: 3rd Avenue Saskatoon, 2013

Generally, the planter should be inspected annually for vegetation health and density, infiltration and contamination testing, and structural stability. At the beginning and end of the growth season, the downspout and splash pad (if applicable) should be inspected for clogs or leaks.

Weeds, litter, and debris should be removed every 1-2 months. If sediment has accumulated beyond 100 mm, it should be removed by hand. The downspout, inlet, and underdrain should be flushed in the spring. Dead plants should be removed and replaced annually. Mulch should also be replaced as required annually.

Soil may need to be replaced when contaminated or clogged.

Gravel and underdrain layers should last 25-50 years if the rest of the planter is maintained.

11.5 Limitations

- Contained and flow-through boxes require downstream stormwater options, either LID-BMP or conventional pipes.
- Irrigation will be required during periods of drought.

12 NATURALIZED DRAINAGE WAYS

12.1 Descriptions

A naturalized drainage way is functionally a managed small creek. It may have a constant flow and will use several elements such as wetland zones, drop structures, natural materials, and vegetation in place of a storm sewer main. Constructing a naturalized drainage way will improve existing drainage paths to prevent erosion and improve habitat. They are larger than a grassed swale, more continuous and engineered than urban wetlands, and use slow velocities and increased contact time to encourage infiltration, evapo-transpiration, and natural filtration.

A naturalized drainage way provides habitat for a wide variety of plants and wildlife. They provide a water source, multilayered vegetation, and diverse conditions to encourage nesting, feeding, and hiding. Vegetated slopes and banks help maintain the channel capacity by preventing erosion and filtering sediments before they reach the channel.

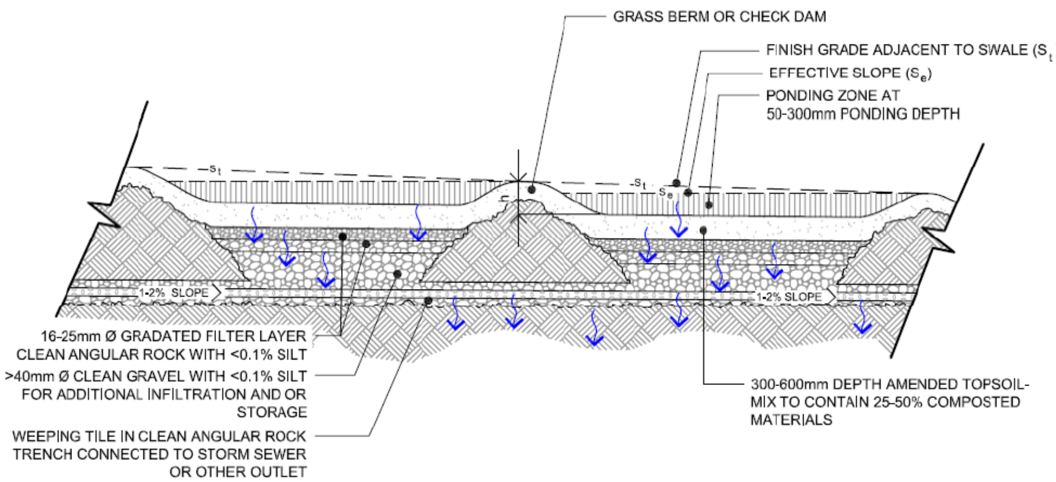


Figure 24: Cross Section of Naturalized Drainage Way (Drainage Services, 2014)

12.2 Applications

Typically, naturalized drainage ways are best located near the outlet of developed basins. This provides the frequent flow (or continuous baseflow from groundwater) to provide water to the plants and wetlands along the channel. It also prevents stagnant standing water and mosquito breeding.

They can be installed as retrofit projects in areas with over capacity storm trunks or currently eroded streams, or may be incorporated into new developments as a responsible method of preventing future problems. They are not suited to areas with very flat or very steep topography. Each implementation is very site specific and must be designed to use the local drainage, topography, and development characteristics.

12.3 Design Considerations

Figure 25: Naturalized Drainage Way in Aspen Ridge, Saskatoon

A naturalized drainage way can incorporate natural features such as wetlands, stream path, and recharge zones. It is important to take care to maintain natural water fluctuations and avoid sedimentation or pollutant deposition. Soils must be suitable to grow vegetation and withstand storm flows when vegetated.

If the slope is greater than 1%, drop structures need to be incorporated to slow flow velocities. Model and check flow velocities for 2, 5, 20, 25, and 100 year storm events. Velocities over 1.5 m/s may be erosive to banks and harm vegetation. This may be unavoidable for infrequent events, but maintenance inspections should be conducted following these large rainfalls.

The design flow depth should be 0.6 – 1.2 m during a 2-year design event. Ponding depth should be below 0.15m following the same 2-year design storm event. Slopes less than 0.1% will not drain sufficiently.

Depending on the surrounding development, many other features may need consideration in designing a naturalized drainage way. There may be a need for pedestrian access that is functional throughout all seasons and expected flow volumes. Vegetation height must be suitable to allow driver sight lines along roadways. Plant species in or near the channel base should be winter hardy, and able to tolerate the predicted flow velocities and near constant inundation in water. Side slope plants should be drought tolerant and tolerate brief inundation. Salt tolerant species are suitable adjacent to roadways.

The high water level on a 100-year design event should not compromise adjacent structures. Side slopes should be 3.5:1 or shallower. The drainage way should be at least 3m from all building foundations.

12.4 Operation and Maintenance

Street sweeping and sediment removal will help the naturalized drainage way function properly over the long term. Naturalized drainage ways should be inspected quarterly during the first two years, and then in the spring and fall in subsequent years. If roadway or parking lot runoff is received, soil testing for salt content is recommended annually. Irrigation may be required during the establishment phase.

Weed control and mowing will be required monthly. Removal of litter and debris will be required quarterly, and possibly more frequently at the opening and discharge of culverts. Pruning, sediment disposal, and erosion repair may be required annually. Plants, mulch, and soils may require replacement after several years. Soil only requires replacement if the runoff contaminates it.

12.5 Limitations

- Impractical in very flat or very steep topography
- May experience some erosion during large storm events
- Sediment accumulation at culverts will lead to weed problems. Maintenance is critical to ensure success.
- Require large spaces for implementation, which may prevent use in highly developed sites
- Dangers from high flow rates or flash floods must be assessed to ensure public safety is ensured in areas with pedestrian or cyclist paths
- Impeded in areas with many driveway crossings

13 RAINWATER HARVESTING FOR RE-USE

13.1 Description

At its simplest, rainwater harvesting for re-use is as familiar as the rain barrel hooked to a backyard downspout. The concept of capturing and storing rainwater for later irrigation or greywater use is simple. Stored rainwater is also removed from the downstream stormwater system. It can also reduce summer demands for potable water by allowing irrigation needs to be met or partially met with harvested rainwater.


Figure 26: Residential rain barrel

Larger systems may use large tanks (on the rooftop, adjacent to a building, or underground cisterns) to capture a larger volume of water. The water captured at the Access Transit Garage, pictured below with three 35,000 L storage tanks, is used in the bus wash, as well as to flush toilets in the building.

Care should be taken to prevent damage from freeze/thaw cycles. Above ground tanks or cisterns requires an overflow and a drain to allow for winterization and cleaning. Underground cisterns require cleanout ports or manhole access.


Figure 27: 35,000 L Tanks at Access Transit Garage, Saskatoon

13.2 Application

Use of captured rainwater is governed by federal and provincial legislation, but rainwater in Saskatchewan is acceptable for irrigation, washing (such as car washes) and for toilet flushing.

Rain barrel systems are simple – the direction of a downspout into a container and then manually removing for landscape watering.

Rooftop cisterns are more challenging to direct water into, but easier to remove the water via gravity distribution. Buried cisterns will require pumping, but capture and store large amounts of water easily. Buried cisterns should be in native soil; if installing in filled locations, consult a geotechnical and structural engineer for advice. Overflows should be directed away from foundations, with lot grading to direct flow to the storm sewer system in a way that prevents damage.

Only roof surfaces provide rainfall runoff suitable for reuse. Other surfaces – parking lots, sidewalks, grassed areas – will introduce contaminants like salt, bacteria, and metals.

13.3 Design Considerations

As with other LID features, rainwater harvesting should be designed by a qualified professional to ensure good performance. Cisterns in particular require careful design and installation, as they are less visible and accessible for further maintenance. They will also have directions from the manufacturer that must be followed.

The volume of rainwater available from the roof surface is assumed to be 75% of the volume of rain that falls onto it. Some water will evaporate, be held in local depressions, or leak from the system.

Because rainfall is unpredictable, a cistern may be connected to a municipal water supply for top-up if needed. A backflow device must be installed to prevent cross contamination to the water supply. A first-flush diverter should be designed to divert the first 0.5mm of runoff away from the storage facility to avoid clogging or contamination. This water could be diverted to another LID facility to achieve treatment. Metal roofing provides cleaner rainwater than asphalt shingles. If a cistern is located in a building, it must be included on the drawings submitted for building permits.

A cistern should be inspected during construction for compliance with the plumbing code, and be tested during commissioning to ensure it is leak free and functioning correctly with the re-use system.

Roofs will require gutter screens (maximum screen size 10 mm) to keep leaves out, and a system of gutters, downspouts and pipes to carry water to the tank or cistern. The cistern will require an overflow pipe or subsurface drain to direct water once full. All hose bibs and faucets at the end of the delivery system must be marked "Warning: Non-potable water – Do not drink". If connected to a top-up water supply, a level indicator such as a float will be needed to trigger filling, and a backflow prevention device will be needed on the filling pipe.

13.4 Operation and Maintenance

Operation of a rainwater harvesting system focuses on keeping the system clean and making use of the rainwater to allow refilling in the next rain event.

Inspect filters monthly. Inspect cistern, pipes, pumps, and roof gutter screens quarterly. Check the irrigation hook up in the spring, and winterize the system in the fall by making sure outdoor tanks, pipes, and hoses are empty.

Leaves should be removed from the gutter screens at least quarterly. Prune nearby vegetation to minimize leaves and debris accumulating on the roof. Repair any leaks or crack and clean the filters in the spring and fall. Flush the inlet and outlet in the spring. The cistern will need to be cleaned or flushed annually or when sedimentation exceeds 25 mm.

13.5 Limitations

- Minimal improvement of water quality
- Often require a potable water supplement, as rainfall is not consistent enough in SK to rely on fully
- Careful design and installation is required to ensure backflow prevention devices are installed and cross-contamination of the potable water supply is not possible if a backup water supply is present

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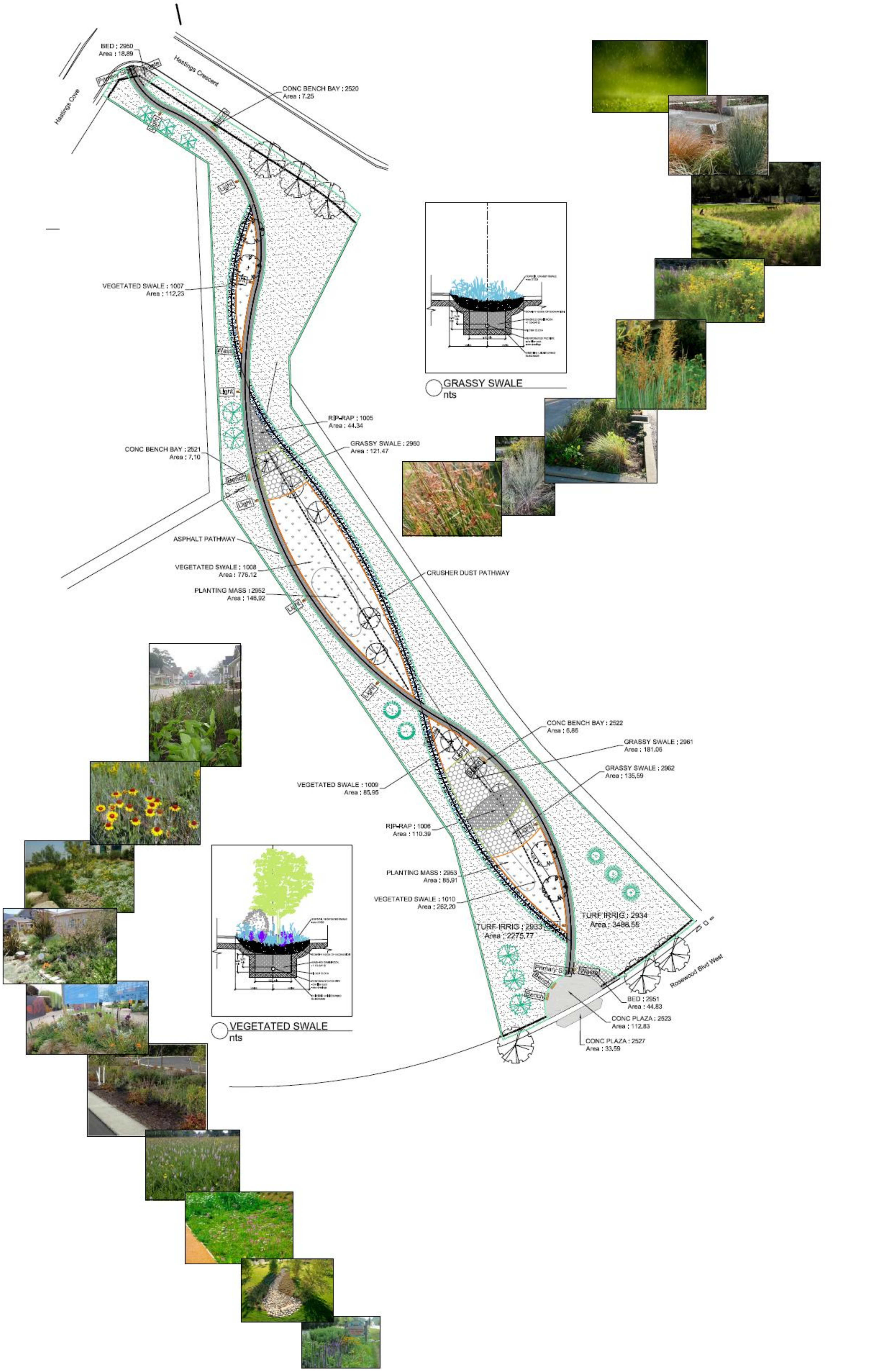
Appendix A: Bitz Park Design Drawing (Grassy Swale and Vegetated Swale)



Landscape Plan

PARKS DESIGN

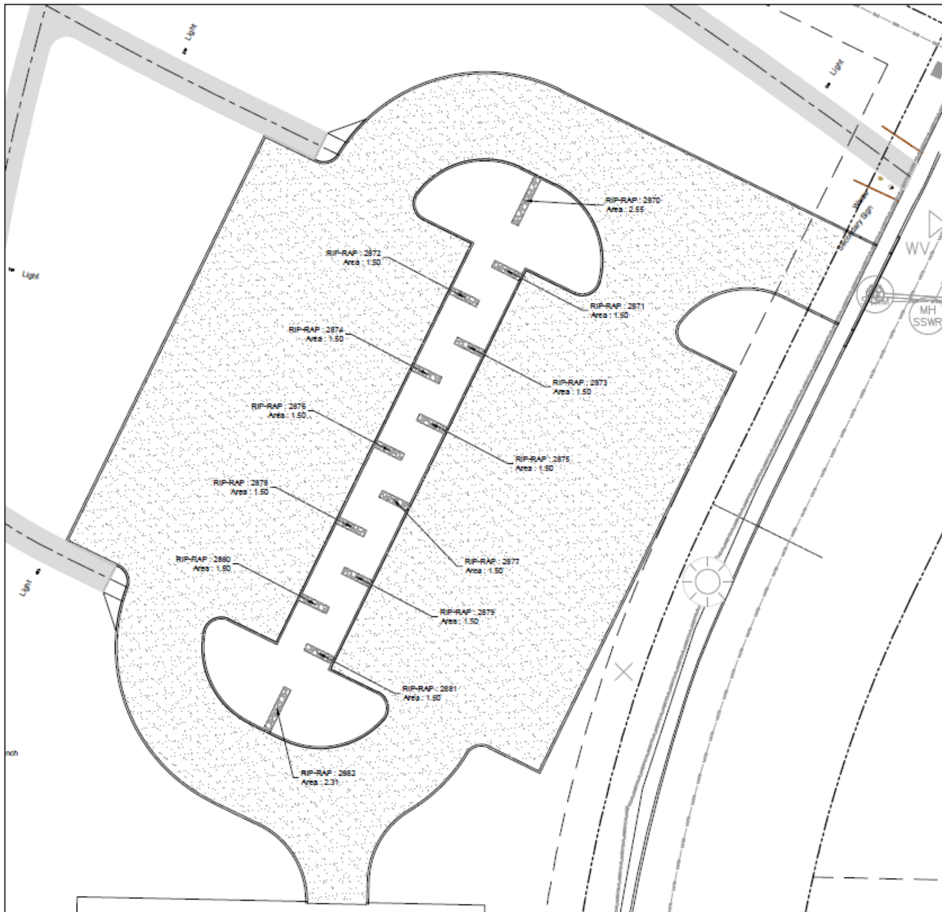
Bitz Park

130418 SC. (24x36) - 1:500 OTHER SIZES - NTS

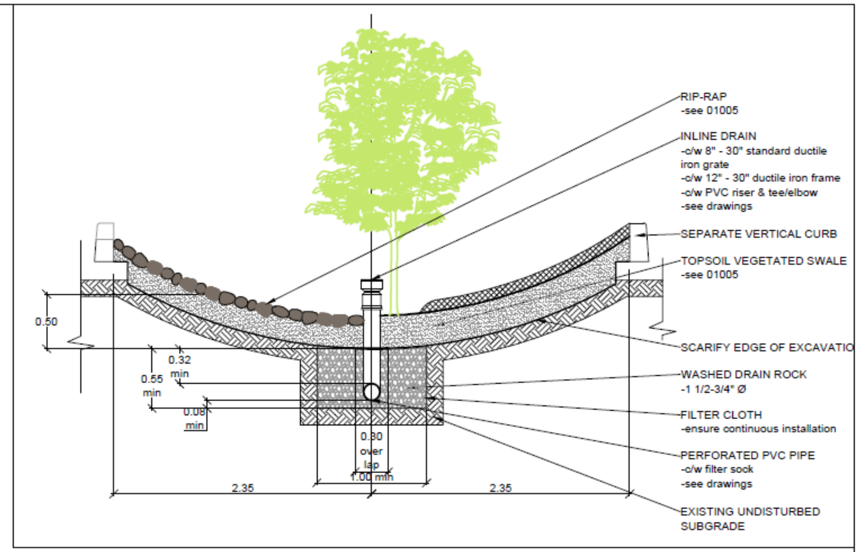
City of Saskatoon
Parks Branch

Appendix B: Evergreen District Park MR21 (Parking Lot with Treed Swale)

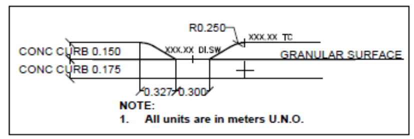
24"X36" (ARCH D) (609.6 mm x 914.4 mm)



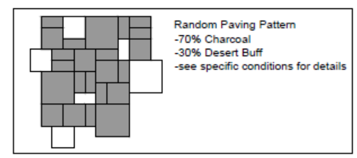
Parking lot Plan



Drainage Swale Section A-A
1:30 (1:60)



Curb Inlet Section
1:30 (1:60)



Unit Paving Pattern
1:30 (1:60)